The Transformative Potential of Early Screening for Dyscalculia,

The Discounted Specific Learning Disability

by

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Sam Wertheim, a highly accomplished educator, and mathematician, has dedicated over two decades to shaping mathematics education in the United States at various levels. His extensive experience spans roles such as Special Education and Math teacher, Director of Mathematics, liaison for the New York State Education Department, and contributor to the US Department of Education's NIMAC sector. Sam's primary focus has been creating high-quality mathematics materials for students who require additional support. Notably, he played a pivotal role as a lead content creator and curriculum architect for Great Mind's Eureka project, STEM Scope Curriculum, National Center for Teaching Quality (NCTQ), both in New York state and nationwide.

Sam's contributions extend beyond the classroom, as he has served as a Graduate Mathematics professor at Touro University, delivering lectures and workshops at prominent organizations like NCTM and NYSED. His academic background includes Master's degrees in Mathematics, Behavioral Psychology, and Japanese Language and Culture, further enriching his multidisciplinary expertise. Currently pursuing a doctoral degree in Mathematics, Cryptography, and Cyber Security at Capella University, Sam is thrilled to continue advancing mathematics education and supporting the academic growth of students in the United States, especially those with diverse learning needs.

Abstract

This whitepaper explores the importance of early screening for dyscalculia in young children. This learning disability affects a child's ability to understand and work with numbers, which can significantly impact their academic and personal lives. This paper discusses the prevalence and symptoms of dyscalculia and the challenges associated with identifying it in young children. We then review current screening methods and highlight the importance of early detection and intervention. Finally, we provide our version of an up-to-date screener that screens the areas associated by diagnosticians with dyscalculia from ages 3 to adult, a survey for other potential causes of a math difficulty such as vision and hearing, provide recommendations for educators, parents, and policymakers on next steps towards determining the presence of dyscalculia and effective, evidence-based interventions that can be implemented immediately. We hope this whitepaper will increase awareness and understanding of dyscalculia and promote efforts to ensure that all children have access to the support they need to succeed in math by providing a new screener and resources.

Keywords: Dyscalculia, screener, students with disabilities, mathematical concepts, interventions

Introduction

In our current world and the foreseeable future, our proficiency at using math – basic and advanced- is even more important in determining our futures. Mathematical skills are critical for seeking and holding a job and career as well as everyday life; think computers, smartphones, our bank and credit cards, and keeping track of health and prescription information. Most jobs require us to use math, and the fields of technology, science, medicine, and others demand a thorough understanding of advanced mathematical concepts. It was estimated in 2009 by Jaya et al. that innumeracy was more prevalent than illiteracy and that 22% of Americans were innumerate. In May of 2022, the U.S. Institute of Education Sciences estimated that as of 2017, that percentage had increased, and an estimated 33% of Americans had low numeracy skills or were innumerate. That translates to 69 million adults having difficulty doing calculations with whole numbers, comprehending living on a budget, reading a simple table in the news, understanding how to read the figures in a simple graph, estimating the tip for a restaurant bill, or measuring ingredients when preparing a meal. In the last 20 years, there has been a push to address illiteracy through early identification with universal screeners, but the same focus has not been there for innumeracy. Even with the increased need for math skills due to technology, there have not been national campaigns to address the problem (Bryant, 2008; De Visscher, 2018; National Center for Education Statistics, 2022).

During an individual's school life, poor math skills will negatively impact a child's academic achievement, usually diminishing access to the advanced math classes that are required for a multitude of career paths, increasing the likelihood of dropping out of school, and contributing to unemployment (or under-employment), in adulthood. The impact of innumeracy on everyday adult life is apparent in bankruptcies, lower-wage job opportunities, unemployment, and a higher probability of physical and mental health issues, including anxiety and suicide (Dowker et al., 2016; Duncan et al., 2007; Geary, 2010; Jacobsen, 2020).

There is also a cumulative economic impact estimated in the billions of dollars in lost revenue and increased costs in social support when large percentages of a population are unemployed, underemployed, or in need of social support due to the inability to perform the normal numeracy actions of an adult. According to OECD (2016) and IES (2022) estimates, the share of adults at or below Level 1 in numeracy ranged from 61.9% in Chile to 8.1% in Japan, with the United States at around 33%.

The 2022 National Assessment of Educational Progress highlights a nearly universal decrease in average math scores for both 4th (5-point decrease) and 8th grades (8-point decrease) compared to scores in 2019 (Duran et al., 2022). The disparities between students with and without IEPs were even more apparent. In fourth grade, 84% of students with IEPs scored below proficient compared to 61% without IEPs. In eighth grade, 93 % of students with IEPs scored below proficient compared to 70% without IEPs.

This same disparity between those with and without IEPs is smaller in reading. 70% of 4th graders and 63% of 8th graders with IEPS scored below proficient compared to 25% and 33%, respectively, for those without IEPs. The higher rates of proficiency in reading compared to math can be attributed to there having been a much more intense focus on identification and intervention for students with reading struggles than has been the case for math in the last decades (Hroncich, 2022).

Table 1

4th and 8th Graders Scoring Below Proficient in Math and Reading Students with and without IEPs (NAEP, 2022)

% Math Scores Below Proficient		
	Non IEP Students	**IEP Students**
4th grade	61%	84%
8th grade	70%	93%
% Reading Scores Below Proficient		
4th grade	25%	70%
8th grade	33%	63%

Many factors can cause poor numeracy skills; frequent moves, excessive absenteeism, poor instruction, intellectual and emotional disabilities, and motivation, to name a few. However, one neurodevelopmental learning disorder estimated to affect 5-7% of the worldwide population is the learning disability specific to math called dyscalculia. If diagnosed, it can be addressed, and individuals with this disability can, in most cases, demonstrate numeracy skills equivalent to their non-impacted peers (Haberstroh & Schulte-Korne, 2019; Kuhl et al., 2021). Early screening for dyscalculia and other math difficulties, and seeking a formal diagnosis and then assignment of appropriate supports and evidence-based interventions is critical to address the short and long term personal and social impacts of the learning disorder (Aquil & Ariffin, 2020).

Although there has been an increase in knowledge and interest in the disorder, it has been estimated that the ratio of research on dyslexia compared to dyscalculia could be 14:1 (Devine, 2018; Haberstroh & Schulte-Korne, 2019; Price & Ansari., 2013). The disparity in research leads to a lack of knowledge and a dramatic difference in the numbers of students identified and diagnosed as dyscalculic. Dyscalculia is less well known, and there are fewer screening and diagnostic tools (Jaya, 2009), but its prevalence is similar to dyslexia- 5-7% of the population (Menon et al., 2020; Price & Ansari, 2013; Santos et al., 2022). Add to that an estimated comorbidity of 35-70% with other neurological disabilities, including dyslexia, and suddenly there are a staggering number of students who are at risk of failing math when early identification and intervention can mitigate the problem in many cases (Kisler et al., 2021; Litkowski et al., 2020).

Even at a conservative estimate level of 5% of the 55+ million students in US public and private schools in the Fall of 2022 having dyscalculia, that would amount to approximately 2.75M students (about the population of Kansas) with some degree of math learning disability. At the higher estimate of 7%, that would equal 3,850,000 students. The most recent IES data is for the 20/21 school year, which records the number of students served in K-12 schools with disabilities as 6.7 M, with 1.2M diagnosed as Specific Learning Disability (SLD), the majority diagnosed with SLD-Reading compared to the other SLD types- including dyscalculia (Kurth & Jackson, 2022). It must be noted that not all students with a learning disability are diagnosed as their academic performance is not impacted by their disability explaining some of the disparity in numbers noted above.

Why does dyscalculia usually go undiagnosed? There are several possible reasons. Early literacy campaigns and a focus on dyslexia have led to more awareness and, as a result, more tools and actions for students struggling with reading and being diagnosed with dyslexia. It is also more socially and culturally acceptable to struggle with math compared to reading. The phrase, “I am bad at math.” does not engender the same anxiety and demand for diagnosis of the problem and support for the child as does the phrase, “I am bad at reading”. Research has also been grossly underfunded for dyscalculia compared to dyslexia resulting in the lack of validated and reliable assessments to identify students with dyscalculia, resulting in less identification (Geary, 2004; Halberda et al., 2008; Price & Ansari, 2013).

Like reading, there are foundational skills upon which most math domains are based- sorting and classifying, recognizing abstract symbols (numerals) and their concrete counterparts, counting to ten, and the operations of addition and subtraction, all of which begin before the age of three. Conceptual understanding and procedural fluency of the basic operations in first and second grade underlie success in Operations & Algebraic Thinking (OA) and Numbers in Base Ten (NBT), which are the basis for more advanced math's (Fuchs et al., 2012). In the various US State Mathematics Standards, students begin learning number sense and base ten in pre-K and kindergarten (ERIC, 2022; New York State Education Department, 2017, NCTM, 2019). They are expected to master addition and subtraction by the end of 2nd grade, multiplication by the end of 3rd grade and multi-digit operations by the end of 4th grade. Failure to master these can lead to failure to master the more advanced math concepts and skills needed for middle and high school and job success, as indicated by the performance of students with disabilities on the NAEP 2022.

It is common for teachers in upper elementary and middle school to request help when students are three or more years behind and struggling to master basic math foundational skills, and have not been diagnosed as having a disability. In math, most screening and diagnosis are aimed at the student already in school, 3rd grade, and beyond and showing signs of struggling. At that point, multiple years of potential support have been lost.

Students with dyscalculia or the Specific Learning Disability-Math struggle and can have significant difficulties with composing and decomposing numbers, retrieval of number combinations, conceptualizing and applying number concepts, limited working memory, and inefficient problem-solving strategies. However, the neurosciences and the use of the fMRI and other advanced tools support being able to identify the risk for dyscalculia in early childhood, well before 3rd grade, and successfully intervene, enabling students with dyscalculia to achieve age-appropriate math achievement levels (Bailey et al.; 2020; Brendefur, 2018; Bugden et al., 2020). Early identification in the years preceding 3rd grade and intervention in the specific math problem areas is effective and yields the best prognosis for students (Haberstroh & Schulte-Korne, 2019).

Just as not everyone who struggles with reading has dyslexia, the low number of students scoring proficient or above on math suggests there are likely to be undiagnosed math learning disabilities and many students struggling with math but not having a disability. The large numbers of students whose test scores are below proficient underscore the importance of identifying and addressing the math difficulties of all students, especially those with disabilities.

Early math skills strongly predict later math achievement (Kroesbergen et al., 2022; Mattison et al., 2023). The impact of poor math mastery is a signal for developing and widely utilizing screeners to identify students and interventions that can mitigate, if not ameliorate, the math deficits and struggles. While much progress has been made with screeners for dyslexia and addressing the foundational skills for reading, that is not the case for numeracy issues. Therefore, a simple, easy-to-use screener, such as is currently done for vision and literacy, and administered by a teacher or parent should be used for early detection and is warranted and long overdue. For this whitepaper, we support screening students as early as possible, even before Kindergarten, to assess and address potential issues immediately (Al Otaiba, 2020). In addition, intervention should target the skills identified as fundamental for success in math. We have developed an easy-to-use screener and survey that collects information from educators and guardians, quickly assesses performance on what is commonly agreed upon as the primary indicators of possible dyscalculia and provides an action and intervention plan for adults to use as the formal diagnosis is undertaken.

Dyscalculia: What is it?

Dyscalculia or the Specific Learning Disorder- Math is a neuro-developmental disorder with persistent difficulties in acquiring number-related skills, which cannot be attributed to intellectual disabilities or neurological disorders according to the Diagnostic and Statistical Manual for Mental Disorders, 5th Edition or DSM5-TR as it will be called going forward (American Psychiatric Association, 2022). Our educational and legal system uses the term disability, which entitles the individual to recognized status as a person with a disability and therefore entitled to special services and accommodations in the educational system (Üstün et al., 2021). According to the DSM5-TR, "...dyscalculia is a term used to describe difficulties learning number-related concepts or using the symbols and functions to perform math calculations. Problems with math can include difficulties with number sense, memorizing math facts, math calculations, math reasoning, and math problem solving" (American Psychiatric Association, 2022). There is a high probability that one or more students in every classroom will have dyscalculia, as it is estimated to impact as much as 7% of the world's population, or approximately 1 in 15 children, adolescents, and adults (Butterworth, 2003; Haberstroh & Schulte-Korne, 2019; Menon et al., 2021; Price & Ansari, 2013; Ustun, 2021).

In layperson's terms, dyscalculia impacts a child's ability to acquire arithmetical skills due to a neurodevelopmental disorder, not intelligence or schooling. It usually manifests in the early school years, frequently as children learn number sense and base ten concepts and shows persistence over at least six months (Clements et al, 2013). This difficulty with non-symbolic and symbolic numerical processing means the child will struggle to quickly estimate and manipulate magnitudes and perform mental math without writing out the process. There is also a reliance on verbal or physical strategies during counting, such as finger counting or counting aloud (Grant et al.; 2020; Lopes-Silva et al., 2016). Children typically lag behind their peers, which is unexpected based on their intelligence and performance in other school subjects; they struggle with one or more of the four mathematical domains identified in the DSM-5 TR: number sense, memorization of arithmetic facts, accurate and fluent calculation, and accurate mathematical reasoning. It can lead to a diverse range of other difficulties with mathematics, from math anxiety to math avoidance, following procedures, being able to solve multi-step problems, and being slow to solve problems. It is unexpected, occurs across all ages, and does not appear to be gender-specific (APA, 2022; Ashraf et al., 2021; Butterworth, 2003; Butterworth, 2012; Geary, 2013; Price & Ansari, 2013; Ustun, 2021).

