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GRADUATE SCHOOL OF EDUCATIONAL SCIENCES

EFFECT OF THE DIFFERENT COMPONENTS OF WORKING MEMORY ON MULTIPLICATION SKILLS OF 3RD GRADE CHILDREN

BY

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EFFECT OF THE DIFFERENT COMPONENTS OF WORKING MEMORY ON MULTIPLICATION SKILLS OF 3RD GRADE CHILDREN

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ABSTRACT

EFFECT OF THE DIFFERENT COMPONENTS OF WORKING MEMORY ON MULTIPLICATION SKILLS OF 3RD GRADE CHILDREN

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The basic arithmetic operations skills of the students play important role to solve math problems as prerequisite knowledge. Therefore, in the first years of primary education, four-operation skills are involved in math curriculum at most. The cognitive process of dealing with numbers and counting abilities are associated with working memory which is the part of this process. The purpose of this present study is to investigate the extent to which components (central executive, phonological loop and visual-spatial sketchpad) of working memory explaining multiplication skills of 3rd grade children.

The study was carried out during the spring semester of 2015-2016 academic year at Istek Kemal Atatürk Primary School in Istanbul. 60 third grade students (23 female and 37 male) whose parents were received permission were involved in the study. In order to evaluate the participants' capacity of central executive (CE), phonological loop (PL) and visual-spatial sketchpad (VS) components, the tasks named as the counting recall test (CRT), digit span test (DST) and block recall test (BRT) were designed and administered by computers. In addition, participants' multiplication skills were evaluated by multiplication test (MT). Linear multiple regression analysis was used in order to analyze how well the predictor variables predicted multiplication skills. The results of multiple regression analysis revealed that the best predictor variable of multiplication skills was the central executive component of working memory.

Key words: Working Memory, Central executive, Phonological Loop, Visual-spatial Sketchpad, Multiplication Skills

ÖZET

ÇALIŞAN BELLEĞİN FARKLI BİLEŞENLERİNİN

3. SINIF ÖĞRENCİLERİNİN ÇARPMA BECERİSİNE ETKİSİ

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Matematik problemlerin çözümünde öğrencilerin işlem yapma becerileri çok önemli rol oynar. Bu nedenle ilkokulun ilk yıllarında matematik programlarında en çok yer kaplayan beceri dört işlem yapma becerisidir. Bilişsel bir süreç olan sayılarla uğraşma ve işlem yapma becerileri, bu sürecin bir parçası olan çalışan bellekle de ilişkilidir. Bu çalışmanın amacı çalışan belleğin bileşenlerinin üçüncü sınıf öğrencilerinin çarpma becerilerini ne ölçüde açıkladığını araştırmaktır.

Çalışma 2015-2016 öğretim yılı ilkbahar döneminde İstanbul İstek Kemal Atatürk İlköğretim Okulu'nda gerçekleştirilmiştir. Çalışma ebeveynlerinden izin alınan 60 üçüncü sınıf öğrencisi üzerinde yürütülmüştür. Katılımcıların çalışan belleğin, merkezi yürütücü, fonolojik döngü ve görsel-uzamsal öğelerine ilişkin kapasitelerini ölçmek için, counting recall, digit span ve block recall olarak adlandırılan görevler tasarlanmış ve bilgisayar aracılıyla uygulanmıştır. Öğrencilerin çarpma becerilerini ölçmek için ise çarpma testi kullanılmıştır. Bağımsız değişkenlerin çarpma işlemi becerisini ne ölçüde iyi tahmin ettiğini analiz etmek için lineer çoklu regresyon analizi kullanılmıştır.

Sonuçlar 3. sınıf öğrencilerinin çarpma becerilerini en iyi yordayan değişkenin çalışan belleğin yürütücü kontrol öğesi olduğunu göstermiştir.

Anahtar Kelimeler: Çalışan Bellek, Merkezi Yürütücü, Fonolojik Döngü, Görsel-Uzamsal, Çarpma Becerisi

To My Mom, Hatun Boz

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Basic arithmetic operations skills of the student played important role in the problem solving process. Therefore, the development of arithmetic operation skills is the core curricular purpose in math. Children's educational development may be affected severely if they have difficulties in these areas (Berg, 2008). Children especially have difficulties while they are solving multiplication problems (Rotem & Henik, 2013). The activities of understanding of aspects of number and counting are cognitive process (Hubber et al., 2014) where children store, monitor and manipulate information in their mind and they are associated with working memory (De Stefano & LeFevre, 2004; Raghubar, Barnes, & Hecht, 2010). Therefore, the main purpose of this study to investigate the role of working memory in multiplication skills of the students.

Working memory is described as "short-term storage and processing, and used in various cognitive tasks, such as reading, reasoning and mental arithmetic" (DeStefano & LeFevre, 2004, p. 1759). Working memory is engaged in controlling, "regulating and actively maintaining information" required for various activities and can be valued as a 'flexible workplace', or 'desktop of the brain (Nyroos & Hörnqvist, 2012, p. 240). Baddeley and Hitch (1974) introduced a multiple-component model of working memory. According to Baddeley (1992), working memory is the system which is used for short-term storage and where the information about cognitive tasks are manipulated. This model contains the phonological loop (PL) for maintaining and rehearsing verbal information and the visual-spatial sketchpad (VS) for holding and manipulating visual–spatial information (Baddeley, 1992). Both the PL and the VS are directly related to central executive (CE), which coordinates activities in the cognitive order. This multi-componential is concerned about mental process. For example, mental codes are used in mathematical tasks. The CE is also known as “an attentional controlling system” involved in the coordination of performance on separate tasks, selective attention, set shifting, and inhibition (Baddeley, 1996, p.8). Firstly, the items should be manipulated and then this information should be repeated in these tasks. Thus, the slave systems deal with only storage of information, however the CE also relies on the coordination of information (Van den Bos, Van der Ven, Kroesbergen & Van Luit, 2013).

As the organizational system, the CE provides children's problem solving by the help of chosen appropriate strategies. Gathercole and Pickering (2000) found that standardized test scores in mental arithmetic of children at 7 years of age and again at 8 years of age showed the relationship between CE and these scores. There are many studies about PL which is involved in transforming symbol and number strings into verbal code when solving basic arithmetic problem by using verbally counting strategies (Imbo et al, 2007; Fürst & Hitch, 2000). According to Heathcote (1994), the VS is suggested for adults when solving multi-digit operations.

In contrast, older children are engaged in nonverbal problems more than verbal problems since they can symbolize and form codes for both types of problems in verbal manner and then solve the problems without using mental model (Hitch et al., 1988). Children learn to label quantitative symbols verbally in school-age, and since children must store verbal information, this verbal approach would appeal to phonological working memory. When children learn to solve larger problems, they may need to demand more phonological working memory, and this could be challenging to perform mental process. Furthermore, children also learn using strategies, such as using their fingers for counting. Therefore, the need to VS would be increased, but the demand to a mental model would be reduced (Bull, Johnston & Roy, 1999). Children are relied on PL to hold numbers in mind when they use their fingers in order to solve the verbal problem. Children in school-age do not need more to the mental model for calculation because they are able to use methods for verbal symbols. Besides, the arithmetic problems which require attention and planning are more relied to the CE (Rasmussen & Bisanz, 2005).

The findings about relation between different components of working memory and multiplication demonstrated that simple multiplication problems depended on only CE process, while complex multiplication required both PL and CE processes (Liu et al, 2015). Hecht (2002) examined CE and PL which were used in simple arithmetic and he found that CE was engaged in all strategies (e.g. counting, transformation, retrieval), whereas PL was hold in only counting. Imbo and Vandierendonck (2007) mentioned in their study that simple arithmetic problems can be solved by using different strategies where CE and PL resources are needed. For instance, while retrieval strategy (knowing that $6 \times 4 = 24$) is used mostly, non-retrieval or procedural strategies (transformation and counting) are used as well for multiplication problems.

In conclusion, the CE, VS and PL components of working memory affect children's math learning. When children start their school life, they have implicitly understood numbers and counting. During schooling, working memory enables them to add to their knowledge. It can be said that although the contribution of the different components of working memory to learning different areas of math is not fully understood, working memory is very important for children's math learning. Therefore, the main purpose of this study is to investigate how different components of working memory affect multiplication skills of 3rd grade children in Turkey.

1.1 Math Education

Mathematical thinking arises naturally before children start their education life. They give the meaning to their surroundings when they use their investigation and communication skills in their social environment. Therefore, it is impossible to isolate math learning from the life. Children start to learn math when they do their daily activities, such as playing a game, listening to a story and helping their parents (MoNE: Ministry of National Education, Turkey, 2015). For instance, acquiring number skills, counting and performing mathematical operation are suitable for children's daily activities from early ages (van den Bos, van der Ven, Kroesbergen, van Luit, 2013).

One of the most important purposes of math education is enabling students to make connection between their experiences and math. The primary math curriculum emphasizes on learning concepts, being quick in arithmetic operations, making connection between mathematical concepts, having the ability of communicating by using the language of math, concepts, terms and numbers, making mathematical modelling and reasoning, choosing proper strategies in order to explain relationships between objects, and having the ability of problem solving. The curriculum bases on helping students reveal their experiences and different views, and create mathematical meanings with their concrete experiences (MoNE, 2015).

Another important goal of a math education is to enable students to become problem solvers because it is assumed that students who are good at solving mathematical problems are able to overcome the problems in their daily life. Therefore, problem solving is a main activity in teaching math (Silver, 1985; Schoenfeld, 1992). Problem solving is a series of cognitive activities in order to accomplish the definite purpose (Schoenfeld, 1989). A theoretical framework is required for a given problem in order to understand the cognitive processes of math learning. For instance, Dagenbach and McCloskey's (1992) developed cognitive model of number processing. This model helps to differentiate between input processes and abstract cognitive representations involved in calculations. Numbers are perceived verbally (two times four) or numerically (2×4). Both of them are converted to an abstract representation which is managed through calculation procedures. Then, results are converted to the proper output (numeric or verbal). This process provides to increase children's math skills and use language for math problems. In addition, cognitive manipulation is conducted when numeric symbols are connected with verbal numeric representations (Decker & Roberts, 2015).

In consideration of learning math, arithmetic operations are the initial skill for children's academic life. Since arithmetic operations are the most important prerequisite for problem solving, it has been the core skill of math curriculum for primary learners. Difficulties in this skill bring about considerable problems for children's development in math. For instance, if students are not able to solve simple addition problems, they can not perform more complex addition problems (Geary & Brown, 1991), and also if they do not succeed in addition problems, they cannot develop their multiplication skills (Cooney, Swanson, & Ladd, 1988). Indeed, the calculation abilities form a basis for the advanced mathematical skills (National Council of Teachers of Math [NCTM], 2000; Ashcraft, 1992).

1.2 Primary Education Math Curriculum

Turkish new education system which is called 4+4+4 of schooling has been prevailed since 2012. The compulsory schooling was increased from eight years to twelve years. The twelve- year of schooling was divided into four years in the primary school, four years in the middle school and four years in the high school. However, the average starting age of the children in primary school was decreased to 60- months from 72-months-old (Güven, 2012).

In the view of new education system, the curricula have been changed continuously since 2004 and being administered to primary, middle and high schools. One of the curricula has been built on is math curriculum for primary school. The math curriculum was administered by the Ministry of National Education and all teachers have to use same curriculum in all schools. The Turkish math curriculum includes "learning areas, sub-learning areas, objectives, samples of activities and explanations of activities" and four learning areas: "number, data, geometry and measurement" are involved in this curriculum (MoNE, 2015, p.9). The subject of arithmetic operations is involved in the "number" learning area (MoNE, 2015, p.11).

The new math curriculum (MoNE, 2015);

- gives importance to mathematical concepts in order to provide abstract learning,
- enables students to be involved in the learning process actively,
- gives chance to students to use their abilities and individual differences in learning activities.

Each learning areas in the primary math curriculum have been supplemented with learning methods and techniques, and also teaching activities. The aims of the "numbers" learning area for the arithmetic skills are (MoNE, 2015);

- to enable students to acquire the ability of using the numbers and digits,
- to develop students’ comprehending four arithmetical operations,
- to provide students’ operation and estimation abilities.

