EXAMINING THE EARLY PREDICTORS OF NUMBER SENSE AMONG FIRST GRADERS

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Examining the Early Predictors of Number Sense

among First Graders

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Thesis Abstract

Merve Aşık, "Examining Early Predictors of Number Sense among First Graders"

The aim of the study was to examine the roles of arithmetic performance, reading and the cognitive correlates of mathematics learning as working memory, rapid automatized naming (RAN) and processing speed on number sense, which is defined as the core of numerical cognition. Participants were 142 first grade students from a total of 17 state and private primary schools.

To see the interrelationships among number sense and the other variables aforementioned, correlation analysis was conducted. Correlation analysis indicated that all the variables significantly correlated to each other except RAN and memory measures. To investigate how each variable accounts for the variance of number sense, multiple regression analysis was run. Regression analyses indicated that arithmetic performance, memory for words and reading comprehension accounted for significant variance in number sense.

This study also aimed to describe the distinguishing features of first graders who have good (GNS), average (ANS), and poor number sense scores (PNS) in terms of the variables. Analysis of variance (ANOVA) and Kruskal-Wallis tests were conducted to compare the mean differences between the groups. Results showed that PNS group significantly differed from the GNS group on all the measures. The PNS group was significantly lower than the ANS on arithmetic performance, memory for words, RAN, and reading comprehension. The ANS significantly differed from the GNS on all the measures except RAN and reading comprehension. However, further research is needed to replicate this study in a longitudinal fashion.

Tez Özeti

Merve Aşık, "Birinci Sınıflarda Sayı Algısının Erken Belirleyicilerinin İncelenmesi"

Bu çalışmada aritmetik performans, okuma ve matematik öğreniminin bilişsel öğeleri olan işleyen bellek, hızlı otomatik isimlendirme (HOİ) ve işleme hızının sayısal bilişin temeli olan sayı algısına etkisinin incelenmesi amaçlanmıştır. Araştırmaya devlet ve özel okul olmak üzere toplam 17 ilköğretim okulunda birinci sınıfa devam eden 142 öğrenci katılmıştır.

Sayı algısı ve belirtilen diğer bileşenler arasındaki ilişkiyi incelemek için korelasyon analizleri uygulanmıştır. Korelasyon analizleri, HOİ ve hafıza dışında tüm değişkenler arasında anlamlı bir ilişki olduğunu ortaya koymuştur. Belirtilen her bir değişkenin sayı algısındaki değişimi ne kadar açıkladığını görebilmek için ise çoklu regresyon analizi uygulanmıştır. Regresyon analizleri aritmetik performans, sayı hafızası ve okuduğunu anlama değişkenlerinin sayı algısındaki değişimi anlamlı bir şekilde açıkladığını göstermiştir.

Bu çalışma aynı zamanda iyi (İSA), orta (OSA) ve zayıf sayı algısı (ZSA) seviyesine sahip birinci sınıf öğrencilerinin belirtilen değişkenler açısından ayıredici özelliklerinin betimlenmesini amaçlamıştır. Gruplar arası ortalama farklarını karşılaştırmak için varyans analizi ve Kruskal-Wallis testleri uygulanmıştır. Sonuç olarak, ZSA grubu her değişken bazında İSA grubu ile anlamlı bir şekilde farklılık göstermiştir. ZSA aritmetik performans, sayı hafızası, RAN ve okuduğunu anlama değişkenlerinde OSA grubundan anlamlı bir şekilde düşük bir performans göstermiştir. OSA ise, İSA ile RAN ve okuduğunu anlama değişkenleri dışında anlamlı farklılık göstermiştir. Ancak bu çalışma uzun bir dönemi içeren bir araştırma şeklinde tekrarlanmalıdır.

Dedicated to the memory of

my beloved father

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CONTENTS

TABLES

CHAPTER I

INTRODUCTION

The Importance of Mathematical Knowledge

Mathematics is an important discipline to be able to live independently, to establish social relations and to be employed successfully (Patton, Cronon, Bassett, & Koppel, 1997). Proficiency in mathematics is required to achieve success in the disciplines of science, technology, engineering, and mathematics, to be competitive in the qualified workforce (Jordan, Glutting, Ramineni, & Watkins, 2010). Mathematics is such a necessary skill that has been called "the new literacy" (Schoenfeld, 1995, p. 11). As the National Council of Teachers of Mathematics (NCTM, 2000) states: "Mathematical competence opens doors to productive futures; a lack of mathematical competence keeps those doors closed." (p.5). It is predicted that in the coming years, jobs with the highest rate of growth will require people who are proficient in mathematics and science (National Science Board, 2003).

Turkish Students' Achievement in Mathematics

Results of international studies that Turkey also participated in, namely TIMSS (The Trends in International Mathematics and Science Study) and PISA (The Programme for International Student Assessment), have been reflecting students' mathematics achievement since 1995. TIMSS is organized by the International Association for the Evaluation of Educational Achievement (IEA). PISA has been developed by the

Organization for Economic Co-Operation and Development (OECD). Throughout the past two decades, TIMSS has put forward the trends around the world on mathematics and science achievement at mainly fourth and eighth grades. Besides, this organization has suggested insights on class instruction, learning resources and environment, teacher education to administrators, teachers, researchers and educational policymakers. Thus, TIMSS has high importance for educational changes and improvements. On the other hand, PISA contributes to educational reforms by focusing on students' ability to use their knowledge in challenging real life situations. This organization monitors growth in learning mathematics, science, and reading of nations all over the world (TIMSS, 2011).

Turkey attended TIMSS 1999, 2007 (with eight graders only) and 2011. Nonetheless, the average achievement of Turkish students was below both the international average and averages of all of the participating European countries in these assessments. A remarkable fact from TIMSS 2011 for Turkey was that 7% of Turkish students could reach the advanced benchmark and place to the top of the distribution. On the other hand, only 67% could reach the low benchmark. When other countries like Slovenia, Finland, and Italy were taken into account, it was observed that only 3-4% of the participants reached to the advanced benchmark; but nearly all students (at least 90%) reached to the low level (TIMSS, 2011).

The first time Turkey participated in PISA was in 2003. In that year, the weighted domain was mathematics and students' mathematics performance in Turkey was far below the OECD average. The picture was similar in PISA 2006 when the national curriculum in Turkey was renewed on the constructivist approach. This approach began to be implemented gradually at schools. In 2008, a new national central assessment (Seviye Belirleme Sınavı – SBS) replaced the old assessment

(Ortaöğretim Kurumları Giriş Sınavı – OKS). However, both of the assessments revealed similar results, very low means in mathematics test as occured in PISA assessments. But in PISA 2009 mathematics domain, Turkey rose to rank of 31 among OECD countries and 41 among all countries. With that performance, Turkey was better than the countries like Mexico, Brazil, Serbia and Bulgaria. With this result, Turkey became one of the five countries like Mexico, Greece, Italy and Germany, which improved its mathematics scores between 2003 and 2009 assessments. During this time period, the proportion of Turkish students who were below the basic level in PISA studies decreased from 52% to 42% (PISA 2009 Ulusal Ön Rapor, 2010).

On the other hand, the picture is not so encouraging when Turkey's results in PISA 2009 are examined more deeply in terms of assessment levels. Only 1.3% of the students, half of the OECD average, could reach Level 6 in Turkey. The largest sample was in Level 2 whereas the largest sample of OECD countries was generally in Level 3. Also, the ratio of the students who were below Level 1 in Turkey was two times the OECD average. Thus, the distribution of students' proficiency levels in Turkey showed a right-tailed behavior where the distribution of the OECD countries was a normal one (PISA 2009 Ulusal Ön Rapor, 2010).

When all the data above are considered, it is observed that mathematical capabilities of nations differ much. Some countries demonstrate increasing performance through the years whereas some of them have a decline in their assessment scores. The percentages show that there are students who have problems with some content or cognitive domains of mathematics in the world and in Turkey. On the part of Turkey, the situation is somewhat promising in that the numbers above indicate Turkey's development in mathematics. Nevertheless, this does not change the fact that Turkey is below the average scores in the assessments mentioned. As stated above, there are a high number of students who are far below the base performance level in these assessments. Thus, Turkey's problem of low mathematics performance should be overviewed with its possible causes and solutions to improve this performance should be focused on by the authorities.

The Purpose and Significance of the Study

As seen in the international assessment results, there are still students who have difficulty in mathematics and show low performance in the assessments. Remediation studies for these children should not be the only intervention that must be conducted in the research area. Instead, prevention of this type of difficulties should be the focus of researchers. For prevention of mathematics difficulties, children who are at risk should be identified and intervened as early as possible. In addition, finding the precursors of mathematical learning at early ages is claimed to support these early identification and intervention studies (Passolunghi, Mammarella, & Altoé, 2008).

Research reveals that early numeracy skills are crucial for formal schooling (National Research Council, 2001), and these skills are often called "number sense" (Gersten, Jordan, & Flojo, 2005). Recent studies have shown that mathematics difficulties and disabilities have their roots in weak number sense, as well (Landerl, Bevan, & Butterworth, 2004; Mazzocco & Thompson, 2005). It is also stated that mathematics difficulties often go along with deficits in working memory (e.g., Geary, 1994). Related research revealed an association between deficits in processing speed and arithmetic performance, as well. (Fuchs et al., 2006; Hecht, Torgesen, Wagner, & Rashotte, 2001). Moreover, mathematics difficulties often cooccur with reading difficulties, meaning they share common deficits (Butterworth & Reigosa, 2007; Jordan, 2007).

To sum up, related literature states that early detection of deficits that cause later mathematics difficulties should be identified at early ages before or at the very beginning of formal schooling. There seems to be more than one precursor to be able to make this detection. Thus, the present study is based on the variables stated that affect the acquisition of mathematical skills at the initial years of schooling. Since early numeracy skills are called number sense, this study was mainly based on number sense. The purpose of the study is to examine the roles of arithmetic performance, reading and the cognitive correlates of mathematics learning as working memory, rapid automatized naming (RAN) and processing speed on number sense, which is defined as the core of numerical cognition.

The results of the study will be important because this study examines the effect of different variables including arithmetic performance as a measure of mathematics learning on number sense. However, in related literature there are several examples of longitudinal studies about the prediction of later mathematics performance with the use of number sense. The current study reverses the direction and hypothesizes that arithmetic performance as a math measure may be effective on explaining the variance in number sense. This study will also show what portion of number sense is affected by which of the specified variables. The study will indicate which of the precursors of early mathematics skills which were defined as number sense are to be included in a possible screening tool to be designed in further studies to identify children at risk for mathematics difficulties. This study differs from the previous studies in that it is the first study that describes the characteristics of first graders in terms of number sense and its relation with reading, working memory, rapid automatized naming (RAN) and processing speed.

CHAPTER II

LITERATURE REVIEW

Learning Mathematics is Hard for Some People: Mathematics difficulties

In today's world, mathematics difficulties are a big problematic issue because many children show significant difficulties while learning mathematics (Dowker, 2004, 2005; Geary, 1993; Ginsburg; 1977; Jordan, Hanich, & Uberti, 2003; Ostad, 1998). Unfortunately, it is a fact that between 5% and 8% of school age children are observed to have weaknesses in one or more domains of mathematics such as some deficits in memory or cognition or the problems with potential neural correlates (Geary, 2004; U.S. Department of Education, 2000). Some of these students give effort to keep up with mathematics at their grade level; but some of them have genuine learning disabilities in mathematics (Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2005). At this point, the difference between students with mathematics difficulties and with mathematics learning disabilities should be identified more specifically because there is a considerable difference between them. They both show nearly the same mathematics performance; but students with mathematics difficulties show less impaired academic behavior than the ones with mathematics disabilities (Jordan, 2007). In addition, related studies claim that the problem called "mathematics learning disabilities" or "dyscalculia" is the severe form of mathematics difficulties (Butterworth, 2005; Gross-Tsur, Manor, & Shalev, 1996).

Dyscalculia is a single core deficit of number sense, difficulty in mentally representing and manipulating number magnitudes (Butterworth, 2005). The National Center for Learning Disabilities (2006) notes that mathematics disability or dyscalculia is a term referring to a wide range of life-long learning disabilities involving mathematics skills. Rourke and Conway (1997) described mathematics disability (MD) or dyscalculia as a specific deficit in learning mathematical concepts and mathematical computation which is associated with a dysfunction in central nervous system. The Diagnostic and Statistical Manual of Mental Disorders (DSM–IV-R, fourth edition text revision) defines mathematics disorders as “mathematics ability that falls substantially below expected for the individual’s chronological age, measured intelligence and age-appropriate education” In other words, mathematics learning disabilities are diagnosed when a student’s mathematical achievement is below what is expected considering his intelligence and education (American Psychiatric Association, 1994). Dyscalculia is also characterized by a poor understanding of the number concept and the number system (Vaidya, 2004). It is also known as the cognitive disorder, impairing the typical acquisition of arithmetic skills (Ardila & Rosselli, 2002).

Considering that this study focuses on mathematics difficulties rather than its severe form, the nature of mathematics difficulties should be reviewed in more detail. A group of studies suggest that instead of general cognitive deficits, mathematics learning difficulties have roots in weak number sense which is defined as the “fundamental elementary ability or intuition about numbers” (Dehaene, 1997, p. 3). Detailed explanation of number sense takes place in the coming sections. Research shows that students with weak number sense have difficulty in benefiting from formal instruction in mathematics (Baroody & Rosu, 2006; Griffin, Case, & Siegler, 1994). Moreover, related literature suggests that calculation deficiencies starting from the first year of schooling can turn into weaknesses in number sense in the coming years (Gersten et al., 2005; Malofeeva, Day, Saco, Young, & Ciancio, 2004). Then, weak number sense may result in poor counting procedures, slow fact retrieval and mathematics computation problems, which are also features of mathematics learning disabilities (Geary, Hamson, & Hoard, 2000; Jordan et al., 2003). Related literature shows that mathematics difficulties may be evident in problems with (i) math fact automaticity (Garnett & Fleischner, 1983; Jordan, Levine, & Huttenlocher, 1995); (ii) arithmetic strategies (Geary, 1990; Goldman, Pellegrino, & Mertz, 1988); (iii) interpretation of word problem sentence construction (Englert, Culatta, & Horn, 1987); and (iv) word problem solving skills (Montague & Applegate, 1993).

As stated above, not all children understand number concepts and skills at the same speed. Some of them need structured support for that or perhaps, they have already mathematics difficulties (Gersten & Chard, 1999). To be able to identify the children who need extra support, time, instruction, measuring, and monitoring the development of mathematical understanding is highly important (VanDerHeyden, Broussard, Snyder, George, Lafleur, & Williams, 2011). By this way, identification of children can be realized. Moreover, identifying those who are at risk at early ages allows these children to participate in prevention services before it is too late (Fuchs, Fuchs, Compton, Bryant, Hamlett, & Seethaler, 2007).

In order to differentiate children with mathematics difficulties from those without showing difficulties, there are a few methods to be used. A traditional method to diagnose students who have mathematics difficulties relies on a discrepancy between intelligence and achievement. However, this IQ-achievement discrepancy method has some technical and conceptual problems (Vaughn & Fuchs, 2003). Firstly, the discrepancy between intelligence and achievement may be due to the lack of enough academic knowledge at early grades, not because of the existence of a learning disability. The students at early ages may be unsuccessful; because they may have not had the adequate academic instruction yet (Seethaler & Fuchs, 2010). Secondly, this method is criticized for its" wait-to-fail approach" (Vaughn & Fuchs, 2003). This method works if there is a discrepancy between IQ and achievement. This means that students should wait and experience failure at mathematics for years before they are identified as having mathematics difficulty. Thirdly, this method always leaves a question mark if the discrepancy is because of a disability or poor teaching (Fuchs & Fuchs, 2006). Therefore, this approach is seen untenable (Siegel, 1989). In IQ-achievement discrepancy method, a standardized achievement test is applied, in combination with a measure of intelligence (IQ). Then, a cut-off score to define who have mathematics problems is determined. At this point, defining the cut-off score appears to be another problem; because it is arbitrary and it may be inconsistent between different studies (Fuchs & Fuchs, 2006; Vaughn & Fuchs, 2003).

There are different suggestions for the selection and interpretation of these cut-off scores. It is stated that a mathematics achievement test score lower than 20^{th} or 25^{th} percentile, accompanied by a low-average or higher IQ score are typical hallmarks of mathematics difficulties or disabilities (e.g., Geary et al., 2000; Gross-Tsur et al., 1996; Powell, Fuchs, Fuchs, Cirino, & Fletcher, 2009). On the other hand, Seethaler and Fuchs (2010) use the 15^{th} percentile and Jordan, Hanich, & Kaplan (2003b) use the 35^{th} percentile. Furthermore, the Early Math Diagnostic Assessment (EMDA; The Psychological Corporation, 2002a) which is an individually administered norm-referenced test for use with preschoolers through third grade students to diagnose mathematics difficulties suggests another cut-off criterion. Students who score below the 16^{th} percentile on the EMDA Math Reasoning subtest or the EMDA Numerical Operations subtest at the end of first grade or at the end of the second year of kindergarten, and those who repeated kindergarten, are identified as having math difficulty (EMDA; The Psychological Corporation, 2002a). So, many researchers concluded that the 25th percentile is the upper limit and enough to diagnose learners who struggle in mathematics (e.g., Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007; Murphy, Mazzocco, Hanich, & Early, 2007; Powell et al., 2009; Vukovic & Siegel, 2010).

IQ-achievement discrepancy method lost the reputation of being the major approach to identify learning disabilities when the 2004 reauthorization of the Individuals with Disabilities Education Act (IDEA) was realized. IDEA is a federal program formed to protect the rights of students with disabilities. This program defends the idea that every child should get free education that is appropriate for him/her. IDEA was legislated in 1990 and, reauthorized in 1997 and 2004. The reauthorization was realized by the President Bush's signing a law that has brought new regulations to the implementation of special education services. In this reauthorization, a new way to diagnose disabilities was presented. This new method has to do with documenting a child's inadequate responses to an intervention which has scientific validity and which is based on research (Fuchs et al., 2007). The quality of the child's responses or his/her lack of responsiveness to that effective intervention provides evidence for poor academic growth or a disability. This approach is called response-to-intervention (RTI). Mostly, it occurs in a multitier prevention system, meaning the intervention proceeds step by step.

To be able to implement an RTI model, the first step is to determine the students who are at risk and who need special attention (Fuchs et al., 2007). The related literature says that if these students are identified early (in kindergarten or at first grade), then this allows them to participate in prevention services before the problems turn into substantial academic deficits. The prevention services aims to help these students develop their academic skills as much as their normal achieving counterparts (Fuchs et al., 2007). In this first step of RTI, a construct or a set of skills that stands for a strong predictor of future mathematics disability is to be defined (Seethaler & Fuchs, 2010). To support this view, the research in reading may be overviewed. That is, researchers in this area have documented that poor phonemic awareness and letter-sound knowledge are predictors of future reading difficulty in young children. Accordingly, reading identification studies have focused on these predictors. In addition, early intervention efforts for kindergarten and first grade students who are at risk for reading disability have been proven to be effective (Torgesen, Wagner, & Rashotte, 1999). Likewise, knowing the predictors of mathematics difficulties will reveal which variables identification studies of mathematics should focus on. As a result, intervention services for identified mathematics difficulties are expected to help strikingly the students who suffer from this problem.

The Normal Development of Basic Quantitative Skills

For years, researchers thought that children's understanding of numbers was formed over a long time. But studies done especially in the last 2 decades have shown that humans are born with an innate set of quantitative competencies, just as many animal species (Geary, 2000; 2006).

Geary (2000) proposes in his model that numerical development can be separated into three stages*: infancy and preschool years, primary* and *secondary schooling* and *adulthood*. Related literature notes that there is a "primitive number processor" as a neural part of human body which makes humans sensitive to quantities (e.g. Barth, La Mont, Lipton, Dehaene, Kanwisher, & Spelke, 2006; Butterworth, 1999; Dehaene, 1997; Dehaene & Cohen, 1997; Dehaene, Piazza, Pinel, & Cohen, 2003; Dehaene, Piazza, Pinel, & Cohen, 2005; Dehaene, Spelke, Pinel, Stanescu, & Tsivkin, 1999; Feigeson, Dehaene, & Spekle, 2004; Geary, 1994). Even in the first year of life, human beings show sensitivity to numerical and spatial representations, ordinal relations like "more" or "less" (e.g., Antell & Keating, 1983; Cordes & Brannon, 2008; Starkey & Cooper, 1980; Wynn, 1992). A striking demonstration proves the fact that preverbal infants are sensitive to changes in quantity, to adding or removing objects, which show also their sensitivity to number operations. In the context of "the violation-of-expectation paradigm", Wynn (1992) showed 5-month-old infants a toy which was then covered by a screen. Then, another toy was shown and that was also placed behind the screen. When the screen was removed and there was only one toy present, infants predictably showed surprise and looked longer to the screen compared to the time when there were two toys. It seems that the babies expected two objects behind the screen. It is not likely that babies will learn the numbers 1, 2, 3 or the concept of ratio from their environment in just such a short time after birth. Then, the claim that they have an inborn sense of numbers and counting is highly plausible (Sousa, 2008).

Wynn's work (1992) was followed by Kobayashi, Hiraki, Mugitani, and Hasegawa (2003). They also used the violation-of-expectation paradigm. It is stated that 5-month old babies were surprised as in Wynn's experiment (1992) when their expectation was not fulfilled. The difference in this new study is that Kobayashi et al.,(2003) combined visual stimuli with auditory stimuli. As different number of dolls appeared on the screen, one or two tones followed them. Therefore, not only the number of the visual stimuli; but also that of auditory stimuli became important for the infants.

Both studies provided evidence for basic arithmetic ability to be innate in humans. The follow-up of these studies came from Xu and Spelke (2000). They showed another aspect of infant sensitivity to quantity. In a dot array experiment, they showed dots of different numbers and they observed that 6-month-old infants can discriminate between dot groups of 8 and 16, but not between those of 8 and 12. This means that infants are successful at discriminating when the ratio between the objects is large enough.