The International Classification of Diseases (ICD-11) has a very similar description of dyscalculia- significant and persistent difficulties in learning academic skills, which will include reading, writing, or arithmetic. The individual's performance in the affected academic skill(s) is markedly below what would be expected for chronological age and general level of intellectual functioning, resulting in significant impairment in the individual's academic or occupational functioning (Burns et al, 2010; Carey, 2009). The developmental learning disorder first manifests when academic skills are taught during the early school years. For the individual diagnosed with dyscalculia (6A03.02), the 'Learning difficulties are manifested in impairments in mathematical skills such as number sense, memorization of number facts, accurate calculation, fluent calculation, accurate mathematical reasoning.'

Dyscalculia is not temporary, and there is no cure, but it is also not always an issue in academic development. Because it is not due to a disorder of intellectual development, sensory impairment (vision or hearing), neurological or motor disorder, lack of availability of education, lack of proficiency in the language of academic instruction, or psychosocial adversity; individuals with dyscalculia need not be limited in their academic or career success. There are no treatments or medications that can 'cure' dyscalculia. However, some interventions can improve the understanding of mathematical concepts and procedural fluency; and there are accommodations and modifications in school and life that mitigate the effects of the disorder (APA, 2022; Bailey et al.; 2020; Bugden et al., 2020; Kuhl et al., 2021).

Other terms have also been used interchangeably when describing the struggle to learn and remember arithmetic facts and perform basic operations. They have included mathematical learning difficulties, math disorders, math disabilities, mathematical dyslexia, math learning disability, dyscalculia, and developmental dyscalculia (Mahmud et al., 2020; Van Luit & Toll, 2018). Although the formal definition does not include an assessment score on standardized tests, students are usually identified for screening or for the diagnosis process based on an arbitrary cut-off score to help determine who is eligible for screening or diagnosis. The score is commonly generated via a standardized state assessment and can range from the 2nd to the 40th percentile depending upon the institution (Kroesbergen et al., 2022). The most frequently mentioned percentile is the 25th, where a strong possibility of a learning disability will exist as there is a significant struggle at this level and the student needs further support (Cheng et al, 2018).

What areas of math will be a struggle for individuals with Dyscalculia?

As noted earlier, when diagnosing dyscalculia, the DSM-5-TR requires that number sense, memorization of arithmetic facts, accurate and fluent calculation, and accurate mathematical reasoning be the areas that are evaluated as they are the most common areas of struggle. While these areas are typically found in individuals with dyscalculia, not every child will display weaknesses in all the areas as the within-group differences are of as a great a variety as they are between children with dyscalculia and those without dyscalculia (Kroesbergen et al., 2022; Menon et al., 2020). The cognitive sciences and the neurosciences also describe these deficits as domain-specific and have been found to predictive of later struggles in math achievement and dyscalculia.

They manifest themselves as struggles with:

1. **Number Sense-** the student struggles with recognizing and understanding quantities, number words and Arabic numerals and mapping between them (Geary, 2013). It also includes other number skills such as counting, number patterns, subitizing, using a number line, arithmetic fact retrieval, and problem-solving operations. These difficulties can be used to screen for dyscalculia pre grade 3 (Menon, 2020).
2. **Memorization of Arithmetic Facts-** the student memorized the 4's table yesterday but cannot recall it today or is slower than expected recalling it. This begins as early as kindergarten and 1^{st} grade and can also be used as an early indicator of potential dyscalculia. The student uses immature strategies to process a math fact such as finger counting or counting all. This slower speed in completing problems leads to a significant time difference between a typical student and the student with dyscalculia (Mahmud et al., 2020; Price & Ansari, 2013)
3. **Accurate and Fluent Calculation** -students with dyscalculia show longer solution times, higher error rates and will use the more inefficient or immature and earlier developmental phases of counting strategies to solve a single or

multi-step problem, calculations (Mahmud et al., 2020; Szardenings et al., 2018).

4. **Accurate Mathematical Reasoning**- the student has difficulty with quantity and magnitude judgment (estimating numerosity) and manipulation as well as using abstract representations or numerals to reason with when presented with problems. The issue is one of mapping the numeral or symbol to the actual representation of that quantity or attaching a numeral to the number of items in a set. A student will be asked which is greater- two numerals (symbolic) or 2 sets of items (non-symbolic) or a number and a set of items which are displayed simultaneously, and the student will have difficulty distinguishing between the two. Another example is number sequencing which includes skip counting intervals with increasing or decreasing numbers (Lewis et al., 2022; Menon et al., 2020). The difficulty with magnitude judgment also includes estimating the duration of time and spatial dimensions.

In addition to the four math domain-specific weaknesses there are domain-general difficulties that can be seen across other areas of the brain, namely visuospatial working memory and cognitive control, "which impact the ability to manipulate quantity, retrieve facts and resolve intrusion errors." (Menon et al., 2020; NIH, 2022). This includes executive functions such as working memory and attention, the processing speed of math problems, and phonological skills. Whilst not part of the evaluation for the formal and legal designation of dyscalculia; they are very real areas of struggle and must be addressed via interventions and necessary supports. It also allows for all individuals to reside on a continuum of mathematical abilities that range from severe and possibly permanent difficulties to those with only temporary struggles as the maths' are mastered (Grant et al., 2020; Kroesbergen et al., 2022; Mattison et al., 2023).

These domain-general abilities manifest themselves as struggles with:

1. **Working Memory**: Required for learning and problem solving, working memory is the storage, processing, and recollection of the most recent version of verbal and visuospatial information, in this case the processing of numerical knowledge (Attout & Majerus, 2014; Mahmud et al., 2020). This is the ability to hold in readiness memories of the answer to part one of a multistep problem with numerical information usually being more difficult to access than non-numerical. Visuospatial and spatial working memory appear to be the most severely affected which is associated with pattern recognition, number sense, and mathematical modeling (Viesel-Nordmeyer, 2021, Watson, et al., 2016).
2. **Attention**: The ability to focus on the task at hand rather than other things in the classroom and not be easily distracted is also an area of struggle. This is especially apparent when doing multi-step problems or the student has not achieved automaticity (Kroesbergen et al., 2022, Watson, et. Al., 2016). The student cannot stop themselves from being distracted, and thus has difficulty in both the classroom and in daily life.
3. **Processing Speed:** Students with dyscalculia typically require longer periods of time to complete the problem or retrieve the needed information to complete

the problem. Processing speed has been identified as a central deficit for students with dyscalculia. (Price & Ansari, 2013)

4. **Phonological Processing**: Phonological processing is the ability to recognize and manipulate language sounds, and it is a critical skill for developing reading and math proficiency (Bulat et al., 2017). Phonological processing, also known as rapid naming, is the use of the sounds of one's language (i.e., phonemes) to process spoken and written language (Wagner & Torgesen, 1987). The broad category of phonological processing includes phonological awareness, phonological working memory, and phonological retrieval. Hearing and quickly processing the words or accessing the number fact of 3+4 =7 is necessary to do everyday tasks in both arithmetic calculations and word problems.
5. **Spatial Skills**: Spatial sense is an understanding of shape, size, position, direction, and movement – being able to describe and classify the physical world we live in (Kroesbergen et al., 2022). Later in school, this is referred to as 'geometry’. Kroesbergen found evidence for the relationship between children’s math skills and their visuospatial skills, conservation abilities, and processing speed and they contribute to the understanding of deficits that are specific to mathematical difficulties.
6. **Logical/Non-Verbal Reasoning:** The process of solving problems and forming concepts without using words or language is called non-verbal reasoning (Huijsmans et al., 2020; Kroesbergen et al., 2022; Träff et al., 2016). Logical reasoning is an interconnected skill, partly comprising conceptual understanding and identifying the next steps to a problem solution (Peters et

al., 2020; Träff et al., 2016). Visual perception and ordering to help students identify logical constraints within word problems, along with identifying problem solutions is also an issue (Duran et al., 2020; Morsanyi et al., 2018; Sasanguie et al., 2017). Number-specific executive function is also a key area of logical reasoning. Identifying and categorizing number-specific deep conceptual understanding allows students to see patterns and interrelated concepts.

Table 2

Essential Skill Areas of Struggle for Students with Dyscalculia (Bailey et al., 2014; Jacobsen, 2020; Kroesbergen et al., 2022; Mahmud et al., 2020; McCaskey et al., 2017); New York State Education Department, 2017; Viesel-Nordmeyer, 2021.

Skill	Task
Number Sense	Counting forward and backwards orally, persistent use of fingers to count. Being slow in learning to count and easily losing track. Associating number symbol with number value, 3 + 2 and three blocks and two blocks.
Quantity and Magnitude Judgement	Which is greater, estimating length of elapsed time, estimating space, identifying patterns, placing things in order, money. Position of a number on a number line and understanding place value.
Retrieval of Math Facts	Fluency and automaticity of math facts- the fact is recalculated each time rather than immediately recalled, phone numbers, addresses

Solving Arithmetic Operations	Multi-step problems require a mix of basic and complex skills, difficulty remembering how to do the basic operations of addition, subtraction, multiplication and division, understanding how to solve a word problem or other numerical operations. (13 + 39 = 1+3=4 and 3+9 = 12 so the answer is 412)
Working Memory	Recognizing, remembering, articulating numbers. which is tied to the retrieval of math facts.
Attention	Sustained periods of attention, as fatigue sets in for students with dyscalculia and numbers, suppressing distractions
Processing Speed	Addition, subtraction, multiplication and division in number ranges according to age as a timed activity done in writing and orally
Phonological Processing	Difficulty with verbal working memory with digits and visual-spatial working memory, recalling the steps of verbal directions or a spoken math problem
Spatial Skills	Difficulty working with maps, charts, and graphs, their location, and estimating volume and magnitude
Logical/Non-Verbal Reasoning	Impacts one's understanding of logic and logical reasoning, such as pattern recognition; e.g. skip counting, shape sequence identification: square, square triangle, what comes next.

What Causes Dyscalculia?

Neuroscience has made strides in identifying the underlying causes of dyscalculia as a neurodevelopmental disorder that impacts reasoning about numbers. There are a number of theories about the causes, but there is general consensus that dyscalculia is a multicomponent neurodevelopmental disorder that comprises impaired development and disruptions in the neural pathways in the distributed inter-connected regions of the brain that process numerical information and perform math problem-solving (Räsänen et al, 2021). Recent fMRIs indicate that multiple regions of the brain; frontal, parietal, temporal, visual and hippocampal are activated during the performance of number processing, which involves recognition and memory processing (Dinkel, 2013). The intra-parietal sulcus (IPS) plays a major role in arithmetic tasks and more complex mathematical tasks and fMRIs have shown reduced neural activity in the IPS during the performance of assigned tasks for individuals with dyscalculia (Kucian & von Aster, 2015). Depending upon the researcher, this deficit, disorder, difference, weak or slow development of the circuits; the white matter connecting these areas; can lead to decreased efficiency or ease of access to the areas of the brain involved in mathematical processing, specifically for arithmetic and numerical problem-solving. This underdeveloped interconnectivity is a risk factor for dyscalculia (Kuhl et al., 2021; Martin & Fuchs, 2022; Menon et al., 2021; Grant et al., 2020; Price & Ansari, 2013, Ustun, 2021).

Regions of the Brain and their Role

Frontal Region - The frontal region is responsible for decision-making, reasoning, personality expression, social appropriateness, and other complex cognitive behaviors. Prescott et al. (2010) found that the connectivity patterns in the frontal region are consistent with previous studies linking increased activation of the frontal and parietal regions with high fluid intelligence and are possibly a unique neural characteristic of the mathematically inclined areas of the brain (Padmanabhan & Schwartz, 2017; Siemann & Petermann, 2018). The frontal region is directly linked to conceptual understanding and mathematical reasoning. This may explain why students struggling with dyscalculia show persistent deficits in number processing, which is associated with connectivity of the frontal and parietal regions of the brain (Räsänen et al., 2014; Soares et al., 2018; Van Viersen, 2013)

The prefrontal cortex is the very front of the frontal region and houses the executive functions that enable us to problem solve and pay attention, which is necessary when learning how to map the heretofore meaningless numerals and words to their appropriate magnitude meaning when acquiring number sense or focusing on the operational sign to do a single or multi digit computation problem. The ability to plan and sequence a multi-step problem, ignore distractions or superfluous information in a word problem, and stay focused for the extended period of time needed to solve the problem are also tasks that the student with dyscalculia struggles with (Prescott, et al., 2010). Attention to task is also correlated with better counting, numerical processing, and calculation skills (Lynn, et al. 2022).

Three areas need to connect in order to complete a question about magnitude- the IPS where the magnitude 'concept' resides, the prefrontal cortex telling the student to pay attention and the hippocampus, processing the concept for long term memory (Al Otaiba & Petscher, 2020). The white matter connections between these 3 regions of the brain will determine the ease or speed with which an individual can later retrieve the information needed to work a problem (Nicolson & Fawcett, 2021; Watson & Gable, 2016).

