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Çalışan Belleğin Farklı Bileşenlerinin 3. Sınıf Öğrencilerinin Çarpma Becerisine Etkisi*

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ÖZET

Dört temel aritmetik işlem becerisinin geliştirilmesi, ilköğretim matematik müfredatının ana hedefleridir. Son araştırmalar, bu becerilerin öğrencilerin çalışan bellek kapasiteleriyle ilişkili olduğunu göstermektedir. Bu bulgular doğrultusunda bu araştırmanın amacı, çalışan bellek bileşenlerinin 3. sınıf öğrencilerinin çarpma becerileri üzerindeki etkilerini belirlemektir. Çalışma İstanbul'daki özel bir ilköğretim okulunda 60 üçüncü sınıf öğrencisi (23 kız ve 37 erkek) ile yürütülmüştür. Katılımcıların bileşenler ile ilgili çalışan bellek kapasitesini ölçmek için bilgisayar ortamında sayı hatırlama testi, rakam açıklık testi, blok hatırlama testi adı verilen görevler tasarlanmış ve uygulanmıştır. Ayrıca, katılımcıların çarpma becerileri çarpma testleri ile ölçülmüştür. Verilerin analizinde doğrusal çoklu regresyon kullanılmıştır. Analiz sonuçları, çarpma becerilerinin en iyi yordayıcı değişkeninin, çalışan belleğin merkezi yürütücü (MY) bileşeni olduğunu ortaya koymuştur. Bununla birlikte, çalışan belleğinin fonolojik döngü (FD) ve görsel-uzamsal kopyalama (GUK) bileşenlerinin, 3. sınıf öğrencilerinin çarpma becerileri için önemli bir yordayıcı olmadığı görülmüştür.

Anahtar Sözcükler: Çarpma becerisi, merkezi yürütücü, fonolojik döngü, görsel-uzamsal kopyalama

The Effect of Different Components of Working Memory on Multiplication Skills of 3rd Grade Children

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ABSTRACT

The development of the four basic arithmetic operation skills is the main objective of the primary school mathematics (math) curricula. Recent research shows that these skills are related to working memory capacity of the students. In line with these findings, the purpose of this research is to determine the impacts of the working memory components on the multiplication skills of 3rd graders. The study was carried out with 60 third grade students (23 female and 37 male) at a private primary school in Istanbul. In order to measure the participants' capacity of working memory related to its components, the tasks named as the counting recall test, digit span test, block recall test were designed and administered on computer programs. In addition, participants' multiplication skills were measured by multiplication tests. Linear multiple regression was used to analyze the data. The results of analysis revealed that the best predictor variable of multiplication skills was the central executive component of working memory. However, the phonological loop (PL) and the visuo-spatial sketchpad (VSSP) components of the working memory were not significant predictors for multiplication skills of the 3rd grade students.

Keywords: Multiplication skills, central executive, phonological loop, visuo-spatial sketchpad

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1. INTRODUCTION

In the process of learning math, arithmetic operations are the initial skills for children's academic life. It is assumed that these are basic prerequisites of math skills. Therefore, the development of these skills is the main objective of the primary school

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math curricula. Although the students' arithmetic operation skills are crucial for their success in math, they have difficulties related to multiplication and division operations. Recent studies show that operational skills in math are associated with working memory capability of students. The activities, such as the ability to maintain, monitor, and manipulate information which are indispensable for arithmetic operations depend on the working memory (Raghubar, Barnes, & Hecht, 2010). Derived from the results of these empirical findings, the purpose of this study was to determine the influence of central executive, phonological loop and visuo-spatial sketchpad components of working memory on the multiplication skills of 3rd graders.