In the primary education math curriculum, arithmetic operations are included in the sub-learning areas of addition, subtraction, multiplication and division with natural numbers. In this curriculum, addition and subtraction are taught from 1st grade. Dealing with models to understand different meanings of each two operations, indicating the relationships between them, explaining properties of addition and subtraction, making mental arithmetic operations by using strategies are main objectives of the curriculum. From second grade onwards, giving different meanings by using models is very essential for multiplication and division. As a grade progressed, the relationship between multiplication and division is performed step by step. Across the program, more learning hours are allocated for multiplication in the learning field of numbers and operations. For instance, 16 learning hours are given for addition and 14 hours are given for subtraction, while students are performing multiplication 20 learning hours and division 18 hours in the 3rdgrade. In the 2nd grade, multiplication and division courses are given in 20 hours and 14 hours, respectively, whereas 24 hours are allocated in the math curriculum for both addition and subtraction (MoNE, 2015).

Being able to solve multiplication problems is admitted to be important part of the primary math curriculum. Children start to develop their understanding multiplication and division concepts in the third grade and they are supposed to be very experienced in solving multiplication problems (NCTM, 2000; MoNE, 2015). Besides learning multiplication facts, comprehending quantitative relations between multiplicands is fundamental target to make children develop their math reasoning abilities (Stein, Kinder, Silbert, & Carnine, 2006).

By the second grade, children begin to learn multiplication. Explaining the meaning of multiplication as a repeated addition, multiplying the number (up to 10) with 1, 2, 3, 4 and 5, creating multiplication table up to 6 by using hundred table, realizing that a product does not change when places of multipliers are changed, understanding the effect of 1 and 0 in multiplication are main objectives of math curriculum in the second grade (MoNE, 2015).

Despite the fact that children learn the certain concepts of multiplication in the second grade, they are introduced to acquire multiplication skills properly in the third grade. They are expected to obtain the following skills (MoNE, 2015):

- Explaining multiplication as a mean of multiple,
- Forming a multiplication table,
- Multiplying a two-digit natural number with at most two-digit number,
- Multiplying a three-digit natural number with at most one-digit number,
- Doing carry operations,
- Multiplying natural numbers with 10 and 100 briefly,
- Doing mental multiplication,
- Solving multiplication problems which contain at most two operations.

Besides all these learning activities, the strategies for addition, subtraction and single digit multiplication are very efficient and common (Geary et al, 2004). Especially, for multi-digit multiplication, using strategies is convenient. The strategies, such as; “direct modelling with concrete materials or semi-abstract drawings, methods involving repeated addition (doubling, partitioning methods) are used for multi-digit multiplication” (Fuson, 2003, p. 302). A number of steps involving multiplication and addition is necessary for it. It also depends on the answers for each step being arranged to their correct place value (Bobis, 2007). From this view, Philips (2003) worked with a third grade student who was not good at addition and subtraction. Besides increase in the student’s fluency of addition and subtraction, the fluency of multiplication increased after implementation of a series of strategies.

Addition, subtraction, multiplication and division are known as four operations in math education and they constitute the foundation of math teaching (NCTM, 2000). Proficiency in arithmetic operations, fluency when making calculation and knowledge about strategies are required at first for problem solving and then for solving advanced math problems (Geary, 2003). Fuchs, Fuchs & Fletcher (2008) proved that there were conceptual relationships between problem solving and arithmetic skills. In this perspective, arithmetic skills and fluency are assumed to be prerequisites of math skills.

Consequently, a variety of cognitive processes and strategies are required in order to accomplish these objectives. For instance, an answer of simple sums is retrieved from memory and procedural strategies, such as cunting or decomposition are used while doing complex sums (Hubber et al., 2014). The activities, such as the ability to store, monitor, and manipulate information in mind which are indispensable for arithmetic operations depend on working memory (De Stefano & LeFevre, 2004; Raghubar, Barnes, & Hecht, 2010).

1.3 Working Memory

Working memory is dynamic version of short term memory that was referred in initial information-processing models (Atkinson & Shiffrin, 1968). It is engaged in controlling, regulating and actively maintaining information required for various activities and can be valued as a ‘flexible workplace’, or ‘desktop of the brain’ (Nyroos & Hörnqvist, 2012, p. 240). A variety of cognitive tasks, such as reading, calculating, rearranging, comparing and contrasting, embraces multiple steps and in order to perform these tasks favorably, the long-term store is kept in mind temporarily (Miyake and Shah, 1999).

Working memory plays a significant role in cognitive process and refers to the temporary storage and manipulation of information (Baddeley, 2000; Logie, 1995). It has been studied extensively in the past 55 years. It was first mentioned by Miller, Galanter, and Pribram (1960), and Baddeley and Hitch (1974) also offered working memory model. They proposed working memory model as an alternative to the short-term store inAtkinson & Shiffrin's 'multi-store' memory model (1968). The model affirms three components of human memory: Sensory register, short-term store and long-term store.

Sensory register is the place in which information comes in memory. It is also named as sensory buffer or sensory memory. It is responsible for detecting and holding information carried by stimulus. Then information is transferred to the short-term memory with attention. If the attention is not given, information can be forgotten (Atkinson & Shiffrin, 1968). Sensory register serves for each sense. The visual and auditory systems are studied considerably from this view. For instance, there are several researches for iconic memory (visual system) and echoic memory (auditory system)

(Sperling, 1960). While iconic memory holds visual representations such as shape and color, echoic memory only holds the elements of sound such as; tempo and rhythm (Darwin et al., 1972). Whereas items in iconic memory decay after 0.5-1.0 seconds (Sperling, 1960), Echoic memory has a duration of between 1.5 and 5 seconds (Treisman, 1964).

The view of human memory (Atkinson& Shiffrin, 1968; Waugh& Norman, 1965) presents a magnificent system of the basic mechanism, such as encoding, maintenance and retrieval, and figurations in working memory or short-term memory. Across selective attention, a subset information in the sensory registers is processed and transferred into a short-term store by encoding (Miyake and Shah, 1999).

Short-term store which is also called short-term memory is responsible for receiving and holding information from the sensory register and long-term store (Baddeley & Hitch, 1974). Short-term store has approximately 18-20 seconds duration (Lloyd& Peterson, 1959), but it can proceed up to 30 seconds according to its context (Posner,1966). According to Atkinson & Shiffrin (1968), short-term store can preserve the information longer through rehearsal which refers to repeating items for auditory information and visualizing for visual images. However, the amount of information held in short-term store is 7±2 items (Miller, 1956).

Long-term store is memory system in which information is held permanently. Information is transferred from short-term store to long-term store. According to Atkinson and Shiffrin (1968; 1971), short-term memory which is very complex system involves both limited storage space and control processes. The control processes manage to encode information in long-term memory and maintain information in short-term store. Therefore, the short-term store is assumed to be a working system, and the control processes consist of verbal rehearsal and coding strategies (Logie, 1995).

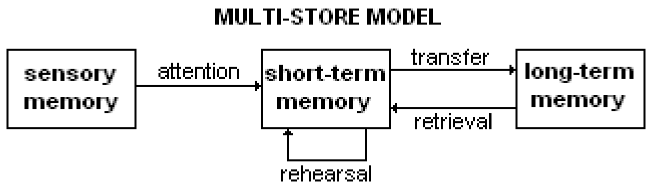

Figure 1. Multi-store model (Atkinson and Shiffrin, 1968)

The information held in short-term store is regarded delicate and may disappear immediately. Therefore, rehearsal is required to preserve the information within the short-term store in the maintenance process and it is transferred to a long-term store which is more durable (Sternberg, 1966). In the retrieval process, the information in the short-term store is considered to be readily available, but it cannot be retrieved if it is not encoded in the long-term store (Miyake and Shah, 1999). Verbal codes are assumed as the prevailing memory code in short-term memory experiments which were done in the 1960s and 1970s. Atkinson and Shiffrin (1968), however, accepted the availability of other short-term memory codes, such as visual and spatial codes, and these such codes are become semantic (meaning-based) codes in long-term memory.

The processes of controlling and regulating have been conceded essential parts of working memory. The concept of control processes was offered in Atkinson & Shiffrin's (1968) modal of human memory. Working memory is acknowledged as a more processing-oriented construct and provides active processing and temporary storage of task-relevant information dynamically.

After all, the point of control and regulation has been regarded as a significant function of working memory and the concept of control processes which is acknowledged as Atkinson & Shiffrin's (1968) model of human memory has restricted efficiency, such as rehearsal, coding and search strategies. Since working memory is assumed a more processing-oriented and dynamic structure for temporary storage of task-relevant information, it requires a more enhanced control system for memorization strategies. From this view, different multiple components of working memory are regulated (Logie, 1995).

Atkinson & Shiffrin's (1968) model was developed by Baddeley and Hitch (1974). They proposed three components of working memory model to explain short-term memory properly in Atkinson & Shiffrin's (1968) multi-store memory model. The model consists of the three components: the central executive and its slave systems: the PL and VS. Then, Baddeley (2000) added a third slave system to this model, the episodic buffer.

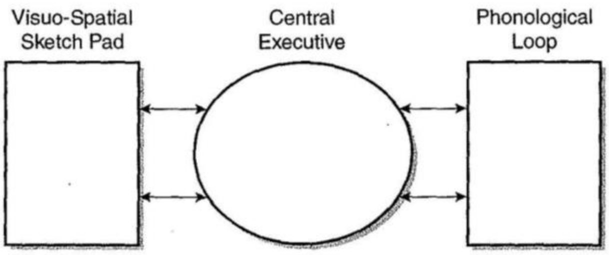

Figure 2. Baddeley's first model of working memory (Baddeley, 1986)

These two slave systems arise from dual-task paradigms. Dual-task paradigm is a procedure of experiment where an individual performs two tasks simultaneously to compare his/her performance with single-task performance. According to Baddeley &

Hitch (1974), performance is very effective when a person performs two simultaneous tasks where two separate perceptual domains, such as; a visual and a verbal task. However, performance is less effective if same perceptual domain is used for each one. Therefore, the components of working memory which serve perceptual domain for tasks are very essential for interpreting human processing resources.

1.4 Components of Working Memory

A multicomponent system of working memory contributes to temporary storage of information for short periods of time to sustain cognitive activities (Baddeley, 1986; Baddeley& Hitch, 1974). A system involving multiple components not only provides the capacity for temporary storage and manipulation of information for various tasks, but also integrates activities (Alloway, et al., 2009). Baddeley (2000) revised the model which was proposed by Baddeley and Hitch (1974). Across this model, working memory contains four limited capacity components: the central executive (CE), the phonological loop (PL), the visual-spatial sketchpad (VS) and episodic buffer.

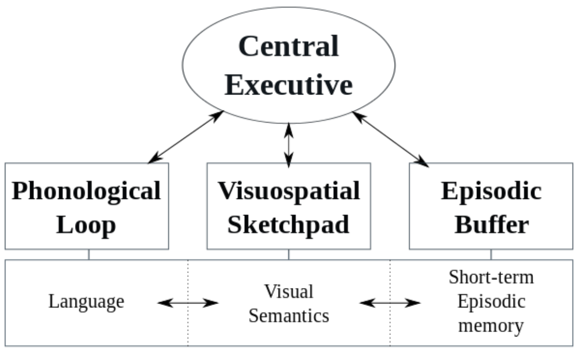

Figure 3. Baddeley’s model

The CE performs various tasks while coordinating and manipulating the information. For example, unnecessary information would be inhibited, retrieval strategies would be switched to activate long term information (Baddeley, 1996; Miyake et al., 2000). The PL and the VS are considered to be slave systems and are responsible respectively for storing phonological and visual- spatial information, while coordination of information is being coordinated by the CE (Oberauer, Süß, Wilhelm & Wittman, 2003). Thus, while the CE component is assumed to work both with PL and VS information, the slave systems are very specific and depend on a domain (D'Amico & Guernera, 2005). The PL enables temporary storage of verbal material, and the VS manages the maintenance and manipulation of visual and spatial representations (Baddeley, 1986). The fourth component, the episodic buffer, specializes in connecting information across informational domains and memory subsystems into integrated chunks (Baddeley, 2000). The episodic buffer is relatively new component of the working memory model and have not been studied properly. For this reason, this component was not considered in the present study.