Similarly, 10- and 12- month-old babies provided evidence for their quantity discrimination abilities in a study where they were presented a choice between two quantities of crackers (Feigenson, Carey, & Hauser, 2002a). The experiment started with the placing of the crackers into opaque containers. Babies saw 1 cracker placed in the container on the left and 2 crackers placed in the container on the right. It was observed that infants chose the container with the greater number of crackers. This experiment showed more than babies' sensitivity to number of quantities. Babies succeeded in discriminating between crackers of 1 v.s 2 and 2 v.s 3; but they failed to distinguish between crackers 2 v.s 4, 3 v.s 4 and 3 v.s 6. This showed that the number of quantities is important for infants to form representations. In other words, discriminating between two quantities is possible for infants if the set size of the quantities does not exceed 3. This is called the "set-size signature of object-file representations". Object file representation is the representation in which the magnitude of the quantities is not explicitly displayed, but only implicitly recognized by the participants.

The primary numerical abilities discussed above, or in other words, the preverbal number knowledge forms the basis for secondary symbolic or verbal number competencies, which include whole numbers, number relations and number operations (Jordan, 2010). This symbolic number system is the one which develops with the input children receive in preschool and kindergarten (Gingsburg, Lee, & Boyd, 2008; Siegler, 2009). Children need the symbolic number system to be able to learn formal mathematics at school (Jordan & Levine, 2009).

Feigenson et al. (2004) mention two core systems of numerical representations. These systems are thought to be innate in humans and in animals. A formal education or cultural learning is not required to adopt these systems. Therefore, it can be said that these primary numerical representations do not seem to need much verbal instruction to develop (Berch, 2005; Dehaene, 1997; Feigenson, Dehaene, & Spelke, 2004). These abilities develop on their own. The first system is "approximate representations of numerical magnitude". Infants and adults form approximate representations for large amount of quantities in this system. In other words, they try to estimate and comprehend a large amount of quantity. To test this ability, experiments of dot arrays are organized. People try to estimate the number of dots given in the arrays. This representation is important because it combines with symbolic number competencies later in life. The other core system is "precise representations of distinct individuals". In this system, people make estimations again, but the quantities are smaller this time. Thus, more accurate estimations are expected from the participants. The cracker experiment mentioned above is mainly used to test these representations. What is important in this experiment is to be able to distinguish the difference in quantities between the containers.

Infancy and preschool quantitative skills development, which is the 1st stage of Geary's (2000) number development model, was discussed above. In that period, the quantitative abilities called "primary abilities" are addressed. These are numerosity, ordinality, counting and simple arithmetic, all of which will be discussed below in detail. Primary school age development takes place in the 2nd stage. In this stage, the secondary quantitative abilities which are number and counting, arithmetic computations and arithmetic word problems are expected to develop. The most difficult concept children should learn at this stage may be base-10 structure because of the national counting word differences. It means that number words in Asian languages follow a pattern like "ten, ten one, ten two … two ten one and so forth. But in European languages, counting words after ten are eleven, twelve … and they do not form a pattern. Therefore, learning base-10 structure in European countries or United States is more difficult for children than their counterparts in Asian countries. As a result of base-10 structure of the former countries' children, they have difficulty in the arithmetic tasks like borrowing or carrying. They have failure in understanding the value of "1" taken from the tens digit in the operation 15 – 8. This period is also crucial for arithmetic word problem solving. Especially the wording of the problem and the lengths of the sentences to be converted to mathematical representation are the factors to be considered while adjusting the difficulty of the problems (Geary, 2000).

The Cognitive Models of Number Processing

To be able to learn how our innate quantifying mechanisms develop, neuropsychologists and cognitive neuroscientists stated a variety of models for number processing. The main question was how numbers around us were encoded and manipulated in our brain. Nearly 20 years ago, McCloskey, Sokol and Goodman (1986) presented the "abstract modular model" to explain this process. In this model, our number processing system is responsible for translating the Arabic symbols or number words into semantic representations. By this way, the numerical inputs in different forms like words, digits or patterns of dots on objects are converted to abstract quantity codes. Then, these abstract codes are used in processes like calculation, interpretation of operation signs, retrieval of mathematical facts and organization of arithmetic procedures (McCloskey, 1992; McCloskey, Caramazza, & Basilli, 1985). This model consists of 3 distinct parts: the comprehension system, the calculation system and the number production system. The first one converts different notations of numbers into a common abstract version. The calculation system evaluates arithmetic facts as being smaller or bigger and realizes the calculation procedure subsequently. Lastly, the production system presents the final output in the desired notation, digit or spoken number words. McCloskey (1992) assumes that all inputs go to a single abstract representation in his model.

Later, Campbell and Clark (1988) argued that McCloskey's model did not completely explain some certain aspects of number processing because it is too modular. They did not think that numbers are represented abstractly. According to their encoding-complex model, number processes can involve several separate codes and are based on multiple forms of internal representations. They hold that there is not additivity between different notations; but there is an interaction between them. Therefore, number skills act as multi-component representational structures and have various combinations according to the type of the task at hand (Campbell & Clark, 1988, p. 204).

Lastly, we have Dehaene's Triple Code Model, in which it is proposed that numbers may be represented in three different codes: auditory-verbal code, visual-Arabic code and analogue magnitude code (Dehaene, 1992, 1997, 2001; Dehaene, & Cohen, 1995, 1997). Each mathematical task relies on one or more of these codes. In the auditory-verbal system, numbers are represented in language modules, in the form of non-numeric words. Simple calculations, verbal counting and retrieval of arithmetic facts are based on this verbal system. In visual-Arabic codes, multi digit operations are mainly performed. The third one, analogue magnitude code directs the numerical comparison and number approximation.

The Basic Quantitative Skills

Skills related to number concepts and representations at early ages are often called as number sense. It is also seen as the outcome of early mathematics learning (Clarke & Shinn, 2004). According to Geary (2000) the early and basic innate quantitative skills that number sense also includes are subitizing, ordinality (quantity discrimination or magnitude comparison), counting and simple arithmetic. Therefore, number sense forms the base for formal mathematics learning at school (Jordan, Kaplan, Locuniak, & Ramineni, 2007). Subitizing is the ability to determine the number of quantities without counting. Ordinality is the understanding of concepts like more, less and equal. Counting is to be able to determine the number of quantities and use counting words. Lastly, simple arithmetic is to be aware of increases and decreases in a set with a small number of elements.

Since all these skills are required for normal mathematical development, a more detailed discussion on each of these skills is needed. Hence, their individual contribution to mathematical development can be revised and their role in the prediction of possible mathematics difficulties can be better understood. Therefore, each of these basic skills will be discussed in detail below.

Number Sense

Research indicates that early numeracy skills form the basis for formal schooling (Gersten et al., 2005). But not every child possesses these skills at a highly developed manner (National Research Council, 2001). Since mathematics is a discipline that develops in a hierarchy, children who lack the necessary skills or who have less-developed early numeracy skills will possibly experience the disadvantage of this situation. This shows the importance of the acquisition of early numeracy skills. These skills enhance learning of more advanced skills. Success in the acquisition of these skills can promote children's self-efficacy for mathematics course. On the other hand, a failure to achieve high in mathematics in the early years can cause children to feel less comfortable and worried in future mathematics (Clarke & Shinn, 2004; Gersten et al., 2005).

These early numeracy skills which are often called number sense are defined as a "frequently mentioned outcome of informal early math learning" (Clarke & Shinn, 2004, p.236). The related literature indicates that it is difficult to operationalize number sense. Therefore, there are many definitions for number sense. Lago and DiPerna (2010) bunched some of those as in Table 1.

Table 1. Operational Definitions of Number Sense

Authors	Definition/Key Skills
Gersten and Chard (1999)	Rote learning; object counting; sequencing numbers; determining which of two numbers is larger; identifying a missing number in a sequence; determining which of two numbers is closer to a third number, and counting on from a given number
Case and Sandieson (1991)	Understanding of the number line; bidirectional knowledge that one can generate a set of objects in either direction by adding or subtracting one unit; knowledge of relative magnitude; and knowledge of the utility of numerical information
Van De Walle (1990)	Quantities (more and less, one-to-neo correspondence, cardinality, ordinality, and understanding of the relative size of numbers); estimation of set size; comparison of set sizes; and counting
Baker, Gersten, Flojo, Katz, Chard, & Clarke, (2002)	Quantity discrimination (magnitude comparison); counting knowledge; number identification; and working memory
Geary (2003)	Digit span; magnitude comparison; and writing numbers from dictation
Mazzocco and Thompson (2005)	Reading one-digit numerals; number constancy; adding one-digit numbers using multiplatives; and making magnitude judgments between different one-digit numbers
Van Luit (2000)	Counting (order number names in the correct sequence, one-to-one correspondence, ordinality, cardinality, counting on, skip counting); subitizing; concepts of comparison (such as great, most, and less); classification (ability to arrange objects in a class or subclass); and seriation (ranking of objects)
Howell and Kemp (2005)	Rote counting beyond 10; counting from a number other than 1; numerical recognition to 10; sequencing numerals 1-10; temporal sequences; making equivalent groups; distinguishing between quantity and size; comparison of quantity to 5 (most/least); and comparison of spoken numbers

Number sense conceptually relies on early numeracy skills that form the basis of numerical knowledge. This numerical knowledge is related to counting, patterns, magnitude comparison and simple arithmetic calculation, as stated above (Berch, 2005; Gersten et al., 2005; Jordan & Hanich, 2003). Another operational definition of number sense is counting skill, number knowledge and the ability to transform numbers by addition and subtraction (Jordan et al., 2007). Number sense is also defined as the awareness that numbers represent quantity and have magnitude, and numbers are in a fixed order in a counting sequence (Griffin, 2004). It refers to the understanding of whole numbers, number operations and the relations between numbers (Malofeeva et al., 2004; NRC, 2009).

Number sense includes abilities of perceiving and interpreting small quantities, comparing numerical quantities, counting and doing simple arithmetic calculations (Berch, 2005). It is a crucial element for learning mathematics and it takes its root in early childhood period (Jordan, 2010). Therefore, number sense gives an insight into a child's early experiences and his/her cognitive level (Dowker, 2005; Lipton & Spelke, 2003).

There is a controversy on not only the definition of number sense, but also the question of how we gain number sense. Some researchers believe that it is a lower order and innate ability, developing with experience. And some others say that it is a higher order ability, developing via formal and informal teaching with experience (Berch, 2005).

The primary (nonverbal) number sense needs no verbal input or instruction to develop or very little. It is present when the individual is just an infant (Dehaene, 1997). This preverbal or primary number sense is the basis for secondary symbolic number sense (Feigenson et al., 2004). Secondary (symbolic or verbal) number sense includes whole numbers, number relations and number operations (Jordan, 2010). Therefore, it acts as a mediator for learning mathematics at school. Number sense is found to have mainly two dimensions; (a) *conventional factor* that includes number combinations and story problems and (b) *basic number skills factor* that includes counting, number knowledge and nonverbal calculation (Jordan, Kaplan, Olah, & Locuniak, 2006).

Apart from the dimension perspective, number sense is overviewed in terms of its components. Number sense is stated to have 5 main components; *counting, number knowledge, number transformation, estimation, number patterns*. Counting is stated to "put abstract number and simple arithmetic within the reach of the child" (Baroody, 1987, p.33). This means that counting enables a child to give numbers and arithmetic their meaning. Weaknesses in counting are stated to play a crucial role in revealing mathematics difficulties (Geary, 2003). Secondly, number knowledge includes mainly discriminating between quantities and it was found to be a strong predictor of arithmetic achievement at first grade (Baker et al., 2002). Number transformations include making calculations in verbal or nonverbal contexts, with or without a physical or verbal manipulative. Estimation is an ability that goes hand in hand with arithmetic development (Dowker, 1997; Rubenstein, 1985). Even around the age of 4, children can estimate a small amount of set sizes (Baroody & Gatzke, 1991). Lastly, being aware of number patterns enhances automaticity, as to be mentioned in arithmetic development part. This is because children see the relationships between number combinations as they master number patterns (Threfall & Frobisher, 1999). In other words, children better realize that 4 + 2 = 6 because 3 + 3 = 6 and 4 is 1 more than 3, 2 is 1 less than the other 3, so the result does not change.

Number sense development is heavily influenced by children's home experiences with number concepts (Case & Griffin, 1990). Literature says that engaging children in number activities and mathematical games help their developing basis for number knowledge (Gersten et al., 2005). Correspondingly, in a study, children who are at risk for mathematical difficulties were spent effort on to teach number sense, and these experienced children demonstrated significant gains on first grade mathematics outcomes when compared to the control group (Griffin, Case, & Siegler, 1994).

Children's number sense is also correlated with the income level. Considering one of the components of number sense stated above, *number knowledge*, it is found that middle-income children have better developed number knowledge than low-income children at kindergarten level (Griffin et al., 1994). Likewise, Jordan and colleagues (Jordan et al., 2006) demonstrated that children from low-income families entered with a generally low-level number sense. They are claimed to have difficulties especially with mathematics story problems based on simple arithmetic. A possible reason for this is that these children may gain fewer experiences with both numbers and literacy. Even after being exposed to a systematic mathematics curriculum and teacher instruction, this income gap does not disappear. These children start learning mathematics through formal schooling with a disadvantage.

As stated above, number sense is found to be important for children's learning tracks in mathematics during elementary school time (Duncan, Dowsett, Classens, Magnuson, Huston, & Klebanov, 2007; Jordan, Kaplan, Ramineni, & Locuniak, 2009). Furthermore, early number sense is found to highly predict important math outcomes at school (Okamoto & Case, 1996; Baker et al., 2002). It allows children to relate mathematical principles to mathematical procedures

(Gersten et al., 2005). According to Berch (2005), number sense enables a child to perform problem solving tasks. During this process, the child understands the meaning of numbers and develops strategies. S/he makes number comparisons, creates procedures to use numbers and brings together his / her knowledge to interpret mathematical information.

Besides, it is stated that students who show mathematics difficulties later in life may actually have developed a weak sense of number in primary school (Geary, Bow-Thomas, & Yao, 1992). In other words, number sense is claimed to predict later mathematics achievement outcomes (Clarke & Shinn, 2004). In a screening study, early number sense is found to be a reliable and powerful predictor of math achievement at the end of first grade (Jordan et al., 2007). In this study, number sense was proved to account for 66% of the variance in first grade math achievement. Deficits on number sense are revealed by weak counting procedures, slow fact retrieval and inaccurate number computation (Geary, Hamson, & Hoard, 2000; Jordan et al., 2003a, 2003b) and these deficits may lead to deficient calculation skill and risk for developing mathematics disabilities (Mazzocco & Thompson, 2005). Therefore, number sense seems to be a very important variable in predicting difficulties in mathematics. Then, to screen students for number sense at an early age can prevent problems that students may face while doing mathematics in coming years.

Subitizing

Subitizing is the rapid perception of numerosities (Kaufman, Lord, Reese, & Volkmann, 1949; Nan, Knösche & Luo, 2006). It is defined as the ability to determine the quantity of small sets without counting. It is seen as the primitive cerebral process of counting (Sousa, 2008). It is a necessary process for young children to develop abstract number representations and arithmetic strategies necessary for counting (Clements, 1999).

In a related study, the children with arithmetic disabilities were found to be slower in processing numbers and subitizing tasks when compared to their normal achieving counterparts (Koontz & Berch, 1996; Landerl et al., 2004; Rouselle & Noel, 2007). But this does not mean that all children who have arithmetic problems also have subitizing problems. The ratio of having both of these problems ranged from 33% to %79 in the age range of 7 to 17, for children who have arithmetic disabilities (Desoete & Gregoire, 2007; Fischer, Gebhart, & Hartnegg, 2008). Nonetheless, this is a percentage that should be taken into account. It indicates that subitizing can be used as a predictor of mathematical difficulties in screening studies. It is expected to prove effective when integrated with other predictor factors.

Quantity Discrimination

Quantity discrimination (QD) or magnitude comparison means distinguishing which of two numbers or which of two sets of objects is larger than the other. It may also refer to which of two numbers is closer to a third number (e.g., which number is closer to 6, 3 or 5?). Together with counting, it helps children do number operations

(Jordan et al., 2010). Quantity discrimination requires that children know which number in a pair is larger (Desoete, Ceulemans, Roeyers, & Huylebroeck, 2009; Gersten & Chard, 1999; Hannula & Lehtinen, 2005; Xu & Spelke, 2000).

At the age of 4, children start discriminating between quantities (Case & Griffin, 1990; Griffin, 2002, 2004). They can tell which group of objects is more or less. And, by the age of 6, most children bring their quantity discrimination knowledge together with their counting knowledge to form a mental number line (Siegler & Booth, 2004). Mental number line is defined as a central structure for whole numbers and it enables children to understand the quantitative worlds around them better (Griffin, 2002). Using mental number line, they understand that, for example 8, which is later in the count list than 5, is greater than 5 (Griffin, 2004). The mental number line is like the one that students learn at school; but it has one important difference (Sousa, 2008). Not all the numbers are placed equally on a scale. As the numbers mentioned get larger, the number line compresses the distance between them. Hence, this makes it difficult for the children to compare large numbers. For example; children can decide which is the larger one, 4 or 5, faster than for the numbers, 86 and 87. The larger pair involves numbers that stand closer to each other on the mental number line. Mental number line provides people with an intuition and imagery about numbers; but it is limited since it includes no negative numbers. Thus, teachers should construct other mental models to enhance complete understanding of mathematics (Sousa, 2008).

As mentioned above, numerical size of the numbers determines to be able to compare them easily. This shows that reaction times of people are in a direct relationship with the numerical size of the stimuli. This is called the numerical size effect. On the other hand, when people are to compare two quantities, there is an inverse proportion between the numerical distance between the numbers and the reaction times. This is called the numerical distance effect. The studies observing QD indicates that the larger the distance between the numbers compared, the faster and more correct answers were taken from the children (Dehaene, 1997; Dehaene, Bossini, & Giraux, 1993; Gevers, Lammertyn, Notebaert, Verguts, & Fias, 2006; Zhou, Chen, Chen, & Dong, 2008). Moyer and Landauer (1967) were the first people to review QD in terms of reaction times (RTs) and get to the result stated above. They presented participants pairs of digits and asked them to press the key that is near to the largest pair. They observed that the reaction time was longer if the digits are close to each other like 8 and 6 rather than 8 and 2.

QD is an important variable in number sense screening studies. It was demonstrated to be a better measure of early mathematics at kindergarten (Chard, Clarke, Baker, Otterstedt, Braun, & Katz, 2005) and first grade (Clarke & Shinn, 2004) when it is compared to measures like oral counting (OC), number identification (NI) and missing number (MN). It has significantly higher correlation than OC, NI, MN with early mathematics measures like Woodcock-Johnson Revised (WJ-R) Applied Problems Subtest (Woodcock & Johnson, 1989) and Number Knowledge Test (NKT; Okamoto & Case, 1996). It was found to be the most reliable measure of early mathematics and the strongest indicator for early identification (Clarke & Shinn, 2004). Also, QD was found to be an important predictor of variation in arithmetic abilities (Durand, Hulme, Larkin, & Snowling, 2005). Thus, QD can be considered as a variable, predicting mathematical difficulties.

Arithmetic

According to Piaget and Szeminska (1941), there are four logical abilities as the requirement of the development of arithmetic. Piaget (1965) believed that the development of number comprehension can be completed if and only if these four abilities are mastered by the child. They are seriation, classification, conservation and inclusion. *Seriation* is the ability to classify a number of objects, considering the differences of their dimensions, ignoring their similarities. It involves ordering of objects, even events. Asking children to order blocks from the smallest to the largest can be used as a task for this ability. Moreover, the order of events in their lives can be asked. It seems inherently nonverbal and even monkeys show some ability of seriation (McGonigle & Chalmers, 1992). Also, this ability seems to be important for predicting number line and number language comprehension in early years (Kingma, 1984; Kingma & Zumbo, 1987). *Classification* is to classify objects, considering their similarities in one or more dimensions. At this stage, the child makes decisions, considering certain attributes of objects. For this ability, sorting activities according to sizes, shapes, colors, etc. can be used. *The inclusion principle* is based on seriation and classification. It is to be able to understand that numbers are indeed series which contain each other. Or, a set of objects can be the elements of another set, just as the boys in a class are also the members of the whole school. Inclusion is seen as the highest form of classification (Piaget & Szeminska, 1941). Lastly, conservation is feeling confident in that the number of objects in a collection can only change after adding or taking out object(s). Sample tasks can be giving two equal rows of materials, asking which row contains more and then spreading out the rows and asking again. Piaget and Szeminska (1952) stated that young children around 5 or 6 ages do often fail conservation of number tasks. Furthermore, Piaget and his fellows suggested that children do not develop a complete understanding of arithmetic before they are seven or eight years old. But many researchers after Piaget have demonstrated that children do not lack of cognition at that age, that much (e.g., Fuson, 1988). These researchers believed that these children have number knowledge and number skill more than Piaget claimed they have.

Arithmetic achievement is necessary to turn linguistic and numerical information into mathematical equations, to interpret mathematical concepts and operations, to select appropriate backup strategies for problem solving (Dowker, 2005). Children use a variety of ways (strategies) to perform arithmetic operations and arithmetic problems. Counting and memorization-retrieval are examples of these strategies (NRC, 2001). During the initial execution of arithmetic operations, children use counting strategies to perform an arithmetic task. After some time, especially between the ages of 7 and 12, children's counting procedures tend to convert into memory representations of basic arithmetic facts (Siegler & Shrager, 1984). These representations require speedy access to long-term memory. Then, memory-based problem solving processes start to take place. During these problem solving processes, access to memory makes the concept "automaticity" appear. An example of these processes can be direct retrieval as "8" quickly in a problem like "5 + 3". Another example is decomposition of an operation like "6 + 7". Here, the student retrieves the answer to "6 + 6", and then answers the main problem by adding "1" to his/her retrieval.

All these show that automaticity and speed of processing are in the broad domain of arithmetic skills. Hence, these two may be two important characteristics of mathematics skill proficiency.

