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Research / Araştırma

Using Basic Number Processing Tasks in Determining Students with Mathematics Disorder Risk

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ABSTRACT

Using basic number processing tasks in determining students with mathematics disorder risk

Objective: This study investigated whether it was possible to determine the risk of having mathematics disorder with a simple screening tool containing four types of basic number processing tasks.

Method: Mathematics Achievement Tests (MAT) and Basic Number Processing Tests (BNPT) were administered to a total of 487 students from first through fourth grade of 12 different elementary schools in Ankara, Turkey. Students with a general learning disorder, mainstreamed students, and students with diagnosis of attention deficit were excluded from the study. Random dot enumeration, canonic dot enumeration, symbolic number comparison and mental number line estimation tasks were used in Basic Number Processing Tests. Based on Mathematics Achievement Test scores, students were grouped into mathematics disorder risk, low achievement, and typical achievement. Students' Basic Number Processing Tests scores were analyzed one by one in comparison to grade level averages.

Results: Based on these comparisons we found that in all four grade levels, students with mathematics disorder risk got scores lower than grade level mean at least in one Basic Number Processing Test.

Conclusion: These results showed that the developed screening tool has a potential in effectively determining students with mathematics disorder risks. The tool might also be helpful in early diagnosis and intervention of students with mathematics disorder risk.

Key words: Dot enumeration, low math achievement, mathematics disorder, number line estimation, numeric comparison

ÖZET

Temel sayı işleme görevleri kullanılarak matematik bozukluğu riskli öğrencilerin belirlenmesi

Amaç: Bu çalışmada, sayı işleme ile ilgili dört çeşit görev içeren basit bir tarama aracı yardımıyla, matematik bozukluğu riskli öğrencilerin belirlenip belirlenemeyeceği araştırılmıştır.

Yöntem: Çalışmada, Türkiye'nin Ankara ilinde bulunan 12 farklı ilkokuldan 1-4. sınıf düzeyindeki 487 öğrenciye Matematik Başarı Testi ve Temel Sayı İşleme Testleri uygulanmıştır. Genel öğrenme bozukluğu, kaynaştırma öğrencisi ve dikkat eksikliği tanısı olanlar çalışmadan dışlanmıştır. Temel Sayı İşleme Testlerinde; rastgele dizilmiş noktaları sayılama, domino dizilmiş noktaları sayılama, sembolik sayı karşılaştırma ve zihinsel sayı doğrusunda tahmin görevleri kullanılmıştır. Öğrenciler; Matematik Başarı Testi puanlarına göre matematik bozukluğu riskli, düşük başarılı ve normal başarılı olmak üzere gruplara ayrılmışlardır. Bu gruplarda bulunan öğrencilerin Temel Sayı İşleme Testi puanları ayrı ayrı sınıf ortalamaları ile karşılaştırılarak incelenmiştir.

Bulgular: Temel Sayı İşleme Testlerinde sınıf ortalamalarına göre yapılan karşılaştırmalarda, dört sınıf düzeyinde de matematik bozukluğu riskli oldukları varsayılan öğrencilerin, en az bir görev türünde ortalamanın altında oldukları bulunmuştur.

Sonuç: Bulgular, geliştirilen tarama aracının, matematik bozukluğu riskli olan öğrencileri ayırt etmede etkili olabileceğini göstermektedir. Çalışmanın, matematik bozukluğu riskli öğrencilere erken teşhis ve müdahalede bulunabilmek için yararlı olacağı düşünülmektedir.

Anahtar kelimeler: Nokta sayılama, düşük matematik başarısı, matematik bozukluğu, sayı doğrusunda tahmin, sayısal karşılaştırma

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INTRODUCTION

Mathematics disorder (MD), also known as "learning disorder specific to mathematics", "arithmetic disorder", "specific mathematics disorder", "number fact disorder", "developmental dyscalculia", causes students to have difficulties in gaining counting and calculation skills, remembering number facts and arithmetic procedures (1) and thereby lagging behind their peers in mathematics classes (2). Students with mathematics disorder also have difficulty in such basic number processing tasks as "enumerating dots" and "perceiving magnitudes from symbolic numbers" (3). This study was inspired by the idea that mathematics disorder, which causes students to have difficulty in numerical operations, can be screened by using the types of simple basic number processing (BNP) tasks that students also have difficulty with.