1.4.1 Central Executive (CE)

One of the most outstanding components of working memory is CE (Baddeley, 2007; Baddeley, Eysenck, & Anderson, 2009). Fundamentally, it executes to direct attentional focus during task performance, dividing and switching between coincident activities or important target information if required, and also connecting to working memory and long-term memory (Baddeley & Hitch, 1974). A variety of concepts were developed for individual functions, such as; using an individual difference perspective and functional neuroimaging (Bledowski, Kaiser, & Rahm, 2010; Cowan, 2005; Oberauer, 2010). According to the individual differences approach (Miyake et al., 2000), a set of executive functions relating to CE component of working memory belongs to correlated but separable components which are inhibition, updating and shifting. "Inhibition" is the ability to restrain dominant responses which are not relevant. Monitoring and coding relevant information, and then replacing old information with more relevant one are attributed to “updating”. Finally, “shifting” provides to switch back and forward between coincident tasks.

This approach (Miyake et al., 2000) supports the concept of working memory executive functions. The CE system of Baddeley (2007) and executive functions are corresponding in their functions. Miyake's executive function model provides appropriate means to understand the CE system of working memory. Logie (2011) asserted that the CE system composes of executive functions’ tasks which are focusing, sustaining attention, switching, updating, inhibition, encoding, and retrieval. In addition, according to Dehn (2014), both working memory and executive functions consist of same activities, such as inhibition, updating, shifting and focusing. This wide range performance in working memory demonstrates the capacity of CE (Engle et al., 1999). In this perspective of working memory capacity, the ability of controlling and allocating attention during complex cognitive tasks is more functional than the ability of storing information. Greater attentional control represents greater working memory capacity.

1.4.2 Phonological Loop (PL)

In the view of the multicomponent model of working memory, information in the form of auditory-verbal or auditory-nonverbal is stored in a phonological code and is maintained by an articulation-based rehearsal system (Baddeley, 2012). Phonological information is held and coded as phonological representations which are maintained in PL, before they are transformed to long term memory (Gathercole & Baddeley, 1993).

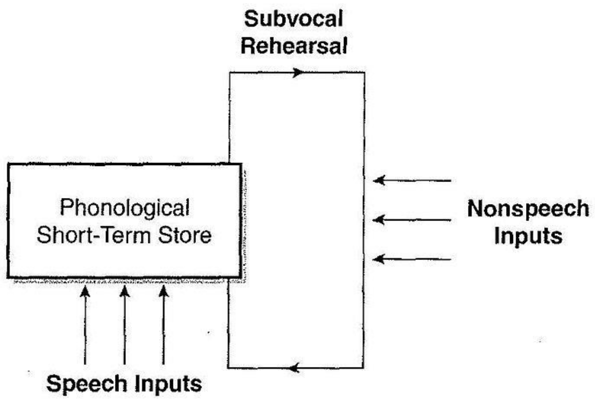

Figure 4. Baddeley's model of the PL (Baddeley, 1986)

In another word, the PL is related to time which is used for storage of short-term verbal information. The performance on the task bases on the speed of articulation and recalled items such as rehearsal of the stimulus. Deteriorated indications are refreshed and recalled more efficiently by the rehearsal of items held in phonological store. Thus, the speed with which such items can be articulated and rehearsed is critical (Baddeley, 1986).

1.4.3 Visual-Spatial Sketchpad (VS)

The VS is known as including two subsystems; one is a passive visual component where materials are retained as their colors and shapes and the other is a spatial system where movement and spatial information are retained (Logie, 1991).

The VS involves spatial short-term memory and object memory. These two different pathways are very important for controlling different functions in the brain. The object memory relies on learning and remembering what an object is, whereas the spatial memory is ability to learn and remember where the representation of an object differs with other objects (Baddeley et al., 2009). This different visual pathway in the brain contributes to finding spatial representation of a person with her/his environment (Denis et al., 2012).

1.5 Components of Working Memory in Math

Each component of Baddeley's working memory model is assumed to have specific roles in math (DeStefano & Lefevre, 2004). The role of working memory especially in arithmetic is considered as a dual task performance. Dual task method relates to the performance of two simultaneous tasks, such as solving simple arithmetic problems, while carrying out a secondary task, such as articulating syllables (Hitch and Baddeley, 1976).

The studies for dual task showed the functions of CE in arithmetic and explained its responsibility for monitoring and coordinating different steps while solving arithmetic problem (Fürst & Hitch, 2000; Imbo & Vandierendonck, 2007b; Imbo, Vandierendonck, & De Rammelaere, 2007). The role of PL in arithmetic is assumed to counting or keeping track of the operands while calculating (Fürst & Hitch, 2000; Imbo &Vandierendonck, 2007b; Noël, Seron, & Trovarelli, 2004). Studies for VS are not widespread but it is acknowledged that the VS manages spatial information, such as number arrangement and carrying in multi-digit calculation (Trbovich & Lefevre, 2003).

The Evidence of studies has indicated the significance of PL in both counting and maintaining information while performing arithmetic operations (Bull, Espy, & Wiebe, 2008; Imbo & LeFevre, 2010; Logie, Gilhooly, & Wynn, 1994). It is studied that PL is involved in addition (Lemaire, Abdi, & Fayol, 1996), subtraction (Seyler, Kirk, & Ashcraft, 2003), and multiplication (Seitz & Schumann-Hengsteler, 2000). PL is responsible for manipulating numerical information when doing carry operations (Logie et al., 1994; Fürst & Hitch, 2000). Hecth (2002) examined PL and claimed that PL differed from general working memory. He defined that PL was responsible for storing intermediate values, while general working memory system was connected with integrating procedures for calculations. It is demonstrated that there are relationships between PL and calculation procedures such as counting, maintaining problem information, and retaining information during counting (Fürst & Hitch, 2000; Logie & Baddeley, 1987).

Various number of studies also have demonstrated the relationship between arithmetic and VS component of working memory (Dumontheil & Klingberg, 2012). According to Simmons et al. (2012), VS plays important role in symbolic magnitude and written additional problems. Logie et al. (1994) also showed the involvement of VS in arithmetic, when problems were given visually. Heathcote (1994) proposed that solving multi-digit sums was regarded with visual and spatial performance. Heathcote (1994) examined that VS was engaged in retaining carries, PL was engaged in retaining interim long-term store through articulatory rehearsal. Geary et al (2007) studied the role of VS in arithmetic operations in children. It was found that VS was responsible when using counting strategies for complex addition, but not for simple addition.

1.6 Working Memory Related to Age

It is mentioned in various studies that the relationship between working memory and math changes with age (McKenzie, Bull, & Gray, 2003; Andersson & Lyxell, 2007; Kyttälä, Aunio, & Hautamäki, 2010; Henry & MacLean, 2003; Holmes & Adams, 2006; Rasmussen & Bisanz, 2005). Younger children are more dependent on visual-spatial strategies to solve arithmetic problems, while older children use verbal strategies which do not necessitate involvement of the VS.

Van der Ven et al. (2013) induced the long-term store for the reduction in the relationship between VS and mathematic ability in children's older ages. However, according to Tronsky (2005), children of any age may consider VS when challenging math problems are presented. Visual-spatial representations, such as; number lines, and visual-spatial strategies, such as; finger counting are used more by younger children (De Smedt et al., 2009; Geary et al., 2004). In older ages, children's answers of math problems turn into verbally memorized, verbal strategies and representations are used more (De Smedt et al., 2009; Holmes&Adams, 2006).

The involvement of VS to all four different math domains varies by age. The relationship with visual-spatial working memory becomes diminished with age in addition and subtraction, but not in multiplication and division (Van de Weijer-Bergsma et al., 2015) since retrieving verbally memorized procedures are used to solve multiplication and division problems, whereas addition and subtraction problems are managed by manipulation and visualization (Van der Ven et al., 2013). According to Van der Ven et al. (2013) about the relationship between VS and arithmetic abilities, addition and subtraction have the non-negligible relationship with VS, whereas the relationship with multiplication and division is not strong enough. On the other hand, verbal and retrieval strategies take place of the strategies in addition and subtraction in later grades.

Although there is enough evidence for the relationship between working memory components and math, the role of the slave system is not understood clearly. It is asserted that only PL can predict math performance of primary school children (Hecht et al., 2001). According to Swanson and Kim (2007), PL component is unique predictor of math achievement only for students who are 6 to 10-year-olds. However, another study about this relationship indicates that PL is also related with math in 7 to 8-year-olds children (Gathercole and Pickering, 2000b). According to Geary and colleagues (2000), there is no association of PL with math for children who has math disabilities. For instance, the PL performance changes between children managing low and high math ability (Bull and Johnston, 1997).

Other components have not been studied properly. Passolunghi and colleagues (2007) mentioned that the central executive had an important role in individual differences in math performance for students who were at the end of first grade, but not PL. However, the CE had involvement with the PL in single digit addition (Noël et al., 2004). The VS ability has not been investigated properly, thus its prediction in math performance is not clear.

Later studies have indicated significant relationship between the VS and individual differences in math performance for primary school children who are at different ages (Holmes & Adams, 2006; Holmes, Adams, & Hamilton, 2008). Gathercole and Pichering (2000a) showed in their study that children who had mathematical disabilities relied on VS resources. The association between the VS and math performance varies by age. Holmes et al. (2008) claimed that 7- and 8-year-old children are more reliant on the VS than 9- and 10-year-old children (Holmes and Adams, 2006). another research showed that 6- and 7-year-old children were addicted seriously to the visual-spatial resources on the arithmetic performance, while impairments of arithmetic performance and VS tasks returned to decrease on 8- and 9-year-old children (McKenzie et al., 2003). In addition, Rasmussen and Bisanz (2005) revealed that math performance of preschooler children was affected by VS, whereas the impact evanished on first grade children.

The long-term memory from studies suggest that the contribution of the VS to math performance is related to age and younger children rely more on VS when performing mathematical skills.

1.7 Working Memory Related to Strategy Use

The effect of working memory in the strategy use when solving calculation problems was investigated in recent studies. Geary and his colleagues (2004) studied the engagement of working memory in the strategy choice of students in 1, 3 and 5 grades when they are solving simple and complex addition problems. The finding demonstrated that the ability of solving complex arithmetic problems relied on higher working memory capacity (Adams & Hitch, 1997). On the other hand, it is supposed that the relations between working memory and complex arithmetic problems relied on particular strategies (Geary et al, 2004). From this view, higher working memory capacity provided more appropriate strategies (i.e. decomposition), while lower working memory resulted in less appropriate strategies (i.e. finger counting).

Working memory components have more important role in procedural than retrieval strategies. It is found that PL which is loaded by an articulatory suppression task makes participants' responses slower when they do calculation to confirm an addition problem without using direct retrieval (Hecht, 2002). Nevertheless, they try various strategies to develop an answer to a problem (Geary et al, 2004; Campbell & Tarling, 1996). For instance, an order of strategies was used to solve single digit addition and subtraction problems with retaining and repeating letter strings which they listened in order to understand the role of working memory in calculation (Imbo and Vandierendonck, 2007b). They used counting and decomposition, but not retrieval strategies. Therefore, it can be asserted that verbal working memory plays a greater role in procedural than in retrieval strategies (Hubber et al., 2014).

1.8 Multiplication Skills

Multiplication skill is a fundamental skill for primary school children. Therefore, being master of this skill is required for students in order to solve multiplication problems. Students start to build on multiplication concepts in third grade and they become able to solve different types of multiplication problems in fifth grade (MoNE, 2015).

Several studies have been investigated to understand the effects of working memory components on multiplication skills. Hecht (2002) studied the distinguished impact of CE and PL components in simple arithmetic. According to Seitz and Schumann-Hengsteler (2000), simple multiplication had association only with CE resources, while complex multiplication necessitates both PL and CE resources. It is also examined that the CE was related to all strategies, such as; retrieval, transformation, counting, whereas PL was related to only counting (Hecht, 2002). Furthermore, the contribution of working memory to complex multiplication was studied and resulted in the significant impairment of working memory and non-retrieval strategies when solving multiplication problems (Tronsky, 2005). Imbo and Vandierendonck (2007b) revealed that direct retrieval and non-retrieval strategies of multiplication associated with both CE and PL, whereas PL was related to only non-retrieval strategies. In this study, the function of working memory in retrieval and non-retrieval strategies was specialized for multiplication performance. In addition to this, Wu (2010) examined the effect of working memory on mental addition and multiplication. The long-term store showed that the children with greater working memory counted on direct retrieval from long-term memory and the children with average working memory performed mental counting strategies more often than the children with below-average working memory.