<u>Counting</u>

The knowledge of counting is crucial for extending humans' quantitative understanding far beyond small numbers (Baroody, 1987; Baroody, Lai, & Mix, 2006; Ginsburg, 1989). Humans learn to say the counting words quickly after they learn to talk (Fuson, 1988). Before kindergarten, most children adopt the key counting principles (Gelman & Gallistel, 1978). These principles are thought to govern children's counting.

According to Gelman and Gallistel (1978), young children start counting between the ages of about 2 and 5. During this period, children's counting is controlled by five key counting principles.

1. *The one to one principle:* Each object to be counted is assigned by one and only one number word.
2. *The stable – order principle:* There is a stable order of number words. Therefore, when somebody is counting a set of objects, s/he should always start from "one" and go on like "two, three, ..."
3. *The cardinality principle:* The counting procedure should be so correct that the final counting word should indicate the number of items in the set counted.
4. *The abstraction principle:* Not only concrete objects, but also abstract objects can be counted in the same way.
5. *The order - irrelevance principle:* The order in which the items in a set are counted is negligible; it does not change the number of elements in that set.

According to Dowker (2005), counting knowledge involves both procedural and conceptual aspects. The procedural knowledge is about a child's ability to complete a counting task and determine the number of objects in a collection (Le Fevre, Smith-Chant, Fast; Skwarchuk, Sargla, & Arnup, 2006). Conceptual knowledge reveals a child's understanding of why a specific procedure works in a given situation. Also, conceptual counting knowledge is a sign of understanding the counting principles mentioned above (Gallistel & Gelman, 1992; Le Fevre et al., 2006; Wynn, 1992). In many studies, the importance of procedural and conceptual counting knowledge in the development of arithmetic abilities is mentioned (Baroody, 1992; Frank, 1989; Fuchs et al., 2007; Gersten et al., 2005; Johansson, 2005; Le Corre, Van de Walle, Brannon, & Carey, 2006; Le Fevre et al., 2006; Sophian, 1992; Van de Rijt & Van Luit, 1999).

As children gain counting knowledge, they start to construct efficient counting strategies. These strategies are mainly count-all and count-on strategies. In count-all strategies, children use the long sum- technique; they start counting from one and count all the addends. It is like starting from 1 and counting up to 8 for the addition operation 3 + 5. In the second technique, count-on, children can use two ways of counting. They can use count-from-first; it means that they start from counting from the first addend 3 in the operation 3 + 5 and count 5 over it. In the second way, they use min-counting strategies. They start counting from the larger addend so that the operation is easier and counting lasts shorter. They start counting from 5 for the operation 3 + 5 (Hopkins & Egeberg, 2009).

Children can often tell the counting words automatically before going to formal school. In addition, they seem to carry the inherent knowledge of counting principles at school age (Fuson, 1988; Gelman & Gallistel, 1978). Nonetheless, some people have the '*principles first*' view (Gallistel & Gelman, 1992) whereas some others suggest that the verbal counting knowledge is a prerequisite for learning the counting principles (Fuson, 1988). This means that some people believe that children must learn the counting principles first and then counting knowledge develops. But some other people are for the idea that children should gain counting knowledge first and then they get ready for learning the counting principles. According to this opinion, children first gain skills for counting. Then, the experience they get guides them to learn the counting principles step by step. For example; they can learn about the order-irrelevance principle when they start counting objects in different orders and always find the same final number at the end. Nonetheless, related literature does not support any of these ideas, meaning both of them may be partially correct techniques.

Related literature shows that children who did not have adequate counting knowledge showed deficiency in their numeracy skills and this stituation often resulted in arithmetic disabilities (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Gersten et al., 2005). Furthermore, children who had disabilities in arithmetic were found to make more errors in counting and still show deficiencies in conceptual understanding even at the age of 6 (Geary, Bow-Thomas, and Yao, 1992). Likewise, it is stated that early difficulties in counting forecast later difficulties in arithmetic domain of mathematics learning (Geary, Hoard, & Hamson, 1999). In a longitudinal study during the period between preschool to second grade, counting ability was found to be the best predictor of the beginner level arithmetic performance (Aunola et al., 2004). In other studies, counting was found to be a precursor of early mathematics learning. This shows that the effect of counting is not limited only to be on arithmetic (Mazzocco & Thompson, 2005; Passolunghi, Vercelloni, & Schadee, 2007). More than that, Dowker (2005) demonstrated that children who had difficulties in any aspect of counting showed overall - below average mathematical performances. Therefore, counting is an important predictor that should be considered in mathematical difficulty screening studies.

To Remediate or to Prevent Mathematics Difficulties: *Early Math Screening*

Today, research on valid screening for potential math difficulties and students at risk is still in its infancy (Gersten et al., 2005). To start with, the time for screening should be determined. Related literature suggests that screening studies to identify students who are at risk for mathematics difficulties should be delayed until the end of or after first grade (Seethaler & Fuchs, 2010). Otherwise, students' low performance may be due to developmental or experimental delay rather than risk for mathematics difficulties. A similar situation is observed in the screening studies for future reading disability. It is demonstrated that screening for future reading disability at an early age produces a high proportion of false positives, meaning students who are identified as having reading disability does not have it, in fact (Catts, Petscher, Schatschneider, Bridges, & Mendoza, 2009). And this result forces schools to provide intervention to students who do not really need help.

To examine the risk of math difficulty, some screening instruments developed in the world are cited in the literature. The first study to report was of Baker et al., (2002). The sample size was nearly 64 – 65. The screening was done in the spring of kindergarten and the outcome was gained in the spring of first grade. The screening measures were Number Knowledge Test (Okamoto & Case, 1996), digit span backward, numbers from dictation and magnitude comparison. The outcome measures were the Stanford Achievement Test 9 (SAT-9) and Number Knowledge

Test (NKT) again. The correlation values between screening and outcome measures were given in the table. In this study, no information on decision utility is provided. An additional screening study is by Gersten et al. ‘s (2005). They concluded that a screening instrument for 5- and 6- year-olds which is based on the skills of counting / simple computation or a sense of quantity / use of mental number lines gives evidence of risk of mathematics difficulty since these skills are seen as aspects of number sense and number sense is known to predict future mathematics outcomes (e.g., Dehaene, 1997; Okamoto & Case, 1996). Specifically, the aspects of number sense such as counting skill or quantity discrimination may provide useful information for forecasting young students who are at risk for mathematics disability (Gersten et al., 2005).

In order to determine who has difficulty in mathematics and really needs help, educators may better focus on screening studies that are based on the possible predictors of mathematics difficulties. The screening studies presented above include many measures of number sense since number sense is stated to be one of those predictors. These measures are examples of the skills mentioned in the development of quantitative skills part. However, it is better to look for more factors that influence mathematics learning performance and that will be added to these screening measures. For example, intelligence and reading are only two of these factors suggested to be focused on in related literature. It is stated that future work should examine the discriminant validity of screening batteries in terms of IQ and reading to increase the effectiveness of a screener (Seethaler & Fuchs, 2010). Within the framework of this study, the rest of the factors that affect mathematics development and that are to be included in screening studies are reviewed below.

The Cognitive Correlates of Mathematics Development

General cognitive competencies related to working memory, visual attention (called processing speed and rapid automatized naming in this study), and language understanding are considered to enhance the development of early number skills (Aunola et al., 2004; Fuchs, Compton, Fuchs, Paulsen, Bryant, & Hamlett, 2005; Geary, 2004; Klein & Bisanz, 2000). Therefore, these constructs are taken into the scope of this study and reviewed in the following sections.

Working Memory

Working memory is defined as the ability to keep items in memory while performing another task (Daneman & Carpenter, 1980). It is believed to have an important role in the acquisition and use of basic skills in education (Hitch & McAuley, 1991). Recent research has been working on the role of working memory in mathematical processes. Working memory is responsible for the processes that are involved in the control, regulation and maintenance of information in our cognition. It is also called the workspace or blackboard of the brain (Atkinson & Shiffrin, 1971; Miyake & Shah, 1999). According to the most cited multi-component working memory model in the literature, Baddeley and Hitch's model (1974), there are two slave systems, or short-term storage systems, called phonological loop and visual-spatial sketchpad. The former is responsible for storage and rehearsal of the verbal information whereas the latter keeps visual and spatial information. There is also a central executive, the core of the working memory, which supervises information integration and coordinates both of these slave systems. The tasks to measure the working memory systems differ from each other, as well. Recall of digit and word sequences assesses the phonological loop whereas recall of visual patterns or sequences of movement do visual-spatial sketchpad (Passolunghi et al., 2008).

Deriving from the facts above, it is not surprising for many authors to have found that memory is related to the acquisition of numerical and arithmetic knowledge at early ages like first and second grade; more specifically, working memory has a very crucial role in calculation and word problem solving as the two main processes of mathematics skills (e.g., Bull & Sherif, 2001; Fuerst & Hitch, 2000; Geary et al., 2000; Hitch, 1978). One of the slave systems, visuospatial sketchpad has been found to best predict early number skill acquisition and arithmetic calculation performance in younger children, where the phonological loop and the central executive seems to be involved in the activities related to counting and solving arithmetic word problems (McLean & Hitch, 1999; Passolunghi, Cornoldi, & De Liberto, 1999; Swanson & Sachse-Lee, 2001). By the end of first grade, verbal working memory takes the role of visual-spatial working memory and becomes the best predictor of arithmetic performance. Meanwhile, phonological loop and central executive goes on supporting to solve problems verbally (Swanson & Sachse-Lee, 2001).

Working memory has been concluded to be a central deficit in children who have mathematical difficulties (Geary, 1993; Hitch & McAuley, 1991; Passolunghi et al., 1999; Passolunghi & Siegel, 2001; Siegel & Ryan, 1989; Swanson, 1993). It is found that the performance of children who have mathematics learning disability on a working memory task is impaired if the task involves processing numerical information; but their performance is similar to that of normal achievers if the task involves sentence processing (Siegel & Ryan, 1989). In addition to that, Hitch and

McAuley (1991) confirmed this finding by showing that children with specific difficulties in mathematics had a selective impairment in numerical information working memory tasks, not verbal span tasks. On the other hand, Passolunghi and Siegel (2001) showed that children with mathematics disability had difficulty in both working memory tasks; numerical and verbal.

The distinction between working memory and short term memory should also be made clear. Short term memory is based on a passive storage system. It recalls the information gained without making any change on it. On the other hand, working memory is more active and holds information by making some manipulation or transformation on it (Cantor, Engle, & Hamilton, 1991). When short term memory and working memory are compared in terms of their effects on mathematics performance, working memory, but not short term memory, is observed to accompany the difficulties in mathematics problem solving or arithmetic (Geary et al., 1999; Passolunghi & Siegel, 2001). Working memory has been shown to be a very significant predictor of mathematical achievement (Keeler & Swanson, 2001). Following studies which included different memory measures confirmed this observation, as well. Short term memory did not account for the variance of prediction of mathematics ability in these studies (Bull & Johnston, 1997; Butterworth, Cipolotti, & Warrington, 1996). Moreover, in a study of first and second graders, it was demonstrated that both short term and working memory predicted mathematics achievement at first grade. On the other hand, only working memory predicted mathematics performance in second graders. This is possibly because short term memory helps calculation strategies become automatic at early ages and first graders benefit from this situation more. In second grade, there are more complex tasks and they require working memory more than short term memory. For example; word problems with larger addends demand selecting the relevant information and focusing the attention on it. Working memory is the one that is involved in these processes considered in this study (Passolunghi et al., 2008).

Processing Speed

Processing speed is the efficiency with which simple cognitive tasks are performed and is claimed to represent a second promising construct for mathematical abilities after working memory (Case, 1985). It helps a person plan and stay on a task. These tasks can be identifying letters or words, naming numbers, quickly scanning, recognizing the stimuli around, perceiving the differences within visual information, ordering this visual information. It may even determine how quickly a person can count numbers. Research has shown that there is an association between deficits in processing speed and in arithmetic achievement; but there is not much study on this relationship. Among these limited number of studies, one suggests that processing speed is related to reading, mathematical and memory skills (Bull & Johnston, 1997). In this study, Bull and Johnston (1997) observed 7 year old children and used measures of short term memory, long term memory and processing speed. The measure of processing speed was visual matching tasks from Woodcock Jonhson III, which were also used in this study. The children were separated into two groups; low and high ability mathematics groups. When reading ability of these children was controlled, processing speed became “the best predictor of mathematics ability” (Bull & Johnston, 1997, p.19). It should be noted that the children participating in this study used the mathematical skills, basic math facts and memorizing rather than higher level mathematics and this shows the skills processing speed is more effective in mathematics. In more recent studies, a relation between processing speed and competency with arithmetic has been revealed, as well. Processing speed was found to be a significant predictor for arithmetic (Fuchs et al., 2006; Hecht et al., 2001).

If processing speed is overviewed in this section, math fluency is a concept to mention about because math fluency measures a person's processing speed while s/he is solving mathematics problems. It is acquired by practicing basic mathematical facts over and over so these facts become automatic. Math fluency with mathematics operations is a feature of mathematical learning at early ages and it is associated with basic knowledge of key calculation principles (Jordan et al., 2003a). Related literature supports the idea that math fluency is a necessity for mathematics achievement at all levels (Hecht et al., 2001) because the more fluent a child in basic arithmetic skills, the easier it will be for that child to perform a given higher level mathematics task. In other words, the automaticity that math fluency provides a child with becomes the foundation for more complex mathematics skills. It is predicted that by repeated instruction and doing practice, mathematical facts processing shifts from a quantitative region of our brain to a region related to automatic retrieval (Dehaene et al., 1999, 2003). And, recent fMRI studies supported this claim by observing shifts of activations from frontal lobes to parietal lobes during shifts from untrained math problems to trained ones (Delazer et al., 2003).

Rapid Automatized Naming (RAN)

Rapid Automatized Naming (RAN) requires a person to rapidly perceive and name a series of objects, colors, letters or numbers. Rapid letter naming is seen as a predictor for beginning readers. Likewise, rapid number naming is sometimes included as a predictor of number sense (Baker, Gersten, & Keating, 2000). Researchers argue that RAN is critical for number concepts and skills (Berninger & Richards, 2002). Clarke and Shinn (2004) states that the measures of RAN are predictive of the rate of development of math skills from fall to spring of the 1st grade. Being consistent with this result, an association between naming speed and mathematics performance is hypothesized by other researchers (Waber, Forbes, Wolff, & Weiler, 2004). Therefore, it can be concluded that deficits in naming speed may also be related to mathematics difficulties. But it should also be noted that there is not much research that investigated the predictive behavior of RAN for later mathematics achievement (Chard et al., 2005).

Reading

Number sense is thought to be surrounded by cognitive functions of the brain; but is seen as independent from memory, language and spatial knowledge (Gelman & Butterworth, 2005; Landerl et al., 2004). Despite this suggestion, there is an observed high co-occurrence between math and reading/language difficulties (Butterworth & Reigosa, 2007; Jordan, 2007). Badian (1983) and Knorpik, Alarcon and DeFries (1997) found that 43% of students who had mathematics disability also have reading difficulties whereas 56% of the students who were reading disabled had low mathematics achievement. Adding to that, it was suggested that mathematics and reading disability may have common cognitive deficits. A core deficit in both disabilities is processing speed (Ackerman & Dykman, 1995) because the children who have reading or mathematics disability or both show slow retrieval of familiar words or arithmetic facts (Geary et al., 1999).

Many studies found that arithmetic and reading may have similar cognitive predictors (Geary, 1993; Hecht et al., 2001). Moreover, deficits in processing words and recalling arithmetic facts are found to be related (Geary, 1993). This is because retrieving arithmetic facts requires retrieval of counting words and the use of phonological skills. In a previously conducted study, preschoolers who had linguistic impairments showed a lower performance than their counterparts on a seriation task which is one of the four abilities needed for the development of arithmetic (Siegel, Lees, Allan, & Bolton, 1981). In accordance with this result, weak mental arithmetic is known to be correlated with weak language acquisition skills. This is because many mathematics processing skills are similar to the language acquisition and reading skills (Sutton & Krueger, 2002).

Furthermore, it is stated that the phonological processing abilities which influence growth in reading and general mathematical computation skills are the same (Hecht et al., 2001). In addition, a crucial link was discovered between phonological awareness abilities of children of 8 years age and the mathematics and literacy scores of the same children when they were at the age of 5. This result showed that poor phonological awareness is linked to weakness in mathematics and literacy (Gathercole et al., 2005). In a study of screening kindergartners and first grades in terms of number sense and mathematics achievement (Jordan et al., 2007), it was found that the older and better reader children were also observed to have strong number sense. This may also confirm the possibility that early literacy and number sense may be both correlated to each other and these two important concepts may have common origins (Aunola et al., 2004).

When reading ability is measured, two reading processes should be taken into account. One is word recognition and the other is reading comprehension. They require different cognitive skills. Word reading is the basic process in reading and mainly needs phonological processing skills. On the other hand, reading comprehension is a more complex process. Besides word reading, memory, attention, vocabulary and previous knowledge is also necessary for reading comprehension (Siegler & Ryan, 1989). Considering mathematics difficulties studies, especially word reading is claimed to have high importance for retrieval of arithmetical facts (Geary, 1993). On the other hand, use of reading comprehension is also crucial for the development of problem solving skills. Previous research suggests that there is interplay between especially mathematics word problem solving performance and reading comprehension skills. This is because both of these are related to reasoning skills, as overviewed in other studies (Fuchs & Fuchs, 2002).

The Studies of Mathematics Difficulties and Number Sense in Turkey

The first study on learning difficulties which also mentioned mathematics difficulty talked about the general characteristics of learning disabilities and the required instruction for these problems (Kavşaoğlu, 1993). Another study on the issue of difficulties students experience in mathematics investigated the difficulties students face while learning algebra (Ersoy & Erbaş, 1998). Algebra tests which were developed by the researchers, considering the 7^{th} and 8^{th} grade mathematics curriculum were conducted. Through students' solutions and explanations on the tests, it was observed clearly that they had many difficulties with algebra. One study focuses on teacher responsibility to develop activities for learning disabled students, specifically teaching fractions in mathematics (Ersoy & Ardahan, 2003). This study emphasizes the importance of teacher guidance and help for these students. Another study examined the relation between students' difficulties in the topic, relations and functions and, their attitude and self-confidence (Dikici & İşleyen, 2004). The study showed that there was a significant correlation between these variables. A more general study was the descriptive study of the topics in mathematics which students perceive as difficult and the reasons behind this (Durmuş, 2004a). A Likert-type questionnaire was developed by the researcher to determine the difficulty index of all the topics in high school mathematics curriculum. The lack of motivation and the abstract nature of mathematical concepts were identified as the reasons for these topics' seeming difficult for students. The study was replicated for middle school curriculum, as well (Durmuş, 2004b). Lastly, a pilot study of the project "Kassel" which was conducted in nearly 15 countries up to the year 2000 was realized (Ersoy & Erbaş, 2005). The aim of the project was to follow student achievement at middle grades and determine the factors that affect success at school like learning difficulties and misconceptions. As a result, it was found that students had difficulties in writing and solving equations and problems. Also, it was stated that students might have some misconceptions about these concepts and thus, a detailed research should be designed by using or developing appropriate instruments which aim identification.

The studies of number sense started in 2003 with the presentation of the paper "Evaluation of Students' Number Sense" at the conference SEMPT 03, Czech (Şengül & Gürel, 2003). But today, the number of number sense studies in Turkey is limited with three thesis studies and a few articles. In the first thesis, 6th grade students were tested for their use of number sense in a descriptive study. As a result, only 9% of 95 students were determined to use number sense (Harç, 2010). In the second one, secondary school students' number sense was examined, considering grade, gender and mathematics performance. Their number sense was seen to be very low and students often used rule-based methods for number sense questions. (Kayhan Altay, 2010). In the last thesis study, 8th graders were analyzed in terms of the components of their number sense about exponents; but no more data about this study is available (İymen, 2012).

A few articles about this topic have been published especially since 2012. In one of these studies, a number sense test about decimal numbers was developed by the researchers and the number sense of 573 students among 6^{th}, 7^{th} and 8^{th} graders was measured. Students' number sense on decimal numbers was found to be very low. In addition to that, a moderate level of correlation was found between mathematical achievement and number sense on decimal numbers topic (Şengül & Gülbağcı, 2012). The same study was repeated with the same instrument with 121 students at 5^{th} grade and the number sense level of students were again low (Şengül & Gülbağcı, 2012). In another study investigating number sense, the strategies which 30 students among 6^{th} graders use while solving percent problems were examined. A test of eight open ended questions which were developed by the researchers was used to collect the data. As a result, it was found that more than half of the students used rule based strategies rather than number sense strategies (Şengül, Gülbağcı, & Cantimer, 2012). Another study on number sense investigated the relationship between number sense and self-efficacy. 119 participants from 7^{th} and 8^{th} graders were given a number sense test taken from the literature. In order to measure self efficacy of students, "A Self-efficacy Scale for Mathematics" (Umay, 2001) was used. The results of the study showed that there was a moderate correlation between number sense performance and mathematical self-efficacy; but the number sense of the participants were not well enough. Moreover, number sense performances increased in proportion to the grade level; but it was not a significant increase (Şengül & Gülbağcı, 2013). In the last study, a number sense scale for middle grade students was developed. By developing such a scale, this study aimed to describe the structural properties of number sense. 584 students from four different schools took the scale. Through a factor analysis, the dimensions of the scale were determined as

(a) flexibility in calculation, (b) conceptual thinking in fraction and (c) the use of reference points (Kayhan Altay & Umay, 2013).

Research Questions

Based on the literature review and the relevant research findings, the following research questions were developed to examine the relationships between number sense and its correlates (working memory, processing speed, RAN) with reading (word reading, reading comprehension).

1. To what extent do arithmetic performance, working memory, RAN, processing speed and reading explain the variance in number sense at 1st grade level?
2. In terms of the variables stated, what are the distinguishing features of 1st graders who have good, average and poor number sense scores?