Parietal Region – The parietal region is the primary sensory area of the brain and is responsible for sensory processing. A specific area of the parietal region, the IPS or intraparietal sulcus, allows us to discriminate between quantities, a key component of number sense (Price & Ansari, 2013, Ustun et al., 2021). Research suggests that individuals with dyscalculia, as compared to simply poor math-performing students, have difficulty differentiating between a set of 5 and a set of 6 (Mazzocco, et. al., 2011). If they have difficulty comparing the magnitude of the symbols, knowing that 6 is greater than 5, there will be difficulty with math achievement (Bugden et al., 2014).

Temporal Region – The temporal region is associated with processing auditory information and with the encoding of memory. The temporal region of the brain is most directly related to elementary number sense and memory related gains or deficits (Kroesbergen, et al., 2022). Anobile et al. (2022), found that dyscalculia and neurotypical development suggests visual perception of numerosity (the number sense) is a building block for math learning and is directly linked to the encoding of memory for mathematics.

Visual Region - The visual cortex is the primary cortical region of the brain that receives, integrates, and processes visual information relayed from the retinas. According to Bulthe et al. (2019), the primary visual cortex is responsible for processing visual information, including numerical symbols, which are important for mathematical reasoning. However, it is important to note that increased connectivity does not necessarily mean better performance or accuracy in mathematical tasks. In the classroom, the visual cortex is closely related to accurate mathematical reasoning and of course the visual input of information needed to do the math.

Hippocampal Region – The hippocampus is a complex brain structure embedded deep in the temporal lobe and has a major role in learning and memory. According to Üstün et al. (2021),the hippocampal region of the brain is activated during symbolic number perception, particularly in students with dyscalculia. The hippocampal region is tied to operations and algebraic operations - through the memorization of arithmetic facts and accurate mathematical reasoning.

TABLE 3

Regions of the Brain and Mathematical Processes

Region	Associated mathematical processes	Associated Questions in DySc
Frontal	Accurate mathematical reasoning and accurate and fluent calculations	7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19
Parietal	Number sense	1, 2, 3, 4, 5, 6

Temporal	Memorization of math (arithmetic) facts	20, 21, 22, 23, 24, 25, 26
Visual	Accurate mathematical reasoning	27, 28, 29, 30
Hippocampus	Memorization of math facts and accurate mathematical reasoning	31, 32, 33, 34, 35, 36, 37

Individuals with dyscalculia show difficulty in using symbolic (Arabic numerals and number words) and non-symbolic representations (dots, sticks, 2-dimensional and 3-dimensional items) when asked to do tasks that represent, access or manipulate number sense (Geary et al., 2013; Mazzocco et al., 2011). The maths are built upon the ability of our brains to map a symbolic number system (Arabic numerals and words) on top of the pre-existing visuospatial number system (the visuals we store in our brains of two's and four's, both 3 and 2-dimensional). This includes subitizing, attaching three's to the abstract representation 3 and discriminating between larger numerosities without counting- greater and smaller based on the ratio between two sets of objects. These differentiation skills can be observed as early as 6-months of age and continue to develop, so they are early indicators of the potential for dyscalculia. In addition, research is suggesting that counting (the ability to orally sequence numbers correctly) is also a good predictor (Geary, 2013).

If you were to look at the brain using an fMRI, the areas that show increased oxygen use or activation during a math task are in the areas of the brain discussed above. Dyscalculic students performing a non-symbolic numerical comparison showed no activation of the right IPS and atypical structural development of the IPS compared to students with typical development. This is now believed to be the slower formation of white matter or myelin sheathing of the neurons which translates to slower speeds of being able to access and process problem-solving requests by the brain (Fields, 2014; Price & Ansari, 2013). Research by Kuhl et al., (2021), expanded on this and found that they could predict with 87% accuracy, students who developed dyscalculia, based upon the functional connectivity of the right posterior parietal cortex (PPC) and the right dorsolateral prefrontal cortex (DLPFC) and the effective connectivity of these two regions by white matter, the neural connections. These are the areas of the brain that are most strongly associated with numerosity and calculation, respectively, and the poor structural and functional connectivity supports the explanation for why dyscalculics need more time to solve problems than children without dyscalculia.

At TouchMath we believe that math performance exists as a continuum that varies over time depending upon a wide variety of factors, with the neurological ability to successfully learn mathematics being multiplied, exacerbated or mitigated by environmental and biological factors. These include environmental factors such as where you live, socioeconomic variables, attendance, adult expectations, trauma, etc. There are also biological factors such as intellectual abilities, emotional factors and neurological variables (Butterworth, 2003).

This combination of difficulties and strengths we believe provides a more accurate picture of the individual at any point time and allows us to determine when to intervene if needed. With early intervention and the right supports, including accommodations and modifications, it is very possible to adapt to being dyscalculic and demonstrate mastery of mathematics and be successful as a student and adult (Bailey et al.; 2020).

The Touch Math Dyscalculia Screener (DySc)

The main goal of the academic team at TouchMath was to design, develop and release a valid and reliable dyscalculia screening tool, the DySc, that could be used as early as age 3 or 4 and through adulthood. A screener should identify children at risk and minimize the chances of inaccurately identifying a student (Grant et al., 2017). It should reflect the complexity of mathematics via a multiple proficiency assessment but allow for the maximum amount of information in the minimum amount of time. It should indicate where the potential for dyscalculia exists and provide the impetus for a diagnostic process to begin that will formally identify individuals with the Specific Learning Disability-Math, Dyscalculia. Being based on foundational math skills that are predictive of later math achievement also allows a screener to be used for instructional decision-making purposes, regardless of the outcome of a diagnostic process. And finally, it should be easily accessible and useable by those that wish to learn more about why a student is struggling with math and how to best address the issue.

A screener 'shortlists' those who will need further testing and possible 'diagnosis', if they are unsuccessful in mastering specific arithmetic and problem-solving domains to supply the appropriate interventions and supports. It cannot be used for diagnosis as it is a quick assessment rather than an in-depth evaluation.

Our screener intends to identify individuals who are struggling with mathematics and will qualify for a diagnosis of dyscalculia. Because of this, screening should happen as soon as a child has significant problems with the early foundations of math development, such as number sense, memorizing math facts, accurate calculation, and mathematical reasoning. Early identification and intervention can prevent further academic struggles during the school year. Indications of a struggle that warrants screening commonly result from scores lower than the 25th percentile on standardized formative and summative tests (Kong et al., 2022; Swanson et al., 2013). However, for younger students, it can be based on observation of the student by educators and guardians (Mueller et al., 2012). The screening process should also provide general information about a child, as the struggle with math may be due to factors unrelated to dyscalculia, such as vision, hearing, and language. These should be ruled out before considering learning disabilities or other factors as the underlying cause of the math difficulties (Hayes et al. 2018).

The latest DSM-5-TR (APA, 2022) estimates that 15% of the population has a specific learning disability, with 85% of that identified group being dyslexic. The numbers for dyscalculia can only be guessed as it is rarely the targeted area of evaluation. Our review of the latest research and the IES data bank (Institute of Education Science, 2021), did not uncover any data collected on the number of students diagnosed with dyscalculia. However, research estimates that the prevalence is similar to dyslexia, and 5-7% of all students have some level of math disability (Hott et al., 2020; Menon et al., 2021; Price & Ansari, 2013; Santos et al., 2022; Ustun, 2021). A recent study by Santos et al. (2022) found that 5% of 304 Brazilian students were diagnosed as dyscalculic when using a mass math assessment tool and subsequent formal diagnostic process. Not all students diagnosed with dyscalculia will need an IEP, as their academic progress is unaffected. However, it does mean that a substantial number of the estimated 2,750,000 to 3,850,000 students with dyscalculia in the US may need specialized support to live up to their full potential and contribute to society.

In order to be diagnosed as dyscalculic, the DSM-5-TR requires impairments in mathematical skills such as number sense, memorizing math facts, math calculations, math reasoning, and math problem solving (APA, 2022). These are the areas of early math performance that research supports as being commonly found in individuals who are later diagnosed as having dyscalculia as well as individuals evidencing lower-than-expected math achievement (Gersten, 2011; Jordan, 2009). In a screener, these can be measured early in a child's life through tasks that measure the skills of number sense, counting skills, arithmetic, and understanding magnitude and comparison.

There have been screening tools developed that assess a variety of these skills and others. We conducted a literature review to find what was available and their components. For most, we could find information but there were some for which we could not find much information as they required payment or the collection of personal information. Our search confirmed our belief that there is a need for a screener that is focused on dyscalculia versus math difficulties; requires only a short test time, is aligned to the domains in the DSM-5-TR that are used by professionals for diagnosis, covers a broad age range, collects information about other possible causes of the math difficulty and provides an action plan and evidence-based interventions to be used with the students.

Current screeners include the Preschool Early Numeracy Scales (PENS; Purpura & Lonigan, 2015), and the Number Sense Screener (NSS; Kaufmann et al., 2013). Both assess the numerical skills of counting, one-to-one, correspondence, number-word-knowledge, etc., and are targeted at preschool to first-grade children and take approximately 10 minutes to administer. Other screeners include the Test of Early

Numeracy Curriculum-Based Measurement, and the Number Knowledge Test (Okomoto & Case, 1996) which also were developed for screening the younger child. Geary et al. (2009) developed a paper and pencil screener, commonly referred to as the "Brief Assessment of Number and Arithmetic Skills" or BANAT, but accuracy rates were only at 51% (Bugden, et al., 2020).

Butterworth (2003) created the Dyscalculia Screener which focuses on tests of basic numerical capacities and numerosity. The concentration of questions encapsulates numerosity as a property of sets, estimated numerosities, magnitude, and basic counting, number stroop, dot counting, item-timed arithmetic, and simple reaction time. It is widely used in the UK and is the foundation for many, if not most, screeners as they are based on his early and continued research on dyscalculia.

The Numeracy Screener (Nosworthy et al., 2013) is a 2-minute test of symbolic (Arabic numerals) and non-symbolic (dot arrays) discrimination ability developed in 2013. While it predicted a large percentage of children who evidenced signs of dyscalculia, it was focused on only two areas of math ability. It was found to have only poor to fair levels of clinical and practical significance (Bugden et al., 2020). It was recommended that additional tools be used to supplement it for screening for dyscalculia. It was also recommended that screening tools that measure symbolic abilities would be better for use as a screener.

Gliga and Gliga's (2012) screening instrument looked at the sub-categories of estimating quantity, counting backward, or repeated sequence counting. This screener's theoretical focus is on the Triple Code Theory or TCT, which proposes the existence of independent number mental math representations.

The Dynamo Assessment was created in 2016 to address deficits in students with mathematical difficulties. The assessment has 647 test items across all standards, intending to create a general intervention and support plan focusing on students ages 6+. While this screener is an assessment style acting as a diagnostic, the generalization of domain areas and focuses on multiple areas of math deficit misses the mark of identifying dyscalculia-specific deficits.

Rasanen et al. (2021) released a study on the development of a Finnish project to develop the Functional Numeracy Assessment. A subproject was the development of a screener for dyscalculia. It used six tasks to screen for the disability- number comparison, digit dot matching, number series, single-digit addition, single-digit subtraction, and multi-digit addition and subtraction. They were able to show that these tasks could be used across genders and from grades 3 to 9. To date, it is available only in Finnish.

There is also the Dyscalculia Screener (Wells, 1997) by Schreuder. This instrument d includes 15 modules, encompassing ANS and approximate number systems, focusing on GPK to 9th grade. A small survey is connected to the screener. The literature review uncovered no peer-reviewed research to date.

Grigore (2020) concentrated tasks for diagnosing and identifying dyscalculia around basic number processing skills. The components of this tool include basic processing skills such as enumeration, linking non-symbolic representations to symbols, transcoding, counting, number comparison, and measurement (number line and analog clock reading). While Grigore's (2020) Diagnostic Assessment of Dyscalculia is more in-depth than Butterworth's (2003), missing areas remain for further evaluation of identifying students with dyscalculia and the magnitude of impact and intervention. To date, it is only available in Turkish.

There has also been a focus in the US and worldwide on developing diagnostic instruments, not screeners that can only be used by licensed professionals during the process of determining if a disability exists and if the individual is entitled to legal and educational services. These include the Italian BDE-2 (Biancardi et al., 2016), the French ZAREKI-R, and the TEDI-MATH (Kauffman et al., 2009). These diagnostic instruments have focused on counting, reading Arabic numerals aloud, writing multidigit numerals read by the tester, answering orally various arithmetic operations questions (3+17; 38-12; 6*7), and identifying which is larger using numerals and or pictures of sets.

Other forms of educational testing exist but are not designed for quick screening but rather for the formal diagnosis of various disabilities such as dyslexia, cognitive, etc. The Wechsler Intelligence Scale for Children, the WISC-V, which measures children's intellectual ability from 6 to 16 years. The WISC was developed to provide an overall measure of general cognitive ability and also measures of intellectual functioning in Verbal Comprehension (VC), Perceptual Reasoning (PR), Working Memory (WM), and Processing Speed (PS) (NIH, 2016). Another common educational assessment, the Woodcock-Johnson IV Tests of Cognitive Abilities (WJ-IV COG), includes 20 tests measuring four broad academic domains: reading, written language, mathematics, semantics, and theoretical knowledge (NIH, 2021). It includes 18 tests for measuring general intellectual ability, broad and narrow cognitive abilities, academic domain-specific aptitudes, and related aspects of cognitive functioning, which licensed professionals use to diagnose a learning disability, including dyslexia and dyscalculia (NIH, 2021).