While in some studies (4) the prevalence of MD in normal population was reported as ranging from 3% to 6.5%, others (5) claimed that it figures between 5%-14% depending on the formulae or criteria used. There are several hypotheses about the epidemiology of MD. One hypothesis claims that it is caused by a core deficit in the region of the brain relevant to number processing. According to the proponents of this hypothesis, specifically, a malfunction in the horizontal segments of the intraparietal sulcus (6) or in the number module (3) causes individuals to have MD.

It is claimed that there is a core number system in the brain which consists of two relevant subsytems called approximate number system (ANS) and exact number system (ENS) (7). The ANS deals the numbers, usually larger than five, in an approximate fashion. This system is also associated with symbolic representations of numbers in counting and calculations. While the numbers are getting larger, representing numbers as approximate magnitudes becomes important especially for small children. In the second system called ENS, on the other hand, numbers are represented as exact numerical magnitudes. For example, the task of quickly and exactly determining the number of dots in a small set (usually <5) without counting, also known as subitizing, is carried out by the ENS.

Another hypothesis about why students have MD is the access deficit hypothesis. It is claimed that the major reason behind MD is not deficits in ANS or ENS but rather in accessing magnitudes from symbols or vice versa (8). According to this position, the difficulty in learning mathematics arises from perceiving numerical magnitudes from symbols or representing magnitudes with symbols.

Students' difficulties in counting, numerical comparisons, and numberline estimations are usually explained in core deficit hypothesis (9-10). Difficulties in symbol use on the other hand are associated with access deficit hypothesis (11). Keeping in mind the fact that MD can be caused by some deficits in basic numerical competencies, in recent years, simple basic numerical tasks are used in screening MD. Some of these tasks are dot counting, symbolic number comparisons (numerical Stroop), analog quantity comparisons, and estimating the relative magnitudes of numbers (3,12-14). It is expected that students with MD risk (MDR) will have difficulty in one or more of these tasks. In this study, dot counting, symbolic number comparisons, and mental number line estimations were used to determine the students with MDR.

Dot counting: In dot enumeration tasks, which are aimed at measuring the numerical learning capacity, subjects are required to rapidly and accurately determine the number of dots presented, usually less than 10 dots (15). Human brain can determine one to three or four dots at a glance without counting (12). Also called as subitizing, this process is claimed to be different in normally achieving children and children with MD (16). Since quickly and accurately determining the number of one to four dots is realized in ENS (7), a disorder in subitizing mechanism is associated with core deficit hypothesis (9).

When the number of dots exceeds 4, some other processes such as groupings or conceptual subitizing and operations on them are involved. So being able to subitize is getting more and more important. Since subitizing is relaized through parallel processing it takes shorter to enumerate a set than determining it via counting, which is realized through serial processing (17). For this reason, it could be said that it is the latency to be taken into consideration when determining the tendency to MD.

The arrangement of dots is also important in dot enumeration tasks. Canonically arranged dots such as two dots side by side, three dots making a triangular shape, and four dots with square arrangement are easy to recognize and that makes both the counting and subitizing more accurate and faster (18). The fact that the students determine the number of canonically arranged dots faster than the dots randomly arranged both in subitizing range (one to four dots) and counting range (six to nine dots) (18) shows that canonically arranging dots has an effect on accelerating numerical processes. The fact that students with MD spend longer time in subitizing tasks (16) made us think that they are going to spend longer time for determining the number of dots arranged either canonically or randomly.

Symbolic number comparison: It seems that representing a quantity with one or several symbols is one of the requisites for progressing in mathematics. Nieder and Dehaene (19) claimed that representing numbers and relations with symbols was unique to human species and this ability made humans make progress in their mathematical thought and technological advances further. Representing a quantity with numerals requires thinking with symbols. Using objects of visuals to represent a quantity requires one to one correspondence while representing a quantity with symbols requires one to many correspondence. Therefore, symbolic representations are more abstract than analog representations. It is also possible that the variability in time elapsed during the recognition of quantity from the symbols is critical for learning further aritmetic skills (20). For this reason, comparing the two numbers represented symbolically seems to be a suitable task for screening arithmetic learning difficulties (21).