CHAPTER III

METHODOLOGY

This chapter discusses the current study's methodology that is used to examine the effect of arithmetic performance, reading and some cognitive correlates on number sense at first grade level. In this section, a description of the participants and a review of instruments used for assessment are also included. A description of the data collection procedure and a summary of data analysis are also presented.

Participants

The study targeted a cross-section of first grade students in various types of primary schools. Convenience sampling was used to select a sample from the population. Especially schools around the city, Beşiktaş were selected since the schools there were observed to be more willing to participate to this kind of studies before. A total of 142 first grade students (70 males and 72 females) were chosen among 17 elementary schools in Istanbul (one private and 16 public schools) participated to the study. These schools represented different demographic characteristics and populations of varying socio-economic status (SES). Only first graders were chosen for the study because recent longitudinal research indicates that kindergarten or first grades are the predictor levels for future mathematics problems (Duncan et al., 2007; Jordan et al., 2009). Kindergarten level could not be considered because this level could not meet the required standard for reading measures.

The age range of the participants was between 6 years 4 months and 8 years 4 months. The mean of the ages was 7 years 1 month and the standard deviation was .38. Most of the participants were recruited from public schools. 131 students from public schools and 11 students from private schools took place in the study. Participants generally had preschool education. One hundred and six students were stated to have attended to a preschool whereas 20 students were stated not to have. On the other hand, no information was recorded about 16 students' early childhood education. Moreover, the majority of students (120 students) were not stated to have a determined learning disability, attention deficit or hyperactivity disorder. Only three students were represented as having one of those problems. However, no information was recorded about 19 students' learning disability status.

Data about parents' educational level were also obtained. Table 2 depicts the percentage of fathers and mothers in different educational attainment levels.

Table 2. Educational Attainment of Parents (N = 142)

	MOTHERS		FATHERS	
	n	%	n	%
Illiterate	1	.7	0	0
Literate	1	.7	1	.7
Elementary Education	41	28.9	28	19.7
Junior High School	13	9.2	15	10.6
Secondary School	41	28.9	44	31.0
Undergraduate Degree	33	23.2	37	26.1
Graduate Degree	3	2.1	7	4.9

Instruments

In this study, nine instruments were used: Demographic Information Form, Number Sense Brief Screener (T-NSB), Arithmetic Performance Test (AR-PE), Turkish Rapid Automatized Naming Test (T-RAN), Number Memory Test (T-MFN), Word Memory Test (T-MFW), Processing Speed Test (PS), Turkish Test of Word Reading Efficiency (T-WR) and Reading Comprehension Measures (R-COMPH) consisting of two different reading passages.

Demographic Information Form

This form was completed by the classroom teachers of the students who participated in the study. This form consisted of questions about the participants such as birthdays, gender, type of the school, education before formal school (e.g. preschool education), having any disability (e.g. learning disability or language or hearing problems), when the student learned to read and Turkish and Mathematics achievement scores at the end of the first semester of 2011-2012. The study was conducted in the second semester; but during the data collection procedure the grades for the second semester were not determined yet. Therefore, first semester’s achievement scores were obtained. On the demographic information form, there was also a part on parents’ educational levels and occupations. At the end of the form, class teachers were asked to write their additional opinions about the student (for a copy of the demographic information form, see Appendix B).

Number Sense Brief Screener (NSB)

This test was originally designed by Jordan, Glutting, & Ramineni (2008). It was developed as a number sense battery to use with children from kindergarten to the middle of first grade (from approximately age 5 to age 6). This age range does not match to the age range that was determined in this study because early childhood education (ECE) is not obligatory for children in Turkey. Therefore, the development of early numeracy skills and reading skills may be acquired until the age of 7, which is not the age range specified for NSB. Besides, the ECE curriculum covers numeracy skills only to a certain extent and teaching reading is not a part of this curriculum. So, to guarantee that the participants have the early numeracy and reading skills required for this test, the administration was realized towards to the end of first grade. It is an untimed measure and it takes nearly 15 minutes to administer. The battery includes a total of 29 items about counting (three items), number recognition (four items), number knowledge (seven items) and number operations (fifteen items). These components are viewed as the elements that children need to acquire during formal schooling. In the counting part, children are assessed by counting up to ten and following the counting strategies. In the number recognition part, they are asked to recognize the numbers shown. In the number knowledge part, they are expected to answer questions related to sequencing. For example; "what number comes after what" type of questions are asked. The number operations part are separated into two; in the first part, children perform non-verbal addition and subtraction using some materials like chips or bottle cap, as used in this study whereas in the second part they are asked to solve addition - subtraction story problems and addition - subtraction number combinations like “How much is 2 and 1?”.

For this study, NSB was translated into Turkish by the researcher. The appropriateness of wording in the translation was checked by a language specialist. Five middle school mathematics teachers and one classroom teacher were assigned to investigate the test items. Based on their feedback, test items were overviewed again. Then, the appropriateness and translation of the NSB items were tested by conducting the test on six first grade students. Subsequently, the problematic wording and instruction parts were edited and modified based on the Turkish Mathematics Educational Curriculum for primary years.

During the implementation of the test, the students only heard the questions or instructions. They were given related materials, when needed. However, they were not given paper and pencil to use when answering the mathematics problems in the test. The test materials included the examiner record form, handouts and bottle caps.

The original NSB was found to be internally consistent with a reliability value, ranged from .82 to .89 at each of six times it was measured at kindergarten or first grade (Jordan et al., 2008). Each item was scored 0 if it is incorrect and 1 if it is correct. Therefore, there is no inter-rater reliability for the test. As the literature suggests, NSB is found to be highly predictive of mathematics achievement both at first and third grade (Jordan et al., 2010).

The Development of Turkish NSB

The researcher who is also a mathematics teacher observed students very carefully and noted the parts to be edited as each child took the test. Besides, middle school mathematics teachers’ qualitative ratings were added to the evaluation, as well.

These notes and the students' data forms were discussed on. The final decision about the wording and the instruction were made and the test was re-written. In other words, the linguist's comments, the examiner's observations, teacher ratings and the record forms were used to test the appropriateness of the Turkish version of NSB. Not only wording or instruction, but also some of the items were changed in the test. Students had problems in understanding the instruction in counting strategies part which included strategies like one-to-one correspondence, cardinality and stable order. It was observed that students knew which counting is right, however; they could not answer correctly because they did not understand what they are supposed to do. Therefore, these items were omitted with the approval of the researcher who designed the battery (Jordan et al., 2008). Then, the number of the test items, therefore, fell down from 33 to 29. Editing was also done on the wording of the non-verbal addition and subtraction, and story problems part. In the original NSB, chips were used as test materials when evaluating non-verbal calculations. In the T-NSB, instead of chips, bottle caps were decided to be used because they were more relevant to Turkish students. In the story problems part, the wording in subtraction operation was problematic. In the subtraction operation of the original test, the verb "take away" was not meaningful for Turkish children. Therefore, this lexical problem was discussed with mathematics teachers and instead of using "take away", it was decided to use the word "to give" while asking this part of the test.

The Arithmetic Performance Test (AR-PE)

It is the arithmetic subtest of Wechsler Intelligence Scale for Children-Revised (WISC-R). It is appropriate for the ages between 6 and 16. It is an individually administered test with 18 items. To implement the test, the examiner first reads aloud the problem and the child is expected to pay attention and give the correct answer without the use of paper and pencil. Therefore, this subtest requires memory activity, concentration and attention to understand orally presented verbal information. Problems in the test are given in story form. Each item has a time limit to be answered and items are written in ascending order in terms of difficulty level. The test is discontinued after four consecutive errors.

Turkish Rapid Automatized Naming Test (T-RAN)

This test measures a person's ability to perceive a visual representation and to remember its name accurately and rapidly. This is also called naming speed. This test can be administered to children between the ages 5 years to 10 years 11 months. RAN test has four subtests: Pictures, colors, numbers and letters. In each subtest, there are five elements and they are repeated randomly ten times in each row of the test where there are five rows. RAN is an individually administered test. The child is given the instructions and is asked to name each element as quickly and as correct as possible. Scoring is based on the time the child uses to name all the items in the test. During the administration of the test, the examiner needs the cards on which test items are presented, a stopwatch and a record form for each student.

The validity and reliability of the Turkish RAN was assessed via a pilot study (Bakır & Babür, 2009). In this study, RAN number subtest of Turkish RAN was used. This subtest consisted of randomly sequenced five numbers (2, 4, 6, 7, and 9).

Test – retest reliability coefficients of the original RAN ranges between .81 and .98. The same value for the T-RAN ranges between .85 and .95. The inter-rater reliabilities of the original RAN indicated coefficients between .98 and .99 (Wolf &

Denckla, 2005). For the T-RAN, this value was between .99 and 1.00 (Bakır & Babür, 2009).

Memory for Digits Test (T-MFN)

It is also a subtest of WISC-R. This test measures the ability of recalling and repeating a series of numbers ranging from two to nine digits in the correct sequence. The test is conducted in two parts; forward and backward digit span. The items are arranged in order of difficulty. The test is discontinued after three consecutive errors. For this study, the sequences of numbers were recorded by the researcher because there were examiners except the researcher. To satisfy uniformity within the examiners, the test items were recorded. After hearing the record, the student repeats the numbers in the same order or in reverse. If the student is not able to repeat all two of the items in the same row, then the test is discontinued.

Memory for Words Test (T-MFW)

It is one of the subtests of Woodcock Johnson III (WJ-III). It measures the ability of recalling and repeating a list of words ranging from one to eight unrelated words in the correct sequence. Like in the digit span test, the words are recorded by the researcher. This time, the student is asked to repeat the words only forward and in the correct order. The test is discontinued after three failures. In this study, considering WJ-III, an alternative of this test was developed by the researcher. The appropriateness of the wording was tested by conducting the test on six first grade children for the first time and four children for the second time. In the first study with six children, the words that children could not understand while the examiner was saying were determined. The items children had difficulty with while recalling and the items which were too easy for them were also observed. The second study with four children was designed to see if the editing on the words was enough. After this study, a few more changes were done on the test and the final version was formed. Unlike the original test with 27 items, the Turkish version consisted of 24 items (for a copy of Turkish Memory for Words, see Appendix C).

Processing Speed Test (PS)

It is one of the subtests, as visual matching of Woodcock Johnson III (WJ-III). Since the test was non-verbal and culture free, its original form was used in the current study. It measures the ability to quickly scan and identify the same two numbers in a given row. Each row includes six numbers. On the task sheet, the number of rows is arranged one under the other and the difficulty level increases as the student goes down. The time limit is 3 minutes. The appropriateness of the test for the students was tested by conducting the test on six first grade students. No problem with identifying the numbers occured.

Turkish Test of Word Reading Efficiency (T-WR)

The original test was developed by Torgesen et al. (1999). This test measures the accuracy and fluency of word reading within a time limit. It has two subtests. The Sight Word Efficiency (SWE) subtest measures the number of real words that can be accurately read whereas the Phonemic Decoding Efficiency (PDE) subtest measures the number of non-words.

This test was adapted to Turkish by Babür, Haznedar, Erçetin, Özerman, & Erdat-Çekerek (2013). At the beginning of the adaptation process, a frequent words list for Turkish was prepared. Then, two forms of each subtest were formed and the pilot study was conducted from first to fifth grade in three different primary schools. The forms were edited according to the pilot study results.

The test-retest reliability coefficients of the original test were found to range between .82 and .97 for all age groups. The inter-scorer reliability is .99 (Torgesen, Wagner, & Rashotte, 1999). Likewise, the alternate form of reliability of the T-WR is .96 and the concurrent validity is .92 (for sample items of word reading test, see Appendix D).

Reading Comprehension Measures

Four reading passages were prepared for first graders to assess reading comprehension skills. Since first graders learn reading and writing in cursive, the passages were written in cursive. The font size in the Turkish Course Books for first graders was used. Fictional and non-fictional stories were used. All of the passages included both knowledge and inferential questions.

At the beginning, three of the passages were taken from Turkish Course Books. The other passage was written by the volunteer students who worked in the project BAP05D101, conducted by Babur (2005-2009). To test the appropriateness of the passages, they were conducted on six children. The results showed that the fictional passages had no problem. But the non-fictional ones were problematic. Some of the questions in these non-fictional passages were difficult for students to understand. Therefore, the non-fictional passages were formed again. The new non-fictional passages were taken from Turkish Course Book for second graders and were tested on first graders again. This time no editing was needed.

However, during the testing process at schools, it was observed that children could hardly finish reading the passages because they were too long. Thus, one of the fictional and one of the non-fictional passages were completely removed from the test. Two passages were left. They were the ones taken from Turkish Course Book for second graders (Table 3).

Table 3. Characteristics of the Reading Comprehension Passages

Reading Passage	Font Size	Font Type	Total Number of Words	Number of Questions
Kedi *(Cat)* (Non-Fictional Passage)	16	Hand writing	133	5
Kumbara *(Moneybox)* (Fictional Passage)	16	Hand writing	137	7

A second grade book was used as a source because the test was conducted in May. This is the time a big majority of first graders learn to fluently read and write in Turkish primary schools. Moreover, students did not have the probability to have seen the passages before since they were in second grade book.

While the editing processes were going on, three classroom teachers and a professor on children literature at Boğaziçi University gave feedback for the appropriateness of the passages.

While being tested, students were asked to read the passages and answer the questions given. Although students saw the questions, the examiners also asked them orally. The entire scoring process was realized by the researcher. Each correct answer got one point. So, the maximum score of this part was 12 (for a copy of the reading comprehension measures, see Appendix E).

Procedure

The test administration took place in May and June, 2012. Conducting all the tests for one individual was nearly one hour. Therefore, it was enough to take each participant once for test administration. However, it was needed to give a break for some students according to their level of attention and interest.

For the administration of the tests, a group of volunteer undergraduate students at Boğaziçi University Mathematics and Science Education were chosen. These volunteers were trained and provided with detailed information and consultation before the administration process. Seven meetings, each of which lasted approximately three hours, were arranged and the volunteer examiners were given training on the administration of the test battery. Each volunteer was given a kit which included all the tests. At the end of all the training sessions, the researcher made a sample video record with a third grade student and the group of volunteers watched this video. In this video, the researcher conducted all the test battery on that student. By this way, the volunteer examiners saw what the administration process would be like. They also asked their questions about the parts which they were not still feeling comfortable.

Before the administration process started, the necessary research permission was granted from the Ministry of Education. Besides, one more research permission was taken from Boğaziçi University Committee on Ethical Conduct in Research with Human Participants. After these requirements were completed, the volunteers were assigned their schools in which they would conduct the battery. Moreover, the schools in which the researcher would conduct the battery were determined. During the implementation, the researcher and the volunteers were continuously in contact about the process and the possible troubles at schools. Volunteers and the researcher herself conducted the battery in quiet, separate rooms at schools.

Data Analysis

The results were computed using The Statistical Package for Social Studies (SPSS-20). For all analyses, the statistical significance level was determined as the alpha level of .05. With the purpose of examining the relationships among number sense, arithmetic performance, reading and some cognitive correlates, correlational analyses were conducted. Then, regression analyses were realized to investigate how much the variables in this study explain the variance in the dependent variable, number sense. For the second question, ANOVA (analysis of variance) was run to compare the mean differences between groups as good, average, poor in terms number sense scores. To support ANOVA results, required post-hoc analyses were also conducted.

CHAPTER IV

RESULTS

In this chapter, the results of the study are presented as answers to the research questions. Firstly, the necessary descriptive statistics was given about each variable in the study. After that, correlations between all the variables and regression analyses, taking number sense as the criterion variable, were conducted. Then, on the basis of the second research question, participants were separated into groups in terms of number sense performance. Finally, the characteristics of these groups in terms of the other variables of the study were explained in detail.

The Preliminary Analysis

At the beginning, group differences in terms of parental educational level for number sense scores of the students were investigated because there is a considerable evidence for the level of parental education as a strong predictor of children's success at schools (Englund, Uckner, Whaley, & Egeland, 2004). Students were classified into two groups in terms of the education levels of parents.

High school education can be regarded as a step to choose an occupation in life. People attend to high schools where they gain an occupation or they attend to a university, after high school education. Thus, high school education is important for one's life and so, was accepted as the cut off point for parental educational levels. High parental educational level and low parental educational level were investigated in two parts; mothers' and fathers' level. The frequencies for education levels of parents are represented in Table 4. In addition, the descriptive statistics of both mothers and fathers' educational levels for number sense performance are demonstrated in Table 5.

Table 4. The Educational Levels of Mothers and Fathers (N = 142)

Educational Level	N (Mothers)	% (Mothers)	N (Fathers)	% (Fathers)
Low level	97	68.3	88	62
High level	36	25.3	44	31
Missing data	9	6.3	10	7.04

Table 5. The Descriptive Statistics for Number Sense Scores Based on the Educational Levels of Mothers and Fathers (N = 142)

Educational Level	Low level (Mothers)	High level (Mothers)	Low level (Fathers)	High level (Fathers)
Mean	25.82	27.33	25.84	27.05
SD	2.483	2.390	2.518	2.459

In Table 4, it is observed that the percentage of mothers in low educational level is higher than the one of fathers in the same level. As represented in Table 5, number sense performance scores of the students whose both parents are at low educational level are lower than the ones whose both parents are at high educational level. To test the significance of this difference, independent samples t-test was conducted on mothers' and fathers' educational levels for number sense scores. The results showed that there was a significant difference between the number sense performance scores of the students with mothers who have low and high educational level (.002, $p < .05$). However, the same value for fathers was not significant (.10, $p > .05$). Thus, only the effect of mothers' educational level on students' number sense performance was considered during the analyses and discussion.

Before answering the research questions of this study, the features of the instruments for each variable in the study will be reviewed. In the literature, RAN letters are assumed to be effective screening measures for beginning readers. Likewise, RAN numbers are sometimes included as predictors of number sense (Baker et al., 2000). Therefore, RAN numbers subtest was used in the current study. While conducting the test, the time each student used to complete the task were recorded in seconds. Lower scores in second indicated faster naming speeds. In word reading part, the time was 60 seconds and the number of words that can be accurately read in this time period pointed out the test score. In the reading comprehension, number sense, number memory and arithmetic performance parts, total score was obtained by the number of the correct answers. In memory for words and processing speed, the total score was equal to the number of correctly answered rows.

Means and standard deviations for the measures; RAN numbers (T-RAN), Word reading (T-WR), Reading comprehension (R-COMPH), Number sense (T-NSB), Arithmetic performance (AR-PE), Number memory (T-MFN), Word memory (T-MFW) and Processing speed (PS) are displayed in Table 6.

Table 6. Means, Standard Deviations, and Minimum / Maximum Scores for the Variables in the Study (N = 142)

Measure	Mean	SD	Min	Max
T-RAN	40.11	10.38	24	77
T-WR	47.34	16.16	2	104
R-COMPH	8.24	2.34	0	12
T-NSB	26.10	2.70	16	29
M-ACH	8.74	1.97	3	14
T-MFN	8.67	2.50	1	14
T-MFW	12.22	2.98	3	18
PS	23.28	5.60	2	36

Note: RAN numbers (T-RAN), Word reading (T-WR), Reading comprehension (R-COMPH), Number sense (T-NSB), Arithmetic performance (AR-PE), Number memory (T-MFN), Word memory (T-MFW), Processing speed (PS)

As presented in Table 6, the mean of the T-NSB, which has 29 items, has a higher mean compared to the other measures. On the other hand, AR-PE has a mean that is nearly half of the top score that could be gained in the test.

Since the evaluation of each measure was different from each other, all the scores were converted into standard scores. Then, the relationships among the variables of the study were examined using Pearson-moment correlation analyses. Correlations are presented in Table 7.

Table 7. Correlations among Variables

	Measure	1.	2.	3.	4.	5.	6.	7.	8.
1.	T-RAN	---	-.41**	-.26**	-.27**	-.21*	-.14	-.16	-.35**
2.	T-WR		---	.40**	.37**	.31**	.40**	.32**	.43**
3.	R-COMPH			---	.46**	.34**	.41**	.29**	.33**
4.	T-NSB				---	.59**	.59**	.40**	.35**
5.	M-ACH					---	.53**	.33**	.46**
6.	T-MFN						---	.54**	.48**
7.	T-MFW							---	.30**
8.	PS								---

**p<.01 and *p<.05

Note: RAN numbers (T-RAN), Word reading (T-WR), Reading comprehension (R-COMPH), Number sense (T-NSB), Arithmetic performance (AR-PE), Number memory (T-MFN), Word memory (T-MFW), Processing speed (PS)

This table reveals that there are significant negative correlations between RAN numbers, word reading (r = -.41, p<.01) and processing speed (r = -.35, p<.01). The results also indicated a significant positive correlation between number sense, mathematics achievement (r = .59, p<.01), number memory (r = .59, p<.01) and reading comprehension (r =.46, p<.01). Moreover, significant positive correlations were found between number memory, arithmetic performance (r = .53, p<.01), word memory (r = .54, p<.01) and processing speed (r = .48, p<.01). Processing speed demonstrate significant positive correlation with arithmetic performance, as well (r = .46, p<.01). However, the correlations between RAN numbers, number memory (r = .-14, p<.01) and word memory (r = -.16, p<.01) were found to be too low.

Presentation of Research Findings

Research Question 1: To what extent do arithmetic performance, working memory, RAN, processing speed and reading explain the variance in number sense at 1st grade level?

The first research question examined the predictability of number sense performance with the use of other variables in this study. Multiple regression analysis was used to determine (a) how much variance the independent variables of the study account for the variance in the dependent variable, number sense; (b) which independent variables are the more important predictors of number sense (Hatcher, 1994b). In other words, to determine the relative predictive importance of the variables in the model for number sense (reading comprehension, word reading, RAN, number memory, word memory, processing speed and arithmetic performance), a regression analysis was run. The initial and final regression model variables and their summary of analysis were given in Table 8.