Recent studies indicate that multiplication facts are stored as a form of verbal representations and their retrieval is based on verbal codes. These studies explain the significant relation of PL component with arithmetic fact retrieval (De Smedt, Taylor, Archibald, & Ansari, 2009). Since multiplication is regarded as an articulatory skill, it can be asserted that PL resources predict this skill as reading, however, numbers and symbolic representations are more dependent on VS component (Simmons, Willis & Adams, 2012). Therefore, the impact of PL becomes decrease in reading these representations.

Although the evidence of the studies demonstrates the important effect of verbal coding in arithmetic fact retrieval, young children use nonverbal mental models when doing calculation (Rasmussen & Bisanz, 2005). The role of VS is remarkable in calculation for them since they apply to VS functions in order to making connection between quantities and number words by using nonverbal mental models when counting objects (Krajewski & Schneider, 2009). However, there is not supporting evidence that nonverbal mental models are efficient when a problem is presented in an audial form.

The researches show that verbal and retrieval strategies play significant role in learning multiplication facts by performing verbal memorization. Roussel and colleagues (2002) revealed that children become experienced in verbal memory strategies (i.e., direct retrieval strategy) gradually. For instance, children rehearse arithmetic facts until they store them in their memory and retrieve them directly if they need to. Multiple-digit multiplication problems are solved by using multiplication algorithms (MoNE, 2015).

The multiplicand is multiplied by each digit of multiplier and added to long-term store, but memorization of the multiplication facts for single digits is necessitated to manage this process (Zhou et al., 2011).

The memorization of multiplication facts (i.e., knowing that 5 × 4 = 20) is acknowledged as direct memory retrieval which is regularly used. The procedural strategies, such as; transformation (e.g., ., 9 × 7 = (10 × 7) – 7 = 70 – 6 = 63), associative property (e.g., 35 × 15 = 35 × 3 × 5) and counting (e.g., 3 × 6 = 3 . . . 6 . . .9 . . . 12 . . . 15 . . . 18) may be alternative choice to solve multiplication problems are nonretrieval and preferred to be used (Hecht, 1999; LeFevre, Bisanz, et al., 1996; Seitz et al., 2000). The involvement of working memory in multiplication reduces the difficulty of problem when strategies are used (Tronsky, 2005). For instance, multiplication algorithm is required for solution when the problem of complex multiplication (e.g., 32 × 18) is tried to be solved without any strategy. In order to diminish the difficulty of the problem, associative property strategy may be used to transform it to different form (e.g., 32 × 6 × 3). However, the involvement of working memory becomes reduced practically when students apply the strategies to solve these multi-digit multiplication problems.

In the view of strategy using, it was examined that normal-achieving students were able to make decision about more appropriate strategy which they met their cognitive capacity to solve the problem (Siegler, 1995). According to Siegler (1988), the direct retrieval strategy provides much faster process to solve problems and it is applied when students can use their memory of multiplication facts. Procedural strategies may contribute to time-consuming and more errors, but if students do not trust their direct retrieval skills, using these strategies can enable them to obtain a correct answer of a problem. For example, Steel and Funnell (2001) studied with 8- to 12-year-old children who used direct retrieval and procedural strategies (e.g., calculation and counting-in-series) to solve multiplication problems. It was attained that retrieval strategy provided faster speed and less error among other strategies. However, it is difficult to understand the specific strategies in which CE and PL resources are required.

1.9 Related Researches

In this section, related various publications and researches in the literature were indicated for both multiplication skills and working memory components.

1.9.1 Researches Related to Multiplication Skills

The several number of researches about multiplication skills were examined and some of them were mentioned in this section.

Wong and Evans (2007) studied with the primary school children in order to improve their recall for basic multiplication fact. The computer-based multiplication program was applied to five classes. For the computer-based program, there were 37 participants whose age range was 120-138 months. There were 27 participants whose age range was 116-138 months, but they used only pencil and paper for the instructions. After these programs were implemented for a month, the study resulted with the increase in the basic multiplication fact recall of both two group of participants.

Bobis (2007) examined the computational fluency with multi-digit multiplication. The aim of this study is to improve the computational fluency of the primary school children. This study focused on the relationships between number learning and children's computational abilities in writing and mentally. The author indicated that the advance of number learning was very important for comprehending math basically and children's computing ability.

Zhang, Ding, Barrett, Xin and Liu (2014) compared the ability of solving multiplication problems between three groups of students who were low-achievers, average-achievers and high-achievers. The participants consisted of 19 high-, 48 average- and 17 low-achieving students. Three different multiplication tests were applied to all participants to understand how they solved these problems. It has been found that whereas low-achievers did not perform correct strategies for the operations without multiplication concepts, high-achievers were successful in solving multiplication problems and using correct strategies.

Zhang, Xin, Harris and Ding (2014) studied the improvement of strategic development in multiplication for the third grade children who had difficulties in math. The purpose of this study was to examine how the strategic training programs improved children's problem solving abilities in multiplication. In this study, micro-genetic analysis was conducted in order to understand children's problem solving abilities and strategic development. The results showed that only three students developed their problem solving skills and ability to select proper strategy.

Reed, Gemmink, Broens-Paffen, Kirschner and Jolles (2015) investigated the fluency of multiplication facts while selecting the correct answer from competing answers. The purpose of this study was to analyze the influence of using two conditions for students' fluency while solving simple multiplication problems. The participants consisted of 282 third and fourth graders. In the practice, they gave their own answer for the "recall condition" and they tried to choose the answer between competing ones for the "choice condition”. It was resulted that practicing the “choice condition” was fast and accurate but not efficient to performance on tests.

1.9.2 Researches Related to Components of Working Memory

There are various number of researches about working memory in literature and some of them were presented in this section.

Passolunghi and Costa (2016) studied pre-school children’s number sense and working memory. The purpose of the study was to confirm and analyze the influence of two teaching techniques on children’s early number skills. The participants consisted of 48 preschool students with the age of five. The programs for both “working memory” and “early numeracy training” were applied to the students for 5 weeks. Both the working memory and early numeracy training programs were implemented for 5 weeks. It was resulted that while the working memory training program developed children’s both working memory and early numeracy abilities, the early numeracy training program developed only their early numeracy abilities.

Sánchez-Torres, Elosúa, Lorente-Omeñaca, Moreno-Izco and Cuesta (2015) examined the “multicomponent model” of working memory. The purpose of the study was to investigate the working memory components which were evaluated by Baddeley and Hitch. There were 42 participants including 21-patient with working memory deficits and 21-healty control group. Clinical measurement was applied to the patients. Working memory deficits are considered nuclear deficits in psychotic disorders. The aim of this study is to evaluate the components of the Baddeley and Hitch working memory model. 21 patients with a psychotic disorder and 21 healthy controls were recruited for the study. It was revealed that there was not strong association between the performances of patients and control group when the amount of tasks were increased.

Souza, Rerko, and Oberauer (2015) investigated the memory refreshing. The aim of this study is to understand how often an item is renewed for improving recalling the item from the visual working memory. Three experiment groups were conducted to the study. It was revealed that refreshing made the visual symbols accessible for recall.

Palmer and Mattys (2016) studied the speech segmentation supported by working memory. The aim of this study was to understand which working memory resources are recruited during statistical learning. Three experiment groups were conducted to the study. It was claimed that statistical learning is supported by working-memory processes that rely on domain-general resources (i.e. phonological rehearsal).

Maehler and Schuchardt (2016) studied the significance of working memory for primary school children's school achievement in the learning disability manner. for school achievement in primary school children with intellectual or learning disabilities. The purpose of this study is to investigate the role of Baddeley's (1986) working memory sensory for the school achievement. A set of 14 tasks for the PL, the VS and CE skills was applied to four-group of children varying in IQ and school success. The study resulted that by the regardless of intelligence, the children with sub-average school achievement showed deficits in working memory performance, whereas the children with regular school achievement did not display working memory deficits.

1.10 The Purpose and Significance of the Research

Arithmetic operations are one of the most important skills which have the first priority of learning math. The four operations: Addition, subtraction, multiplication and division constitute the foundation of math teaching (NCTM, 2000). Children have difficulties while they are solving multiplication problems (Rotem & Henik, 2013). A variety of cognitive processes and strategies are required in order to perform mental and written computation (Bobis, 2007). From this view, the activities, such as the ability to manipulate, monitor and store information in mind which are indispensable for arithmetic operations depend on working memory (Raghubar, Barnes, & Hecht, 2010; De Stefano & LeFevre, 2004).

The overall purpose of this study presented as to investigate the effect of the different components of working memory on multiplication skills of 3rd grade children. For this purpose, the contents of the math curriculum, math learning processes, multiplication skills, working memory and its components, the relationships between components of working memory and arithmetic operations were examined. Research problem statement and sub-problems are structured in the following.

1.11 Research Questions

This study aims to address the following problem: Which components of working memory are able to predict multiplication skills of 3rd grade children. Four sub-questions are formulated to answer this main question:

a) What is the relationship between central executive (CE) component and multiplication skills of 3rd grade children?

b) What is the relationship between phonological loop (PL) component and multiplication skills of 3rd grade children?

c) What is the relationship between visual-spatial sketchpad(VS) component and multiplication skills of 3rd grade children?

d) Which components of working memory is the best predictor of multiplication skills of 3rd grade children.

1.12 Assumptions of the Study

The research is based on the following proposition;

- It was assumed that all participants provided honest and accurate information during the scales.

1.13 Definitions

CE component of working memory: The score of each student who received from the Counting Recall Test (CRT)

PL component of working memory: The score of each student who received from the Digit Span Test (DST)

VS component of working memory: The score of each student who received from the Block Recall Test (BRT)

Multiplication skills: The score of each student who obtained from Multiplication Test (MT)

CHAPTER II

METHOD

This chapter includes six sections. In the first section, research design is summarized. The second section explains the participants of the study. The measuring instruments are explained in third section. Then, data collection procedure and data analysis were presented, respectively.

2.1 Design of the Study

The current study was conducted to correlational design. It is known that correlational design contains two forms. The first form is known as a relational design to interpret the relationships or association between two or more than two variables. This form is also called as a “simple bivariate correlational design”. A second type of correlational design is called as a prediction design. The purpose of this design is to identify variables that can effectively predict some outcome or criterion. The variable being predicted is called the criterion variable, and the variable or variables being used to predict the criterion are called predictors. When a study involves only two variables, the predictive relationship is estimated with a statistical procedure called simple linear regression. When more than one predictor variable is used to predict a criterion, the analysis is called multiple regression. This is an extremely powerful statistical procedure that can estimate the collective as well as the individual contributions of all predictor variables (Tabachnick & Fidell, 2007).

This study aimed to examine whether the different working memory components predicted multiplication skills of 3^{rd} grade children. Based on this objective, the study was defined as a predictive correlational study and linear multiple regression analysis was used.

2.2 Participants

The participants of this research are 60 third grade students at ISTEK Kemal Atatürk Primary School in Istanbul. These 60 students (23 female and 37 male) were included into the study with the permission letter of their parents. Participants' age ranged between 8 and 9.

2.3 Data Collection Instruments

Several number of computer-based measuring instruments which were developed to evaluate the capacity of working memory were present at the literature. Children were given a variety of tasks and how much they remember these tasks was measured in order to evaluate their working memory capacities. In this study, students' capacity of different components of working memory were measured by the instruments: Counting Recall Test (CRT) for central executive (CE) component, Digit Span Test (DST) for phonological loop (PL) component, Block Recall Test for visual-spatial sketchpad (VS) component (Pickering & Gathercole, 2001). The online versions of these tests were developed by Asst. Prof. Dr. Alper Bayazıt. Multiplication Test (MT) was used in order to evaluate students' multiplication skills. The test questions were created with regard to the objectives of third grade math curriculum.

2.3.1 Counting Recall Test (CRT)

In order to determine central executive capacity of the students, Counting Recall Test (CRT) was used. In this test, there are a set of different geometric shapes together on the screen and it is expected that one of the given shapes will be counted and recalled by the students at the and of all series of screens.

The test which was used in this research, started with counting rounded shapes in two consecutive frames on the screen and entering these two numbers which were hold in mind on the frame of the result. After students passed this level, they performed the next level which included three frames of the counting and the frame of the result which they entered three digits. So, next level had one more frame than previous level. The test ended with the level which consisted of ten frames of the counting. Students gained one point for each level. There was no time restriction. Students passed each frame by themselves by clicking "İleri" button.