Students might be distructed by the physical size of the numerals during the comparisons. Because of the effect of "physical size-numerical size" also known as the size congruity effect, students are faster in comparing 2 and 9 if the numeral 9 is also physically larger than when the numeral 2 is physically larger. In other words, if the numerical and physical size are congruent then the comparison is much faster than when they are incongruent (22). Incongruent (numerically smaller is physically larger), neutral (only numerical sizes are different, physical sizes are the same), and congruent (numerically larger number is also physically larger) situations are used in comparison tasks for measuring size-congruity effect (23) in children with different mathematical abilities (24). Since the difficulties in symbolic number comparison tasks are related to symbol-quantity connections they are associated with access deficit hypothesis (11).

Mental Number Line Estimations: Number line is one of the tool in measuring the ability to estimate the relative magnitude of numbers. Number line is also a critical tool for teaching and learning mathematics (25). Estimating the relative magnitude of numbers on a number line is a task that enables us to assess and examine how children represent numerical magnitudes. In this task, subjects are required to estimate a relative place of a number on a numberline of which the starting and end point of the line are denoted with relevant numbers, such as zero at the beginning and 10 at the end (26). In other words, a numerical quantity is represented as an analog mental magnitude on a scaled line. Generally, for students at preschool up to second grade 0-100 numberline, second grade up to sixth grade 0-1000 numberline are used (26).

Mental number line estimation skills, which are thought to improve through education, follow a delayed developmental trend in children with MD. While the estimations of students with MD at the first grade are far more errenous that that of normally achieving students, at the second grade students with MD had very little improvement, low math achievers on the other hand had cought up with normal achievers (27). This finding indicates that there are initial differences in mental numberline estimations of students with MD and others at the first grade and this gap is getting larger over time. Since representing relative magnitudes of numbers is related to number sense or ANS, difficulties in mental number line estimations are associated with core deficit hypothesis (7).

Available evidences (13,16) indicate that there are individual differences between normally achieving students and students with MD measured by basic number capacity tasks. Research shows that it is very important to determine the MD risk as early as possible. There is also a need for further understanding the root causes of MD. To our knowledge, there is neither a tool for widely screening MD risk for school children nor such research in Turkey. In this research, primary school students were administered a curriculum based Mathematics Achievement Test (MAT) and basic number processing tests (BNPT). Students who had very low scores in the achievement tests were determined and labelled as MD risk group. Then, these students' BNPT scores are compared with the age appropriate mean scores in these tests in an attempt to determine MD risk through BNPT scores.

METHOD

The research being reported here was conducted in an ethical and responsible manner and comply with all relevant legislation. Participants were chosen from 12 public schools located in three SES segments of a large metropolitan, mid Anatolian city in Turkey. Classes from each grade level of each school were randomly selected. We planned to reach 126 students from each grade level. Due to unattandence, some students were dropped from the sample. Data were collected from 487 students. The distribution to the grades was 125, 126, 124, and 112 students for grade 1, 2, 3, and 4 respectively. Another 6 students were also dropped from the data because of the excluding criteria such as diagnosed ADHD, mainstreamed or general learning disorder. The final sample was 481 students, 125, 126, 121, and 109 for grade 1, 2, 3, and 4 respectively.

Data were collected by 5 trained research assistants in March, April, and May of 2013. It lasted approximatly two and a half months. The data collection tools used in this study were described in detail below.

Measures

Mathematics Achievement Test (MAT): The Mathematics Achievement Test was previously developed by Fidan and Olkun (28). The test was based on the number domain of the current Turkish State Curriculum (29). There were four achievement tests for four grade levels. The number of items in each test was 13, 15, 16, and 24 items for the first, second, third, and fourth grade respectively. All the questions in the tests were open-ended, short answer form. The reliability coefficients were reported as 0.80, 0.92, 0.93, and 0.96 for the 1^{st}, 2^{nd}, 3^{rd}, and 4^{th} grade respectively. The math achievement test is an untimed test. The administration usually takes one class hour (approximately 40 minutes).