1.1. Working Memory and Mathematics

It is the most important part of the memory system, and temporary storage and manipulation of information are the main functions of the working memory (Baddeley, 2000). This study is based on the multi-component model of working memory developed by Baddeley and Hitch (1974). They describe working memory as consisting of central executive (CE), the phonological loop (PL) and the visuo-spatial sketchpad (VSSP) component. The PL and the VSSP are described as slave systems storing phonological and visuo-spatial information respectively, and coordination of information is coordinated by the CE (Oberauer et al., 2003). In this model, PL, which is stored in a phonological code and maintained by an articulation-based rehearsal system is related to the information in auditory-verbal or auditory-nonverbal forms (Baddeley, 2012). On the other hand, visuo-spatial information is coded and maintained by VSSP component of working memory. The visual 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 from other objects (Baddeley, Eysenck, & Anderson, 2009). CE, meanwhile, controls attention to focus, divides and switches among coincident activities and selects important information, and connects association between long-term memory and working memory (Logie, 2011). Although Baddeley (2000) posited relatively new component which was called episodic buffer as a third slave system, function of this component has been still unclear and has not been studied properly. For this reason, this study excluded this component.

It is assumed that each component of the working memory has specific roles in math. CE component of the working memory is in charge of monitoring and coordination of the different steps of problem-solving processes in math (Imbo, Vandierendonck, & De Rammelaere, 2007). Seitz and Schumann-Hengsteler (2000) indicated that simple multiplication is associated with CE resources, while complex multiplication operation requires both PL and CE resources. It is also found that CE is related to all strategies which are necessary for problem solving; such as, retrieval, transformation, counting, whereas PL is related only to counting (Hecht, 2002).

Fürst & Hitch (2000) explained that there were relationships between PL and calculation procedures such as counting, maintaining problem information, and retaining information during counting. PL is also responsible for manipulating numerical information during carry operations (Logie, Gilhooly, & Wynn, 1994; Fürst & Hitch, 2000). De Smedt et al. (2009) assumed that multiplication facts are maintained as a form of verbal representations and their retrieval depends on verbal codes. Therefore, they found a significant relationship between arithmetic fact retrieval and PL. In addition, it is asserted that only PL can predict math performance of primary school children at age 6 to10 years (Hecht et al., 2001).

Various numbers of studies also indicated that VSSP component of working memory is related to arithmetic skills. According to Simmons, Willis & Adams, (2012), it was crucial for symbolic magnitude and written additional problems. Heathcote (1994) found that VSSP engaged in retaining carries during operations. In addition, the initial stage of calculation requires both PL and VSSP components for encoding of the problem in working memory. While VSSP maintains visually presented information, PL stores verbal information which is related to problem in working memory. On the other hand, studies showed that the association between the VSSP and math performance varies by age. Holmes, Adams, & Hamilton (2008) found that 7 to 8-year-old children were more reliant on the VSSP than 9 to 10-year-old children. The finding supporting this claim at another study showed that 6 to 7-year-old children were addicted seriously to the visuo-spatial resources on the arithmetic performance, but VSSP tasks diminished at 8 to 9-year-old children (McKenzie, Bull, & Gray, 2003). The evidence of these studies has emphasized the significance of working memory components in arithmetic operations with different ages.

1.2. Aim and Importance of the Study

In the current study, the main focus was to examine 8 to 9-year-old children's multiplication skills because children have more difficulties while they are solving multiplication problems (Rotem & Henik, 2013) and a variety of cognitive processes and strategies are required in order to perform mental and written computation (Bobis, 2007). Accordingly, to determine which component of working memory predicts multiplication skills, students' capacity of different components of working memory were measured by different computer-based instruments to understand how much they remember the tasks in each measure of components. Their multiplication skills were evaluated by paper-based test created regarding to the objectives of third grade math curriculum of Turkey.

Objectives which are associated with multiplication operations, take place in 3rd grade math curriculum for the first time in Turkey. It is observed that students have difficulties to learn multiplication operation in the primary school. It is obvious that working memory has critical role for math learning, but the effect of each components of working memory to learning in particular areas of math remains to be obscure to certain extent.

1.3. Research Question

It was hypothesized that to determine the influence of each component of the working memory on multiplication skills of the 3rd grade students could provide evidences to improve students' multiplication skills. Therefore, the research question of this study was formulated as "Which components of working memory is the best predictor of multiplication skills of 3rd grade children?"