In summary, the screening tools noted above assess several early numeracy skills, but do not include all of the areas that are required for use by diagnosticians to determine eligibility. Many have yet to be translated into English and do not include the components that we believe are needed to support educators, parents and students struggling with dyscalculia. In addition, most were difficult to access by the majority of the population (educators and parents) who want to address a child's struggles with arithmetic and math.

Our goal was to develop a relatively quick but easy-to-administer screener, the DySc, based on previously proven question types for assessing the four areas diagnosticians need to examine to determine eligibility. It can be administered individually or in a group setting. It includes information from educators and guardians that could more easily and accurately explain a child's math struggles, namely the failure to pass a vision or hearing screening or having a different primary language at home than is used in school to teach math.

The TouchMath Dyscalculia Screener, DySc, was developed after an exhaustive search of educational, developmental, cognitive, and neuroscience literature. Our search of the online databases included Educational Resources Information Center (ERIC), PsychINFO, Frontiers in Psychology, Frontiers in Education, Google Scholar, Public Medical Library, ResearchGate, and Wiley Online Library. We also searched the journal sites; Exceptional Children, Journal of Learning Disabilities, Journal of Developmental Psychology, and the Journal of Education. We focused on studies that had been released in the last ten years using the terms that have been frequently used to describe this disorder- they include dyscalculia, developmental dyscalculia, math learning disorder, specific learning disability- math and math learning disability, mathematical learning difficulties, math disabilities, mathematical dyslexia, and math learning disability.

The DySc screener is designed so that teachers or guardians can administer it with minimal preparation and no financial investment, assess the areas of math performance that are critical to a diagnosis, can be administered via print materials or digitally, cover a wide range of age groups, and includes an educator/guardian survey to provide a broad view of factors that impact math performance other than dyscalculia (Yoong et al., 2022). The DySc also provides what other screeners do not with the report it generates that includes an action plan and recommended evidence-based interventions to implement while diagnostic procedures are ongoing.

TouchMath Dyscalculia Screener Design and Administration

The DySc screens for difficulties in the areas of mathematics that are shown to be valid indicators of the risk of dyscalculia based on the research we reviewed (see bibliography). The research review supported our decision to develop a screener and survey to accommodate the complexities of mathematics and human learning. Early diagnosis and intervention are the primary goals for this screener as the basic number skills that these students struggle with are the foundation for more advanced math skills, and early numerical skills predict later math achievement (Butterworth, 2003).

Design

The DySc screener is partitioned into three age-centric groups, ages 3-4 years, 5-7 years (pre-kindergarten to second grade) and ages 8 years and above, including adults (grades three and above). There are 16-39 timed valid test items concentrated around four dimensions:

- number sense,
- memorization of arithmetic facts,
- accurate and fluent calculations
- mathematical reasoning,

These are the four dimensions that a diagnostician will use to determine eligibility for educational services (American Psychological Association, 2022). They also correlate to 3 of the areas of numerical cognition that are correlated to the diagnostic tool, Zareki-R and the arithmetic subtests of the SAT and WISC-III (Santos et al., 2022; von Aster & Shalev, 2007). The screener runs on an online platform but can be printed for a paper/pencil experience for younger students or when an adult needs to record the answers. It is also device agnostic, but the screener is not recommended to be administered digitally on cell phones. The DySc is available to schools and individuals and consists of a questionnaire for the student, a survey for the educator/parent, and a report that suggests the next steps and evidence-based interventions that can be taken while waiting for a formal diagnosis.

Scoring on the screener is a two-point rating scale; if a question is not answered or answered incorrectly, a score of zero is assigned; if the question is answered correctly, then a score of 1 is assigned. Total scores determine the recommended action that is reported. Scores will be reported as YES- risk indicators are present and formal evaluation is recommended, as well as appropriate interventions, PARTIAL- some indicators are present and screening again a year later is recommended and intervention should be started and tracked throughout the intervention period for signs of further mathematical delay as a prompt to rescreen at a sooner date, or NO- no risk indicators were found but if the child is struggling an intervention plan is recommended and potentially an evaluation for the cause of the math problem. Thresholds for determining YES, PARTIAL and NO are based upon the 5-7% estimated prevalence of the dyscalculia in the population and the studies that have been done with diagnostic tools such as the Zareki-R where thresholds for further data gathering and diagnosis hover at the 15th percentile (Santos et al., 2022).

Table 4

Scoring and Recommended Actions for the DySc ages 3-4, 5-7 and 8+ years old

Score Range	Descriptor	Note
0 - 12	YES	Risk indicators are present and formal evaluation is recommended, as well as appropriate interventions
13 - 52	PARTIAL	Rome indicators are present and screening again a year later is recommended and intervention should be started and tracked throughout the intervention period for signs of further mathematical delay as a prompt to rescreen at a sooner date
53 - 78	NO	No risk indicators were found but if the child is struggling an intervention plan is recommended and potentially an evaluation for the cause of the math problem

Components of The DySc

The identified areas in the DySc align with the areas identified by the DSM-5-TR as necessary for a diagnosis of SLD-Math or Dyscalculia and form the framework for the screener.

Number Sense

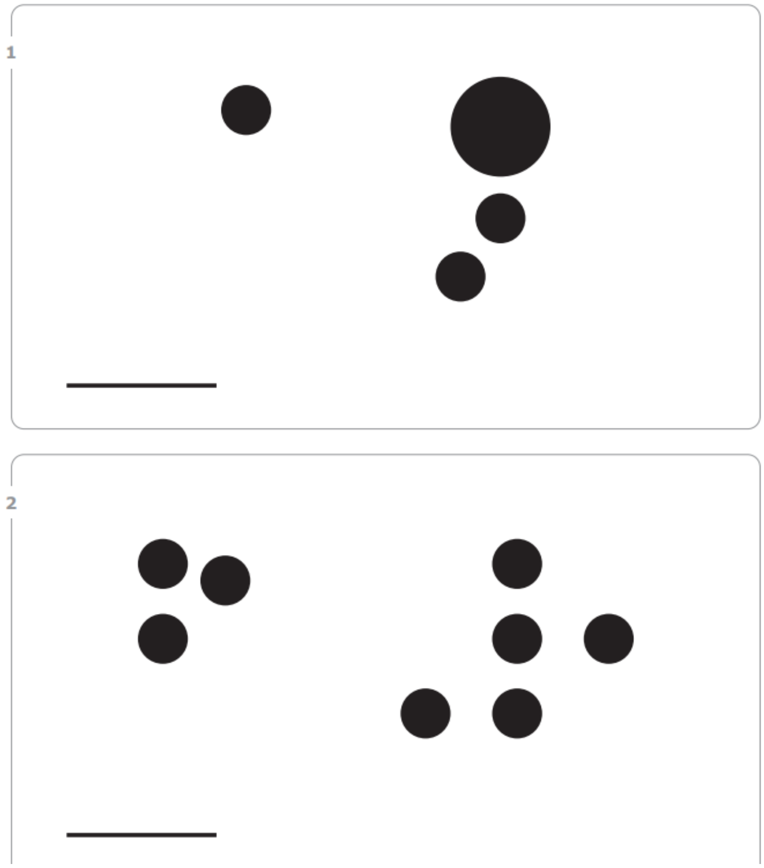
Number sense refers to a person's intuitive understanding of numbers and their relationships, including the ability to compare, estimate, and approximate quantities. It is a fundamental skill that allows individuals to perform basic arithmetic operations, solve problems, and make sense of mathematical concepts. Number sense is developed through experiences, exposure to mathematical concepts, and practice. It is often considered a key foundation for mathematical proficiency and is particularly important in early childhood education. Developing strong number sense skills can improve a person's ability to reason mathematically and make informed decisions in various areas of life.

It includes estimating numerosities without counting, such as when students are presented briefly and simultaneously with two sets of objects and asked which set is greater or smaller (Attout et al., 2018). It also includes comparing numbers and magnitude by being fluent and accurate in estimating or judging magnitude or knowing if 12 is bigger than nine but 18 is much bigger than 9 (Goffin, 2019). This concept can also be thought of as a mental number line. Magnitude judgment is an early predictor of math abilities as magnitude processing develops before ordinal processing (Attout et al., 2018; Gersten, 2011; Hott et al., 2020; Huijsmans et al., 2020). Other examples of number sense are memorizing a string of digits or placing numerals on a number line (Attout et al., 2018) and reading and writing numerals (Gersten, 2011).

In the DySc, number sense is assessed through the use of dot enumeration and number comparison for magnitude. Students are given a series of problems that consist of several different sized dots and are expected to identify the quantity. Dot enumeration is a task where individuals are asked to quickly and accurately determine the number of dots presented to them. This task helps assess a person's ability to recognize and comprehend numerical quantities. It typically involves showing a series of dot patterns, and the individual is required to provide the corresponding number for each pattern.

Number comparison tasks involve comparing two or more numbers and determining their relative magnitude. These tasks help assess a person's understanding of number relationships and magnitude. For example, individuals may be presented with pairs of numbers and asked to identify which one is larger or smaller.

Figure 1: Example of Number Sense Problem used in DySc Tool



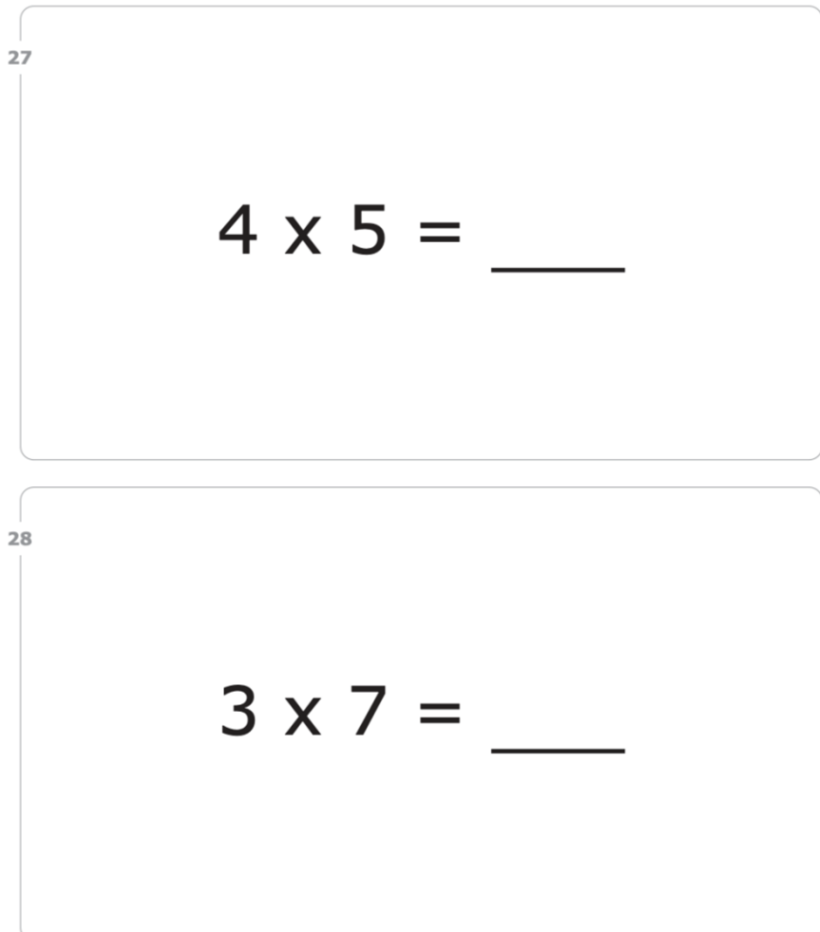
Memorizing Arithmetic Facts

Another key area of the DySc is memorizing facts and being able to do simple arithmetic calculations using all four operations aligned to age. Research has shown these are an important predictor of success in mathematics (Geary, 2011). Furthermore, it has been found that the ability to quickly and accurately recall single-digit math facts is a strong predictor of success in higher-level mathematics. In contrast, the ability to recall multi-digit calculations is less strongly predictive (Barrouillet, Fayol, & Lathulière, 1997).

For example, Barrouillet et al. (1997) found that 5th-grade students who could recall single-digit addition and subtraction facts performed better on various math tasks, including mental arithmetic and problem-solving than students with having more difficulty recalling these facts. However, the same study found that the ability to recall multi-digit calculations was not as strong a predictor of success in math. Therefore, it is important to distinguish between memorizing single-digit math facts and multi-digit calculations and to focus on building a strong recall of single-digit facts as a foundational skill for success in mathematics.

Students are given paper and pencil or use the digital version of the screener to answer a series of six addition, six subtraction, and six multiplication, proceeding from single-digit addition through basic multiplication. The DySc Tool presents the problems horizontally and the child responds in writing or orally. The final two problems of each of the three operations required regrouping (Numbers in Base Ten - NBT). The child has paper and pencil available to use as scratch sheets and can solve the problems in any manner they chose within the allotted time.