Mathematics Disorder Screening Tool: After the administration of MAT, the students were administered BNP Tests. During the administration, the students were placed in a quite room in their regular schools. The tests were administered individually in two sessions arranged one day apart. The BNPT consisted of four subtests; canonic dot counting (CDC), random dot counting (RDC), symbolic number comparison (SNC), and mental number line (MNL) tests. All the tests were developed in an Android environment for tablet PCs. Both students responses and latencies were recorded as real time data points for every questions during the administration.

Canonic (CDC) and Random Dot Counting (RDC) Tests: We used both random and canonically arranged dot counting tasks because we expected that MD students might use more inferior strategies than normally achieving students both of the dot counting tasks. Normally achieving students on the other hand might use, at least in canonically arranged tasks, more sophisticated strategies. This in turn might lead to latency or efficiency differences between MD and normally achieving students. Each of the CDC and RDC tests contained 14 similar tasks. Only the arrangement of dots was different. The number of dots varied from 3 to 9. The students were expected to touch the corresponding numeral placed at the bottom of the touch screen from 0 to 9.

Symbolic Number Comparison (SNC) Test: In this test there were 24 questions. The task is to decide which of the two numbers is more and to touch the more numerous one. The numbers shown were varied in terms of both physical and numerical size however students were asked only to choose the numerically larger one. The numbers to be compared were arranged in three form; consistent (2 and 5, five is also physically larger), neutral (2 and five both in the same physical size), and inconsistent (2 and 5, 2 is physically larger) so that students with different mathematical abilities could be discriminated based on accuracy or efficiency.

Mental Number Line (MNL) Test: In this test, 0-10, 0-20, 0-100, and 0-1000 number lines were used. For the first and second graders, only the first three numberlines were used since they were not expected to count up to 1000 yet. The empty numberlines were denoted zero (0) at the left end and 10-20-100- or 1000 at the right end. Students were expected to place the number shown on the screen to the number line according to its relative magnitude. The number to be estimated and number lines were shown on a touch screen tablet PC. When the numberline was touched a blue vertical line appeared on it. It can be movable in both directions. When the student decided the place of the number he/she took his/her finger off the line and touched the OK button. Previous research (30) showed that the latency was not important in these types of tasks. So we did not record the time.

Before the administration of the BNP Tests, students were habituated with moving objects on the touch screen of a tablet PC with similar movement but on non numerical tasks. Additionally, at the beginning of each test there were 2 or 3 sample items answered at the time of view to show how the items in each test should be answered. With these measures, we tried to remove the irrelevant effects for students to answer the questions.

Statistical Analysis

Outliers were removed before the analysis. Outliers were determined based on each individual's average time for each test separately. Then, based on Math Achievement Test, administered for each grade level, students were divided into three groups as mathematics disorder risk (MDR), low achievers (LA), and normal achievers (NA). In each grade level, the lower 10% was assigned to MDR, 11-25% to LA, and 26% and up to NA. Additionally, the students at the cutoff points were assigned to the group where majority of these students belong to.

For the CDC, RDC, and SNC tests the Inverse Efficiency Scores (IES) were calculated. This score is suggested to be used where the percentage of correct answers were high and there was a correlation between the latency and accuracy (31). IES is calculated by dividing the total time to answer the items to the percentage of correct answers. For the MNL tests, the total of absolute errors (TAE) were calculated. Both IES and TAE scores are expected to be inversly proportional to MAT.

In order to see whether the newly developed tests (CDC, RDC, SNC, and MNL) can discriminate MDR students from the other groups both IES and TAE scores were converted into t distribution. So that, different test results can be compared in one graph.

RESULTS

The lowest 10% of the students based on MAT scores, revealed that 20 students from the first grade, 13 from the second, 15 from the third, and 11 from the fourth grade consisted of the MDR groups. The converted scores of these students were examined in graphs. So that, MDR students' BNPT scores were compared to the average scores of each cohort group.