2. METHOD

The current study was conducted using the descriptive correlational design. The purpose of this design was to identify variables that can effectively predict some outcomes or criterion. The criterion variable was the multiplication skills of the students while the components of the working memory were predictors in this study. When more than one predictor variable is used to predict a criterion, the analysis is called multiple regression.

This study aimed to determine the predictive power of the different working memory components of the multiplication skills of 3rd grade primary schoolers. Based on this objective, the study was defined as a predictive correlational study and linear multiple regression analysis. 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).

2.1. Participants

The sample of this research consisted of 60 third-grade students at a private primary school in Istanbul. Snowball and convenience sampling strategy were used for this research due to the availability of a target group at a certain time (Dörnyei, 2007). At first, the computer availability of the schools was the first condition to select subjects for the research. Thus, samples of the research were selected from a private school which met this condition. The selected school had only three third classes and all typically developing children in these classes, whose parents accepted to take part in this study were taken as participants. There were not any other exclusion criteria for the selection of participants. These 60 students (23 female and 37 male) were included into the study with the consent letters of their parents. Participants' ages ranged between 8 and 9.

2.2. Materials

In this study, students' capacity of different components of working memory were measured via the instruments: Counting Recall Test (CRT) for central executive (CE) component, Digit Span Test (DST) for phonological loop component, and Block Recall Test (BRT) for visuo-spatial sketchpad component (Pickering & Gathercole, 2001). 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.

The tests were applied to the participants in the computer laboratory of the school as small groups. A computer was provided for each student. Each of them had their own account to log in to the system where they took the working memory tests. All tests included videos that explained all the instructions on how to manage the tests step by step before they started taking them. After they started the tests, they were not given any instructions.

2.2.1. Counting recall test (CRT)

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 end 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 held in mind on the frame of the result. After students passed this level, they performed the next level which included three frames of counting and the frame of the result which they entered was three digits. The subsequent levels had one more frame than the previous level. The test ended with the level, which consisted of ten frames of counting. Students gained one point for each level. There was no time restriction. Students passed each frame by themselves by clicking the "forward" button.

2.2.2. 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 was seen on the screen and then the participants were expected 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 in their minds and entered them in the same order on the result page. Each level had one digit more than the previous level. The test included ten levels in which ten-digit numbers were seen. Each number was seen on the screen for 1 second. There was no time restriction when they entered numbers to the frame of the result.

2.2.3. 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 appear on the screens in front of the students in random arrangement. A set of blocks blinks one by one and then the students are responsible for selecting the blinked blocks in the same order they blinked. The test which was used in this research, started with one blinked block and students clicked the place of the block. After they passed the first level, two blocks blinked one-by-one at the second level. After the last block disappeared, students clicked the place of the blinked blocks in the same layout. One more block with respect to the previous level was added to the number of blocks. The test included ten levels in which ten blocks blinked. A blinked block stayed on the screen for 1 second.

2.2.4. Multiplication test (MT)

MT was used to determine multiplication skills of the participants. The test consists of 22 multiplication operations. Each number was chosen differently in order to enable students to multiply with all numbers in the multiplication table. Each answer was evaluated with either one or zero according to its definite result. Cronbach's alpha was used to find the reliability of the multiplication test. The coefficient was .80 and this showed that the test was highly reliable.

2.3. Data Analyses

In this study, the predictive model was used to predict values of the dependent variable from multiple independent variables. There were three independent variables to predict the dependent variable in this study. Therefore, the multiple regression analysis which was used to predict the outcome from more than one predictor, 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 VSSP) used to predict the criterion were called predictor variables in this study. 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 conduct data analyses.

3. FINDINGS

3.1. Data Analyses

Descriptive statistics of the data were displayed in Table 1. The data in this table indicates normal distribution.

Table 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

3.2. Correlational Analyses

Pearson correlation coefficients computed to find out strength and direction of the relationship between predictor variables (CRT, DST and BRT) and criterion variables (MT) are displayed in Table 2. All working memory measures show positive and significant correlation with MT except DST. There are also positive correlations between MT scores and DST, but it is not statistically significant.

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

*Correlation is significant at 0.05 alpha level.