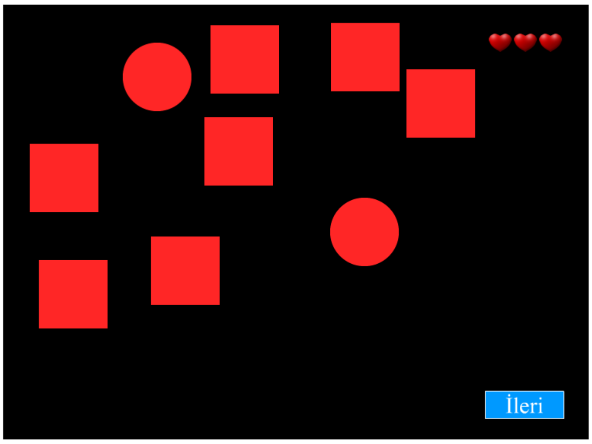

Figure 5. CRT Step 1 (example of 1st level)

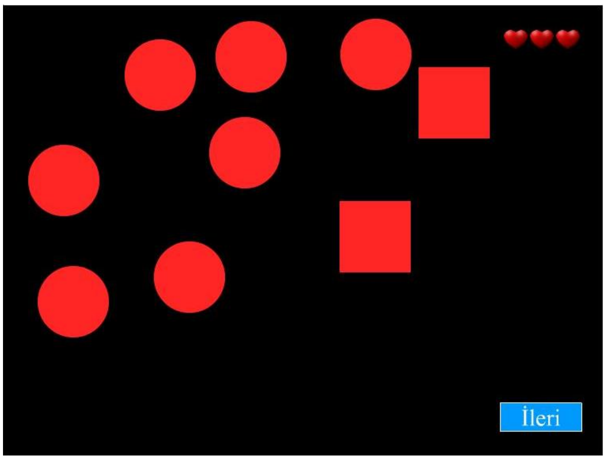

Figure 6. CRT Step 2 (example of 1st level)

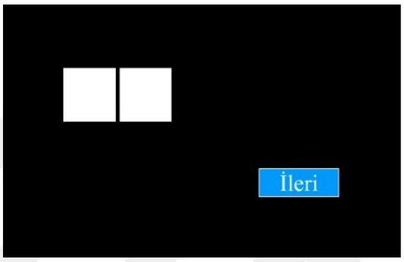

Figure 7. CRT Result Page (example of 1st level)

For validity of the CRT, comments form was used. Three specialists who study in the area of cognitive science and educational science wrote their comments for each test of working memory. They approved the CRT to measure components of working memory.

Alternative-form method was used in order to understand the reliability of the CRT. The Backward Digit Span Test was also applied to the same participants as an alternative test. In order to estimate the reliability, the correlation between these two parallel tests was considered. There were positive and statistically significant correlation between the CRT and the Backward Digit Span Test ($r(58)=.29$, and $p=.02$, $p<.05$). After the reliability test, the CRT was decided to use as a scale of the CE capacity.

2.3.2 Digit Span Test (DST)

In order to determine phonological loop capacity of the students, Digit Span Test (DST) was used. In this test, a string of numbers word is seen on the computer screen and then the students will be responsible to repeat it in the same order.

The test which was used in this research, started with two-digit numbers which were seen one by one. Students kept these two numbers at Figure 8 and Figure 9 and entered them in order to the result page at Figure 10. Next level had one more digit than previous level. The test included ten level in which ten-digit numbers were seen. Students had to enter 2- 6 respectively and one-by-one in the example shown below. Each number was seen on the screen 1 second. There was no time restriction when they enter numbers to the frame of the result.

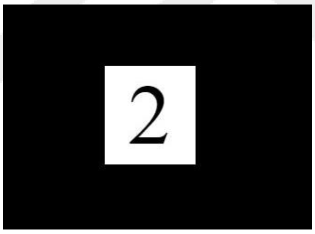

Figure 8. DST step 1 (example of 1st level)

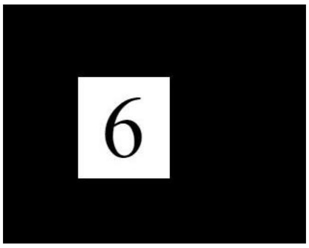

Figure 9. DST step 2 (example of 1st level)

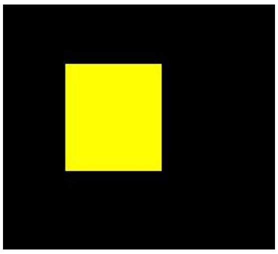

Figure 10. DST the result page (example of 1st level)

For validity of the DST, comments form was used. Three specialists who study in the area of cognitive science and educational science wrote their comments for each test of working memory. They approved the DST to measure components of working memory.

Alternative-form method was used in order to understand the reliability of the DST. The Backward Digit Span Test was also applied to the same participants as an alternative test. In order to estimate the reliability, the correlation between these two parallel tests was considered. There were positive and statistically significant correlation between the DST and the Backward Digit Span Test ($r(58)=.38$, and $p=.00$, $p<.05$). After the reliability test, the DST was decided to use as a scale of the PL capacity.

2.3.3 Block Recall Test (BRT)

In order to determine visual-spatial sketchpad capacity of the students, Block Recall Test (BRT) was used. In this test, a number of blocks appears to the students as a random arrangement on their computer screen. A set of blocks blinks one by one and then the students will be responsible to select blinked blocks in the same order they blinked.

The test which was used in this research, started with a block that blinked and students clicked the place of the block. After they passed the first level, two blocks blinked one-by-one (Figure 11) at the second level. After the last block disappeared, students clicked on the place of the block that blinked in the same order. (Figure 12). The number of blocks increased one more than the previous level. The test included ten levels in which ten blocks blinked. The block that blinked stayed on the screen 1 second.

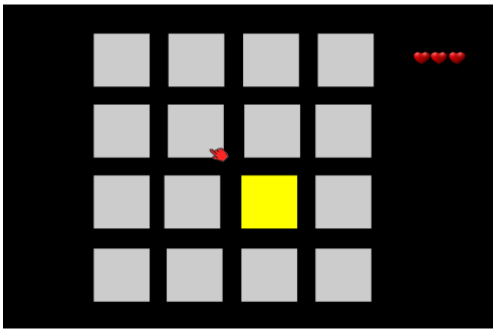

Figure 11. BRT step1 (example of 2nd level)

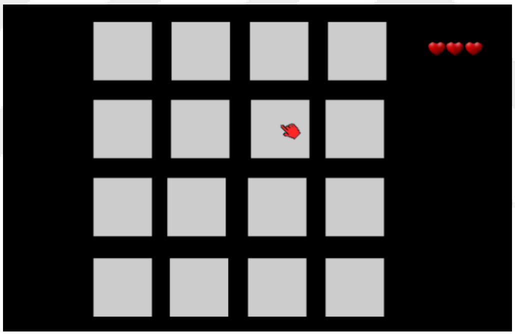

Figure 12. BRT the result page (example of 2nd level)

For validity of the BRT, comments form was used. Three specialists who study in the area of cognitive science and educational science wrote their comments for each test of working memory. They approved the BRT to measure components of working memory.

Alternative-form method was used in order to understand the reliability of the BRT. The Block Recall Test 2 was also applied to the same participants as an alternative test. In order to estimate the reliability, the correlation between these two parallel tests was considered. There were positive and statistically significant correlation between BRT and the Block Recall Test 2 ($r(58)=.30$, and $p=.02$, $p<.05$). After the reliability test, the BRT was decided to use as a scale of VS capacity.

2.3.4 Multiplication Test (MT)

MT is used to determine multiplication skills of 3rd graders. The test was prepared according to learning objectives of math curriculum of Turkey. It includes five groups of questions. Each group of questions involves different objectives of multiplication skills in the 3rd grade math curriculum:

- First group of questions involves the objective of multiplying a two-digit natural number with one-digit number and includes four separate questions.
- Second group of questions involves the objective of multiplying a two-digit natural number with two-digit number and includes four separate questions.
- Third group of questions connects to the objective of multiplying a three-digit natural number with one-digit number and includes four separate questions.
- Forth group of questions is composed of the objective of multiplying at most three-digit natural numbers with 10 and 100 briefly and includes five questions.
- Fifth group of questions involves the objective of multiplying at most three-digit natural numbers with multiples of 10 briefly and includes five questions.

Therefore, there are 22 questions in the multiplication test. Each number was chosen differently in order to enable students to multiply with all numbers from multiplication table. The students used carry operations while doing multiplication. Each answer was evaluated according to its definite result. The student received one point if his/her answer was correct. He/she received zero point if his/her answer was incorrect.

Cronbach's alpha was used in order to estimate the reliability of the multiplication test. The coefficient was .80 and this showed that the test was highly reliable because the cronbach's alpha was found between .80-1.00 (Field, 2005).

2.4 Data Collection Procedure

A set of four scales which consists of CRT, DST, BRT and MT were administered to collect data. Before collecting data, permission was taken from ISTEK Kemal Atatürk Primary School and then, permission letter was sent to each student's parent to apply these tests. The scale administration took place in 2016 spring semester on May. The tests were applied to three classes in the computer laboratory. There were approximately twenty students in each class. Three sessions were done and each session completed in an hour. Instructions of the scales were explained to each class before applying the tests. Students were divided into four groups and an instructor guided to each group of students during the class hours. The measures took 40 minutes to complete.

A computer was equipped for each student. Each of them had their own account to log in the system where they applied the working memory tests. All tests included video and all instructions about how to manage tests were explained step by step before they started applying them. After they started the tests, they were not met any instructions above the questions in order to avoid cognitive load. They had three chances for each test to complete the test.

2.5 Data Analyses

In this study, the predictive model fitted to our data to predict values of the dependent variable from more independent variables (Field, 2005). There were three independent variables to predict the dependent variable in this study. From this view, the multiple regression analysis which was used to predict outcome from more than one predictors was chosen. The MT (for multiplication skills) being predicted was called the criterion variable, and the CRT (for CE), DST (for PL) and BRT (for VS) being used to predict the criterion were called predictor variables in this study. This is an extremely powerful statistical procedure that can estimate the collective as well as the individual contributions of all predictor variables (Tabachnick & Fidell, 2007). Before the regression analysis, the simple bivariate correlational design was used to describe the relationships among the variables.

SPSS 20.0 (Statistical Package for Social Sciences) for windows was used to execute data analyses.

CHAPTER III

RESULTS

In this chapter, the results of this study are presented in three sections. In the first section, the results of descriptive statistics are explained. The second section includes inter-correlations between the predictor variables and the criterion variable. In the third section, the results of multiple regression are presented with the checked assumptions.

3.1 Results of Descriptive Statistics

Descriptive statistics were used to define the predictor variables called as: Visual-spatial Sketchpad (VS) (measured by Block Recall Test (BRT), Phonological Loop (PL) (measured by Digit Span (DST)) and Central Executive (CE) (measured by Counting Recall Test (CRT)) components of working memory, and the criterion variable which was multiplication skills (measured by MT). Table 3.1 showed the means, standard deviations of the whole variables by using test scores. The maximum and minimum scores of these variables were also displayed in Table 3.1.

Table 3.1

Descriptive Statistics of the Students' Scores

	Min	Max	Mean	SD	N
MT	5	22	14.5833	4.12225	60
CRT	2	8	5.5667	1.38229	60
DST	2	8	5.8167	1.01667	60
BRT	2	7	5.3000	1.35672	60

The maximum scores of the working memory tests were hypothetically limitless, except BRT whose maximum scores were 25. The minimum and maximum scores of the students were displayed in Table 3.1. The minimum and maximum scores were 2 and 8 points for CRT, 2 and 8 points for DST, and 2 and 7 points for BRT. In addition, the students received minimum 5 points and maximum 22 points from the MT.

Table 3.1 showed that the mean of the MT scores was 14.6 with the standard deviation of 4.1. The mean of the CRT scores was 5.6 with the standard deviation of 1.4. The mean of the DST scores was 5.8 with the standard deviation of 1.0. The mean of the BRT scores was 5.3 with the standard deviation of 1.4. It can be said that the mean scores of CRT, DST and BRT were close to each other.