Results of first graders categorized as MDR: The BNPT scores of the 20 students who were assumed to be MDR based on their MAT scores are presented in Table 1. Of the 20 students, 7 students (S1-S7) got scores above the class average in all of the 4 BNP Tests. Two students (S8 and S9) got scores above the class average in three tests (CDC, RDC, and MNL). Again, two students (S10 and S11) got scores above the class average in three tests (RDC, SNC, and MNL). Three students (S12-S14) got above average scores in CDC, SNC, and MNL tests, while another 3 students got above average scores in SNC and MNL tests, and still another 2 students (S18 and S19) got above average scores in MNL test. Only one student (S20) got below average scores in all of the 4 BNP tests. In other words, 12 students in CDC, 11 in RDC, 15 in SNC got above average scores. Of the 20 students, 19 got above average scores in MNL tests.

Table 1: Comparison of the scores of first grade students who are assumed to be MDR to the class average

TESTS	STUDENTS																				TOTAL
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	
CDC	x	x	x	x	x	x	x	x	x	-	-	x	x	x	-	-	-	-	-	-	12
RDC	x	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	11
SNC	x	x	x	x	x	x	x	-	-	x	x	x	x	x	x	x	x	-	-	-	15
MNL	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	19

(MDR: Mathematics Disorder Risk, CDC: Canonic Dot Counting, RDC: Random Dot Counting, SNC: Symbolic Number Comparison, MNL: Mental Number Line, S: Student, above average scores were denoted with "x", and below average with "-")

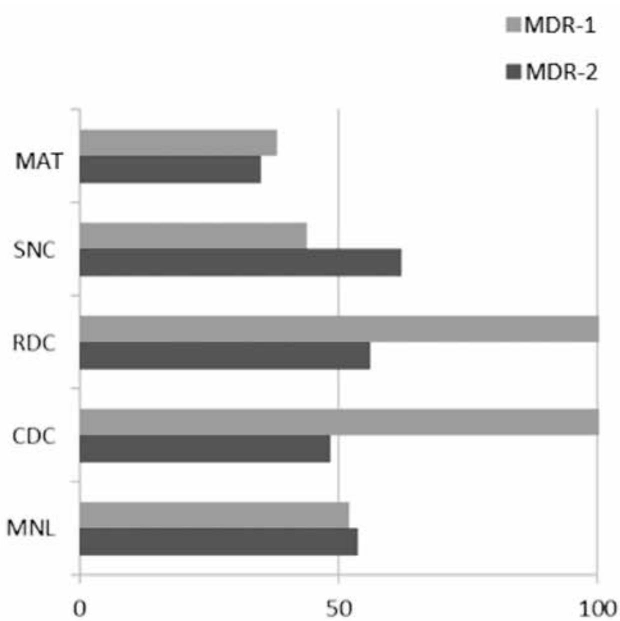

Figure 1: Comparison of BNPT scores of two first graders who are assumed to be MDR

(MAT: Mathematics Achievement Test, SNC: Symbolic Number Comparison, RDC: Random Dot Counting, CDC: Canonic Dot Counting, MNL: Mental Number Line, MDR: Mathematics Disorder Risk)

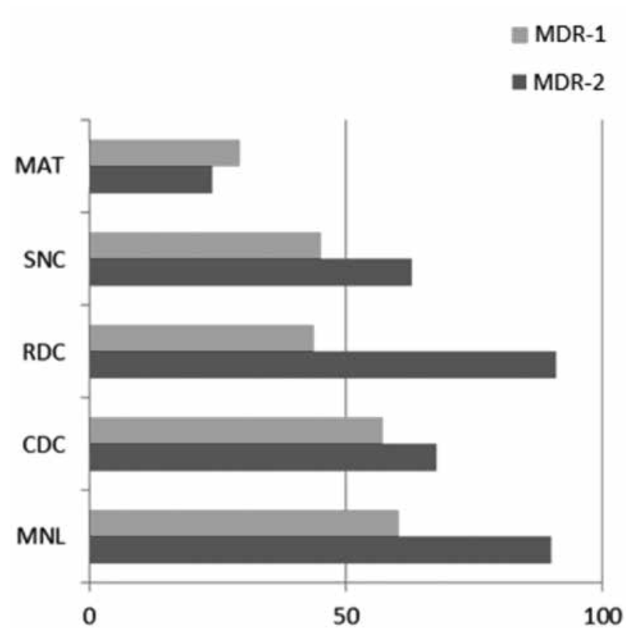

Figure 2: Comparison of BNPT scores of two second graders who are assumed to be MDR