At the beginning of the statistical analysis, the assumptions of normality, linearity, independent errors and homoscedasticity of the multiple regression analysis were examined (Tabachnick & Fidell, 2007). The Q-Q plots were used in order to test the assumptions of normality. Data for MT, CRT, DST and BRT does not vary more from a straight line; hence the data is normally distributed.

In addition to Q-Q tests, the skewness and kurtosis were used for each variable in order to examine normality. No violation of normality assumption was found so that the multiple regression analysis could be conducted (see Table 3).

Table3.
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

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

The Durbin-Watson test was utilized to test the assumption of independent errors of this study. The value of the Durbin-Watson was 1.34, which meant that the error term was independent. Thus, the assumption of independent errors was not disrupted. The scatter plot of regression standardized residuals against regression standardized predicted values was preferred to examine the assumption of homoscedasticity (Field, 2005). The residuals were distributed randomly around zero in the scatterplot. Therefore, this scatterplot proves the homoscedasticity.

The statistical problems are created by multicollinearity and singularity if the correlation among the variables is .90 or greater than .90 (Tabachnick & Fidell, 2007). Since the values of VIF changed between 1.11-1.16, and tolerance statistics ranged between .904 - .857, there was no evidence that multicollinearity was a problem for the suggested model.

3.3. Regression Analyses

A 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 (VSSP) predicted the overall multiplication skills of third grade primary school students. The contributions of ways of CRT, DST and BRT explaining the multiplication skills are presented in Table 4.

Table 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 results indicate that the combination of four variables explains 17 % of the total variance ($R^2 = .17$). The overall results of the multiple regression analysis indicate that CRT, DST and BRT significantly predicted the multiplication test. Table 4 shows that CRT was the most important and significant predictor of the MT with a significant regression weight. A moderate effect size emerged for CRT ($\beta = .30$, $p = .027$). However, DST and BRT were not significant predictors of the MT.

The partial regression plots of the independent variables were used in order to see how strong the correlation between the dependent and the independent variables was. According to the partial regression plots of predictor variables, although the correlations between the dependent variable: MT and the independent variables: CRT, DST and BRT are not strong, there is linear and positive correlation between the MT and the predictors: CRT, DST and BRT.

4. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

The purpose of this research was to determine the influence of the working memory components on multiplication skills of the 3rd grade students. The results of the analysis showed that CE component was the most significant predictor of multiplication skills, while PL and VSSP components of the working memory were not significant predictors for multiplication skills of the 3rd grade students. In the light of the above results, it can be interpreted that for 3rd grade students, the multiplication skills rely on executive functions of working memory more. This study was conducted under the expectation that performing multiplication operation required cognitive processes such as coordinating, executing and monitoring which are related to functions of CE. Hence, the findings of this research are consistent with several studies which have investigated the positive and significant influence of CE on math skills (e.g. Fürst & Hitch, 2000; Seitz, Schumann-Hengsteler, 2000). To illustrate, Hecht (2002) showed that transformation and counting used in multiplication relied on the executive working memory, Similarly, Imbo et al. (2007) asserted that CE had significant role in carry and borrow operations used in multiplication. According to these findings, it can be asserted that the strongest relationship was among the CE and multiplication skills. Students who had higher multiplication test scores performed higher CRT scores.

On the other hand, the results of this research indicated that relationship between PL and multiplication skills was insignificant, although a variety of previous studies indicated a significant role for the PL in arithmetic operations. There was evidence that PL has functions such as counting, and retrieving multiplication facts (e.g., 4×9 = 9…18…27…36) related to multiplication skills. (Imbo & Vandierendonck, 2007). In addition, Logie and Baddeley (1987) found that the passive phonological store played a significant role in maintaining numbers (e.g., reciting multiplication tables). Moreover, Logie et. al. (1994) asserted that complex multiplication facts required both PL and CE processes. However, the involvement of PL in math performance varies across age group of students. For instance, Hecht and colleagues (2001) investigated the effect of PL component on math ability of the students from second grade to fifth grade and they also claimed that only PL could predict the math performance of the second and third graders. Another study also showed that verbal storage was only associated with the math performance for 6 to 10-year-old children (Swanson & Kim, 2007). Unexpectedly though, the results of this study contradicted with the above research findings. On the other hand, this unexpected result can be explained by the findings of Gathercole and Pickering (2000) who posited that PL was related with math performance in 7- to 8-years of age, but that this relation diminished when ability of CE was developed.