Figure 2: Memorizing Arithmetic Facts



Accurate and Fluent Calculations

Accurate and fluent calculations are of core significance to screening Dyscalculia in students (Kankaras et al., 2016). Students will focus on an arithmetic calculation which can be defined as making simple calculations using all four operations aligned to their age- group. Students were given paper and pencil or used the digital version of the screener to answer a series of six addition, six subtraction, six multiplication, and six division problems. These calculation subtasks became progressively more difficult through division. The child had paper and pencil available and could solve the problems however they chose. For younger students, ages 3 and above, accurate and fluent calculations are related to basic math facts where students have some core automaticity but are still calculating using memory with fluency.

Figure 3: Example of Accurate and Fluent Calculations

30

$$20 + \underline{\qquad} = 100$$

Reasoning and Problem-Solving

Accurate mathematical reasoning incorporates counting forward and backward without reference to objects, such as skip counting in patterns with a missing number (Gersten, 2011). Mathematical reasoning also includes solving math problems, including conceptual understanding and word problems. Reasoning in math is based on mathematical puzzles, propositional logic, predicate logic, elementary set theory, elementary number theory, and counting principles. This enables students to develop problem-solving and reinforces learning.

Students are presented with 12 of the total 39 problems that require them to solve problem solving situations such as missing numbers and number pattern predictions. This is partitioned into age appropriate questions to identify dyscalculia traits and not developmentally inappropriate math questioning.

Figure 4: Example of Reasoning and Problem Solving

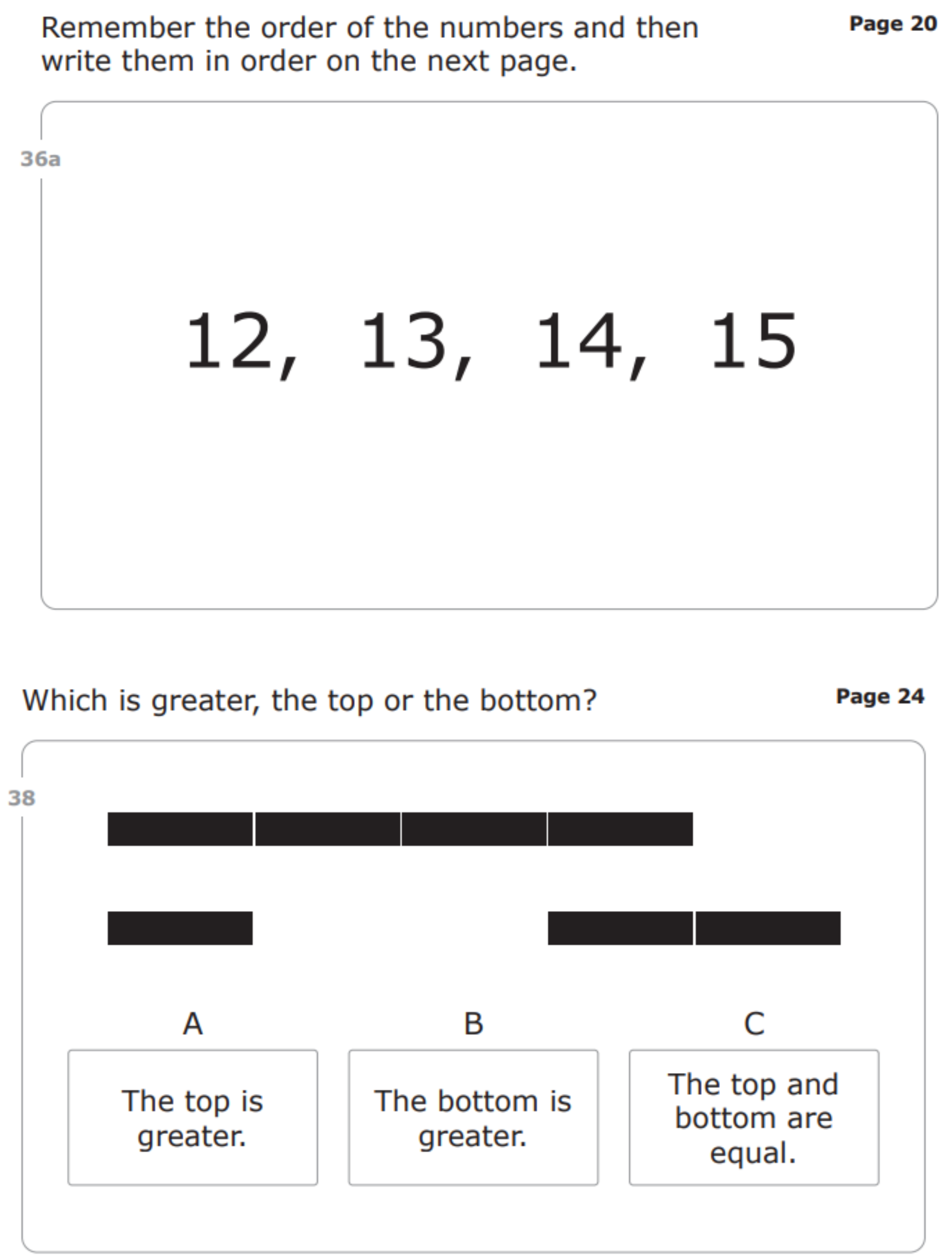


Table 5

Item Analysis Profile

Dyscalculia Profile Item Analysis – Dyscalculia Screener	
Type	**Item #'s**
Number Sense	1, 2, 3, 4, 5, 6
Memorization of Math Facts	20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Accurate and Fluent Calculation	31, 32, 33, 34, 35, 36, 37
Accurate Mathematical Reasoning and Problem-solving	7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19

Item Development

The DySc item bank was developed by a team of content experts based on the PK-algebra items developed for assessment and lessons in the TouchMath curriculum. The test items were specifically developed for the DySc or were selected and modified from the existing TouchMath item bank. They have been reviewed and refined through a multi-step process involving members of the screener development team.

In order to ensure item reliability and validity for the screener, guiding principles were followed during the development process. These were:

- Items are written as questions, with no open-ended stems and only one answer
- Items are written in a consistent manner
- Items are aligned to the math domain being assessed
- Items measure the skill being assessed

- Items are written without age, gender, ethnic, religious or disability bias
- Items are written in clear, concise language at the appropriate age range
- Answers are presented in a clear, easy to understand and choose format
- Distractors are approximately the same length and plausible
- Distractors address a variety of typical errors that students may make
- Items show consistency of student response
- Results should be generalizable to the population
- Student performance can be predicted from item responses
- Target goals can be developed from the item responses

The test items are single-answer and multiple choice which offers an easy and efficient way to assess a student's skills and knowledge and for those administering the DySc to score the student's responses. This also provides higher reliability as answering and scoring will be more consistent over time (Abdulrahim et al, 2011).

Screener Validation

Screener validation refers to the process of testing and evaluating a screening tool to determine whether it is effective at identifying individuals with a specific condition or risk factor. The goal of validation is to establish the reliability and validity of the tool, which are important indicators of its usefulness and accuracy.

Reliability refers to the consistency and stability of a screening tool over time and across different contexts. A reliable screener will produce consistent results when administered multiple times to the same individual or group of individuals. Validity, on the other hand, refers to the accuracy of a screener in identifying the condition or risk factor it is designed to detect. A valid screener will accurately identify individuals with the condition or risk factor and minimize the number of false positives (i.e., individuals who are identified as at risk but do not actually have the condition).

To establish the reliability and validity of the screener, we administered the DySc Tool to a sample of individuals and the results were compared to a gold standard measure (e.g., a university professor or psychologist). The data collected was then analyzed to determine the sensitivity (the proportion of individuals with the condition who are correctly identified by the screener) and specificity (the ratio of individuals without the condition who are correctly identified as not at risk) of the screener.

The DySc Tool and the initial sample results were carefully reviewed within the four validity parameters: content, construct, criterion, and reliability (Chu et al., 2022). Content validity: This involves checking the screener to ensure that it accurately measures the symptoms and characteristics of dyscalculia. Construct validity: This consists in testing the screener to see if it correlates with other measures of dyscalculia, such as standardized tests or clinical diagnoses. Criterion validity: This involves comparing the screener's results with a more comprehensive assessment of dyscalculia to see how well the screener identifies individuals with the condition. Reliability: This consists in testing the consistency and stability of the screener's results over time and across different raters. There will be ongoing validity reviews as the sample size of those taking the DySc increases.

Administration of the Dyscalculia Screener

The DySc screening tool has been built with easy administration in mind as teachers and parents will be the primary individuals implementing the tool. But there will still need to be standardization of the delivery in order to gain the most accurate results, which will include some planning and attention to detail. Steps to follow include:

1. Choose the appropriate age equivalent screener
2. Prepare the screener environment
2. The adult delivering the screener needs to read the instructions
3. Prepare screener materials
4. Explain screener procedures to students, digital or print
5. Administer the screener and ensure that timing rules are followed
6. Monitor the testing process to ensure that students are following the rules and procedures.
7. Collect and score the tests

Scoring the DySc and Interpreting the Results

Scoring the DySc

The DySc scores automatically when using the digital version. With the print version, the individual administering the screener is expected to (1) use the DySc Testing Booklet and read all information carefully before giving the screener to the student/child, (2) give the screener, then carefully add up the points, (3) Input the point value digitally on the online platform, (4) access the report and use the recommendations as appropriate.

Interpreting the Screener Results

The DySc tool consists of various subtests, each of which measures specific math skills based on the current key indicators in the DSM-5-TR. It is used to 'shortlist' students, through the identification of risk factors for dyscalculia in the DSM-5-TR, who are in need of further formal testing and diagnosis. Interpreting the results of the DySc requires understanding the screeners scoring and interpretation procedures. The goal of the screener is to provide a variety of scores; raw scores, standard scores, percentile ranks, and dyscalculia risk score, which are used to interpret an individual's performance on the subtests. The report will provide an overview of the student's performance on the screener. It will include information on the specific tasks or assessments that were used and the student's scores or performance levels:

a. Raw Score: Raw scores will indicate the number of items answered correctly and where appropriate the time elapsed for completing that subtest
b. Sub scores: Sub-scores are provided for each of the 4 areas related to DSM5-TR. These sub scores provide more detailed information about a student's strengths and weaknesses in the specific areas of math that were screened.
c. Risk Score: The dyscalculia risk score is arrived at by simply adding up the number answered correctly. The score for a student indicates one of three possible actions:
    - YES- a range of 0 - 12 correct indicates that there are definite markers for dyscalculia and further evaluation is recommended as well as interventions

- PARTIAL- a range of 13 - 52 correct means there are some indicators present and screening at a later date is recommended as well as immediate interventions
- NONE- a range of 53 - 78 correct means there are no indicators of risk for dyscalculia but since the student is struggling interventions will be useful

False Positives and Negatives

In education testing, false positives and false negatives are types of errors that can occur when interpreting test results.

A false positive occurs when a student is identified as having a certain condition or characteristic based on a test or assessment, but they do not actually have the condition or characteristic. For example, a student may be identified as having a learning disability based on a screening test, but further evaluation shows that they do not meet the diagnostic criteria for a specific learning disability.

A false negative, on the other hand, occurs when a student is not identified as having a certain condition or characteristic based on a test or assessment, but they do actually have the condition or characteristic. For example, a student with dyscalculia may not be identified as having a math disability based on a screening test, but further evaluation reveals that they do have significant difficulties with mathematics.

False positives and false negatives can have significant implications for students and their educational outcomes. False positives can lead to unnecessary interventions or stigmatization, while false negatives can result in a lack of support and intervention for students who need it. It's important for educators and professionals to use a variety of assessments and evaluation tools and to interpret test results with caution, taking into account multiple sources of information and considering the individual needs and characteristics of each student.

If a child shows mastery of the skills or concepts targeted during the resulting interventions, there is the possibility of a false positive, the child was incorrectly providing answers that indicate they show indicators of dyscalculia. The child may have not been engaged during the screening or failed to understand what was being asked of them. The opposite result, a false negative, with the child showing no indicators of dyscalculia but continuing to have struggles with math is also possible. In this case, the screener can be administered again as soon as is practical and a Child Study Team should gather separate documentation about the child's math performance in the four target areas. The survey is an additional piece of observational data that will decrease the number of false positives and negatives as it has the potential to catch disparities in perfomance on the screener that enable the adults to make a more nuanced decision about the student's needs for support.

It is important that the screener and survey results and the report be provided to members of the Child Study Team or the team that is determining if a formal diagnosis process should be undertaken. Bringing the screener results and all academic information is a piece of this process.

Educator/Guardian Survey

The educator/guardian survey is integral to the larger dyscalculia screener. Simply assessing the child's ability to perform the designated mathematical skills does not provide a well-rounded picture of the child that could show if a child's math difficulties are due to an unrelated problem. We believe that a screener for math difficulties should not be administered unless simple screeners such as vision and hearing have been completed or administered in conjunction with the screener. Because vision and hearing screeners are commonly done on an annual basis in most schools in the US, results should be readily available or easily requested by the parent or guardian. It is recommended that there be confirmation of their completion beforehand.