Table 8. Summary of Regression Analyses for the Variables Explaining the Variance of Number Sense

Dependent Variable	Independent Variable	SE	B	t-value	p-value
Initial Step	Seven Variables Together (Initial Model)				
T-NSB	AR-PE	.11	.35	4.65	.00
	T-MFN	.10	.32	3.63	.00
	R-COMPH	.08	.18	2.56	.01
	T-WR	.01	.04	.56	.58
	T-RAN	.02	-.11	-1.51	.14
	PS	.04	-.10	-1.28	.20
$R = .72, R^2 = .51, (p = .00), F(7, 138) = 19.56, p < .05$					
Final Step	Achievement, Number Memory and Reading Comprehension (Final Model)				
T-NSB	M-ACH	.10	.35	4.88	.00
	T-MFN	.08	.32	4.27	.00
	R-COMPH	.08	.20	3.03	.003

$R = .70, R^2 = .49, (p = .00), F(3, 141) = 44.45, p < .05$

Note: RAN numbers (T-RAN), Word reading (T-WR), Reading comprehension (R-COMPH), Number sense (T-NSB), Arithmetic performance (AR-PE), Number memory (T-MFN), Word memory (T-MFW), Processing speed (PS)

In the regression analyses, raw scores were used since standard scores did not give meaningful results. All the variables were included in the regression analyses at the initial step. The initial model accounted for 51% of the variance in number sense at first grade, with arithmetic performance, number memory and reading comprehension reaching significance. The final model which included these variables that show significance in the initial model accounted for 49% of the variance in predicting performance on number sense. The beta weights presented in the initial model suggest that arithmetic performance (β = .35, p< .05) and number memory (β = .32, p< .05) mean scores contributed the most to variance of number sense scores. Reading comprehension represented the third variable, effecting number sense performance (β = .18, p<.05). Thus, the best model predicting and explaining the variance in number sense performance was found to include arithmetic performance, number memory and reading comprehension.

In related literature, it was stated that effect sizes should also be reported for quantitative study findings (APA, 2001; AERA, 2006). This is because being statistically significant has some limitations. Statistical significance does not lead to practical significance, meaning a study can be statistically significant; but may not be important in a practical manner (Huck, 2012). Effect sizes enable researchers to explain the importance of effects and make meaningful interpretations on the data (Zientek, Ozel, Ozel, & Allen, 2012). Effect sizes in this study were calculated for both the initial and final model. Cohen's (1988) f^2, where values of .02 represent small effect, values of .15 shows a medium effect and values of .35 denote a large effect, was used. Results showed that both of the models had large effect sizes (f^2 = 1.04, .96 respectively). Furthermore, large effect size means that it is enough to be visible even to the naked eye.

Research Question 2: In terms of the variables stated, what are the distinguishing features of 1st graders who have good, average and poor number sense scores?

This second question aims to examine the characteristics of first graders as groups in terms of number sense performance. The descriptive statistics for number sense scores were presented in Table 9. In order to compare the means of the groups formed for the variables of the study and seek if there are significant differences between these means, one-way ANOVA (analysis of variance) was conducted. Since one of the assumptions of ANOVA is the normal distribution of data, normality of the scores gained through each measure was tested before conducting ANOVA. Skewness and Kurtosis values show evidence of normality. Hence, the numerical indices that assess the skewness and the kurtosis of all the measures used in this study are presented in Table 10.

Table 9. The Descriptive Statistics for Number Sense Test Scores

The measure of statistics	The value
Mean	26.10
Median	27
Mode	28
Standard Deviation	2.70
Variance	7.27
Range	13
Minimum	16
Maximum	29

Skewness is a measure of the data graph's symmetry. If there is a lack of symmetry, meaning the distribution of the data is not a normal distribution, skewness leans to the left or the right of the graph. The skewness of the normal distribution is zero. If the skewness value is negative, then data are skewed left and if the value is positive, data are skewed right (Gravetter & Wallnau, 2007).

As seen in Table 9 above, most of the scores on number sense end up being high and they pile up on the right side of the graph. This condition shows a skewed distribution. Since the tail of data points to the lower end, the distribution is a left-skewed or negatively skewed distribution and it has a negative value. In this distribution, the mean is pulled toward to the scores on the right of the curve. Thus, the mean of the test is relatively high. Then, the mode is on the right-hand peak of the tail and it is greater than both the median (28 > 27) and the mean (28 > 26.10). In addition, the median is also greater than the mean (27 > 26.10).

On the other hand, kurtosis determines the peakness of the data. High and positive kurtosis means the peak is distinct near the mean. Low and negative kurtosis means there is flat top in the graph. Standard distribution is also arranged to have a kurtosis of zero. Some researchers accept the idea that the skewness and kurtosis of a distribution which is approximately normal should be between -1.0 and +1.0 and some others kurtosis should be between -3.0 and +3.0 (Huck, 2012).

Table 10. The Skewness and Kurtosis Values of the Variables in the Study

Measure	Skewness	Kurtosis
T-RAN	1.02	1.03
T-WR	.41	1.44
R-COMPH	-1.17	1.92
T-NSB	-1.50	2.63
AR-PE	-.13	.25
T-MFN	-.29	.20
T-MFW	-.55	.18
PS	-.59	2.20

Note: RAN numbers (T-RAN), Word reading (T-WR), Reading comprehension (R-COMPH), Number sense (T-NSB), Arithmetic performance (AR-PE), Number memory (T-MFN), Word memory (T-MFW), Processing speed (PS)

When the skewness and kurtosis values in Table 10 are evaluated, considering the normality ranges above, the only variables whose data distribution is not normal are RAN, reading comprehension and number sense. Since the groups to be compared in the second research question had already been formed according to number sense scores, number sense scores were not included in ANOVA analysis. However, the non-normality case of RAN and reading comprehension were considered separately during the analysis.

After the descriptive statistics of the dependent variable, *number sense* and the normality check of the other variables in the study were computed, it was decided to separate the sample into three groups; students having poor number sense (PNS), average number sense (ANS) and good number sense (GNS). Separation into three groups was favored because the significance of the mean differences between the ANS and GNS group were aimed to examine over and above the mean differences with the PNS group. For this purpose, a cut-off point score was needed. As stated in the literature review part, the old-fashion to identify disabilities was to use IQ-achievement discrepancy method. In this method, a specific score was determined as the borderline and the scores below that borderline were accepted as the evidence of disabilities. However, the literature often presents such borderlines for achievement tests, not number sense tests. In other words, there was not a determined cut-off point score for the number sense battery used in this study. This conclusion was also supported by the developer of the original NSB, Jordan. Therefore, the mean and the standard deviation of the study were the elements mainly considered to determine such a cut-off point score. The average was selected as the main reference point. The scores one standard deviation above and below the mean were considered as the average group because going one standard deviation further than the mean was accepted to reveal similar scores to the mean. Thus, the distance, one standard deviation was found to be appropriate for this study. However, one standard deviation distance above the mean caused only full scores of the number sense test to be classified as the GNS group; but this time, students who made only one mistake out of all test had to be included in ANS group. Nonetheless, it does not seem to be appropriate to classify students with only one wrong answer as having average number sense. This is because that mistake may be due to many different reasons like not understanding the question or losing attention because of the long test conduction time; but not because due to lack of knowledge. Therefore, the ANS group was decided to include the scores .5 standard deviation above and one standard deviation below the mean. The rest above the mean formed the GNS and the left below the mean formed the PNS groups. The descriptive statistics for each of these groups was presented in Table 11.

Table 11. The Descriptive Statistics for the T-NSB Score Intervals

Score Intervals	Frequency	Percent	Mean	Standard Deviation
16-23 (PNS Group)	19	13.3	20.63	2.22
24-27 (ANS Group)	70	49.3	25.83	.98
28-29 (GNS Group)	53	37.3	28.42	.50

Note: the Poor Number Sense Group (PNS), the Average Number Sense Group (ANS), the Good Number Sense Group (GNS)

As seen in the table, the majority of the participants stayed in the ANS group (n = 70) and then, in the GNS group (n = 53). There is a third group PNS (n = 19), which includes the participants who have much more difficulties in answering the questions in T-NSB. This means that ANS group constitutes approximately 50% of the sample while GNS group represents nearly 40% and the PNS group is nearly 15% of the total sample. Also, the high value of the variance of the PNS group when compared to the other two groups reveals that the performances of the students in this group demonstrated more variability than the ones in the other two groups.

After separating the sample into groups based on number sense scores, the mean differences for all the measures were examined to be able to mention about the characteristics of the groups. Table 12 shows the means and standard deviations of each group in terms of memory, RAN, reading, processing speed and arithmetic performance.

Table 12. The Means and Standard Deviations of the Variables Stated for Each Group Based on Number Sense

Groups	AR-PE	T-MFN	T-MFW	R-COMPH	T-WR	T-RAN	PS
	Mean (sd)	Mean (sd)	Mean (sd)	Mean (sd)	Mean (sd)	Mean (sd)	Mean (sd)
PNS	6.42 (1,5)	6.05 (2.2)	10.11 (3.2)	6.05 (3.6)	36.89 (20)	46.53 (13.1)	20 (5.1)
ANS	8.59 (1,7)	8.11 (2.2)	11.80 (2.8)	8.41 (1.8)	45.5 (13)	39.80 (8)	22.7 (5.4)
GNS	9.77 (1.7)	10.34 (1.8)	13.53 (2.5)	8.8 (2)	53.45 (16.1)	38.23 (11.4)	25.23 (5.4)
Total Sample	8.74 (2)	8.67 (2.5)	12.22 (3)	8.24 (2.3)	47.34 (16.2)	40.11 (10.4)	23.28 (5.6)

Note: the Poor Number Sense Group (PNS), the Average Number Sense Group (ANS), the Good Number Sense Group (GNS)
RAN numbers (T-RAN), Word reading (T-WR), Reading comprehension (R-COMPH), Number sense (T-NSB), Arithmetic performance (AR-PE), Number memory (T-MFN), Word memory (T-MFW), Processing speed (PS)

It is seen in the table that the groups which are formed according to the number sense scores show the same behavior in terms of their performance in all other measures. As can be predicted, the PNS has the lowest means in all other measures and has the highest mean in seconds in RAN numbers because longer time in seconds indicate low performance on RAN test. On the other hand, the GNS group has the highest means in all measures. And, the ANS group is the one between the other two.

To be able to test the significance of the mean differences across number sense performance groups given above, one-way ANOVA was conducted because there is one dependent variable and there are sample groups more than two. At this point, the main assumptions of ANOVA should be discussed. The results of a one-way ANOVA are reliable if the following assumptions are met: firstly, each group should be a random subset of the whole sample. This was satisfied because participants were selected randomly among a large group of first graders. Secondly, the score of each participant should be independent from what happens to other participants during the study and this assumption was also satisfied in this study. Third, the population of each group should be normally distributed on the measures conducted. As stated above, only the data of RAN numbers and reading comprehension did not show normality. Thus, other methods that do not require a condition such as normality were used to compare the mean differences for these variables. Lastly, each group should have equal variance or homogeneity of variance (Huck, 2012). The variables RAN numbers and reading comprehension also did not represent homogeneity, as tested by Levene Statistic with the significance values of .00 and .14, respectively. Except these two, data of all the other variables satisfied the assumption of being equally varied, namely homogeneity. Therefore, ANOVA was conducted on the data of the measures except RAN numbers and reading comprehension. ANOVA, which was computed to compare the mean scores of the groups for the variables of the study, yielded the results in Table 14.

Table 13. ANOVA Summary Table of the Variables of the Study by Number Sense Performance Levels

Variable	Sum of Squares	df	Mean Square	F	Sig.
Word reading	4283.621	2	2141.811	9.170	.000
Arithmetic perf.	160.459	2	80.229	28.973	.000
Number memory	299.524	2	149.762	36.020	.000
Word memory	188.028	2	94.014	12.331	.000
Processing speed	428.749	2	214.375	7.472	.001

*$p < .05$

RAN numbers (T-RAN), Word reading (T-WR), Reading comprehension (R-COMPH), Number sense (T-NSB), Arithmetic performance (AR-PE), Number memory (T-MFN), Word memory (T-MFW), Processing speed (PS)

As seen in the table, the means of the groups for all variables of the study are not equal to each other (Huck, 2012) and there is an overall difference among the means between the groups. In other words, the equality of the means of the groups were tested and it was found that there is at least one mean that is different from the others, significantly at the $p < .05$ level. However, ANOVA only shows that there is a significant difference between the group means; but does not tell about where this significance lies. This situation brings out new questions; that is; why the ANOVA yielded such a significant F value or, which mean(s) were significantly different from which other ones. To be able to answer these questions, Post-Hoc Tukey tests were conducted. In fact, there are many post-hoc tests based on different assumptions. The use of this post-hoc test was because Tukey HSD had an easily calculated procedure and it was appropriate for both equal and unequal sample sizes. The results of the Tukey’s post hoc test are presented below.

The PNS group had significantly lower AR-PE and T-MFN than both the ANS and GNS group at the .05 p-level (both at p = .00). Moreover, the PNS group's T-MFW, PS and T-WR scores were significantly lower than only the GNS group (all at p =.00), but not the ANS group for these variables.

The Tukey's post hoc analyses also confirmed that the ANS group had significantly lower AR-PE, T-MFN, T-MFW than the GNS group all at p = .00 and significantly lower PS and T-WR at p = .03; .02 respectively.

On the other hand, to test the significance of the mean differences on reading comprehension and RAN number subtest, a non-parametric test, Kruskal-Wallis was conducted. Because these two measures did not show normality and homogeneity required for ANOVA, Kruskal-Wallis test, which was accepted as the analog of ANOVA, was used. It is also called the one-way ANOVA of ranks (Huck, 2012).

The comparison of the differences between the groups on reading comprehension with the Kruskal-Wallis analysis revealed significant differences with H = 63.55, 2 df, p = .007 < .05. Likewise, the comparison of the mean differences on RAN numbers presented significance with H = 103.83, 2 df, p = .008 < .05.

Similar to ANOVA, it was needed to perform a post-hoc test after Kruskal-Wallis. This was because Kruskal-Wallis indicated that there was a significant between group means on these two measures; but which specific groups were likely to differ from one another was not still known. Bonferroni test was used for the post-hoc analyses because it is a flexible test that is easy to compute and that can be used with any kind of statistical test.

The results for RAN numbers showed that the PNS group had significantly lower T-RAN than both the ANS (p = .03 < .05) and the GNS group (p = .00 < .05) at the .05 p-level. However, there was no significance between the means of the ANS and GNS on T-RAN ($p = 1.0 > .05$).

Also, on reading comprehension, the PNS group were significantly lower than the ANS ($p = .00 < .05$) and the GNS group ($p = .00 < .05$). But the mean differences between the ANS and the GNS were not significant again with $p = .99 > .05$).

CHAPTER V

DISCUSSION

This chapter discusses the results of the study and is organized around the research questions. It is divided in four sections: a review of findings, educational implications of the study, limitations of the study and suggestions for further research.

Review of Findings

The primary goal of the study was to determine the roles of arithmetic performance, reading and the cognitive correlates of mathematics learning as working memory, rapid automatized naming (RAN) and processing speed on number sense. Furthermore, the features of first graders who have good, average and poor number sense performance were described in terms of arithmetic performance, reading and cognitive correlates of mathematics learning.

The first research question of the study was formed, considering the primary goal of the study. It was addressed to examine the extent arithmetic performance, reading and the cognitive correlates of mathematics learning explain the variance in number sense at first grade level. A total of 142 students (70 males and 72 females) were the participants. All the participants were native Turkish speakers. Correlation and regression analysis were conducted to answer this first research question.

Correlation analyses revealed that arithmetic performance as a component of mathematics learning was significantly correlated with number sense performance (r

=.59, p < .01). This was in congruence with previous studies, which stated that children's number sense performance between kindergarten and first grade predicted their performance in general mathematics achievement from first to third grade (Jordan et al., 2007; Jordan et al., 2009).

Working memory is stated to have an important role in the acquisition and use of basic skills in education (Hitch & McAuley, 1991). Furthermore, the researchers demonstrated that it is related to the acquisition of numerical and arithmetic knowledge at early ages like first and second grade (e.g., Bull & Sherif, 2001; Fuerst & Hitch, 2000; Geary, Hamson, & Hoard, 2000; Hitch, 1978; Dehn, 2008). In line with this finding, the present study indicated a significant correlation between working memory, especially number memory and the measure of early numeracy skills as number sense ($r = .59$, $p < .01$). Moreover, number memory showed also a high correlation with arithmetic performance as a mathematics measure ($r = .59$, $p < .01$), which was consistent with Lezak (1995) who noted that a direct connection exists between working memory and mathematics achievement. Likewise, results of this study present correlation between both word memory and arithmetic performance ($r = .33$, $p < .01$) and, word memory and number sense ($r = .40$, $p < .01$). This result is accordance to the finding of Passolunghi and Siegel (2001), which was that children with mathematics disability had difficulty on both working memory tasks; numerical and verbal.

Findings of the current study, about the relationship between number sense and processing speed, were somewhat different than previous research (Bull & Johnston, 1997). It was reported previously that processing speed was a factor strongly correlated to mathematical ability in children (Bull & Johnston, 1997).

However, in the current study, results indicated low significant correlations between processing speed and number sense ($r = .35$, $p < .01$).

Previous studies observed high co-occurence between mathematics and reading/language difficulties (Butterworth & Reigosa, 2007; Jordan, 2007). Especially word reading was stated to have high importance for retrieval of arithmetical facts (Geary, 1993). Torgesen et al., (2001) proposed that the correlation between math-calculation ability and word reading skills was .59, with the mediation of phonological processing ability. In the same study, it was demonstrated that there was also a significant relationship ($r = .51$) between word reading skills and math fact recall. Interestingly, the correlations of word reading with number sense ($r = .37$, $p < .01$) and arithmetic performance ($r = .31$, $p < .01$) were not that much high. The importance of reading comprehension for especially mathematics problem solving was discussed in the literature since both of these processes require reasoning skills (Fuchs & Fuchs, 2002). Nonetheless, the current study demonstrated a moderate significant correlation of reading comprehension to only number sense ($r = .46$, $p < .01$); but a low correlation ($r = .34$, $p <.01$) to arithmetic performance.

Rapid Automatized Naming (RAN) is argued to be important for number concepts and skills (Berninger & Richards, 2002). Especially, RAN number subtest is seen as a predictor of number sense by some researchers (Baker et al., 2000). In addition, a relation between RAN and mathematics performance is suggested by some others (Waber et al., 2004). However, the results of this study are not in line with the literature. The negative correlation of RAN to number sense ($r = -.27$, $p < .01$) and arithmetic performance ($r = -.21$, $p < .05$) shows a too low significance.

Furthermore, the multiple regression analysis showed that in an initial model when all the variables hypothesized to account for the variance in number sense were included, only three measures came out to be significant predictors for number sense, *arithmetic performance*, *number memory* and *reading comprehension*. Among these measures, arithmetic performance made the largest contribution to the variance of number sense. In related studies, number sense was stated to be a powerful predictor of later mathematics achievement (Jordan et al., 2007; Jordan, Glutting, & Ramineni, 2010). For instance; Jordan et al., (2007) showed that number sense accounted 66% of the variance in mathematics achievement. However, a study which focused on the prediction of number sense through mathematics achievement could not be found although related searches were carried out many times with different key words. This increases the importance of the current study since this study is the first to examine the relations between these constructs in the reverse direction.

The present findings on the relationship between number sense and working memory are in keeping with Locuniak and Jordan's (2008) findings. In their study, they examined the predictors of calculation fluency, which number sense was suspected to predict. The regression model explained the variance in calculation fluency 16% more when number sense tasks were added to the model. This means that number sense predicted calculation fluency over and above other predictors. Moreover, digit span backward which was accepted as a working memory measure (Schofield & Ashman, 1986) showed significance both before and after number sense tasks were added. This shows that working memory and number sense are constructs that behave in accordance with predicting the development of mathematical skills. Furthermore, the current study adds to the body of knowledge on early mathematics development by looking at number sense, in particular, and examining the effect of working memory on its variance. The findings showed that they behaved in the same way again and working memory became the second large contributor to explain the variance in number sense. There are a number of reasons why working memory is important for the development of number sense. Working memory is stated to be important especially during early mathematics learning because it is the time children still use counting procedures to give answers to mathematics problems (Geary, Hoard, Byrd-Craven, & DeSoto, 2004). Secondly, the development of counting, as a component of number sense, appears to result in the development of memory representations of mathematical facts. This means that children are expected to make direct retrieval for number operations like 5 + 3 after some time they start formal schooling. And, this can be possible if they use memory-based problem solving. In addition, working memory goes on being the key element for mathematics skills when children go into being an adult. It was stated that poor working memory leads to difficulties in mathematics performance in coming years (Lezak, 1995).

There is little research taking mathematics ability and reading comprehension into consideration. One of these studies conducted on fourth grade students (Tuohimaa, Aunola, & Nurmi, 2008). The results showed that the covariance between mathematics word problem solving scores and reading comprehension skills was strong enough (standard estimate = .67) to say that the better reading comprehension skills, the better mathematics problem solving performance. In accordance with this finding, reading comprehension became the third variable predicting the variance in number sense, as the base for problem solving. Reading comprehension accounted for 20% of the variance of number sense in the final model. Reading comprehension is expected to be effective in explaining the variance in number sense because number sense itself includes understanding the meaning of numbers. Moreover, there is an analogy between reading and mathematics; the relations between numbers are converted into mathematical language using symbols whereas the relations between words, sentences in a passage are converted into a different verbal language using simpler, summarizer words.

Locuniak and Jordan's (2008) findings was also in line with the results of the current study on the non-accordance of word reading and number sense. In their study, word reading did not affect the variance in calculation fluency significantly before and after number sense tasks were added. Likewise, word reading did not show significance in the variance for number sense in the initial model of this study and explained only 4% of the total variance. Both in the study above and in the current study, there was a time limit as 1-min for this test. But in the current study, students get stressed when they saw a stopwatch in the examiner's hand. During the test administration processes, some of the students lost their attention and motivation as time passed. They could hardly read the shortest words correctly. Hence, the non-significance of word reading in this study is probably due to such a time problem.