Finally, results of this study indicated VSSP component of the working memory was not significant predictor for multiplication skills of the 3rd grade students. Although Hubber, Gilmore and Cragg (2014) assume that VSSP may be responsible for holding the sum in mind, rather than using strategies, Lee and Kang (2002) claimed that multiplication process slowed down by visual memory load, therefore further studies are required to explain the role of the VSSP in math skills. Besides these studies, recent research has shown that the effect of VSSP on math success changes with the age of the students. For instance, Rasmussen and Bisanz (2005) demonstrated that VSSP was related to the math performances in early childhood, but this relationship was not seen in the first-grade students. However, Soltanlau, Pixner, and Nuerk, (2005) reported that multiplication performance of the 4th grade students was associated with their VSSP capacity. Similarly, Holmes and his/her colleagues (2008) found that the role of VSSP was more significant at the math performance of 7 to 8-year-old students than the 9 to 10 years old ones. Consequently, it was suggested that VSSP was also an insignificant variable for 8 to 9-year-old students' multiplication skills who were subjects of this research.

The limitations for this study warrant the discussion. First, the predictor variables explained 17% of the variance in third grade children's multiplication skills. A greater amount of variance may have been explained if other correlates of multiplication skills had been included. For instance, the effects of pre-knowledge (e.g. addition, multiplication table) of multiplication was not taken account, although previous research has demonstrated that it plays an important role in children's multiplication competence (Rotem & Henik, 2013). Second, participants' individual differences were not considered in this study, even though the contribution of PL (Gathercole & Pickering, 2000) and VSSP (Hubber et al., 2014) to math achievement varies across individual differences. On related issues, future research might include measures of pre-knowledge of multiplication and individual differences.

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 while its visuo-spatial sketchpad (VSSP) and phonological loop (PL) components play insignificant roles in multiplication skills of 3rd grade students. In the light of the findings, it could be suggested that math instruction should include modified instructions increasing working memory capacity and different working memory strategies suitable for students' developmental features should be implemented. Moreover, instruction should be designed to encourage students to use their own strategies while solving multiplication problems. Furthermore, instructional designers should develop the strategies of CE component of working memory for students' multiplication skills in order to give teachers the chance to develop activities according to classroom settings.

Considering the implications of this study, it can be claimed that the participants' levels of multiplication performance were not different from each other. Participants who have difficulties while performing multiplication operation can be selected for further research studies. Moreover, participants can be chosen from different types of schools and different grade levels for further studies. Finally, besides testing students' working memory skills, their prerequisite knowledge of multiplication may be examined before.

Research and Publication Ethics Statement

The authors hereby declare that they have not used any sources other than those listed in the references.

Contribution Rates of Authors to the Article

This study was produced from the first author's master thesis. Therefore, the first author participated in every part of the research. The second author, the supervisor of the first author, made contributions to each part of the article as much as the first author.

Statement of Interest

The authors hereby declare that there is no conflict of interest.

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6. GENİŞ ÖZET

Dört işlem becerileri problem çözme becerisi için önkoşul niteliği taşımaktadır. Bu nedenle ilköğretim matematik programlarında dört işlem becerilerine yönelik kazanımlar önemli yer tutmaktadır. Öğrencilerin işlem yapma becerileri matematik öğretiminde büyük önem taşımasına rağmen, onların özellikle çarpma ve bölme işlemlerini öğrenmede güçlük çektikleri görülmektedir. Öğrencilerin bu becerilerini geliştirmek için sorunun kaynağının belirlenmesi önem taşımaktadır. Son yıllarda yapılan çalışmalar çalışan belleğin, öğrencilerin işlem yapma becerileri üzerinde rol oynadığını göstermektedir. Bu çerçevede, sunulan araştırmanın amacı, çalışan belleğin bileşenlerinin (merkezi yürütücü, fonolojik döngü ve görsel-uzamsal kopyalama) üçüncü sınıf öğrencilerinin çarpma becerilerini ne ölçüde yordadığını ortaya koymaktır.