The survey is a collection of the educator and parent's knowledge of the student. I should be used in conjunction with the DySc in the event there is a request for formal evaluation to provide a more detailed description of the circumstances around the student and to decrease the possibility of false postives and negatives. Questions that are asked in the survey are as follows:

- Has the student had a vision screening in the last year? (Yes/No)
- Does the student currently wear glasses? (Yes/No)
- Have you noticed the student having difficulties seeing? (Yes/No)
- Has the student had a hearing screening in the last year? (Yes/No)
- Were the directions read aloud to the student by proctor or by computer? (Yes/No)

- Does the student have a primary language other than English? Is a different language spoken at home? (Yes/No) (Select Language)
- Has the student had frequent absences? (Yes/No)
- Has the student experienced trauma? (Yes/No)
- Does the student currently have an IEP or has been diagnosed for a disability? (Yes/No)
- Does the student have trouble recognizing and remembering numbers – knew it yesterday but not today? (Often/Occasionally/Never)
- Is the student slow in learning to count and loses track easily when asked to count to 10? (Often/Occasionally/Never)
- Has the student shown difficulty identifying which is greater or smaller, shorter or taller? (Often/Occasionally/Never)
- Has the student shown difficulty associating the numeral with that same number of objects – 5 as to 5 blocks or 5 kittens in a picture? (Often/Occasionally/Never)
- Does the student have difficulty placing things in order – which is first, second, or third? (Often/Occasionally/Never)
- Does the student count all objects when asked how many are in 2 sets – a set of 4 balls and a set of 3 balls is not 4+3=7 but rather 1,2,3,4,5,6,7? (Often/Occasionally/Never)
- The student still uses their fingers to count. (Rank 1–5: 1 Never, 3 Occasionally, 5 Often)

- The student does not like games that involve counting. (Rank 1–5: 1 Never, 3 Occasionally, 5 Often)
- The student avoids doing math homework. (Rank 1–5: 1 Never, 3 Occasionally, 5 Often)
- The student has trouble with estimating time. (Rank 1–5: 1 Never, 3 Occasionally, 5 Often)
- The student has difficulty using and/or reading graphs or charts. (Rank 1–5: 1 Never, 3 Occasionally, 5 Often)
- The student has difficulty with phone numbers and addresses. (Rank 1–5: 1 Never, 5 Often)
- The student has difficulties with following directions to find a place, gets lost/confused with left and right, or how far away a place is. (Rank 1–5: 1 Never, 3 Occasionally, 5 Often)
- The student has difficulty estimating if they have the money for a purchase. (Rank 1–5: 1 Never, 3 Occasionally, 5 Often)
- The student misplaces items around the house. (Rank 1–5: 1 Never, 3 Occasionally, 5 Often)
- The student has difficulty answering basic math facts such as 3+3, 5+10, 4x10. (Rank 1–5: 1 Never, 3 Occasionally, 5 Often)
- The student has difficulty with knowledge of money. (Rank 1–5: 1 Never, 3 Occasionally, 5 Often)

- The student skips numbers or reads them backwards. (Rank 1–5: 1 Never, 3 Occasionally, 5 Often)
- The student has difficulty with multi-step tasks such as chores, getting ready for the day, etc. (Rank 1–5: 1 Never, 3 Occasionally, 5 Often)
- The student has trouble learning sequences such as movements, dances, or sports. (Rank 1–5: 1 Never, 3 Occasionally, 5 Often)
- The student is anxious during math tasks. (Rank 1–5: 1 Never, 3 Occasionally, 5 Often)
- The student needs additional time to complete work. (Rank 1–5: 1 Never, 3 Occasionally, 5 often)

The DySc Report

Upon completion of the screener and the survey, a report will be generated that consists of four subsections; results of the DySc Tool screening, a copy of the DySc Educator/Guardian Survey, a Recommended Action Plan, and a Recommended Intervention Plan based upon the students results.

DySc Screening Results

This section provides an overview of the student's performance on the screener, consisting of a raw score that provides for each of the four subtests, the number of items answered correctly and the amount of time involved. This will give interested adults a view into how the child performs with problems involving number sense, arithmetic facts, calculations and math reasoning and problem solving.

It also provides a risk score that is derived from the raw scores and depending upon where the total scores fall in a range of 0 to 78 the child will show the following risk score:

YES- a range of 0 to 12correct indicates that there are definite markers for dyscalculia and further evaluation is recommended as well as interventions.

PARTIAL- a range of 13 to 52 correct means there are some indicators present and screening at a later date is recommended as well as immediate interventions.

NONE- a range of 53 to 78 correct means there are no indicators of risk for dyscalculia but since the student is struggling interventions will be useful.

The risk score will determine the Recommended Action Plan and the Recommended Intervention Plan that are provided in the DySc Report.

Educator/Guardian Survey

Also included in the report will be a copy of the Educator/Guardian Survey that can also be shared with interested adults and used to provide further information for any support or diagnosis requests made by the teacher or parent. The survey is color-coded with items related to risk factors showing yellow or red if they are present and those that are not present showing as green. This allows the adults to do a quick comparison of similarity between the survey and the screener and determine if there may be further information needed as to the presence or lack of presence of risk factors.

Next Steps- A Call to Action

Once the screener is completed and the report generated, there will be one of three recommended courses of action the parent or educator can take to help the student. They are as follows based on the Risk Score:

YES - If the screener has a score that indicates yes, indicators of potential dyscalculia were evidenced. The recommendation will be: (1) Speak with your child's teacher and share your concerns. (2) Ask for more information on how to have your child evaluated for a learning concern based upon the policies of your public school district, independent or parochial school. If you are a home-school parent, you will want to talk to the home-school liaison from the district or directly approach an independent school psychologist, psychiatrist, or pediatrician. (3) Maintain your child's self-esteem by reassuring them that they are smart, that anyone can have difficulties with math, and that you are working with experts to determine why and how to support him/her best.

If a formal diagnostic procedure is warranted and comes back as positive, share the proper name of the disorder- Specific Learning Disability- Math or Dyscalculia- with your child. There are support groups that can help with the best way to explain it based on your child's age. Explain that there are supports and interventions that can help them learn math, and you are there to help, as are their teacher and/or parents. Plan on using some of the research-based evidence-supported interventions shared below and be sure to share with your child's teacher or parent, as the case will be immediate. Regardless of whether the student is formally diagnosed and provided with an IEP, the process can take a while, and interventions that can make learning math easier should not wait.

PARTIAL- If the DySc Tool indicates that some risk indicators were present but not enough to clearly signal the need for further evaluation, the recommendation will be to test again in 6 months to a year but to provide intervention support immediately in the areas of math where the student is struggling.

NONE- If the DySc Tool does not show risk indicators at that time but the parents or teachers see that the student is struggling with math, but there is no clear indication that it is in the areas that will be used for the diagnosis, the report will recommend testing again in a year or two, utilize working memory interventions, talk with the teacher, and focus on early numeracy skills until there is no visible struggle.

During the screening and potential diagnostic process, there is the opportunity to have the student be supported via the Response to Intervention process. This can also be implemented regardless of the DySc screener results as it is usually a required step used in the larger diagnostic process to collect data from any interventions used and is a good framework for delivering any interventions that are implemented before a formal diagnosis. In addition, the RtI (Response to Intervention) approach can have benefits to students struggling in math, particularly at risk of dyscalculia and may actually provide information before another screener is done to confirm the presence of indicators of risk (IES, 2021; Berkeley, et al., 2020; Riley-Tillman, 2020). The Response to Intervention (RTI) process is a multi-tiered approach to providing academic and behavioral support to students in schools. It involves a collaborative effort between teachers, parents, and other educational professionals to identify students who are struggling, provide them with interventions and support, and monitor their progress over time. Typically it involves the following steps (US Department of Education, 2017) which are :

Tier 1: In the first tier, all students receive high-quality, evidence-based instruction and support in the general education classroom. Teachers monitor student progress and may provide additional support or interventions to students who are struggling.

Tier 2: In the second tier, students who are not making adequate progress with Tier 1 instruction receive additional targeted support and interventions in small group settings. Progress is closely monitored, and interventions may be adjusted based on student response.

Tier 3: In the third tier, students who continue to struggle despite Tier 1 and Tier 2 interventions receive more intensive, individualized support. This may include one-on-one instruction, specialized interventions, and/or referrals for special education services.

Recommended Intervention Plan

This section of the report will provide specific recommendations for interventions that will help the student improve the targeted math skills of number sense, math facts, math calculation, and mathematical reasoning. Recommendations for specific teaching strategies, technology tools, or specialized instruction will be grouped according to the needs of the child, the four math areas of struggle, the most effective instructional strategies for students struggling with math, and the most effective learning strategies that a child can use as they master the math or approach mastery (Kim et al., 2022).

Although dyscalculia does not have a cure, there is an ever-growing body of research that supports the effectiveness of using early interventions as soon as a child shows they are having difficulties mastering skills and concepts to improve math (Abd Halim, 2018; APA, 2022; Chodura et al., 2015; Dennis et al., 2016; Mahmud, 2020; Manon et al., 2021; Mononen, 2014).

Research also supports matching the intervention to specific content areas of math to increase the intervention's effectiveness and personalize it to the child (Chodura et al., 2015; Haberstroh & Schulte-Korne, 2019; Nelson et al., 2022). However, rather than wait for a child to fail or prove they have a disability, interventions should be implemented immediately as the procedures for diagnosis can take months or longer while the child loses time in successfully building the foundational skills and concepts needed.

It has been shown that with evidence-based interventions, students with dyscalculia can achieve age-appropriate math levels (Bailey et al., 2020; Dennis et al., 2016; Kuhl et al., 2021). It must be noted that most intervention research has been done with elementary-age students rather than secondary students.

We have assembled the key intervention strategies supported by the evidence, that can be readily done by parents and educators, have a strong to moderate effect size in the research and, where warranted, targeted them to the particular area of struggle for the child. The interventions we have focused on are not all-inclusive but effective in all areas of math and, in many cases, for specific areas of math. Because of that we have not felt the need to go deeply into each intervention but rather to give enough of a description for practioners and researchers to recognize the intervention. We have defined interventions for the struggling student as having four distinct components. The teacher/educator determines the best combination to implement based on the students' needs at a particular time. The four areas are:

1. The Child-student supports that impact the ability to learn math.
2. The Math-the particular area of math that will be targeted.
3. The Instructional Strategies- the strategies the teacher chooses to use
4. The Learning Strategies- strategies the teacher has the child learn as temporary or permanent supports.

The interventions are presented in a specific order deliberately. It is critical to support the child first, in order to prevent further anxiety or disengagement with a task that they find difficult and may cause them to believe they are ‘dumb’ or incapable of mastering math.

1. **The Child- Student Support Interventions**

This group of interventions is aimed at supporting the student with improving math anxiety, self- efficacy, working memory, and attention span.

Math Anxiety Interventions

Math anxiety is a common experience for many students, and it can significantly impact their academic performance and confidence. Fortunately, there are a number of interventions that can help to reduce math anxiety (Jordan et al., 2013). These include:

- Positive self-talk: Encourage students to use positive self-talk, such as "I can do this," "I am good at math," or "I can learn from my mistakes." Positive self-talk can help to boost confidence and reduce anxiety.
- Breaking down complex problems: Encourage students to break down complex math problems into smaller, more manageable steps. This can help to reduce feelings of being overwhelmed and make the problem-solving process less daunting.
- Math games and puzzles: Incorporating math games and puzzles into instruction can help to make math more enjoyable and engaging. This may help to reduce negative associations with math and reduce anxiety.
- Errorless learning: Errorless learning is an instructional strategy that increases the likelihood that the student always respond correctly. Rather than respond to an incorrect answer from a student with “no, the answer is not 10. 7+4 =11; the teacher repeats the problem with the correct answer so that what is retained in memory is the correct response. “7+4 = 11, say it with me.” Initial mistakes are prevented so that they are not the most recent memory of the student.
- Activating prior knowledge is a strategy that alerts the student that they will be encountering new information but that there are previous links currently in their memory that are connected. Teacher prompts might include, “ tomorrow we are going to be learning double-digit addition, very much like what you already do, but there will be two numbers instead of one.”

- Real-world applications: Show students how math is used in real-world situations. This can help to make math more relevant and meaningful, and reduce feelings of anxiety.
- Relaxation techniques: Teach students relaxation techniques, such as deep breathing or visualization, that can help to reduce anxiety in math class or during math tests.
- Peer tutoring or support groups: Encourage students to work with peers who are supportive and can provide guidance and feedback. This can help to reduce feelings of isolation and increase confidence in math.
- Professional counseling: If a student is experiencing severe math anxiety impacting their academic performance, it may be helpful to refer them to a professional counselor who can provide additional support and guidance.

Reducing math anxiety is not a quick fix, but a process that takes time and effort. It's important to be patient and persistent in implementing interventions and providing ongoing support and encouragement to students who are struggling with math anxiety.

Self-Efficacy Interventions

Self-efficacy has long been identified as a major contributor to success or lack of success in math. Students with high self-efficacy, the belief that they have done well in the past, an 'I can do it' attitude, and a belief they can do the presented task determine a student's engagement with the math task (Bandura, 2012). It can determine how much effort they will put into the lesson and how long they will tolerate frustration at the task's difficulty. If they are successful, it reinforces the can-do attitude and their judgment of their own competence, and vice versa with failure. If my self-efficacy is high, my math anxiety will be low, and vice versa. Moreover, this also increases mastery of the targeted math skill or concept (Berkowitz, Schaeffer, et al., 2015), and is a strategy that can be combined with any instructional, learning, or student support strategy. It can also be provided directly to the student so that their self-efficacy improves. The most effective ways to help bolster self-efficacy are:

- Ensuring the students participate in and master a task via errorless learning (see above).
- Giving verbal, not written feedback from others including peers, teachers, parents and more proficient adults with verbalization by the adult of the student's capability being the most important to support self-efficacy (Bandura, 2012; Zakariya, 2022).
- Providing the emotional aspect of feeling secure and not fatigued or stressed also bolsters feelings of competence and self-efficacy.
- Providing the child with anxiety coping strategies such as breathing and relaxation techniques can also address this issue and are particularly useful for high-stress situations such as test-taking.
- Gamification or computer-assisted instruction also addresses self-efficacy and anxiety issues as the child competes against themselves, has immediate feedback,

and is in a low-risk non-social environment (Baten & Desoete, 2018; Kohn et al., 2020).