Lago and DiPerna (2010) examined the factor analytic structure of number sense and observed that a two-factor model best fitted the data from the sample of kindergarten students. One of these factors was rapid naming measures which also included RAN numbers. The study showed that students with higher levels of number-related skills showed better performance in naming tasks. However, T-RAN indicated no significance on the variance of number sense in this study. This result is consistent with the remaining question Lago and DiPerna (2010) specified. They stated that although RAN was among the factors explaining number sense, it was not clear whether RAN was really included in the number sense construct or separated from it. It was proposed that correlations among the factors may sometimes point out the presence of a higher order factor in research studies (Fabrigar, Wegener, MacCullum, Strahan, 1999; cited in Lago & DiPerna, 2010). RAN numbers, therefore, may not be directly affecting the variance of number sense; but indicate an indirect effect over another variable. This can be a possible explanation why RAN numbers p-value is not significant in the model.

As noted above, Bull and Johnston (1997) found that processing speed was the best predictor of mathematics ability. This study is not supportive of this view as it was found that processing speed does not affect significantly the variance of number sense. This could be due to the time problem like it was in word reading part. To analyse this problem in more detail, it should be noted that processing speed requires the ability to stay on a given timed task and this ability is affected by motivation and time pressure. In Bull and Johnston's (1997) study, there was not a time limit for students to complete the visual matching task which was also used in this study. However, participants in the current study tried to complete the task within a 3-min time limit. Thus, the time pressure may have caused the non-significance of processing speed.

The second research question was addressed to determine the features of first graders who have good, average and poor number sense performance were described in terms of arithmetic performance as a math measure, reading and cognitive correlates of mathematics learning. ANOVA was conducted for the groups' means on the variables stated above with the exception of RAN and reading comprehension measures because of their non-normality. The results indicated that there were significant differences between the groups on all the measures entered in to ANOVA. In order to specify what causes this significance, Tukey's post-hoc analyses were conducted.

In the current study, the PNS group answered very few items when compared to the ANS and the GNS group on number memory test. Thus, significance between these group means was observed. This finding is consistent with the previous research. It states that children who have mathematics difficulties show more impaired performance in numerical information working memory tasks than their normal achiever counterparts (Hitch & McAuley, 1991; Siegel & Ryan, 1989). On the other hand, it was found that the PNS group had a significant mean difference only between the GNS group on word memory measure in this study. This result goes along with the view, noted above by Passolunghi and Siegel (2001). They found that children who had disabilities in mathematics also had difficulty in both numerical and verbal working memory tasks. One possible explanation for the significance on memory measure is that children with smaller working memory capacity have a limited storage to fill in whereas larger working memory means more available space for knowledge. Larger working memory enables to pass from counting to direct retrieval in making number operations which many children with poor number sense or difficulties in mathematics suffer from.

In a longitudinal study, children who were poor math achievers were also accepted as having mathematics learning disability and they were identified with the use of standardized mathematics achievement measures like KeyMath-Revised and WJ-Revised (Mazzocco & Thompson, 2005). In line with Mazzocco and Thompson (2005), the current study indicated that the PNS group scored the least in arithmetic performance test as a measure of mathematics when compared to the ANS and the GNS group, showing a significant difference. This is because weak number sense means not understanding the meaning of numbers, sequencing, number line, counting and many other components that form the core for later mathematics achievement.

Without getting the notion of four operations or order of numbers, to achieve on an assessment over a specific mathematics curriculum would not be possible.

The present study found that the mean difference between the PNS and the GNS group was significant; the PNS group got the lowest score in the visual matching processing speed task. This result is in accordance with Bull and Johnston's (1997) finding that low-ability mathematicians were significantly slower than in processing speed tasks than the high ability group. This result can be interpreted in different ways. The children in the PNS group may have slow information processing, which means that their long-term memory access takes much time while solving mathematics problems. Or, they may have problems with automaticity. So, their response time gets longer.

The mean difference between the PNS and the GNS group was significant on the measure of word reading, as well. However, a study of number sense which included word reading as a group measure could not be found. Only the correlation between word reading and arithmetic was presented in studies. One of these studies, (Fuchs et al., 2006) indicated that especially sight word efficiency enhanced efficiency in arithmetic word problem solving. Moreover, number sense tasks do not include symbolic language all the time. For instance, children's word efficiency is required for number combinations, which are sometimes posed in problem format. It helps to have access to every word of the written problem. Even a person reads aloud the problem; children often feel the need to follow it by themselves. The PNS group is expected to have difficulties in following the problem words and resolving the whole problem. Then, this causes low performance even on easy number sense tasks.

In the literature, mathematics difficulties studies often focus on mean differences between two groups; low and high ability. Hence, the comparison of the average and good group could not be found to discuss with the finding of this study. The current study has a high importance because of this reason, as well. The performances of the ANS and GNS group was evaluated and compared in terms of the variables in the study. The results indicated that the ANS group differed significantly from the GNS group on all the measures entered into the ANOVA. The ANS group' performance on arithmetic performance, number and word memory, processing speed and word reading was significantly lower than the one of the GNS group.

At the beginning of the analyses, these two groups' scores in other measures were expected to be close to each other. This is because their number sense scores were so similar that it was confusing how to separate these participants into two groups. Even after forming the groups, the means of these groups on other measures were thought to be close to each other and no significant difference was expected. However, the assumptions before the analyses were not satisfied. The significant difference between number sense performance and mathematics achievement of the ANS and GNS group may be due to the lack of overlap in the test items of mathematics achievement test and number sense test. This means that the number sense battery's nearly all the items were at a moderate level of difficulty and the group members scored very similarly. But the items in other measures got more difficult as proceeded. Therefore, the ANS who could be accepted as successful as number sense performance could not show the same level of success in other measures. In other words, they showed their real performance which could not realized during the number sense battery. This situation indicated that the participants of the ANS group some of whom were thought to deserve to be in the

GNS group at the beginning of the analysis were really in the group they should have been in.

There is little research investigating the relation of RAN numbers and later arithmetic performance as a math measure in a predictive fashion (Chard et al., 2005). Furthermore, a number sense study comparing RAN numbers performance between groups could not be found. This is one more point, highlighting the importance of the current study. The findings showed that the PNS group differed significantly from both of the other groups on RAN numbers measure whereas there was no significant difference between the ANS and the GNS group this time. The justification for this result is probably that the structure of the tests was similar to each other. In other words, RAN numbers and number sense were both at moderate level of difficulty. And, the PNS group consisted of students who show difficulties in mathematics, indeed and does not show similarity to the students in the ANS group, therefore. As such, the mean difference on RAN numbers present significance for these two groups. The non-significance between the ANS and the GNS group may be due to the same explanation. The behaviors of students in these two groups on number sense test seem to be similar. Since the structure of two tests is somewhat like each other, their behaviors on RAN numbers are similar, as well. So, no significance between mean differences of these two groups was observed.

As noted above, research on the relation of reading comprehension and mathematics skills is not much. Moreover, it is highly difficult to find number sense studies that consider group differences on reading comprehension. In this study, the PNS group showed significant difference between the other two groups on this measure like it behaved on RAN numbers. Likewise, there was no significant difference observed between the ANS and the GNS group. The possible explanation for this finding may be the same with the one given for RAN numbers above. The reading comprehension test did not get difficult as proceeded like number sense battery. Therefore, the behaviors which the groups showed were like the ones they showed on their number sense performance.

Related literature discusses on the effect of the parents' educational attainment on students' academic performance. Maternal education level was found to predict positively the children's mathematics performance (Lewis, 2000). This means that the higher the maternal education level, the more likely the children would be at higher levels at mathematics performance. This is explained in the way that mothers with higher educational attainment provide more support for their children during preschool education. These mothers also have higher expectations on educational issues for their children and they are more interested in their children's school life at first grade level (Englund et al., 2004). In accordance with these findings, the mean differences of number sense scores of students with low and high educational level mothers were found to be significant in the current study. One explanation for this finding is that as the level of education increases, mothers become more aware of their children's need to be interested in. Then, these mothers try to learn what to do to help their children in the correct way for their academic and behavioral development. The literature states that paternal education also positively predicts children's mathematics performance. However, the mean differences for fathers' educational level were not found as significant in this study. This may be due to the grade level of the sample. In other words, first grade is the time children start formal schooling and they need mother support more than the support of fathers during this period. Thus, significance may not be satisfied at fathers' side.

Educational Implications of the Study

Results of the current study have potential implications for the prediction of number sense in young children. In prediction for mathematics difficulties literature, longitudinal studies were often designed with the use of number sense measures to make predictions for later mathematics outcomes. The current study investigates the issue in a reverse direction. It was hypothesized that mathematics measures may also have a role in the development and change in number sense. Thus, this study is the first to examine the effects of so many different variables including arithmetic performance as a mathematics measure on the variance of number sense. The significance of the study appears more clearly when it was observed that there was not a study describing the current situation of number sense and the factors affecting its development in Turkey. In recent literature, many studies have been conducted on the relation of working memory and mathematics development to number sense. However, more research is needed to examine the relationship between reading, processing speed and RAN to number sense performance.

The second major implication is that this study emphasized the current situation beyond designing a number sense screening tool. It indicated that arithmetic performance, number memory and reading comprehension were the variables explaining the variance in number sense the most. Therefore, this study showed a route for which key elements should be considered while designing a number sense screening tool.

The third implication arises at the point of comparison of number sense group profiles. By comparing the profiles of the students with poor, average and good number sense, a more refined understanding of strengths and weaknesses for each group was provided. This profiling was believed to be of value to especially classroom teachers when evaluating their students' mathematics performance.

Limitations

The study has a number of limitations. This study included only first graders. To be able examine developmental differences more thoroughly, it would be better to include second graders, as well.

Reading comprehension, word memory and the translated version of the number sense battery were developed by the researcher; but the reliability and validity studies of these measures were not realized with an acceptable number of children. Therefore, the use of these measures might have affected the results.

The number sense battery was stated to be appropriate for children from the age 5 to 6 when children attend to early childhood education (ECE). However, ECE is not obligatory in Turkey. This means that at that age some of the children have a higher academic level of mathematics knowledge whereas their counterparts without ECE are at a lower level. To overcome this difference, the administration process took place at the end of first grade when their level may have been closer. Nonetheless, this situation may have affected the results of the study.

The duration of test administration for each child was nearly one hour. This time duration was long for some participants. Therefore, they may have been bored and lost their attention. This may have affected the results of the study.

Suggestions for Further Research

In the current study, the possible key elements of a number sense screening tool that is to be designed in the future were determined. Future research should design such a screening tool with these elements and examine the reliability and validity of the tool on a large sample from kindergarten to the end of first grade.

During the test administrations, it was realized that students' understanding of the problems in the mathematics achievement test was highly related to the wording of the problems. Therefore, future research should use the data of the study to investigate the relationship between mathematics achievement and word reading, considering each question in the test separately.

For further research, the relationship between RAN, processing speed, word reading and number sense should be investigated on a longitudinal study. Although these variables did not indicate significance on the regression analyses in this study, their effects over a long time period across different grade levels has remained unexplored.

Moreover, this study can be replicated with a larger sample and in a longitudinal fashion. This time logistic regression can be used and considering each group stated in this study separately, the effect of each independent variable on the variance in number sense can be investigated.

APPENDICES

APPENDIX A

MEB AND INAREC PERMISSION

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ
Sosyal Bilimler Enstitüsü

Sayı: B.30.2.BÜN.0.41.00.00.300.99/2012-62

2 Mayıs 2012

İlgili Makama,

Sosyal Bilimler Enstitüsü, İlköğretim yüksek lisans öğrencisi Merve Aşık'ın "1.Sınıf Öğrencilerin Sayı Algısı,Okuma,Hafıza ve İşleme Hızı Performansları Arasındaki İlişkileri Ortaya Koyan bir Model Çalışması" adlı tez çalısması için 14-31 Mayıs 2012 tarihleri arasında ekte belirtilen okullarda çalışma yapması için gerekli iznin verilmesi hususunda yardımlarınızı rica ederim.

Saygılarımla,

Prof.Dr.Cevza Sevgen
Enstitü Müdürü

EK: Uygulama Yapılması Planlanan Okullar

T.C.
İSTANBUL VALİLİĞİ
İl Millî Eğitim Müdürlüğü

Sayı : B.08.4.MEM.0.34.14.00-020-/ 65639 14/05/2012
Konu : Anket (Merve AŞIK)

VALİLİK MAKAMINA

İlgi : a) Boğaziçi Üniversitesi Sosyal Bilimler Enstitüsü'nün 02/05/2012 tarihli
Ve 2012-62 sayılı yazısı
b) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğü'nün 07.03.02012 tarihli ve
3616sayılı 2012/13 No.lu Genelgesi.
c) Milli Eğitim Komisyonunun 11/05/2012 tarihli tutanağı.

Boğaziçi Üniversitesi Sosyal Bilimler Enstitüsü İlköğretim Yüksek lisans öğrencisi Merve AŞIK'ın **"1.Sınıf Öğrencilerinin Sayı Algısı, Okuma, Hafıza ve İşleme Hızı Performansları Arasındaki İlişkileri Ortaya Koyan Bir Modelleme Çalışması"** konulu Tezine dair, Anket çalışmasını İlimiz, Ümraniye, Üsküdar, Beşiktaş, Sarıyer, İlçelerinde bulunan devlet ve özel İlköğretim okullarında öğrenim gören 1. sınıf öğrencilerine yönelik, sayı algısı ölçme araçları, okuma ölçme araçları, hafıza ölçme araçları, işleme hızı testi ile ilgili anket uygulama isteği hakkındaki ilgi (a) yazı ve ekleri müdürlüğümüzce incelenmiştir.

Yüksek lisans öğrencisi Merve AŞIK'ın söz konusu talebi; bilimsel amaç dışında kullanılmaması koşuluyla, okul idarelerinin denetim, gözetim ve sorumluluğunda ilgi (b) Bakanlık emri esasları dâhilinde uygulanması, sonuçtan Müdürlüğümüze rapor halinde (CD formatında) bilgi verilmesi kaydıyla Müdürlüğümüzce uygun görülmektedir.

Makamlarınızca da uygun görüldüğü takdirde Olurlarınıza arz ederim.

Dr. Muammer YILDIZ
Milli Eğitim Müdürü

OLUR
... /05/2012

Harun KAYA
Vali a.
Vali Yardımcısı

5070 Sayılı Kanuna Göre HARUN KAYA tarafından 44510566835921154 SeriNolu Sertifika ile 14.05.2012 16:58:24 Tarihinde Elektronik Olarak İmzalanmış

NOT: Verilecek cevapta tarih, numara ve dosya numarasının yazılması rica olunur.
STRATEJİ GELİŞTİRME BÖLÜMÜ E-Posta: sgb34@meb.gov.tr,
ADRES: İl Milli Eğitim Müdürlüğü D Blok Bab-ı Ali Cad. No:13 Cağaloğlu
Telefon: Snt.212 455 04 00 Dahili: 243, Faks: 212 520 05 64 Şb.Md.: 212 511 16 65

T.C.
İSTANBUL VALİLİĞİ
İl Millî Eğitim Müdürlüğü

Sayı : **B.08.4.MEM.0.34.14.00-044-/** .... /..../05/2012
Konu : Anket (Merve AŞIK)

BOĞAZİÇİ ÜNİVERSİTESİ REKTÖRLÜĞÜ
(Sosyal Bilimler Enstitüsü)

İlgi : a) 02/05/2012 tarihli ve 2012-62 sayılı yazınız.
b) Valilik Makamının 14/05/2012 tarihli ve 65639 sayılı onayı.

Boğaziçi Üniversitesi Sosyal Bilimler Enstitüsü İlköğretim Yüksek lisans öğrencisi Merve AŞIK'ın **"1. Sınıf Öğrencilerinin Sayı Algısı, Okuma, Hafıza ve İşleme Hızı Performansları Arasındaki İlişkileri Ortaya Koyan Bir Modelleme Çalışması"** konulu tezine dair Anket çalışmasını, İlimiz, Ümraniye, Üsküdar, Beşiktaş Sarıyer İlçelerinde bulunan devlet ve özel İlköğretim okullarında öğrenim gören 1. sınıf öğrencilerine yönelik, Anket uygulama isteği ilgi (b) Valilik Onayı ile uygun görülmüştür.

Bilgilerinizi ve ilgi (b) Valilik Onayı doğrultusunda gerekli duyurunun anketçi tarafından yapılmasını, işlem bittikten sonra 2 (iki) hafta içinde sonuçtan Müdürlüğümüz Strateji Geliştirme Bölümüne rapor halinde bilgi verilmesini arz ederim.

M.Nurettin ARAS
Müdür a.
Şube Müdürü

EKLER:
Ek-1 Valilik Onayı.
Ek-2 Anket Soruları.

NOT: Verilecek cevapta tarih, numara ve dosya numarasının yazılması rica olunur.
STRATEJİ GELİŞTİRME BÖLÜMÜ E-Posta: sgb34@meb.gov.tr,
ADRES: İl Milli Eğitim Müdürlüğü D Blok Bab-ı Ali Cad. No:13 Cağaloğlu
Telefon: Snt.212 455 04 00 Dahili: 243, Faks: 212 520 05 64 Şb.Md.: 212 511 16 65

BOĞAZİÇİ ÜNİVERSİTESİ
İnsan Araştırmaları Kurumsal Değerlendirme Kurulu (İNAREK) Toplantı Tutanağı
2013/2

15.04.2013

Merve Aşık,
Boğaziçi Üniversitesi, İlköğretim Bölümü 34342 Bebek, İstanbul
merve.asik@boun.edu.tr

Sayın Araştırmacı,

"1.Sınıf Öğrencilerinin Sayı algısı, Okuma, Hafıza, İşleme Hızı ve Hızlı Otomatik İsimlendirme Performansları Arasındaki İlişkileri Ortaya Koyan Bir Model Çalışması" başlıklı projeniz ile yaptığınız Boğaziçi Üniversitesi İnsan Araştırmaları Kurumsal Değerlendirme Kurulu (İNAREK) 2013/37 kayıt numaralı başvuru 15.04.2013 tarihli ve 2013/2 sayılı kurul toplantısında incelenerek etik onay verilmesi uygun bulunmuştur.

Saygılarımızla,

Prof. Dr. Hande Çağlayan (Başkan)
Moleküler Biyoloji ve Genetik Bölümü,
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İstanbul

APPENDIX B

DEMOGRAPHIC INFORMATION FORM

Uygulayıcı adı:

Tarih:

Öğrenci Bilgi Formu

Bu form, öğrencinin sınıf öğretmeni tarafından doldurulacaktır.
Lütfen aşağıdaki bölümü eksiksiz olarak doldurunuz.

• Öğrenci Adı-Soyadı : ....

• Öğrencinin Doğum Tarihi: ----/ ---- / -------

• Okulu: ....

• Sınıfı: ....

• Öğrencinin Cinsiyeti: Kız ( ) Erkek ( )

• Öğrencinin Okulöncesi Eğitimi: Var ( ) Yok ( )

• Annenin Eğitim Düzeyi :

Okuryazar değil ( ) Okuryazar ( ) İlkokul ( )

Ortaokul ( ) Lise ( ) Üniversite ( )

Lisansüstü ( )

• Babanın Eğitim Düzeyi :

Okuryazar değil ( ) Okuryazar ( ) İlkokul ( )

Ortaokul ( ) Lise ( ) Üniversite ( )

Lisansüstü ( )

• Annenin Mesleği: ____________________________

• Babanın Mesleği: ___________________________

• Öğrencinin işitme problemi var mı? Evet ( ) Hayır ( )

• Öğrencinin dil ve konuşma problemi var mı? Evet ( ) Hayır ( )

• Öğrencinin okuma yazmada sorunu var mı? Evet ( ) Hayır ( )

• Öğrenme güçlüğü, dikkat eksikliği ve/veya hiperaktivite bozukluğu gibi tanılardan herhangi birini almış mı?

Evet ( ) Hayır ( ) Bilgim Yok ( )

Evet, ise hangisi ? --

• Öğrenciniz okumayı ne zaman öğrendi?

-
____

•Türkçe ders notu (birinci yarıyıl): _________________

•Matematik ders notu (birinci yarıyıl): _________________

•Öğrencinizin akademik durumu ve gelişimi hakkında eklemek istedikleriniz:

<u>KATKILARINIZ İÇİN ÇOK TEŞEKKÜR EDERİZ. ☺</u>

APPENDIX C

TURKISH MEMORY FOR WORDS (T-MFW)

Öğrenci adı – soyadı:

Numarası:

Okulu:

Uygulayıcı adı – soyadı:

Uygulama Tarihi:

KELİME HAFIZASI

1	çocuk						
2	kapi						
3	ev						
4	kiz	ağaç					
5	çay	kitap					
6	ben	üç					
7	uyku	elma	çanta				
8	çimen	baba	kayak				
9	kalem	duvar	abla				
10	yap	bak	gündüz				
11	kedi	çeşme	kutu				
12	kuş	rüzgar	tilki				
13	dolap	hepsi	akşam	Ceviz			
14	balik	defter	sepet	Güneş			
15	bebek	deniz	bahçe	Koş			
16	kardeş	uzak	oda	Senin	tek		
17	oyun	kadin	lamba	Git	sabun		
18	ekmek	konuş	havuç	Kapi	bardak		
19	horoz	okul	çorap	Yüz	otur	bizim	
20	uçak	adam	resim	Kara	senin	ama	
21	zaman	neden	tabak	Yildiz	dayi	iki	
22	lezzet	peri	aslan	Bitir	hayat	muz	kapak
23	araba	kaşik	peynir	Toka	fare	kazak	çilek
24	işik	zor	silgi	Etek	sonra	hali	bulut

APPENDIX D

SAMPLE ITEMS OF WORD READING TEST

DENEME

el

ben

bak

gel

koş

su

gitti

boncuk

DENEME

Mu

Vı

Kük

Pam

Hınk

Anhasi

Kudula

Öspüte

1

APPENDIX E

READING COMPREHENSION MEASURES

KEDİ

Kedi, dünyanın her yerinde en çok beslenen hayvandır. Bir kedinin gözlerine bakın. Onu sevdiğinizi belli ederseniz hemen yanınıza gelir. Ayaklarınıza dolanır. Kendisine kızılıp bağırıldığında ise ortadan kaybolur. Kedilerin çoğu oyun oynamayı sever. Et yemeye, süt içmeye hepsi bayılır.