3.2 Correlation Coefficients between Predictor Variables: CRT, DST and BRT and Criterion Variable: MT

The Pearson Product-Moment Correlation Coefficients computed to find out strength and direction the relationship between predictor variables (CRT, DST, and BRT) and criterion variable (MT) are displayed in Table 3.2. The inter-correlations among variables ranged from .23 to .37. There were positive and statistically significant correlation between MT scores and CRT scores ($r(58)=.37$, and $p=.004$, $p<.05$).

Moreover, BRT scores (r(58)=.26 and p=.046, p<.05) showed a significant correlation with MT scores. There were also positive correlations between MT scores and DST scores (r(58)=.23 and p=.074, p>.05), although it was not statistically significant.

Table 3.2

Pearson Product-Moment Correlation Coefficients between Predictor Variables: CRT, DST and BRT and Criterion Variable: MT

Variables	1	2	3	4
1. Multiplication Test	-			
Sig. (2-tailed)	-			
2. Counting Recall Test	.37*	-		
Sig. (2-tailed)	.004	-		
3. Digit Span Test	.23	.33*	-	
Sig. (2-tailed)	.074	.010	-	
4. Block Recall Test	.26*	.24	.26*	-
Sig. (2-tailed)	.046	.062	.043	-

*Correlation is significant at 0.05 alpha level.

3.3 Multiple Regression Analysis

A standard multiple regression analysis was administered to determine components of working memory which were able to predict multiplication skills of 3rd grade children. In this research, three sets of predictor variables, CRT (CE), DST (PL) and BRT (VS) were predicted the overall multiplication skills of third grade primary school students. The aim of the study was to examine to what extend each set of predictor variables predicted adjustment over and above the other sets. In accordance with the aim of the study, multiple regression analysis was employed to identify variables that explain the variance among the MT scores of third grade primary school students.

3.3.1 Checking Assumptions

At the beginning of the statistical analysis, the assumptions of the multiple regression analysis were examined. According to Tabachnick & Fidell (2007) there are four important assumptions: (1) Assumptions of normality, (2) assumptions of linearity, (3) assumptions of independent errors and (4) assumption of homoscedasticity.

1.Assumptions of normality: The normality assumption can be defined that being make sure the data are distributed normally around all variables before conducting to statistical analysis. Non-normally distributed variables can diverge from relationships (Tabachnick & Fidell, 2007). In order to test this assumption, various methods can be chosen: Kolmogorov-Smirnov (KS) test, skewness, kurtosis, visual inspection of data plots and Q-Q plots enable researchers to obtain useful information for normality. In this research, the Q-Q plots were used in order to test the assumptions of normality. Q-Q plots are used mostly to test the assumption of normality. Observed value and expected value are given on a plotted graph in this method. It is known that the data is not normally distributed if the plotted value distorts most from a straight line. If the value is around a straight line, this means data is normally distributed.

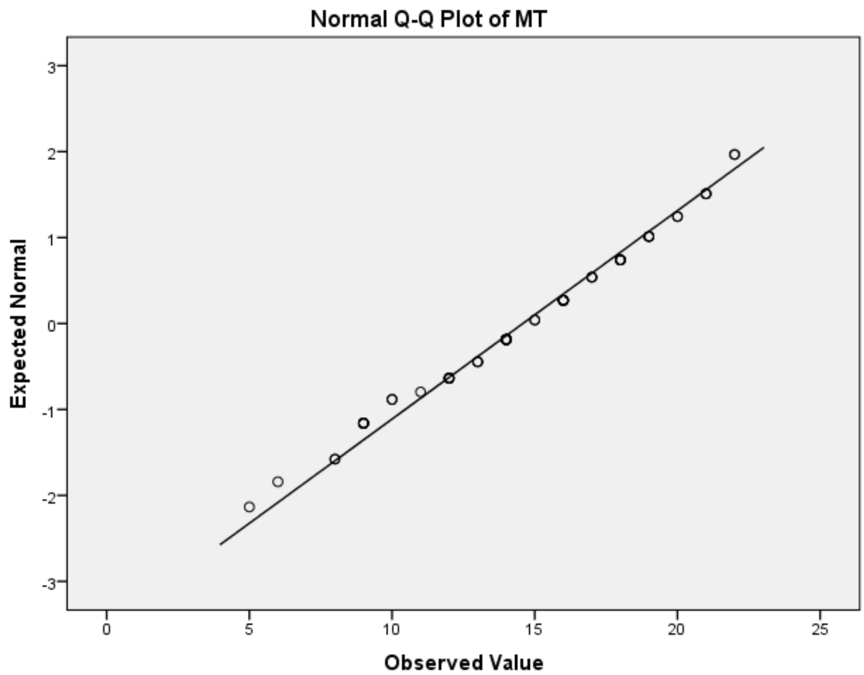

Figure 13. Normal Q-Q plot of MT

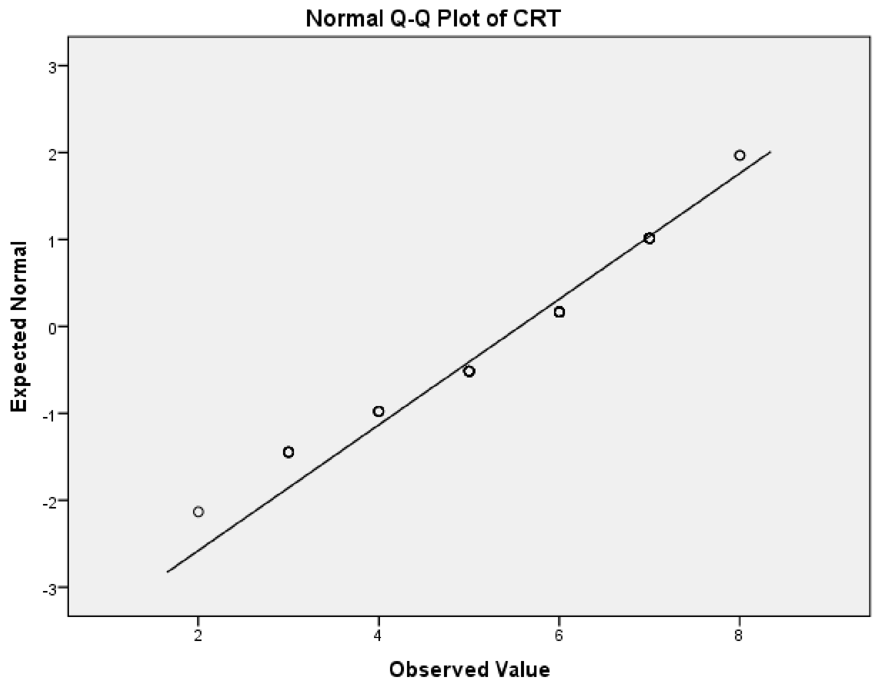

Figure 14. Normal Q-Q plot of CRT

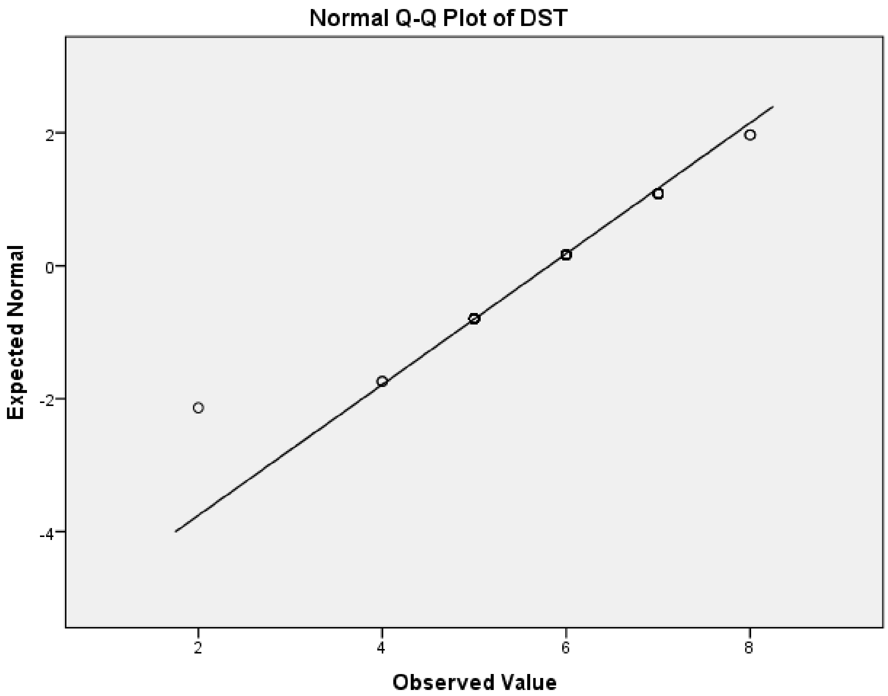

Figure 15. Normal Q-Q plot of DST

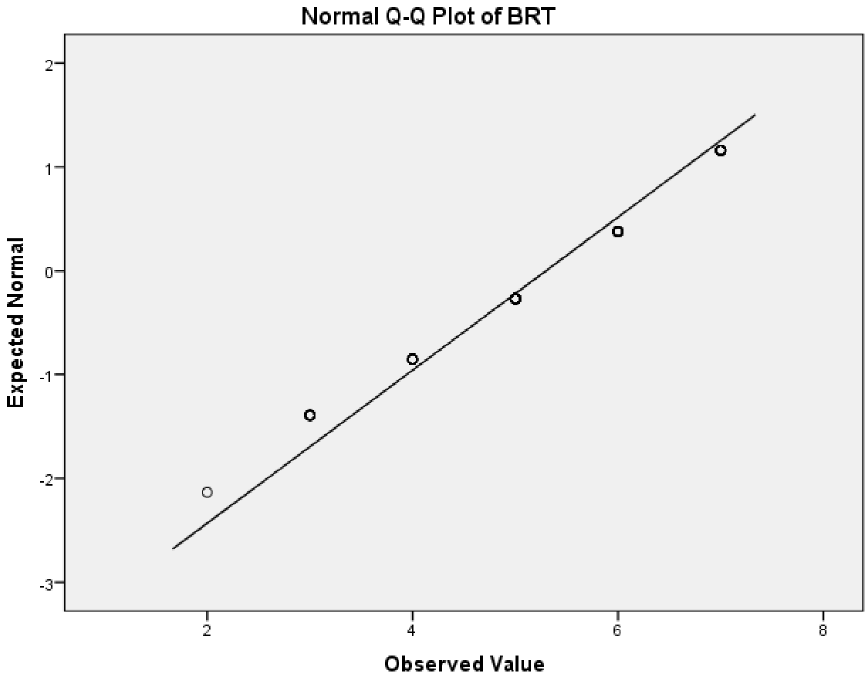

Figure 16. Normal Q-Q plot of BRT

Data for MT (shown in Figure 13), CRT (shown in Figure 14), DST (shown in Figure 15) and BRT (shown in Figure 16) did not vary more from a straight line, then the data was normally distributed.

In addition to Q-Q tests, the skewness and kurtosis were used for each variable in order to examine normality (shown in Table 3.3). Using skewness and kurtosis for normality test is also well-known. Skewness is measuring of a distribution asymmetry of a variable. A normal distribution of a skew value is zero for the symmetric distribution. Kurtosis is a measure of the peakedness of a distribution. The standard error is reported by SPSS for the skewness and kurtosis scores. The data are normal statistically if the error is greater than ±2.58(Field, 2005).

Table 3.3

Skewness and Kurtosis Values for MT, CRT, DST and BRT

Variables	**Skewness**	**Kurtosis**
MT	- .232	- .563
CRT	- .641	- .160
DST	- .619	2.311
BRT	- .445	- .639

Applying the rule of thumb of dividing each value by its standard error (the standard error was .309 for skewness; .608 for kurtosis), MT gave -.75 for skewness and -.93 for kurtosis, both well within ±2.58 limits, suggesting that the departure from normality was not too extreme. The values of CRT were -2.08 for skewness and -.26 for kurtosis, which meant the normality assumption was not violated for CRT scores. DST gave -2.00 for skewness and 3.80 for kurtosis, which meant the score for kurtosis exceeded the 2.58 limit. BRT gave -1.44 for skewness and -1.05 for kurtosis. The scores for BRT provided normal distribution.

The assumptions of normality were examined and no violation of normality assumption was found so that the multiple regression analysis could be conducted.