(MAT: Mathematics Achievement Test, SNC: Symbolic Number Comparison, RDC: Random Dot Counting, CDC: Canonic Dot Counting, MNL: Mental Number Line, MDR: Mathematics Disorder Risk)

In Figure 1, BNPT scores of the 2 students from the MDR group are depicted in a graph (Figure 1). In the graph, it is shown that the first student (MDR-1) spent longer time than the average to respond CDC and RDC tests. The same student got higher than the average score in MNL test too but received below average score in SNC test only. The second student (MDR-2) on the other hand, received above average scores in SNC and RDC tests, but below average in CDC test. This student also got above average score in MNL test. At the first grade level, 19 out of the 20 students who are in MDR group got above average scores in at least one or more of the BNP tests.

Results of second graders categorized as MDR: There were 13 students in this group. As depicted in Table 2, 8 of these 13 students (S1-S8) got above average scores in all of the BNP tests, 3 students (S9-S11) in three tests (CDC, RDC, and SNC), the remaining 2 students (S12 and S13) in two tests (CDC and MNL). In other words, all 13 students assumed to be MD in the second grade, received above the class average in CDC test. Eleven of them got above average scores in RDC and SNC, and 10 students got above average scores in MNL test.

In Figure 2, BNPT scores of the 2 students from the MDR group are depicted in a graph (Figure 2). In the graph, it is shown that the first student (MDR-1) spent

Table 2: Comparison of the scores of second grade students who are assumed to be MDR to the class average

TESTS	STUDENTS													TOTAL
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	
CDC	x	x	x	x	x	x	x	x	x	x	x	x	x	13
RDC	x	x	x	x	x	x	x	x	x	x	x	-	-	11
SNC	x	x	x	x	x	x	x	x	x	x	x	-	-	11
MNL	x	x	x	x	x	x	x	x	-	-	-	x	x	10

(MDR: Mathematics Disorder Risk, CDC: Canonic Dot Counting, RDC: Random Dot Counting, SNC: Symbolic Number Comparison, MNL: Mental Number Line, S: Student, above average scores were denoted with "x", and below average with "-")

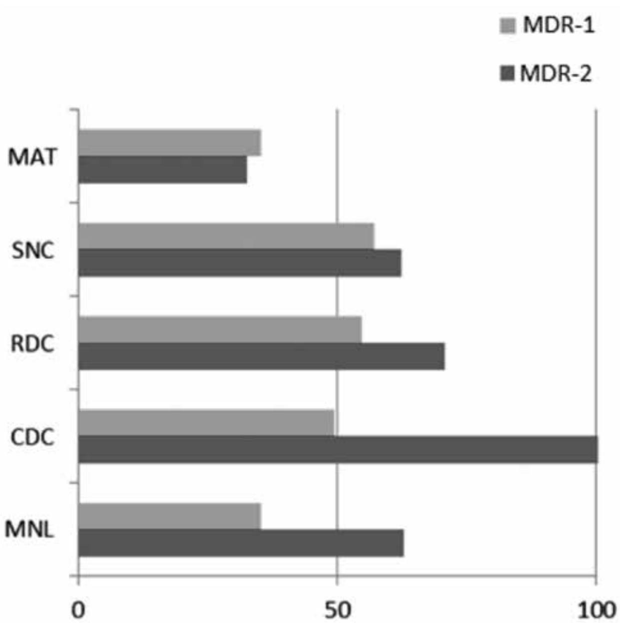

Figure 3: Comparison of BNPT scores of two third graders who are assumed to be MDR

(MAT: Mathematics Achievement Test, SNC: Symbolic Number Comparison, RDC: Random Dot Counting, CDC: Canonic Dot Counting, MNL: Mental Number Line, MDR: Mathematics Disorder Risk)