Bu çalışmanın kuramsal temeli Baddeley ve Hitch'in (1974) çalışan bellek modeline dayanmaktadır. Bu modele göre çalışan bellek, bilişsel görevlerin yerine getirilmesi için gerekli olan bilgilerin kısa süreli bellekte korunması ve bilgilerin göreve göre düzenlenmesinde önemli rol oynar. Modelin, merkezi yürütücü (MY), fonolojik döngü (FD) ve görsel-uzamsal kopyalama (GUK) olmak üzere üç bileşeni vardır. MY, dikkatin performans göreve odaklanmasını, sürdürülmesini ve kısa süreli bellek ile uzun süreli bellek arasında ilişki kurulmasını sağlar. FD ve GUK ise fonolojik ve görsel-uzamsal bilgilerin kısa süreli bellekte korunmasından sorumludur.

Araştırmalar çalışan belleğin her bir bileşeninin dört işlem becerilerinde kendine özgü rol oynadığını göstermektedir. Çalışan belleğin bileşenlerinden MY, matematik problemlerinin çözümünde, farklı adımların izlenmesi ve eşgüdümün sağlanmasından sorumludur. Bunun yanı sıra, MY'nin problem çözme için gerekli olan hatırlama, transfer etme, sayma gibi stratejilerle ilişkili olduğu düşünülmektedir. Örneğin, uzun süreli bellekte basit çarpma probleminin cevabını etkinleştirmek için yürütücü çalışma belleği kaynakları gereklidir. Ayrıca, MY'nin karmaşık çarpma probleminde işlem yaparken, taşıma işlemi için önemli rol oynadığı değerlendirilmiştir.

Uzun süreli bellekte basit bir çarpma probleminin cevabını etkinleştirmek için yönetici çalışma belleği kaynakları gereklidir. Dahası, Hecht (2002) çarpma işleminde kullanılan geri alma stratejilerinin (yani dönüşüm ve sayma) yönetici çalışma hafızasına dayandığını göstermiştir. Imbo ve diğ. (2007), CE'nin çarpma işlemlerinde kullanılan taşıma ve ödünç alma işlemlerinde önemli bir rol oynadığını belirtmiştir. Ayrıca, CE'nin karmaşık çarpma işleminde taşıma işlemi için önemli olduğu ifade edilmiştir.

Çalışan belleğin FD bileşenine yönelik araştırmalar, FD'nin matematik işlemi yapılırken hem sayma hem de bilginin kısa süreli bellekte korunmasında rol oynadığını göstermektedir. Ayrıca FD'nin eldeli işlemlerde de sayısal bilginin korunmasından sorumlu olduğu düşünülmektedir. Çarpma işlemi ile FD arasındaki ilişkinin, çarpma işlemiyle ilgili olguların sözel olarak kodlanması ve sözel olarak hatırlanmasından kaynaklandığı savunulmaktadır. Ancak, araştırmalar bu ilişkinin sadece ilkokul öğrencileri için geçerli olduğunu göstermiştir.

Alan yazında, matematik becerileriyle çalışan belleğin GUK birleşeni arasında da ilişki olduğunu gösteren çeşitli araştırmalar bulunmaktadır. GUK çok basamaklı işlemlerde, basamakların yerini, eldeli sayının düzenlenmesini ve saymayı sağlar. Araştırmalar, GUK'un işlem yapma becerisiyle ilişkisinin çocuğun yaşına göre değiştiğini göstermektedir. GUK'u 7-8 yaşındaki çocuklar, 9-10 yaşındaki çocuklara göre daha fazla kullanmaktadırlar. Ayrıca, 6-7 yaşındaki çocuklar, 8-9 yaşındakilere göre aritmetik performansında daha fazla görsel kaynaklara ihtiyaç duymaktadır. Yaşa bağlı değişkenliğin yanında, GUK'un matematik başarısına katkısı bireysel farklılıklara göre de değişir. Yapılan araştırmalar, bireysel farklılıklara dayanan farklı depolama sistemlerinin kullanıldığını göstermiştir. Bu açıdan, katılımcılar görsel depolamayı kullanmakla kısıtlandıklarında sözlü depolamayı kullanmak için başvururlar. Ayrıca, yapılan bir çalışmada bireysel farklılıklar nedeniyle, hangi katılımcıların sayıları görselleştirdiğine karar vermenin zor olduğu iddia edilmiştir.