2. Assumptions of linearity: Multiple regression analysis is only used to predict the relationships between predictor variables and criterion variables when the relationships are linear. The results of the multiple regression analysis can not give the correct relationships if the relationships among the variables are not linear. The method of testing residual plots is desirable to detect the linearity.

In order to examine the linearity assumptions, the normal plot was composed. The straight line in Figure 17 represents the normal distribution and the points represent the observed residual.

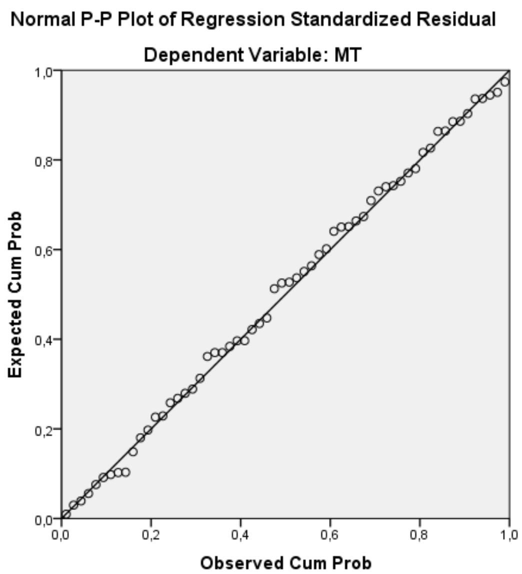

Figure 17. Normal P-P Plot of Regression Standardized Residual

3. Assumptions of independent errors: In order to test the assumption of independent errors of this study, the Durbin-Watson test was utilized. The prediction errors must be independent, but not correlated with each other. The value of the Durbin-Watson is ranged between 0-4. The residuals are not correlated with each other if the value is 2; the correlation is negative if the value is greater than 2; and the correlation is positive if the value is less than 2 (Field, 2005). In the present study, the value was 1.34 that meant

the error term was independent. indicated the independence of the error term. Thus, the assumption of independent errors was not disrupted.

4. Assumption of homoscedasticity: The standard deviation of residuals should be equivalent for all dependent variable scores for the assumption of homoscedasticity (Tabachnick & Fidell, 2007). The scatter plot of regression standardized residuals against regression standardized predicted values is preferred to examine the assumption of homoscedasticity (Field, 2005). The residuals were distributed randomly around zero in the scatterplot (see Figure 18). Therefore, this scatterplot proved the homoscedasticity.

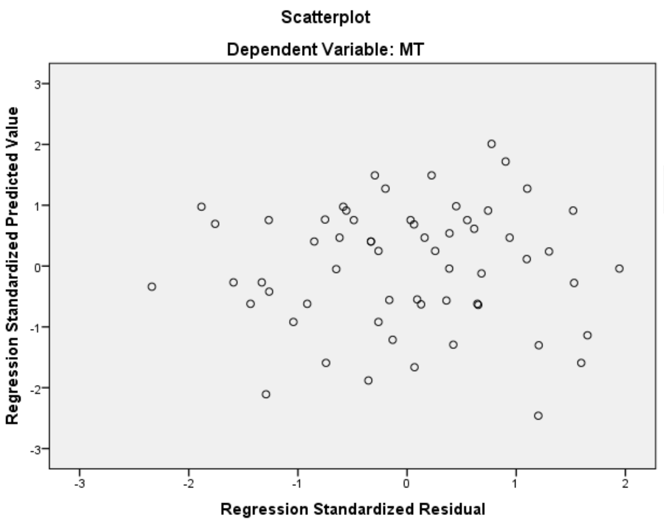

Figure 18. Regression Scatterplot

The statistical problems are created by multicollinearity and singularity if the correlation among the variables is .90 or greater than .90 (Tabachnick & Fidell, 2007). The predictor variables were not correlated highly with each other (see Table 3.2) in this study. Therefore, multicollinearity and singularity did not contribute to any problem for the current study. In addition, tolerance and variance inflation factor (VIF) can determine the multicollinearity. Tolerance must not be less than .10 (Menard, 1995) and

VIF must not be greater than 10 (Myers, 1990) for detecting the multicollinearity. Since the values of VIF changed between 1.11-1.16, tolerance statistics ranged between .904 - .857, there was no evidence that multi-collinearity was a problem for the suggested model.

3.3.2 Results of the Multiple Regression Analysis

As Table 3.3 indicated, the combination of three predictor variables together (CRT, DST and BRT scores) explained a significant amount of variance in MT scores of 3rd grade children:

$$R^2 =. 17;\ \text{adjusted}\ R^2 =.13;\ F\ (3,56) = 3.89,\ p=.014,\ p < .05$$

Table 3.4

Multiple Regression Analysis for the Ways of CRT, DST and BRT

Predictor Variables	***B***	***SE***	***β***	***t***	***p***	***Partial Corr.***
CRT	.88	.39	.30	2.27	.027	.29
DST	.37	.53	.09	.70	.486	.09
BRT	.50	.39	.16	1.28	.207	.17

The contributions of ways of CRT, DST and BRT explaining the multiplication skills were presented in Table 3.3. The results indicated that the combination of four variables explained 17 % of the total variance (R^2 = .17). The overall results of the multiple regression analysis indicated that CRT, DST and BRT significantly predicted the multiplication test. As the partial correlations in Table 3.3 indicated, CRT was the most important and significant predictor of the MT with a significant regression weight. However, DST and BRT were not significant predictors of the MT.

The regression equation of multiplication skills is written towards the results of the regression analysis:

Multiplication skills = 4.86 + 0.88 CRT + 0.37 DST + 0.50 BRT

The partial regression plots of the predictor variables were used in order to see how strong the correlation between the criterion and the predictor variables.

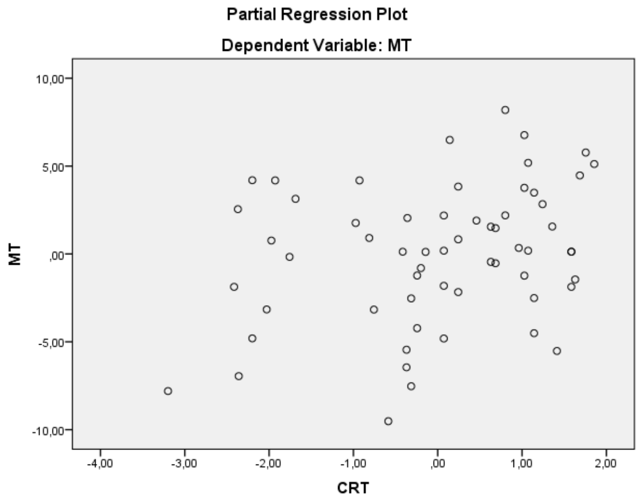

Figure 19. Partial Regression Plot of CRT

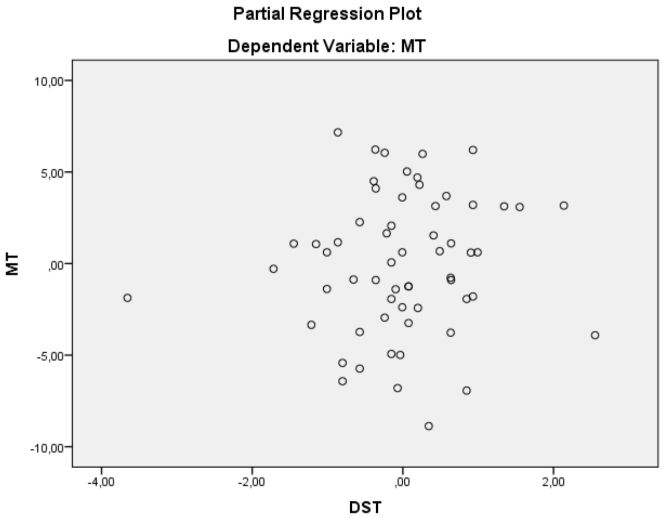

Figure 20. Partial Regression Plot of DST

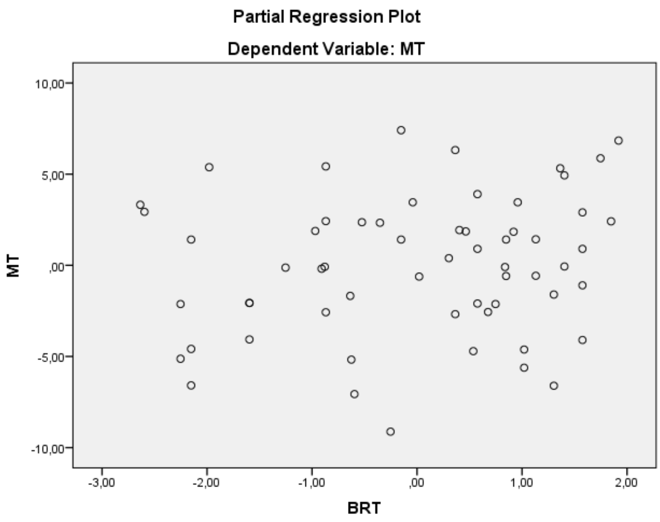

Figure 21. Partial Regression Plot of BRT

According to the partial regression plots of predictor variables, although the correlations between the criterion variable: MT and the predictor variables: CRT, DST and BRT were not strong, there was linear and positive correlation between the MT and the predictors: CRT (see Figure 19), DST (see Figure 20) and BRT (see Figure 21).

CHAPTER IV

DISCUSSIONS AND RECOMMENDATIONS

This study examined the extent to which components of working memory (CE, PL and VS) explain the multiplication skills of the 3rd grade students. In this section, the discussion of the results and recommendations of the research are presented. The discussions for the predictors of multiplication skills are presented in the first section. Second section includes recommendations for further research.

4.1 Discussion of the First Sub-Problem's Results

The first sub-problem of this study was determined as "What is the relationship between CE component and multiplication skills of 3rd grade children?". Pearson correlation coefficient was computed in order to examine the relationships between multiplication skills and CE component of working memory. CRT was used in order to assess CE. The results of bivariate correlation analysis showed that CRT was significantly correlated with multiplication skills. Therefore, multiplication skills were significantly and positively correlated with CE. Moreover, since the correlational coefficient of CRT was greater than .30, the multiple regression analysis was conducted for CRT.

From the view of the studies, it was expected that there was a strong correlation between CE component and multiplication skills. Several studies have been carried out on CE component in the literature. These studies showed the significant positive relation of

CE component to multiplication skills in line with the findings of the present research (e.g. Siegler, 1995; Fürst & Hitch, 2000; Schumann-Hengsteler, 2000; Tronsky, 2005; Imbo, Vandierendonck, & De Rammelaere, 2007; Imbo & Vandierendonck, 2007b). They proved the functions of CE in arithmetic and explained its responsibility for monitoring and coordinating different steps during arithmetic problem solving. All number magnitude tasks entail processes of perceiving, coding, interpreting, comparing and updating information (Kolkman, Hoijtink et al., 2013). Solving the multi-digit multiplication task used in the current study requires cognitive processes such as switching between operations, retrieving arithmetic facts, calculating and storing intermediate results, and performing carrying or borrowing operations (Geary, 1993; Fürst & Hitch, 2000; Andersson, 2008). These abilities are related to coordinating, executing and monitoring. Therefore, these tasks, used also in multiplication, are closely linked to the executive resources.

The recent studies have also demonstrated that executive processes play a significant role in multiplication. Thibodeau, LeFevre and Bisanz (1996) revealed that executive working memory resources were required to activate answer of a simple multiplication problem in long-term memory. Moreover, Hecht (2002) showed that non-retrieval strategies (i.e., transformation and counting) used in multiplication relied on executive working memory. Imbo et al. (2007) asserted that CE had significant role for carry and borrow operations used in multiplication. Moreover, the CE was evaluated to be significant for the carry operation in complex multiplication (Imbo, Vandierendonck, &Vergauwe, 2008; Seitz & Schumann-Hengsteler, 2000). On the other hand, other studies have showed that involvement of CE varies by individual differences. For instance, Bull et al. (1999) demonstrated that children with different math performance were inconsistent with measure of the CE. Furthermore, McLean and Hitch (1999) claimed that children with poor arithmetic skills were impaired particularly on executive processing.

According to these findings, it can be asserted that there was a strongest relationship among the CE and multiplication skills. Students who had higher multiplication test scores performed higher CRT scores.