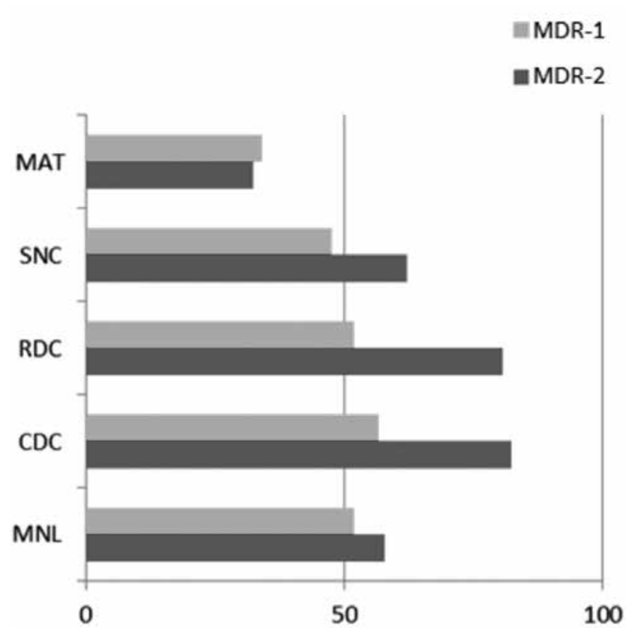

Figure 4: Comparison of BNPT scores of two fourth graders who are assumed to be MDR

(MAT: Mathematics Achievement Test, SNC: Symbolic Number Comparison, RDC: Random Dot Counting, CDC: Canonic Dot Counting, MNL: Mental Number Line, MDR: Mathematics Disorder Risk)

longer time than the average to respond CDC and MNL tests. The same student received below average score in SNC and RDC tests. That means, this student did better than class average in these two tests. The second student (MDR-2) on the other hand, received above average scores in all 4 BNP tests. In fact, it could be said that this student got very high RDC and MNL scores. At the second grade level, all of the students who are in MDR group got above average scores in at least two or more of the BNP tests.

Results of third graders categorized as MDR: There were 15 students at the third grade level who were initially categorized as MDR. As shown in Table 3, 7 out of 15 students (S1-S7) got above average scores in 4 of the BNP tests (Table 3). Two students (S8 and S9) in three tests (CDC, SNC, and MNL), one student (S10) in three tests (CDC, RDC, and SNC), two students (S11 and S12) in two tests (RDC and SNC), one student (S13) in MNL test only, got higher scores than class averages. The remaining 2 students (S14 and S15) got below average scores in all the 4 BNP tests. That means, these 2 students did better in BNP tests but worse on MAT. To put in another way, there were 10 students who got above average scores in CDC, RDC, and MNL tests, and 12 students in SNC test.

Table 3: Comparison of the scores of third grade students who are assumed to be MDR to the class average

TESTS	STUDENTS															TOTAL
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	
CDC	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	10
RDC	x	x	x	x	x	x	x	-	-	x	x	x	-	-	-	10
SNC	x	x	x	x	x	x	x	x	x	x	x	x	-	-	-	12
MNL	x	x	x	x	x	x	x	x	x	-	-	-	x	-	-	10

(MDR: Mathematics Disorder Risk, CDC: Canonic Dot Counting, RDC: Random Dot Counting, SNC: Symbolic Number Comparison, MNL: Mental Number Line, S: Student, above average scores were denoted with "x", and below average with "-")

Table 4: Comparison of the scores of fourth grade students who are assumed to be MDR to the class average

TESTS	STUDENTS											TOTAL
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	
CDC	x	x	x	x	x	x	x	x	x	-	-	9
RDC	x	x	x	x	x	x	x	x	-	-	-	8
SNC	x	x	x	x	x	x	x	-	-	-	-	7
MNL	x	x	x	x	x	x	x	x	x	x	x	11

(MDR: Mathematics Disorder Risk, CDC: Canonic Dot Counting, RDC: Random Dot Counting, SNC: Symbolic Number Comparison, MNL: Mental Number Line, S: Student, above average scores were denoted with "x", and below average with "-")

In Figure 3, BNPT scores of the 2 third grade students from the MDR group are depicted in a graph (Figure 3). In the graph, it is shown that the first student (MDR-1) spent longer time than the average to respond SNC and RDC tests but got below average scores in other tests. The second student (MDR-2) on the other hand, received above average scores in all 4 BNP tests. In fact, it could be said that this student got very high score in CDC test. When all students' graphs were examined, it was seen that at the third grade level, 13 out of 15 students who are in MDR group got above average scores in at least one of the BNP tests.