Working Memory Interventions

Students with dyscalculia commonly have issues with working memory. Working memory is an important cognitive skill that allows us to temporarily store and manipulate information such as the retrieval of math facts. It is considered to be a domain general area of struggle (Geary, 2013). It plays a crucial role in a wide range of academic activities, including reading, math, and problem-solving. Improving working memory can, therefore, have a significant impact on academic performance. Effective interventions include:

- Presenting information in chunks that can be more easily accessed and maintained when completing problems. Chunking involves breaking down information into smaller, more manageable chunks of information (Dueker, 2022). This includes teaching to remember the number in chunks to break down longer strings of numerals, memorizing a phone number, or using rhythmic skip counting. Other examples include grouping vocabulary by word families- such as the operations and turning them into an anagram or silly phrase or using a modified Frayer chart.
- Another strategy is taking multistep tasks and presenting the information in subsets of the task, making sentences shorter, or using paper to reveal information slowly. Drawing lines where place value is being worked or circling

key information in word problems are all simple steps to take that help the student, and students can be taught to do them when performing other tasks.

- Providing wait times that are long enough to process info, especially new concepts, skills, and procedures is an effective intervention (Geary, 2013; Gersten, 2011).
- Using mnemonic strategies that involve using mental images or associations to help students remember information. Teaching students to remember a list of words by creating a story or visualizing each word in a unique way.
- Verbal rehearsal, which involves repeating information aloud to oneself to help store it in working memory is another strategy(Bergman-Nutley & Klingberg, 2014).
- Visual-spatial strategies involve using mental images or spatial relationships to help remember information (Arsalidou & Taylor, 2011). Teaching students to use a spatial map to remember the location of items in a room is an example.
- Computer-based games and training programs are available that can help improve working memory. These programs often involve games or activities that challenge students to remember and manipulate information.

When implementing any of these interventions, it's important to provide explicit instruction and practice opportunities. Additionally, it's important to ensure that the interventions are appropriate for the student's age and cognitive abilities and that there is proof of efficacy for that intervention.

Attention Span Interventions

Attention span is a critical factor in a child's ability to learn and perform well academically. Children with shorter attention spans may struggle to stay focused in class or complete assignments. For children who have been diagnosed with ADHD, a consult with the educational or therapy provided is a needed step. Intervention strategies that can be used to increase attention span in children include:

- Break tasks into small, manageable chunks: Smaller, more manageable chunks of information or tasks makes them less overwhelming and easier for a child to accomplish. Completing the first 3 steps is always easier than doing a set of 10 steps. This can help children stay focused and engaged.
- Increase physical activity: Children benefit from regular physical activity, which can help improve focus and concentration. Encourage activities such as recess, physical education classes, or after-school sports programs. Children benefit from short movement breaks during the day. This can help release energy and increase focus during other activities. Another example would be the use of stations or centers in the classroom along with a scheduled rotation. This builds in movement during the class period and also provides structured routines. Even when we are training, best practice is to change the activity or focus every 15-20 minutes.
- Use visual aids: Visual aids, such as diagrams, charts, or videos, can help capture a child's attention and make the learning experience more engaging and memorable. Another idea is to use the student's interest to inspire the visual supports. We often use the student's particular interest or "fascination" to help us

develop the visual supports. The student is more likely to attend to something that normally he/she might ignore.

- Provide clear instructions: Children with shorter attention spans benefit from clear, concise instructions. Break down tasks into steps and give frequent reminders about what needs to be done.
- Use positive reinforcement: Praise and rewards for good behavior and focus can be motivating and help children stay on task.
- Include errorless learning: Always start a problem-solving response by the teacher with the correct answer so that students can hear and remember what is correct rather than remembering that the first response by the adult was, wrong, the answer is 8 not 7.

It's important to remember that every child is different, and what works for one child may not work for another. Be patient and persistent in trying different strategies to find what works best for each child. Also, consult with a child's teacher or a mental health professional if the child's attention span is consistently shorter than expected for their age.

2. **The Mathematics Interventions**

Mastery of number sense, being fluent and accurate in arithmetic facts, understanding whole number computation, and mastery of problem solving and reasoning are critical for being able to master the math progressions. These foundational areas are positively related to performance in other math skills and can predict performance in later years on math assessments (Fuchs et al., 2012: Jordan et al., 2013). Students with dyscalculia show evidence of difficulty in these areas and interventions that target distinct areas of struggle are effective.

The research suggests that the deliberate intervention on or training of specific areas of math weaknesses works by actually enabling the student to learn the needed skill or concept using the typical neural pathways and decreasing the future load on working memory and attention systems once mastered (Aquil, 2020; Chodura et al., 2015; Dennis et al., 2016) This constitutes the strengthening of the typical pathways and areas of the brain rather than compensatory areas being enabled. Plasticity in the neural circuits or adding additional white matter, myelin, to the neural pathways was supported (Menon et al., 2021).

It must be noted that by intervening specifically in these four areas, other areas of math need not be ignored and, in fact, should not be. But for the purpose of the DySc Report, we have focused on the four foundational skills most commonly noted as being a struggle for students with dyscalculia. It is also important to note that by targeting these areas, there will be the potential to impact the ability of the child to show the mathematical habits of mind and skill that the National Council of Teachers of Mathematics (NCTM) feels are needed in order to be successful in mathematics as they grow older.

Number Sense

Number sense is a rudimentary system we are born with, but its continued development makes formal math possible. Therefore, intervention in the form of the explicit instruction of number sense is critical to improving this skill when a student shows signs of struggle (Dennis et al., 2016; Geary, 2013; Nelson, 2019), as number sense enables students to succeed in the classroom (Halberda, et al., 2008; Kucian, 2015; Kucian et al., 2011; Wilson, Dahaene et al., 2006).

Instructional interventions that have shown success in improving number sense include (Fyfe, 2019):

- Games that require counting and recognize that one number is larger than another, such as Chutes and Ladder or Connect 1. This focuses the intervention on attaching the numerical symbol to the magnitude and helps with addition and subtraction.
- Using manipulatives and visual aids or the concrete-representational- abstract framework to understand the connection between the physical object and its abstract symbol. Using the TouchMath technique has been shown to be effective in teaching math facts. It is a multisensory approach, combining visual, auditory, and tactile actions as the student places dots or object pictures on the concrete object, drawing or the abstract numeral. This simultaneously allows the child to connect the concrete, semi-concrete and abstract version of the numeral. As the child reaches mastery in number recognition, the dots are removed.
- This can include dice, counters, TouchMath numerals, texture cards, etc.(Yikmis, 2016.)
- Having students draw the physical item or represent it with dots, squares, etc. before attaching the appropriate symbol to the drawing. The use of the TouchMath BiDiWi sheet is an effective instructional strategy.

- Multisensory math instruction involves using a variety of senses to help children learn math concepts, this includes having them touch, look at, hear the numeral and say the numeral in order to enable greater connections in the areas of the brain needed for memory of the numerals. For example, using visual aids, such as pictures and diagrams, can help children understand math concepts, while tactile activities, such as tracing numbers, can help children develop their phonological processing skills.

Number sense is an important aspect of math that involves understanding the relationships between numbers and their properties. Learning strategies that can help students improve their number sense in math:

- Use fingers to count with or finger tapping, drawing TouchPoints
- Play math games: Math games can be a fun and effective way to develop number sense. Board games for students 6 and under such as Candyland, Go Fish, and Connect 4, as well as games that use spinners or dice, can hreinforce number sense skills while providing for engagement fun.
- Use manipulatives: Manipulatives are physical objects that can be used to represent numbers and help students visualize math concepts. Examples of manipulatives include blocks, tiles, and number lines, Touch Numerals.
- Estimate and round numbers: Estimating and rounding numbers can help develop a sense of number magnitudes and improve mental math skills. Practice rounding to the nearest ten, hundred, or thousand is an example.

- Compare numbers: Comparing numbers develops a sense of the relationships between numbers. Practice comparing numbers using symbols such as <, >, and =.
- Break numbers down: Breaking numbers down into smaller parts to understand their properties and relationships. For example, break 24 into 20 and 4 or 10 and 14 to help understand ithe composition of the numeral.
- Visualize numbers: Visualizing numbers such as picturing numbers on a number line or using diagrams.
- Practice mental math: Practicing mental math also improves number sense and the ability to do calculations mentally. Practicing basic operations such as addition and subtraction, then progressing to more complex problems is the recommended progression.
- Counting games: Counting games can help children practice their phonological processing skills by counting out loud. Examples of counting games include counting objects in a room, counting steps as the student walks up and down stairs, and counting the number of times one can bounce a ball.
- Math manipulatives: Blocks, beads, and counters, help children develop their phonological processing skills by allowing them to physically manipulate objects while orally counting and doing 1:1 correspondense problems.
- Music activities- Music-based math activities can help children develop their phonological processing skills while having fun. Examples of music-based math activities include singing math songs, clapping out math problems, and playing math games that involve music.

Memorization of Arithmetic Facts

Chodura et al. (2015) and Dennis et al. (2016) found in their meta-analysis of interventions for children with mathematical difficulties that training in basic arithmetical competencies, the math facts, was especially effective for the child with dyscalculia.

Instructional strategies that have shown success in improving memorizing math facts include:

- Using the TouchMath technique has been shown to be effective in teaching math facts. The multisensory approach, combining visual, auditory, and tactile actions as the student places dots or object pictures on the concrete object, drawing or the abstract numeral; simultaneously allows the child to connect the concrete, semi-concrete and abstract version of the math fact. As accuracy and mastery are met, the dots are removed (Fletcher, et al., 2010)..
- Extensive rehearsal or regular practice. Setting aside regular practice time each day to help the child build fluency with arithmetic facts. This could involve using flashcards, practicing mental math, or playing math games that focus on arithmetic skills such as dominoes. Incorporating games and activities that are fun makes memorizing arithmetic facts more engaging and enjoyable for the child. This could include using online resources, math apps, or board games that focus on arithmetic skills. Memorizing math facts is easy to make into short fun, beat my last score games.

- Use visualization to help the student visualize arithmetic facts in their mind. Encourage them to create mental images or use manipulatives such as blocks or counters to help them visualize the facts
- Focus on one set of facts at a time in order to not overwhelm the student by trying to memorize all arithmetic facts at once. Instead, focus on one set of facts at a time, such as addition or subtraction, and gradually add more sets as mastery is reached.
- Provide positive reinforcement, especially adult verbal praise that is specific to the problem or task performed. This can also include a small reward if appropriate when progress or mastery of arithmetic facts is demonstrated.
- Being patient and supportive and remembering that memorizing arithmetic facts can be a challenge for the student with dyscalculia is essential. Encouraging the child to keep practicing and trying their best is critical.
- Use of quick sprints or math fluency tests to assist in memorization of math facts also is needed. It is important that these timed tests do not have the student compete against others; only themselves for increasing accuracy and then speed.

Learning strategy interventions that are especially effective for memorizing math facts include:

- The use of counting all or on with one's fingers, placing TouchPoints on numerals or tally marks to support counting
- Fact tables that the child fills in only for the facts not memorized.

- Practicing the facts over and over again can help to reinforce them in the memory.
- Remembering the patterns and chunking long numbers such as the sing-song cadence of saying the 5's tables and chunking phone numbers.
- Number rhymes can help children learn number sequences and improve their phonological processing skills. For example, reciting "One, two, buckle my shoe" can help children learn the numbers one to ten in sequence.
- Using the Frayer-model, BIDIWI, and other visual aids, such as charts, diagrams, or pictures, that can help to make math facts more concrete and easier to remember.
- Finding and playing games involving math, such as "Math Bingo" or "Math War" to boost motivation.

Whole Numbers Computation that is Accurate and Fluent

Understanding and being fluent in using whole numbers has been positively related to achievement in other math skills and is predictive of subsequent algebraic reasoning success. These skills are the foundation for many of the subsequent math skills needed for the entirety of the math progression, and failure to master one can impact future fluency (Avant & Heller, 2011; Calik & Kargin, 2013; Fyfe, 2019; Fuch et al., 2012; Jordan et al., 2013; Kim et al., 2022). When students learn to do the operations, they are evaluated on accuracy or successful acquisition of the skill and then fluency or the speed at which they can perform the computation. Because of the importance of speed and accuracy or automaticity, interventions for working on whole numbers and their operations should ensure the student can do the operation and then increase the speed or fluency. Research also supports that frustration and anxiety decrease if a student can perform the operation accurately and then move to increase the speed of computation (Fuchs et al., 2008).