Kedilerin farklı özellikleri olabilir. Bazı kedilerin kuyruğu uzun, bazı kedilerin kuyruğu kısadır. Bazı kedilerin de göz rengi değişik olabilir. Örneğin; Van kedisinin gözlerinin biri mavi, diğeri yeşildir.

Burhan EREN

Ebe Sobe Dergisi

Ağustos – 2004

(Düzenlenmiştir.)

KEDİ

DEĞERLENDİRME SORULARI

Öğrenci adı soyadı: Numarası: Okulu: Uygulayıcı adı soyadı: Uygulama Tarihi:	SÜRE:

1. Parçaya göre dünyanın her yerinde en çok beslenen hayvan nedir?

2. Bir kedi onu sevdiğinizi anlarsa ne yapar?

3. Bir kedi ne zaman ortadan kaybolur?

4. Parçaya göre kedilerin yapmayı sevdiği şeyler nelerdir?

5. Parçaya göre kedilerin hangi özellikleri birbirinden farklı olabilir?

KUMBARA

Eren’e ablası doğum gününde bir kumbara hediye etti. Eren buna çok sevindi. O günden sonra harçlığının bir kısmını kumbarasına atmaya başladı. Aradan aylar geçti. Ablasının doğum günü yaklaştı. Eren ablasına bir kitap hediye etmeye karar verdi. Fakat kitabı almaya harçlığı yetmedi. Birden aklına biriktirdiği paralar geldi. Kumbarasını açtı. İçinden kitap için gerekli parayı aldı. Kumbarasını kapattı. Eren sevinç içinde kitapçıya gitti.

<table>
<tr><td colspan="2">KUMBARA
DEĞERLENDİRME SORULARI</td></tr>
<tr><td><u>Öğrenci adı soyadı:</u>
<u>Numarası:</u>
<u>Okulu:</u>
<u>Uygulayıcı adı soyadı:</u>
<u>Uygulama Tarihi:</u></td><td>SÜRE:</td></tr>
<tr><td colspan="2">1. Bu öyküde kimler var?
2. Eren harçlığını alınca ne yapıyor?
3. Eren neden ablasına hediye almak istiyor?
4. Eren kitabı alabilmek için ne yaptı?
5. Kumbarasında para biriktirmek Eren’in işine nasıl yaradı?
6. Sen Eren’in yerinde olsaydın harçlığınla ne yapardın?
7. Doğum günlerinde niçin hediye alırız?</td></tr>
</table>

REFERENCES

Ackerman, P. T., & Dykman, R. A. (1995). Reading – disabled students with and without comorbid arithmetic disability. *Developmental Neuropsychology, 11,* 351-371.

American Educational Research Association. (2006). Standards for reporting on empirical social science research in AERA publications. *Educational Researcher, 35 (6),* 33-40.

American Psychiatric Association. (1994). Diagnostic and statistical manual of mental disorders (4th ed.) Washington. DC: Author.

American Psychological Association. (2001). *Publication manual of the American Psychological Association* (5th ed.). Washington, DC: Author.

Antell, S. & Keating, D. P. (1983). Perception of numerical invariance in neonates. *Child Development, 54,* 695-701.

Ardila, A., & Rosselli, M. (2002). Acalculia and dyscalculia. *Neuropsychology Review*, 12, 179-231.

Atkinson, R. C., & Shiffrin, R. M. (1971). The control of short-term memory. *Scientific American, 225,* 82-90.

Aunola, K., Leskinen, E., Lerkkanen, M. K., & Nurmi, J. E. (2004). Developmental dynamics of math performance from preschool to grade 2. *Journal of Educational Psychology. 96 (4),* 699-713.

Babur, F. N., Haznedar, B., Erdat-Çekerek, E., Erçetin, G., & Ozerman, D. (2009). Çocuklarda okuma güçlüğü: kelime okuma testlerinin geliştirilmesi. 19. Ulusal Özel Eğitim Kongresi, 22-24 Ekim 2009, Marmaris, Aydın.

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (vol. 8, pp. 47– 90). New York: Academic Press.

Badian, N. A. (1983). Dyscalculia and nonverbal disorders of learning. In H. R. Myklebust (Ed.), *Progress in learning disabilities* (Vol. 5, pp. 235-264). New York: Stratton.

Baker, S., Gersten, R., & Keating, T. J. (2000). When less may be more: A 2-year longitudinal evaluation of a volunteer tutoring program requiring minimal training. *Reading Research Quarterly, 35,* 494-519.

Baker, S., Gersten, R., Flojo, J., Katz, R., Chard, D., & Clarke, B. (2002). *Preventing Mathematics Difficulties in Young Children: Focus on Effective Screening of Early Number Sense Delays (Technical Report No. 0305).* Eugene, OR: Pacific Institutes for Research.

Barbaresi, M. J., Katusic, S. K., Colligan, R. C.,Weaver, A. L., & Jacobsen, S. J. (2005). Math learning disorder: Incidence in a population-based birth cohort, 1976-1982, Rochester, Minn. *Ambulatory Pediatrics, 5,* 281–289.

Baroody, A. J. (1987). The development of counting strategies for single-digit addition. *Journal for Research in Mathematics Education, 18,* 141-157.

Baroody, A. J., & Gatzke, M. R. (1991). The estimation of set size by potentially gifted kindergarten-age children. *Journal for Research in Mathematics Education,* 22, 59 – 68.

Baroody, A. J. (1992). Remedying common counting difficulties. In J. Bideaud, C. Meljac, & J. P. Fischer (Eds.), *Pathways to number: Children's developing numerical abilities* (pp. 307-324). Hillsdale, NJ: Lawrence Erlbaum.

Baroody, A. J. & Rosu, L. (2006). Adaptive expertise with basic addition and subtraction combinations – The number sense view. Paper presented at the *Meeting of the American Educational Research Association*, San Francisco, CA.

Baroody, A. J., Lai, M.-L., & Mix, K. S. (2006). The development of young children's early number and operation sense and its implications for early childhood education. In B. Spodek & O. Saracho (Eds.), *Handbook of research on the education of young children* (pp. 187-221). Mahwah, NJ: Lawrence Erlbaum Associates.

Barth, H., La Mont, K., Lipton, J., Dehaene, S., Kanwisher, N., & Spelke, E. (2006). Non-symbolic arithmetic in adults and young children. *Cognition, 98*, 199-222.

Berch, D. B. (2005). Making sense of number sense: Implications for children with mathematical disabilities. *Journal of Learning Disabilities, 38,* 333-339.

Berninger, V. & Richards, T. (2002). *Brain literacy for educators and psychologists.* San Diego, California: Academic Press.

Bull, R., & Johnston, R. (1997). Children's arithmetical difficulties: Contributions from processing speed, item identification, and short-term memory. *Journal of Experimental Child Psychology, 65*, 1-24.

Bull, R., & Sherif, G. (2001). Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. *Developmental Neuropsychology, 19,* 273–293.

Butterworth, B., Cipolotti, L., & Warrington, E. (1996). Short-term memory impairments and arithmetic ability. *Quarterly Journal of Experimental Psychology, 49A*, 251- 262.

Butterworth, B. (1999). *What counts: How every brain is hardwired for math*. New York: Free Press.

Butterworth, B. (2005). Developmental dyscalculia. In Campbell, J. I. D. (Ed.), *Handbook of Mathematical Cognition* (pp. 455-467). Hove: Psychology Press.

Butterworth, B. & Reigosa, V. (2007). Information processing deficits in dyscalculia. In D. Berch & M. Mazzocco (Eds.), *Why Is Math So Hard for Some Children?* (pp. 65-81). Baltimore, MD: Paul H. Brookes Publishing Co.

Campbell, J. I. D., & Clark, J. M. (1988). An encoding-complex view of cognitive number processing: Comment on McCloskey, Sokol, & Goodman (1986). *Journal of Experimental Psychology: General*, 117, 204-214.

Cantor, J., Engle, R. W., & Hamilton, G. (1991). Short term memory, working memory, and verbal abilities: How do they relate?. *Intelligence, 15,* 229-246.

Case, R. (1985). *Intellectual development: Birth to adulthood.* New York: Academic Press.

Case, R., & Griffin, S. (1990). Child cognitive development: The role of central conceptual structures in the development of scientific and social thought. In E. A. Hauert (Ed.), *Developmental Psychology: Cognitive, perceptuo-motor, and neurological perspectives* (pp. 193-230). North-Holland: Elsevier.

Case, R. & Sandieson, R. (1991). Testing for the presence of a central quantitative structure: Use of the transfer paradigm. In R. Case (Ed.), *The mind's staircase: Exploring the conceptual underpinnings of children's thought and knowledge* (pp. 117-132). Hillsdale, NJ: Erlbaum.

Catts, H. W., Perscher, Y., Schatschneider, C., Bridges, M. S., & Mendoza, K. (2009). Floor effects associated with universal screening and their impact on the early identification of reading disabilities. *Journal of Learning Disabilities, 42,* 163-177.

Chard, D., Clarke, B., Baker, B., Otterstedt, J., Braun, D., & Katz, R. (2005). Using measures of number sense to screen for difficulties in mathematics: Preliminary findings. *Assessment Issues in Special Education, 30,* 3-14.

Clarke, B. & Shinn, M. R. (2004). A preliminary investigation into the identification and development of early mathematics curriculum-based measurement. *School Psychology Review, 33,* 234-248.

Clements, D. H. (1999). Subitizing: What is it?Why teach it? *Teaching Children Mathematics*, 5, 400-405.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.) Hillsdale, NJ: Lawrence Erlbaum.

Cordes, S. & Brannon, E. M. (2008). Quantitative competencies in infancy. *Developmental Science, 11,* 803-808.

Daneman, M., & Carpenter, P. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning & Verbal Behavior, 19,* 450-466.

Dehaene, S. (1992).Varieties of numerical abilities. *Cognition, 44,* 1-42.

Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology: General, 122,* 371–396.

Dehaene, S. (1997). *The number sense: How the mind creates mathematics*. New York, NY: Oxford University Press.

Dehaene, S. (2001). Précis of the number sense. *Mind & Language*, 16, 16-36.

Dehaene, S., Cohen, L. (1995). Dissociable mechanisms of subitizing and counting: Neuropsychological evidence from simultanagnosis patients. *Journal of Experimental Psychology: Human Perception & Performance, 20*(5), 958-975.

Dehaene, S. & Cohen, L. (1997). Cerebral pathways for calculation: Double dissociation between rote verbal and quantitative knowledge of arithmetic. *Cortex, 33,* 219-250.

Dehaene, S., Spelke, E., Pinel, P., Stanescu, R., & Tsivkin, S. (1999). Sources of mathematical thinking: Behavioral and brain-imaging evidence. *Science, 284,* 970- 974.

Dehaene, S., Piazza, M., Pinel, P., & Cohen, L. (2003). Three parietal circuits for number processing. *Cognitive Neuropsychology, 20,* 487-506.

Dehaene, S., Piazza, M., Pinel, P., & Cohen, L. (2005). Three parietal circuits for numberprocessing. In J. I. D. Campbell (Ed.), *Handbook of Mathematical Cognition* (pp.433-454). New York: Psychology Press.

Delazer, M., Domahs, F., Bartha, L., Brenneis, C., Locky, A., Trieb, T. & Benke, T. (2003). Learning complex arithmetic – and fMRI study. *Cognitive Brain Research, 18,* 76-88.

Desoete, A., Ceulemans, A., Roeyers, H., & Huylebroeck, A. (2009). Subitizing or counting as possible screening variables for learning disabilities in mathematics education or learning? *Educational Research Review, 4,* 55–66.

Desoete, A., & Grégoire, J. (2007). Numerical competence in young children and in children with mathematics learning disabilities. *Learning and Individual Differences, 16,* 351–367.

Dikici, R. & İşleyen, T. (2004). Bağıntı ve fonksiyon konusundaki öğrenme güçlüklerinin bazı değişkenler açısından incelenmesi. *Kastamonu Eğitim Dergisi, 12(1),* 105-116.

Dowker, A. (1997). Young Children's Addition estimates. Mathematical Cognition, 3, 141 – 154.

Dowker, A. D. (2004). *Children with Difficulties in Mathematics:What Works?* London : DfES.

Dowker, A. D. (2005). *Individual Differences in Arithmetic: Implications for Psychology, Neuroscience and Education.* Hove: Psychology Press.

Duncan, G. J., Dowsett, C. J., Classens, A., Magnuson, K., Huston, A. C., Klebanov, P., et al. (2007). School readiness and later achievement. *Developmental Psychology, 43*, 1428- 1446.

Durand, M., Hulme, C., Larkin, R., & Snowling, M. (2005). The cognitive foundations of reading and arithmetic skills in 7- to 10-year olds. *Journal of Experimental Child Psychology, 91*, 113–136.

Durmuş, S. (2004a). Matematikte öğrenme güçlüklerinin saptanması üzerine bir çalışma. *Kastamonu Eğitim Dergisi, 12(1),* 125-128.

Durmuş, S. (2004b). İlköğretim matematiğinde öğrenme zorluklarının saptanması ve zorlukların gerisinde yatan nedenler üzerine bir çalışma. VI. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi, Marmara Üniversitesi, İstanbul. İndirilme tarihi: 20.09.2006, http://www.nef.balikesir.edu.tr/~osi nan/files/ozetler,pdf

Englert, C. S., Culatta, B. E., & Horn, D. G. (1987). Influence of irrelevant information in addition word problems on problem solving. *Learning DisabilityQuarterly, 10*, 29-36.

Englund, M., Luckner, E., Amy, W. J. L., Gloria, & Egeland, B. (2004). Children's achievement in early elementary school: Longitudinal effects of parental involvement, expectations, and quality of assistance. *Journal of Educational Psychology, 96 (4), 723-730.*

Ersoy, Y. & Erbaş, K. (1998). İlköğretim okullarında cebir öğretimi: öğrenmede güçlükler ve öğrenci başarıları. *Cumhuriyetin 75.yılında İlköğretim 1.Ulusal Sempozyumu, Başkent Öğretmen Evi,* Ankara.

Ersoy, Y. & Ardahan, H. (2003). İlköğretim okullarında kesirlerin öğretimi – II: Tanıya yönelik etkinlikler düzenleme. İndirilme tarihi: 15. 12. 2004, www.matder. org.tr.

Ersoy, Y. & Erbaş, A. K. (2005). Kassel projesi cebir testinde bir grup Türk öğrencinin genel başarısı ve öğrenme güçlükleri. İlköğretim – Online, 4 (1), 18-39. İndirilme tarihi : 18.01.2006, http://www.ilköğretim-online.org.tr.

Fabrigar, L. R., Wegener, D. T., MacCullum, R. C., & Strahan, E. J. (1999). Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods, 4*, 291-314.

Feigenson, L., Carey, S., & Hauser, M. (2002a). The representations underlying infants' choice of more: object files versus analog magnitudes. *Psychological Science*, 13 (2), 150–156.

Feigenson, L., Dehaene, S., & and Spelke, E. (2004). Core systems of number. *Trends in Cognitive Sciences*, *8*, 307-314.

Fischer, B., Gebhardt, C., & Hartnegg, K. (2008). Subitizing an visual counting in children with problems acquiring basic arithmetic skills. *Optometry and Vision Development, 39,* 24–29.

Frank, A. R. (1989). Counting skills: A foundation for early mathematics. *Arithmetic Teacher, 37,* 14–17.

Fuchs, L. S., & Fuchs, D. (2002). Mathematical problem-solving profiles of students with mathematics disabilities with and without comorbid reading disabilities. *Journal of Learning Disabilities, 35,* 563-573.

Fuchs, L. S., Compton,D. L., Fuchs,D., Paulsen, K., Bryant, J.D.,&Hamlett, C. L. (2005). The prevention, identification, and cognitive determinants of math difficulty. *Journal of Educational Psychology, 97*(3), 493–513.

Fuchs, D., & Fuchs, L. S. (2006). Introduction to response to intervention: What, why, and how valid is it? *Reading Research Quarterly, 41(1),* 93-99.

Fuchs, L., Fuchs, D., Compton, D., Powell, S., Seethaler, P., & Capizzi, A., et al. (2006). The cognitive correlates of third-grade skill in arithmetic, algorithmic computation and arithmetic word problems. *Journal of Educational Psychology, 98*, 29-43.

Fuchs, L. S., Fuchs,D., Compton,D. L., Bryant, J.D., Hamlett, C. L. & Seethaler, P. M. (2007). Mathematics screening and progress monitoring at first grade: Implications for responsiveness to intervention. *Exceptional Children, 73 (3),* 311-330.

Fuerst, A. J., & Hitch, G. J. (2000). Separate roles for executive and phonological components of working memory in mental arithmetic. *Memory & Cognition, 28*, 774–782.

Fuson, K. (1988). *Children's Counting and Concepts of Number.* New York: Springer-Verlag.

Gallistel, C. R. & Gelman, R. (1992). Preverbal counting and computation. *Cognition, 44,* 43-74.

Garnett, K. & Fleischner, J. (1983). Automatization and basic fact performance of normal and learning disabled children. *Learning Disability Quarterly, 6*, 223-230.

Gathercole, S. E. , Tiffany, C., Briscoe, J., Thorn, A., et al. (2005). Developmental consequences of poor phonological short-term memory function in childhood: a longitudinal study. *Journal of Child Psychology and Psychiatry and Allied Disciplines 46*(6):598-611.

Geary, D. C. (1990). A componential analysis of an early learning deficit in mathematics. *Journal of Experimental Child Psychology, 49,* 363-383.

Geary, D. C. (1993). Mathematical Disabilities: Cognitive, neuropsychological, and genetic components. *Psychological Bulletin, 114*, 345-362.

Geary, D. (1994). *Children's mathematical development: Research and practical applications.* Washington, DC: American Psychological Association.

Geary, D. (2000). From infancy to adulthood: the development of numerical abilities, *European Child and Adolescent Psychiatry, 9(2),* 11-16.

Geary, D. C. (2003). Learning disabilities in arithmetic: Problem solving differences and cognitive deficits. In H. L. Swanson, K. Harris, & S. Graham (Eds.), Handbook of learning disabilities (pp. 199 – 212). New York: Guilford Publishers.

Geary, D. C. (2004). Mathematics and learning disabilities. *Journal of Learning Disabilities, 37,* 4–15.

Geary, D. (2006). Development of mathematical understanding. In D. Kuhn, R. Siegler, W. Damon, & R. Lerner (Eds.), *Handbook of child psychology: Vol. 2, Cognition, perception, and language* (6th ed.). (pp. 777-810)

Geary, D. C., Bow-Thomas, C. C., & Yao, Y. (1992). Counting knowledge and skill in cognitive addition: A comparison of normal and mathematically disabled children. *Journal of Experimental Child Psychology, 54*, 372-391.

Geary, D., Hoard, M., & Hamson, C. (1999). Numerical and arithmetical cognition: Patterns of functions and deficits in children at risk for a mathematical disability. *Journal of Experimental Psychology, 74,* 213-239.

Geary, D. C., Hamson, C. O., & Hoard, M. K. (2000). Numerical and arithmetical cognition: A longitudinal study of process and concept deficits in children with learning disability. *Journal of Experimental Child Psychology, 77,* 236-263.

Geary, D. C., Hoard, M. K., Byrd-Craven, J., & DeSoto, M. C. (2004). Strategy choices in simple and complex addition: Contyributions of working memory and counting knowledge for children with mathematical disability. *Journal of Experimental Child Psychology, 88*, 121-151.

Geary, D. C., Hoard, M. K., Byrd-Craven, J., Nugent, L., & Numtee, C. (2007). Cognitive mechnanisms underlying achievement deficits in children with mathematical learning disability. *Child Development, 78,* 1343-1359. doi: 10.1111/j. 1467-8624.2007.01069.x

Gelman, R., & Gallistel, C. R. (1978). *The children's understanding of number.* Cambridge, MA: Harvard University Press.

Gelman, R. & Butterworth, B. (2005). Number and language: how are they related? *Trends in Cognitive Sciences, 9(1),* 6-10.

Gersten, R., & Chard, D. (1999). Number sense: Rethinking arithmetic instruction for students with mathematical disabilities. *Journal of Special Education, 44,* 18–28.

Gersten, R., Jordan,N. C., & Flojo, J. R. (2005). Early identification and interventions for students with mathematics difficulties. *Journal of Learning Disabilities, 38,* 293–304.

Gevers, W., Lammertyn, J., Notebaert, W., Verguts, T. & Fias, W. (2006). Automatic response activation of implicit spatial information: Evidence from the SNARC effect. *Acta Psychologica, 122,* 221–233.

Ginsburg, H. P. (1977). *Children's Arithmetic: How They Learn It and How You Teach It.* New York: Teachers' College Press.

Ginsburg, H. P. (1989). *Children's arithmetic.* Austin, TX: PRO-ED.

Ginsburg, H. P., Lee, J. S., & Boyd, J. S. (2008). Mathematics education for young children: What it is and how to promote it. *Social Policy Report, 22,* 3-22.

Goldman, S. R., Pellegrino, J. W., & Mertz, D. L. (1988). Extended practice of basic addition facts: Strategy changes in learning disabled students. *Cognition and Instruction, 5,* 223-265.

Gravetter, F. J. & Wallnau, L. B. (2007). *Statistics for the Behavioral Sciences.* (7th Ed.). Belmont, CA: Wadsworth. Thomson/Wadsworth, c2004

Griffin, S., Case, R., & Siegler, R. S. (1994). Classroom lessons: Integrating cognitive theory and classroom practice. In K. McGilly (Ed.), *Rightstart: Providing the Central Conceptual Prerequisites for First Formal Learning of Arithmetic to Students at risk for School Failure* (pp. 25-50). Cambridge, MA: MIT Press.

Griffin, S. (2002). The development of math competence in the preschool and early school years: Cognitive foundations and instructional strategies. In J. M. Roher (Ed.), *Mathematical cognition* (pp. 1-32). Greenwich, CT: Information Age Publishing.