4.2 Discussion of the Second Sub-Problem's Results

The second sub-problem of this study was determined as "What is the relationship between PL component and multiplication skills of 3rd grade children?". In order to investigate the relationships between multiplication skills and PL component of working memory, the Pearson correlation coefficient was measured. DST was used in order to assess PL. From the results of bivariate correlation analysis, it was detected that the relationship between PL component of working memory and multiplication skills was not significant. The multiple regression analysis revealed that no effects were found for the PL.

As unexpected, the findings contradicted that the PL was associated with multiplication skills of 3rd grade students, while the previous studies proved the role of PL in arithmetic (Hitch, 1978; Logie et al., 1994; Ashcraft, 1995). They showed that PL functions were required to store intermediate and partial results while solving arithmetic problems. For example, using counting strategies to solve multiplication facts (e.g., 4×9 = 9…18…27…36) relies on PL functions and needs transitional results stored (Imbo &Vandierendonck, 2007). According to Logie and Baddeley (1987), the passive phonological store played a significant role in maintaining numbers (e.g., reciting multiplication tables). Liu and his friends asserted that complex multiplication facts required both PL and CE processes. Furthermore, Imbo and Vandierendonck (2007) mentioned in their study that simple arithmetic problems can be solved by using different strategies where CE and PL are needed. However, Hecht (2002) found that PL was hold in only counting.

On the other hand, it can be hypothesized that the multiplication skills based on spatial relations among magnitudes and numbers and for this reason, the PL would not play an important role in multiplication skills (e.g. Dehaene et al., 1993). However, this inference does not mean that the PL does not have association with math learning since previous studies demonstrated the relations between math skills and the PL (Meyer, Salimpoor, Wu, Geary, & Menon, 2010). For instance, the PL can be implicated in verbal counting skills which are asserted to be significant for early development of math learning (Kolkman, Kroesbergen et al., 2013).

The involvement of PL in math performance varies across age group of students. Hecht and colleagues (2001) investigated the effect of PL component on math ability from children’s second grade to fifth grade. The researchers found that the PL was the one and only predictor of math skills. Swanson and Kim (2007) showed that phonological storage was associated with math performance at 6-10 ages. On the other hand, Passolunghi and colleagues (2007) demonstrated that at the end of first grade, the PL was not an important predictor of math achievement for the children who were individually different. Gathercole and Pickering (2000b) revealed that the ability of the PL was related to math skills in ages 7-8, however this relation dissipated when evaluating the CE ability (Holmes & Adams, 2006). According to Bull and Johnston (1997), low-achieving and high-achieving children in math were different in the PL abilities at age 7, but the difference disappeared when examining reading abilities.

In summary, the findings in the current study demonstrated that the PL component was not significantly correlated with multiplication skills although a variety of previous studies showed a significant role for the PL in arithmetic operations.

4.3 Discussion of the Third Sub-Problem Results

The third sub-problem of this study was determined as "What is the relationship between VS component of the working memory and multiplication skills of 3rd grade children?". In order to investigate the relationships between multiplication skills and VS component of working memory, the Pearson correlation coefficient was measured. Block recall test (BRT) was used in order to assess the VS. From the results of bivariate correlation analysis, it was detected that the relationship between VS component of working memory and multiplication skills was significant. However, the multiple regression analysis showed that VS was not a significant predictor of the MT.

It was expected that the VS was a significant predictor of the MT. However, the findings contradicted with previous studies showing relationships between VS and arithmetic skills (Heathcote, 1994; Trbovich & LeFevre, 2003; Dumontheil & Klingberg, 2012; Simmons et al., 2012). It was found that the VS played important role in symbolic magnitude and written additional problems. Hubber, Gilmore and Cragg (2014) revealed that VS may be involved in holding the sum in mind, rather than in performing different strategies. Although Lee and Kang (2002) claimed that multiplication slowed with visual memory load, it is difficult to draw conclusions across the shortage of studies about VS.

Besides these studies, recent researches have showed that the effect of the VS to math achievement changes from age to age. For instance, Rasmussen and Bisanz (2005) demonstrated that the VS was related with math in preschoolers, but this relation disappeared in first graders. Meyer et al (2010) stated that while the CE and PL components were correlated with arithmetic performance during the early stages, VS component played significant role during later stages. Moreover, Soltanlou et al. (2005) reported that multiplication skills were associated with VS in fourth grade. Holmes and Adams (2006) and Holmes and colleagues (2008) found that the VS played a significant role in the math performance of children aged 7-8 comparing to that with 9-10 ages. The current study supports the findings about age and it can be said that the VS was not assumed to be a significant predictor for third grader children.

The contribution of VS to math achievement also varies across individual differences. For example, Hubber et al (2014) showed that using different storage system based on individual differences. From this view, when participants are restricted to use visual-spatial storage, they apply to use verbal storage. Moreover, Seron et al. (1992) asserted that due to individual differences, it was difficult to decide which participants visualize numbers.

In summary, there has been no agreement on the effects of extrinsic VS component of working memory on multiplication skills.

4.4 Discussion of the Fourth Sub-Problem Results

The fourth sub-problem of this study was determined as "Which components of working memory is the best predictor of multiplication skills of 3rd grade children?". The present study has reported no significant correlation of multiplication skills with PL component of working memory. VS component of working memory showed correlations with multiplication skills. However, the VS was not a significant predictor of MT in multiple regression analysis.

The results of the multiple regression analysis showed that CE component was computed approximately 7.6 % of the total variance of multiplication skills of the participants. The results revealed that CE component was the most significant predictor of multiplication skills. Participants who got higher score from the MT were assumed to get higher scores from the CRT. Therefore, the multiplication skills were more relied on executive functions of working memory (LeFevre & Bisanz, 1996; Hecht, 2002; Imbo et al., 2007; Seitz & Schumann-Hengsteler, 2000; Imbo, Vandierendonck & Vergauwe, 2008). According to previous researches and the findings in this study, it can be said that the CE component of working memory is the best component of multiplication skills of 3rd grade children.

In conclusion, this study showed that the central executive (CE) component of working memory plays a significant role in multiplication skills of 3rd grade children. Unexpectedly, the findings of this study contradicted that the phonological loop (PL) and visual-spatial sketchpad (VS) components of working memory play significant roles in multiplication skills of 3rd grade students.

4.5 RECOMMENDATIONS

This study focused on the analysis of the relationship of multiplication skills to different component of working memory for 3rd grade school students. It is expected that the findings will suggest valuable implications for math teachers, educators and curriculum developers. According to the results of the present study, the recommendations were identified:

1. Curriculum designers should develop the strategies of CE component of working memory for students' multiplication skills.
2. Participants can be chosen from different types of school and different grade levels for further studies.
3. New scoring procedures of working memory may be developed.
4. Besides testing students' working memory skills, their prerequisite knowledge (i.e. addition and multiplication table) of multiplication may be examined.
5. Since the CE component of working memory is significantly correlated with multiplication skills in the current study, further researchers should examine its effect on multiplication problems different from the present study (i.e. word problems).
6. Curriculum designers should immerse the CE component in math curriculum in order to give chance to teachers to develop activities according to classroom settings.
7. The CE component may be used to assess students' working memory level before applying multiplication activities.
8. Teachers should use instructions and activities according to students' working memory level.
9. Math curriculum should include modified instructions and activities to reduce working memory load and different strategies based on students' developmental stage and individual needs.
10. Curriculum should be designed to encourage students to use their own strategies while solving multiplication problems.
11. Teachers should use individualized programs for students with math difficulties.

12. Although PL and VS components did not seem to be related to multiplication skills in the present study, the relation between these two constructs may be investigated for different settings.
13. The effect of PL and VS components on multiplication skills should be examined for students with different ages.
14. PL and VS components may be used in order to investigate their relations to different arithmetic skills because some arithmetic skills (i.e. addition and multiplication table) are prerequisites of multiplication skills.
15. In the current study, the participants' levels of performance were not different from each other. Participants who have learning disabilities can be selected for further research studies.

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Appendix A: List of Abbreviations

CE: Central Executive

PL: Phonological Loop

VS: Visual-spatial Sketchpad

CRT: Counting Recall Test

DST: Digit Span Test

BRT: Block Recall Test

MT: Multiplication Test

MoNE: Ministry of National Education

NCTM: National Council of Teachers of Math

Math: Math

N: Sample size

p: Significance level

SD: Standard deviation

df: Degrees of freedom

min: Minimum

max: Maximum

Appendix B: Parent Permission Letter / Veli İzin Formu

Veli İzin Formu

Sayın Veli,

Yeditepe Üniversitesi, Eğitim Programları ve Öğretim bölümü yüksek lisans programında "Çalışan Belleğin Matematik İşlem Becerisine Etkisi" araştırılarak sonuçları ile tez çalışması yapılacaktır. Öğrencilere kağıt üzerinde çarpma işlemi testi ve bilgisayar ortamında yurtdışında yaygın olarak kullanılan hafıza testleri uygulanacaktır. Bilgisayar ortamında uygulanacak hafıza testleri aşağıdaki gibidir:

- Yapılan hesabı hatırlama
- Sayı zinciri
- Ters sayı zinciri
- Görünen blokları hatırlama
- Görünen blokları sıralı hatırlama
- Sayı Görünen blokları sıralı hatırlama

Mayıs (2016) ayı içerisinde uygulanacak bu çalışmaya sadece 3. Sınıf öğrencileri dahil edilecektir. Test sonuçları öğretmenler ve velilerimizle paylaşılacaktır.

Katılımınız araştırmanın sonuçlandırılması ve matematik derslerine sağlayacağı katkı için önemlidir.

Desteğiniz için şimdiden çok teşekkür ederim.

Selma Boz
Matematik Öğretmeni

İSTEK KEMAL ATATÜRK İLKOKULU MÜDÜRLÜĞÜNE

Velisi bulunduğum aşağıda adı-soyadı yazan öğrencinin, yukarıda bahsi geçen uygulamalara katılmasına izin veriyorum.

ÖĞRENCİNİN — Velisi

Adı-Soyadı: …………………………… — Adı-Soyadı (imza, tarih)

Sınıfı: …………. Okul No: ……….

Appendix C: Belirtge Tablosu

Matematik 3. sınıf	**Kazanımlar**					
	Bilişsel Alan					
	Kavrama	**Uygulama**				**Analiz**
KONULAR	Çarpma işleminin kat anlamını açıklar.	Çarpım tablosunu oluşturur.	İki basamaklı bir doğal sayıyla en çok iki basamaklı bir doğal sayıyı; en çok üç basamaklı bir doğal sayıyla bir basamaklı bir doğal sayıyı çarpar.	10 ve 100 ile kısa yoldan çarpma işlemi yapar.	Zihinden çarpma işlemini yapar.	Doğal sayılarla çarpma işlemini gerektiren problemleri çözer ve kurar.
Çarpım tablosu oluşturma	✓	✓				
Eldeli çarpma işlemi			✓			
Bir basamaklı doğal sayı ile iki basamaklı doğal sayıların çarpma işlemi			✓			
İki basamaklı doğal sayı ile iki basamaklı doğal sayıların çarpma işlemi			✓			
Üç basamaklı doğal sayı ile iki basamaklı doğal sayıların çarpma işlemi			✓			
10 ve 100 ile kısa yoldan çarpma işlemi				✓	✓	
Çarpma işlemi gerektiren problemler						✓

Appendix D: Multiplication Test/ Çarpma Testi

Ders: Matematik	**Tarih:**
Konu: Doğal Sayılarla Çarpma İşlemi	**Süre:**
Ad, Soyad:	**Sınıf/Şube:** **Okul no:**

Sorular

1) Aşağıdaki çarpma işlemlerini yapınız.

$$54 \times 2 \qquad 13 \times 5 \qquad 48 \times 3 \qquad 98 \times 7$$

2) Aşağıdaki çarpma işlemlerini yapınız.

$$14 \times 13 \qquad 36 \times 23 \qquad 45 \times 42 \qquad 67 \times 64$$

3) Aşağıdaki çarpma işlemlerini yapınız.

$$124 \times 2 \qquad 736 \times 5 \qquad 987 \times 6 \qquad 798 \times 9$$

4) Aşağıdaki sayıları kısa yoldan çarpınız.

7×10	28×10	356×10	8×100	100×43
…………	………….	……………	…………...	………….

5) Aşağıdaki sayıları kısa yoldan çarpınız.

8×40	45×50	842×70	9×600	800×5
………...	……………	……………	………….	…………..