Results of fourth graders categorized as MDR: There were 11 students at the fourth grade level who were categorized as MDR. As shown in Table 4, 7 out of 11 students (S1-S7) got above average scores in all of the BNP tests. One student (S8) in CDC, RDC, and MNL tests, one student (S9) in CDC and MNL tests, two students (S10 and S11) in MNL test got above average scores. In this grade level, all the students who are assumed to be MDR got above average in MNL test. Nine of them in CDC, 8 of them in RDC and 7 of them in SNC test recevied above average scores.

In Figure 4, BNPT scores of the 2 fourth grade students from the MDR group are depicted in a graph (Figure 4). In the graph, it is shown that the first student (MDR-1) got above average scores in CDC, RDC, and MNL tests but got below average scores in SNC test. The second student (MDR-2) on the other hand, received above average scores in all 4 BNP tests. When all students' graphs were examined, it was seen that at the fourth grade level, all students who are in MDR group got above average scores in at least one or more of the BNP tests.

The finding that 7 out of 20 students at the first grade, 8 out of 13 students in the second grade, 7 out of 15 students at the third grade, and 7 out of 11 students at the fourth grade who are classified as MDR got above average scores in all of the BNP tests show that majority of the screened students had difficulty in all of the tasks specifically designed for screening MD tendency. In other words, these students spent longer time for answering CDC, RDC, and SNC tests than the average of their classmates. They also made more errors on MNL tasks than the average of their age cohorts. In addition, all of the students at the second and fourth grade, and 19 out of 20 students (%95) at the first grade, and 13 out of 15 students (%87) at the third grade who were screened as MDR got above average scores in at least one of the 4 BNP tests.

DISCUSSION

The results of this study showed that the developed screening tool could be effectively used in determining the students with MD risk. The finding that majority of the students who were classified as MDR got higher scores than the average of their clasmates in CDC, RDC, SNC, and MNL tests indicates that these tests have discriminative properties for MDR.

Using dot counting paradigms, CDC and RDC tests were designed based on exact number system (ENS) in the core systems of human cognition. The fact that MDR students spent longer time in responding these tasks could mean that their number module has some defect or develomental disorders (32) and seem to support the core deficit hypothesis (9). The finding that these students got more than average scores in both CDC and RDC tasks could mean that their subitizing mechanisms might have some sort of disorder (9).

The finding that some students had difficulties and spent longer time to answer the questions in SNC test could mean that they had some sort of disorders that could be explained with access deficit hypothesis (ADH) (11).

The finding that many of the MDR students made more errors than their age cohorts in estimating the relative magnitudes of numbers on the number line (MNL) also lend support to the core deficit hypotesis (33). This time however their approximate number system (ANS) rather than the ENS has some sort of disorder. Majority of the students who are assumed to be MDR made larger errors in MNL tasks, which is thought to be improved through education (13,27). This finding shows that MNL task could be used in discriminating MDR students from their normal peers.

The finding that not all the students who are categorized as MDR had difficulties in all of the BNP tests deserves more attention. It is important for three reasons: 1) MDR students may not have difficulty in all of the tasks designed for screening MD, 2) Different types of tasks should be used in screening MD, 3) there might be still other reasons for having MD.

In this research the criterion for categorizing students as MDR was loose and just based on the MAT. The only cirterion for the exclusion was having a general learning disorder, mainstreeming, or a diagnosed ADHD. Therefore, some students who were placed in MDR might have been in LA or vice versa. In fact, some students did not have any difficulty in BNP tests but still were in MDR group. A fine grained grouping may reveal better results. In addition, different cut off points may also reveal somewhat different results. Still however, the finding that the majority of the students who are categorized as MDR had difficulty in BNP tests indicates that these tasks can reliably be used as early screening as well as diagnosis and intervention.

Even there were few, some students got normal scores in BNP tests but still had below average math scores. This could mean two different things: first, their math scores could have been measured wrong. Second, there might be still other tasks to be included in the screening tool. For example, the task of comparing analog quantities (34), both small and large quantities, ordering numbers (35), and transcoding tasks could be included in the screening tool. Further research can include the fMRI and eye tracking methodology to reveal the brain bases of MD.

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