Griffin, S. (2004). Building number sense with number worlds: A mathematics program for young children. *Early Childhood Research Quarterly, 19,* 173-180.

Gross-Tsur, V., Manor, O., & Shalev, R. (1996). Developmental Dyscalculia: Prevalence and demographic features. *Developmental Medicine and Child Neurology, 38,* 25-33.

Hannula, M. M., & Lehtinen, E. (2005). Spontaneous focussing on numerosity and mathematical skills of young children. *Learning and Instruction, 15,* 237–256.

Harç, S. (2010). *6.sınıf öğrencilerinin sayı duyusu kavramı açısından mevcut durumlarının analizi*. Unpublished master's thesis, Marmara University, Istanbul.

Hatcher, L. (1994b). *A step by step approach to using the SAS system for univariate and multivariate statistics.* Cary, NC, SAS Institute Inc.

Hecht, S., Torgesen, J., Wagner, R., & Rashotte, C. (2001). The relations between phonological processing abilities and emerging individual differences in mathematical computational skills: A longitudinal study from second to fifth grades. *Journal of Experimental Child Psychology, 79,* 192-227.

Hitch, G. J. (1978). The role of short-term working memory in mental arithmetic. *Cognitive Psychology, 10,* 302–323.

Hitch, G. J., & McAuley, E. (1991). Working memory in children with specific arithmetical learning difficulties. *British Journal of Psychology, 82,* 375–386.

Hopkins, S. & Egeberg, H. (2009). Retrieval of Simple Addition Facts. *Journal of Learning Disabilities, 42 (3),* 215-229.

Howell, S. & Kemp, C. (2005). Defining early number sense: A participatory Australian study. *Educational Psychology*, 25, 555-571.

Huck, S. W. (2012). Reading Statistics and Research. (6th edition) Boston: Allyn & Bacon.

İymen, E. (2012). *8. Sınıf öğrencilerinin üslü ifadeler ile ilgili sayı duyularının sayı duyusu bileşenleri bakımından incelenmesi.* Unpublished master's thesis.

Johansson, B. S. (2005). Number-word sequence skill and arithmetic performance. *Scandinavian Journal of Psychology, 46,* 157–167.

Jordan, N. C., Levine, S. C., & Huttenlocher, J. (1997). Calculation abilities of young children with different patterns of cognitive functioning. *Journal of Learning Disabilities, 28*, 53-64.

Jordan, N. C., Hanich, L., & Uberti, H. Z. (2003). Mathematical thinking and learning difficulties. In Baroody, A. & Dowker, A. (Eds.), *The Development of Arithmetical Concepts and Skills* (pp. 359-383). Mahwah, NJ:Erlbaum.

Jordan,N. C., Hanich, L.B., & Kaplan,D. (2003a). Arithmetic fact mastery in young children: A longitudinal investigation. *Journal of Experimental Child Psychology, 85,* 103–119.

Jordan,N. C., Hanich, L.B., & Kaplan,D. (2003b). A longitudinal study of mathematical competencies in children with specific mathematics difficulties versus children with comorbid mathematics and reading difficulties. *Child Development, 74,* 834–850.

Jordan, N. C., Kaplan, D., Olah, L., & Locuniak, M. N. (2006). Number sense growth in kindergarten: A longitudinal investigation of children at risk for mathematics difficulties. *Child Development, 77,* 153–175.

Jordan, N. C. (2007). Do words count? Connections between mathematics and reading difficulties. In D. Berch & M. Mazzocco (Eds.), *Why Is Math So Hard for Some Children?* (pp. 107-120). Baltimore, MD: Paul H. Brookes Publishing Co.

Jordan, N. C. (2007). The need for number sense. *Association for Supervision and Curriculum Development,* 63-66.

Jordan, N.C., Kaplan, D., Locuniak, M.N., & Ramineni, C. (2007). Predicting first-grade math achievement from developmental number sense trajectories. *Learning Disabilities Research & Practice, 22*(1), 36-46.

Jordan, N. C. & Levine, S. C. (2009). Socioeconomic variation, number competence, and mathematics learning difficulties in young children. *Developmental Disabilities Research Reviews, 15,* 60-68.

Jordan, N. C., Kaplan, D., Ramineni, C., & Locuniak, M. N. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology, 45,* 850- 867.

Jordan, N.C. (2010). Early predictors of mathematics achievement and mathematics learning difficulties. In Tremblay RE, Barr RG, Peters RDeV, Boivin M, eds. *Encyclopedia on Early Childhood Development* [online]. Montreal, Quebec: Centre of Excellence for Early Childhood Development;1-6. Available at: http://www.child encyclopedia.com/documents/JordanANGxp.pdf

Jordan, N. C., Glutting, J., Ramineni, C., & Watkins, M. W. (2010). Validating a number sense screening tool for use in kindergarten and first grade: Prediction of mathematics proficiency in third grade. *School Psychology Review, 39,* 181-195.

Jordan, N. C., Glutting, J., & Ramineni, C. (2010). The importance of number sense to mathematics achievement in first and third grades. *Learn Individ Differ, 20(2),* 82-88.

Kaufman, E. L., Lord, M. W., Reese, T. W., & Volkmann, J. (1949). The discrimination of visual number. *American Journal of Psychology, 62,* 498–525.

Kavsaoğlu, Z. S. (2003). Öğrenme güçlükleri. *Ankara Üniversitesi Eğitim Bilimleri Fakültesi Dergisi, 26, 2.* doi: 10.1501/Egifak_0000000489

Kayhan Altay, M. (2010). *İlköğretim ikinci kademe öğrencilerinin sayı duyularının; sınıf düzeyine, cinsiyete ve sayı duyusu bileşenlerine göre incelenmesi.* Unpublished doctoral dissertation, Hacettepe University, Ankara.

Kayhan Altay, M. & Umay, A. (2013). İlköğretim İkinci Kademe Öğrencilerine Yönelik Sayı Duyusu Ölçeği' nin Geliştirilmesi. *Eğitim ve Bilim, 38(167).*

Keeler, M. L. & Swanson, H. L. (2001). Does strategy knowledge influence working memory in children with mathematical difficulties?. *Journal of Learning Disabilities, 43(*5), 418-434.

Kingma, J. (1984). Traditional intelligence, Piagetian tasks, and initial arithmetic in kindergarten and primary school grade one. *Journal of Genetic Psychology, 145,* 49-60.

Kingma, J. & Zmbo, B. (1987). Relationship between seriation, transitivity, and explicit ordinal number comprehension. *Perceptual and motor skills, 65,* 559-569.

Klein, J. S. & Bisanz, J. (2000). Preschoolers doing arithmetic: The concepts are willing but the working memory is weak. *Canadian Journal of Experimental Psychology, 54*(2), 105–115.

Knopik, V. S., Alarcon, M., & DeFries, J. C. (1997). Comorbidity of mathematics and reading deficits: Evidence for a genetic etiology. *Behavior Genetics, 27(5),* 447 – 453.

Kobayashi, T., Hiraki, K., Mugitani, R., & Hasegawa, T. (2003). Baby arithmetic: One object plus one tone. *Cognition, 91,* B23-B34.

Koontz, K. L., & Berch, D. B. (1996). Identifying simple numerical stimuli: Processing inefficiencies exhibited arithmetic learning disabled children. *Mathematical Cognition, 2,* 1–23.

Lago, R. M. & DiPerna, J. C. (2010). Number sense in kindergarten: A factor-analytic study of the construct. *School Psychology Review, 39 (2), 164-180.*

Landerl K, Bevan A, Butterworth B. (2004). Developmental dyscalculia and basic numerical capacities: A study of 8–9-year-old students. *Cognition, 93*:99-125.

Le Corre, M., Van de Walle, G., Brannon, E. M., & Carey, S. (2006). Re-visiting the competence/performance debate in the acquisition of the counting principles. *Cognitive Psychology, 52,* 130–169.

Le Fevre, J. A., Smith-Chant, B. L., Fast, L., Skwarchuk, S.L., Sargla, E., Arnup, J. S., et al. (2006). What counts as knowing? The development of conceptual and procedural knowledge of counting from kindergarten through Grade 2. *Journal of Experimental Child Psychology, 93,* 285–303.

Lewis, A. C. (2000). "Playing " with equity and early education. *Phi Delta Kappan, 81,* 563-564.

Lezak, M. D. (1995). *Neuropsychological assessment (3rd ed.).* New York: Oxford University Press.

Lipton, J. S. & Spelke, E. S. (2003). Origins of number sense: Large-number discrimination in human infants. *Psychological Science, 14*(5), 396 – 401.

Locuniak, M. N. & Jordan, N. C. (2008). Using kindergarten number sense to predict calculation fluency in second grade. *Journal of Learning Disabilities, 41 (5),* 451-459.

Malofeeva, E., Day, J., Saco, X., Young, L., & Ciancio, D. (2004). Construction and evaluation of a number sense test with Head Start children. *Journal of Educational Psychology, 96,* 648-659.

Mazzocco MM, Thompson RE. (2005). Kindergarten predictors of math learning disability. *Learning Disabilities Research and Practice*, *20(3):*142-155. 20.

McCloskey, M. (1992). Cognitive mechanisms in numerical processing: Evidence from acquired dyscalculia. *Cognition, 44(1-2*), 107-157.

McCloskey, M., Caramazza, A. & Basilli, A. (1985). Cognitive mechanisms in number processing and calculation: Evidence from dyscalculia. *Brain & Cognition*, *4*(2), 171-196.

McCloskey, M., Sokol, S.M., Goodman, R.A. (1986). Cognitive processes in verbal number production: Inferences from the performance of brain-damaged subjects. *Journal of Experimental Psychology*: *General*, 115, 307-330.

McGonigle,B. O. & Chlamers, M. (1992). Monkeys are rational! *The Quarterly Journal of Experimental Psychology, 45B*, 189-228.

McLean, J. F., & Hitch, G. H. (1999). Working memory impairments in children with specific mathematics learning diffculties. *Journal of Experimental Child Psychology, 74,* 240–260.

Miyake, A., & Shah, P. (1999). Toward unified theories of working memory: Emergin general consensus, unresolved theoretical issues, and future research directions. In A. Miyake & P. Shah (Eds.) *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 442-481) . New York: Cambridge University Press.

Montague, M., & Applegate, B. (1993). Middle school students' mathematical problem solving: An analysis of think-aloud protocols. *Learning Disability Quarterly, 16,* 19-30.

Moyer, R. S. & Landauer, T. K. (1967). Time required for judgements of numerical inequality. *Nature, 215,* 1519-1520.

Mullis, I. V. S., Martin, M. O., Foy, P. & Arora, A. (2011). TIMSS International Results in Mathematics. TIMSS & PIRLS International Study Center, Lynn School of Education, Boston College. Chestnut Hill, MA, USA.

Murphy, M. M., Mazzocco, M. M. M., Hanich, L. B., & Early, M. C. (2007). Cognitive characteristics of children with mathematics learning disability (MLD) vary as a function of the cutoff criterion used to define MLD. *Journal of Learning Disabilities, 40,* 458-478. doi: 10.1177/00222194070400050901

Nan, Y., Knösche, T. R., & Luo, Y.-J. (2006). Counting in everyday life: Discrimination and enumeration. Neuropsychologica, 44, 1103–113.

National Center for Learning Disabilities. (2006). Dyscalculia. LD Online.

National Council of Teachers of Mathematics. (2000). *Principles and standards in mathematics education*. Reston, VA: National Council of Teachers of Mathematics.

National Research Council. (2001). *Adding it up: Helping children learn mathematics.*

National Research Council. (2009). *Mathematics learning in early childhood: Paths toward excellence and equity.* Committee on Early Childhood Mathematics, C. T. Cross, T. Wood, & H. Schweingruber (Eds.). Washington, DC: The National Academies Press.

National Science Board. (2003, August 14). The science and engineering workforce : Realizing Americas' potential. Retrieved from http://www.nsf/gov/nsb/document/2003/nsb0369/

Okamoto, Y., & Case, R. (1996). Exploring the microstructure of children's central conceptual structures in the domain of number. In R. Case & Y. Okamoto (Eds.), *The role of central conceptual structures in the development of children's thought: Monographs of the Society for Research in Child Development* (Vol. 1-2, pp.27-58). Malden, MA: Blackwell.

Ostad, S. (1998). Developmental differences in solving simple arithmetic problems and simple number fact problems: A comparison of mathematically normal and mathematically disabled children. *Mathematical Cognition, 4,* 1-19.

Passolunghi, M. C., Cornoldi, C., & De Liberto, S. (1999). Working memory and inhibition of irrelevant information in poor problem solvers. *Memory & Cognition, 27*, 779–790.

Passolunghi, M. C., & Siegel, L. S. (2001). Short term memory, working memory, and inhibitory control in children with specific arithmetic learning disabilities. *Journal of Experimental Child Psychology, 80*, 44– 57.

Passolunghi, M. C.,Vercelloni, B.,&Schadee, H. (2007). The precursors of mathematics learning:Working memory, phonological ability and numerical competence. *Cognitive Development, 22*, 165–184.

Passolunghi, M. C., Mammarella, I. C., & Altoé, G. (2008). Cognitive abilities as precursors of the early acquisition of mathematical skills during first through second grades. *Developmental Neuropsychology, 33; 3*, 229-250.

Patton, J., Cronon, M., Bassett, D., & Koppel, A. (1997). A life skill approach to mathematics instruction: Preparing students with learning disabilities for the real-life demands of adulthood. *Journal of Learning Disabilities, 36,* 178-187.

Piaget, J. & Szeminska, A. (1941). La genése du nombre chez l'enfant [The development of numbers in children]. Neuchatel, France: Delanchaux et Niestlé.

Piaget, J. & Szeminska, A. (1952). *The child's conception of number.* New York: Humanities Press.

Piaget, J. (1965). *The child's conception of number*. New York: Norton.

PISA 2009 Ulusal Ön Rapor [National Preliminary Report], 2010.

Powell, S. R., Fuchs, L. S., Fuchs, D., Cirino, P. T., & Fletcher, J. M. (2009). Effects of facts retrieval tutoring on third grade students with math difficulties with and without reading difficulties. *Learning Disabilities Research and Practice, 24,* 1-11. doi: 10.1111/j.1540-5826.2008.01272.x

The Psychological Corporation. (2002a). *Early math diagnostic assessment.* San Antonio, TX: Author.

Rourke, B. P., & Conway, J. (1997). Disabilities of arithmetic and mathematical reasoning : Perspectives from neurology and neuropsychology. *Journal of Learning Disabilities,* 30; 1, 34-46.

Rousselle, L., & Noël, M. P. (2007). Basic numeric skills in children with mathematics learning disabilities: A comparison of symbolic vs. non-symbolic number magnitude processing. *Cognition, 102,* 361–395.

Rubenstein, R. N. (1985). Computational estimation and related mathematical skills. Journal for Research in Mathematics Education, 16, 106 – 119.

Schoenfeld, A. H. (1995, May). Report of Working Group 1. In C. B. Lacampagne, W. Blair, & J. Kaput (Eds.), *The algebra initiative colloquium*: Vol. 2. Papers presented at a conference on reform of algebra, December 9-12, 1993 (pp. 11-18). Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement, National Institute on Student Achievement, Curriculum, and Assessment. Retrieved from http://www.eric.ed.gov/PDFS/ED385437.pdf

Schofield, N. J. & Ashman, A. F. (1986). The relationship between digit span and cognitive processing across ability groups. *Intelligence, 10 (1),* 59-73.

Seethaler, P. M. & Fuchs, L. S. (2010). The predictive utility of kindergarten screening for math difficulty. *Exceptional Children, 77 (1),* 37-59.

Siegel, L. S., Lees, A., Allan, L., & Bolton, B. (1981). Non-verbal assessment of Piagetian concepts in preschool children with impaired language development, *Educational Psychology, 1,* 153-158.

Siegler, R. S. & Shrager, J. (1984). Strategy choices in addition and subtraction: How do children know what to do? In C. Sophian (Ed.), Origins of cognitive skills (229-293). Hillsdale, NJ: Erlbaum.

Siegel, L. S. (1989). IQ is irrelevant to the definition of learning disabilities. *Journal of Learning Disabilities, 22,* 469 – 478.

Siegel, L. S., & Ryan, E. B. (1989). The development of working memory in normally achieving and subtypes of learning disabled children. *Child Development, 60,* 973–980.

Siegler, R. S. & Booth, J. L. (2004). Development of numerical estimation in young children. *Child Development, 75(2),* 428-444.

Siegler, R. S. (2009). Improving the numerical understanding of children from low-income families. *Child Development Perspectives*, *3,* 118-129.

Sophian, C. (1992). Learning about numbers: Lessons for mathematics education from preschool number development. In J. Bideaud, C. Meljac, & J.-P. Fischer (Eds.), *Pathways to number: Children's developing numerical abilities* (pp. 19–40). Hillsdale, NJ: Lawrence Erlbaum.

Sousa, D. (2008). *How the Brain Learns Mathematics*. Corwin Press, CA.

Starkey, P. & Cooper, R. G. (1980). Perception of numbers by human infants. *Science, 210,* 1033-1035.

Sutton, J. & Krueger, A. (Eds.). (2002). *EDThoughts: What we know about mathematics teaching and learning.* Aurora, CO: Mid-continent Research for Education and Learning.

Swanson, H. L. (1993). Working memory in learning disability subgroups. *Journal of Experimental Child Psychology, 56*, 87–114.

Swanson, H. L., & Sachse-Lee, C. (2001). Mathematical problem solving and working memory in children with learning disabilities: Both executive and phonological processes are important. *Journal of Experimental Child Psychology, 79*, 299–321.

Şengül, S. & Gürel, Z. (2003). Evaluation of students' number sense. Paper presented at SEMPT 03. Department of mathematics and mathematical education, Faculty of Education, Charles University, Czech.

Şengül, S. & Gülbağcı, H. (2012). Evaluation of Number Sense on the Subject of Decimal Numbers of the Secondary Stage Students in Turkey. *International Online Journal of Educational Sciences, 4 (2),* 296-310.

Şengül, S. & Gülbağcı, H. (2012). An investigation of 5th grade Turkish students' performance in number sense on the topic of decimal numbers. *Procedia-Social and Behavioral Sciences, 46*, 2289-2293.

Şengül, S., Gülbağcı, H., & Cantimer, G. G. (2012). 6.sınıf öğrencilerinin yüzde kavramı ile ilgili sayı hissi stratejilerinin incelenmesi. *The Journal of Academic and Social Science Studies, 5(8),* 1055-1070.

Şengül, S. & Gülbağcı, H. (2013). 7. ve 8.sınıf öğrencilerinin sayı hiss ile matematik öz yeterlikleri arasındaki ilişkinin incelenmesi. *The Journal of Academic and Social Science Studies, 6(4),* 1049-1060.

Threfall, J. & Frobisher, L. (1999). Patterns in processing and learning addition facts. In A.Orton (Ed.), Pattern in the teaching and learning of mathematics (pp. 39 – 46). London : Cassell.

Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (1999). Test of Word Reading Efficiency. Austin, TX: PRO-ED.

Tuohimaa, P. M. V., Aunola, K., & Nurmi, J. E. (2008). The association between mathematical word problems and reading comprehension. *Educational Psychology, 28 (4),* 409-426.

Umay, A. (2001). İlköğretim matematik öğretmenliği programının matematiğe karşı öz - yeterlik algısına etkisi. *Journal of Qafqaz University, 8.*

U.S. Department of Education. (2000). Twenty-second annual report to Congress on the implementation of the Individals with Disabilities Education Act. Washington DC : Government Printing Office.

Waber, D., Forbes, P., Wolff, P., & Weiler, M., (2004). Learning impairments classified according to the double-deficit hypothesis. *Journal of Learning Disabilities, 37,* 451-461.

Wolf, M. & Denckla, M. B. (2005). *The Rapid Automatized Naming and Rapid Alternating Stimulus Tests.* Austin, TX: PRO-ED.

Woodcock, R. M., & Johnson, M. B. (1989). Woodcock- Johnson Psycho-Educational Battery–Revised. Allen, TX: DLM Teaching Resources.

Wynn, K. (1992). Addition and subtraction by human infants. *Nature, 358,* 749-750.

Xu, F. & Spelke, E. S. (2000). Large number discrimination in 6-month-old infants. *Science,7,* 164-169.

Vaidya, S. R. (2004). Understanding dyscalculia for teaching. *Education,* 124, 4, pg. 717

Van de Rijt, B. A. M., & Van Luit, J. E. H. (1999). Milestones in the development of infant numeracy. *Scandinavian Journal of Psychology, 40,* 65–71.

VanDerHeyden, A. M., Broussard, C., Snyder, P., George, J., Lafleur, S. M., & Williams, C. (2011). Measurement of Kindergartners' Understanding of Early Mathematical Concepts. *School Psychology Review, 40, 2,* 296-306. *School Psychology Review, 30,* 363-382.

Van De Walle, J. (1990). *Elementary school mathematics: Teaching developmentally.* White Plains, NY: Longman.

Van Luit, J. E. H. (2000). Improving early numeracy of young children with special education needs. *Remedial and Special Education, 21,* 27-41.

Vaughn, S., & Fuchs, L. S. (2003). Redefining learning disabilites as inadeaquate response to instruction: The promise and potential problems. *Learning Disabilites Research & Practice, 18,* 137-146.

Vukovic, R. K., & Siegel, L. S. (2010). Academic and cognitive characteristics of persistent mathematics difficulties from first through fourth grade. *Learning Disabilities Research and Practice, 25,* 25-38. doi: 10.1111/j.1540-5826.2009.00298.x

Zhou, X., Chen, C., Chen, C., & Dong, Q. (2008). Holistic or compositional representation of two-digit numbers? Evidence from distance, magnitude, and SNARC-effects in a number - matching task. *Cognition, 106,* 1525–1536.

Zientek, L. R., Ozel, Z. E. Y., Ozel, S., & Allen, J. (2012). Reporting confidence intervals and effect sizes: Collecting the evidence. *Career and Technical Education Research, 37 (3),* 277-295.