Dört işlem becerilerinden çarpma, ilk kez 3. sınıf matematik öğretim programında yer almaktadır. Öğrencilerin bu beceriyi öğrenmede, toplama ve çarpma becerilerine göre daha fazla güçlük çektikleri görülmektedir. Yapılan araştırmalar, çalışan belleğin çarpma işlemlerinin yapılmasında önemli rol oynadığını göstermektedir. Ancak çalışmalar arasında bazı farklılıklar olduğu ve yaşa göre farklılık gösterdiği görülmektedir. Bu çerçevede, öğrencilerin çarpma becerisini geliştirmek için, bu becerinin ilk öğrenildiği sınıfta, çarpma işlemi ile çalışan belleğin birleşenleri arasındaki ilişkinin incelenmesinin yararlı olacağı düşünülmüştür. Bu amaçla araştırma problemi "Çalışan belleğin hangi bileşeni 3. sınıf öğrencilerinin çarpma becerilerini en iyi yordamaktadır?" olarak ifade edilmiştir.

Bu araştırmada ilişkisel betimleme modeli kullanılmıştır. Çalışma İstanbul'da özel bir ilköğretim okulunda 23'ü kız, 37'si erkek olmak üzere toplam 60 üçüncü sınıf öğrencisi üzerinde gerçekleştirilmiştir. Çalışma, ebeveynlerin izin verdiği öğrencilerle yürütülmüştür. Katılımcıların çalışan belleğin, merkezi yürütücü, fonolojik döngü ve görsel-uzamsal kopyalama öğelerine ilişkin kapasitelerini ölçmek için, sayı hatırlama (counting recall), rakam açıklık (digit span), blok hatırlama (block recall) olarak adlandırılan görevler tasarlanmış ve bilgisayar aracılıyla uygulanmıştır. Öğrencilerin çarpma becerilerini ölçmek için ise 22 soruluk çarpma testi kullanılmıştır. Veriler analiz edilirken, bağımsız değişkenlerin çarpma işlemi becerisini ne ölçüde yordadığını belirlemek için doğrusal çoklu regresyon analizi kullanılmıştır. Analizden önce, verilerin çoklu regresyon analizinin sayıltılarına uygun olup olmadığına bakılmış ve verilerin söz konusu analize uygun olduğu belirlenmiştir. Analiz sonuçları 3 değişkenin birlikte, toplam varyansın %17'sini ($R^2 = .17$) açıkladığını göstermiştir. Ancak istatistiksel olarak anlamlı bulunan en kuvvetli değişken, çalışan belleğin MY bileşenidir. FD ve GUK'un başarıyı açıklama gücü ise istatistiksel olarak anlamlı bulunmamıştır.

Araştırma, 3. sınıf öğrencilerinin çarpma becerilerini en iyi yordayan değişkenin, çalışan belleğin yürütücü kontrol öğesi olduğunu göstermiştir. Bu bulgu çarpma işleminin MY ile ilişkili olduğunu gösteren araştırmaları destekler niteliktedir. MY işlem yaparken, dikkatin odaklanmasını, sürdürülmesini ve kısa süreli bellek ile uzun süreli bellek arasında ilişki kurulmasını sağlar. Ayrıca, hatırlama, transfer etme, sayma gibi stratejilerin kullanılmasından sorumludur. Bu işlevlerin tümü matematikle ilgili becerilerin öğreniminde önemli rol oynar. Bu nedenle, öğretim programlarında, çalışan belleğin MY bileşeninin kapasitesini geliştiren stratejilerin öğretimine ve etkinliklere yer verilmesinin yararlı olacağı söylenebilir.