Instructional interventions that have shown success in improving math computation are:

- Timed trials or practices with paper and pencil where the student only competes against themselves to improve accuracy and speed.
- Computer games that enable practice for memorization and fluency,
- Using concrete and semi-concrete versions of the facts as well as visual aids is effective in teaching computation. When presented using a multisensory approach these activities have been shown to be effective. In addition, the provision of additional concrete referents such as finger tapping and semi concrete referents such as TouchPoints or tallies helps students move forward in the progressions (Abdou, 2020; Cihak & Faust, 2008; Green, 2009; Simon & Hanrahan, 2004; Urton et al., 2022; Yikmis, 2016.)
- Flash cards and dominoes, with the focus being to increase accuracy before speed by working on increasing the speed of number facts retrieval by students doing math facts timed activities.
- Conceptual understanding of arithmetic procedures such as using a mind map or mathematical modeling to assist in conceptual understanding (Powell, Fuchs, et al., 2009).

- Word problem-solving such as breaking problems down into smaller steps (Fuchs, Fuchs, et al. 2012)

Learning strategy interventions that are especially effective for math computation include:

- Using number bonds/fact families templates by the student can enable them to tackle problems that are normally difficult.
- When unsure of the skip counting sequence and/or multiplication facts for a specific number, the student writes down the number to be used, adds TouchPoints and uses repeated counting to build themselves a skip counting sequence and the multiplication facts for that number. It should be noted that the use of adding TouchPoints to a number, finger tapping and other learning strategies does not prevent acquisition of math facts or automaticity, strategies such as these are used as a support system and are dropped when no longer needed (Vinson, 2005).
- Use mnemonics for the order of operations, process for long division, and whole part relationships for fractions and ratios.
- Use of a number line to assist with addition, subtraction, rounding, greater than, and less than.

Accurate Mathematical Reasoning

Mathematical reasoning is the process of deciding; using critical, creative, and logical thinking (Erdem & Gürbüz, 2015). It is a critical skill for success in math and other STEM fields (Bulat et al., 2017; Espina et al., 2021). Accurate mathematical reasoning refers to the process of using logical and precise methods to arrive at correct solutions to mathematical problems. Key elements include:

- Understanding mathematical concepts: In order to reason accurately in mathematics, one must have a solid understanding of the underlying concepts and principles. This includes understanding the definitions of mathematical terms and symbols, as well as how to apply these concepts in different contexts (Yoong et al., 2022).
- Using appropriate mathematical methods: Accurate mathematical reasoning also involves using appropriate methods and techniques to solve mathematical problems. This may include using formulas, algorithms, or mathematical models to arrive at a solution.
- Checking for errors: Accurate mathematical reasoning requires attention to detail and the ability to identify and correct errors in one's work. This may involve double-checking calculations, verifying assumptions, or checking for consistency with previous work.
- Communicating results clearly: Finally, accurate mathematical reasoning involves the ability to communicate mathematical results clearly and concisely. This may involve using appropriate mathematical notation, providing clear explanations of

the methods used, and presenting results in a way that is understandable to others. Overall, accurate mathematical reasoning is a critical skill for success in many academic and professional fields, and requires a combination of knowledge, skills, and attention to detail.

Instructional interventions that have shown success in improving mathematical reasoning are:

- Logic games, such as Sudoku and crossword puzzles, can help children develop their logical reasoning skills by improving their ability to analyze relationships and make connections between different pieces of information.
- Explicit, systematic instruction of problem solving strategies, such as breaking a problem down into smaller parts and looking for patterns, can help children develop their logical reasoning skills by teaching them how to analyze complex information and make connections between different pieces of information.
- Math talks involve presenting children with open-ended questions and encouraging them to explore different solutions. This can help children develop their logical reasoning skills by encouraging them to think critically and analyze relationships between different pieces of information.
- Number sense activities, such as counting, skip counting, and number patterns, can help children develop their logical reasoning skills by improving their ability to analyze relationships and make connections between different pieces of information.

- Mathematical reasoning tasks involve presenting children with complex problems and asking them to solve them using logical reasoning. These tasks can help children develop their logical reasoning skills by teaching them how to analyze complex information and make connections between different pieces of information.
- Tangrams are a set of seven shapes that can be combined to create a variety of different designs. Using tangrams can help children develop their spatial skills by allowing them to manipulate shapes and visualize how they fit together.
- 3D visualization exercises involve presenting children with 2D drawings and asking them to imagine what the object would look like in 3D. These exercises can help children develop their spatial skills by improving their ability to visualize objects in space.
- Block building involves using blocks to create structures and designs, such as Legos or Kinex. This activity can help children develop their spatial skills by allowing them to manipulate objects in three dimensions and visualize how different shapes fit together.
- Spatial puzzles, such as jigsaw puzzles and maze puzzles, can help children develop their spatial skills by improving their ability to visualize and manipulate objects in space.

Overall, these interventions can help children develop their logical reasoning skills and improve their math proficiency. It is important to note that these interventions should be tailored to the individual needs and learning styles of each child, as each child is unique.

Effective learning strategies for students struggling to demonstrate mastery include:

- Using self checking of math problems through inverse operations, such as addition and subtraction checks (5-2=3 and 3+2=5)
- Creating a story map of the problem and talking out loud through the steps.
- Looking at a completed Frayer-chart and trying to identify any errors; error analysis.

3. **Instructional Strategy Interventions**

In the course of improving the student's math skills in the four targeted domains, there are instructional strategies that research supports as being especially effective. These evidence-based actions or interventions that the educator can take include:

- Multisensory interventions act to increase motivation and boost conceptual knowledge gain (APA, 2022; Mahmud, 2020). This includes dance which involves the whole body, as well as choral response, which is not only engaging and provides for engaging practice but also is known to help the brain retrieve facts (Doi, 2018). It also includes the use of presenting visual, auditory and tactile sensations concurrently as is used in the TouchMath materials (Abdou, 2020;

Taneja, 2019; Urton et al., 2022; Vinson, 2004; Waters & Boon, 2011; Wisniewski, 2002).

- Systematic explicit instruction has been found to be the most effective approach for students with dyscalculia as well as other populations (Chodura, et al., 2015; Dennis et al., 2016; ERIC, 2022; Mononen, 2014). especially when focused on basic arithmetic competencies. Explicit instruction contains instructional elements such as a review of prerequisite skills, checking for understanding, direct instruction, guided practice, independent rehearsal/practice, etc.
- Immediate feedback helps with math facts (Fuchs, et al., 2012)
- Computer Assisted Instruction (CAI) can adapt to the child's learning speed as students with dyscalculia typically need more structure and time. CAI also provides immediate feedback and the gamification is an important engagement tool for many students (Chodura, et al., 2015; Kohn et al., 2020; Mahmud, 2020; Mononen, 2014) In addition, because it is 1:1, there is the ability for it to be non-competitive and reduce fear of failure as the child is competing against themselves, thus reducing math anxiety. This also includes the use of graphing software as well as gaming software which allows for unlimited practice as well as motivation due to its high engagement factors.
- Extensive rehearsals-especially for fluency and automaticity. All students benefit from multiple opportunities to do or practice a new concept or skill until mastery, including those with dyscalculia. Initial practice sessions should be closely supervised to ensure that the sessions result in reinforcement for accuracy the

first time around and that errorless learning is implemented (Bulat et al., 2017; Espina et al., 2021).

- Timed drills where the student is competing against their own time only and results are immediate and reinforced appropriately are effective for increasing processing speed for retrieving math facts and reinforcing as the student only competes against their own time (Mahmud, 2020).
- Errorless learning and wait time provide time to properly process new information or a problem (Mahmud, 2020), minimizing learning challenges. Another intervention, called mathematical discourse, is the communication styles in the classroom, utilizing strong math vocabulary and teacher-student, student-teacher, and student-student discussions about mathematics that lead to a conceptual understanding of the curriculum being practiced is effective for mathematical problem solving and reasoning.
- Cumulative reviews is strong best-teaching practice. A strong cumulative review ties in different areas of the curriculum and helps students create conceptual frames around the structure of the dependencies of mathematics.
- Concrete-Representational-Abstract (Bouck et al., 2018; Jacobsen, 2020; Mahmud, 2020; Mononen, 2014) clear representations with manipulatives, providing concrete and visual aids for problem-solving and practice so that students can connect abstract symbols and numerals to their numerical values. The use of color is encouraged as it adds an extra element of being engaging to any age student. The use of dice, Touch Numerals, etc. allows student to directly

connect the concrete and the abstract. Using cereal, beads, tiles, and chips also enables a tactile technique for engaging the students and explore the math concept or demonstrating their understanding of it (Cihak & Faust, 2008; Yikmis, 2016; Ellingsen & Clinton, 2017; Fletcher, 2010; Kot et al., 2018; Taneja, 2019).

The list of effective instructional strategies that are research backed has increased over time (Hattie, 2023) and we have highlighted the ones we have found most effective and easy to implement by teachers and parents. Other strategies include peer-assisted learning (Mononen, 2014) teaching examples and non-examples, providing sample problems, explicit vocabulary instruction to make it easier to recognize words tied to a problem, the Universal Design for Learning (UDL), on-going progress monitoring, such as Curriculum Based Measurements,

4. **Learning Strategy Interventions**

When a student has dyscalculia there will usually be areas of mathematics that they will struggle with permanently and there are strategies they can use to solve the problems. The use of a smartphone is one of the most frequently used but if that is not available and the student is in the process of mastering the skill there are alternative ways of approaching the problems that will allow them to solve it in a less efficient but still successful manner.

Learning strategies can be taught as temporary or permanent supports as they learn to master various math concepts and skills. These include:

- Taking time to review work, deliberately teaching students to slow down and read a problem twice, asking themselves if the answer is logical can help them avoid errors
- Using templates and graphic organizers such as Frayer charts, BiDiWi templates help students
- Having students solve a problem and then use the inverse operation to check their work decreases mistakes but also gives the students additional methods to solve problems
- Writing down the steps before attempting to solve a problem (Kroesbergen et al., 2022)
- Having students take large tasks and break them down into smaller tasks and then complete them in order (Arizmendi et al., 2021; Kroesbergen et al., 2022).
- Instructing students in schemas; the frameworks, outlines and plans that are used to solve problems is also an effective intervention (Driver & Powell, 2017). Students can use the schemas to organize information from a word problem in ways that represent the underlying structure of the problem.
- Explicit sharing of the scaffolds that teachers have put in place for a struggling student can enable the student to have a better understanding of how and why they are struggling and the supports they can use to help themselves as they work toward mastery. An example would be the teacher removing distractions from a room to aid a student who is easily distracted. The student in turn could

deliberately choose settings to complete their math work that they recognize as not being distracting.

Discussion

When administering a dyscalculia screener, there are some cautions that should be taken into consideration. We have attempted in our design to accommodate these throughout by the use of appropriate procedures, questions and the collection of additional information that can be used by diagnosticians. These include:

Age and cognitive ability: Dyscalculia screening tools are designed for specific age ranges and cognitive abilities. It is important to use a screener that is appropriate for the age and cognitive ability of the individual being assessed.

Cultural background and language: The screener should take into account the cultural background and language of the individual being assessed to ensure that it is culturally sensitive and appropriate.

Accommodations: Accommodations should be made for individuals with disabilities or special needs to ensure that they have an equal opportunity to participate in the screening process.

Validity and reliability: It is important to use a screener that has been scientifically validated and has shown to be reliable in identifying dyscalculia. The screener has demonstrated validity and reliability in identifying dyscalculia, and additional data collection and review with any appropriate changes will ensure that validity and reliability are maintained .

Ethical considerations: Ethical considerations should be taken into account when administering a dyscalculia screener, including obtaining informed consent from the individual or their legal guardian, ensuring confidentiality, and providing feedback and support to the individual after the assessment.

We would also strongly encourage future studies using this tool to be undertaken in order to provide continued evidence of fidelity, validity, and reliability. Furthermore, it would demonstrate the sensitivity of the tool or the ability to identify those that have dyscalculia as evidenced by diagnosis rates after screening. It should also have specificity (identifies those without the condition). Future studies are needed for research on division as our search uncovered none nor have other searches (Kim, 2022; Price & Ansari, 2013). We also call for additional research on the effectiveness of specific student, math, instructional and learning strategy interventions for dyscalculia, particularly with young students in order to find and support students in the most effective manner and early in their academic path. Another area for research is the combined dyslexia and dyscalculia comorbidity in order to tailor interventions that can address both issues as there appears to be a substantial overlap of appropriate supports.

In conclusion

Dyscalculia is a learning difficulty that affects a person's ability to understand and work with numbers. It appears that the prevalence rate is the same as dyslexia, 5-7% of the population, it is not gender specific and it is dramatically under identified in comparison to dyslexia. There appears to be consensus in the current research that it is a neurodevelopmental disorder that affects the regions of the brain and the supporting neural network that connects those regions involved in numerical processing such that it is difficult to master the key foundational skills and concepts of number sense, arithmetic facts and calculation and math reasoning to such a degree that mastery of subsequent skills is impossible or severely impacted. Working memory, attention span, phonological processing, and processing speed are also impacted.   Struggles in these areas manifest in not only academic struggles with math but in daily tasks that use math such as being on time, judging distance, measuring ingredients, using a budget, determining how much fuel is in a car or the size of a tip.

The evidence from research also supports that with early identification and targeted intervention for those specific areas, the potential for mitigation is immense, to the degree that math performance for an individual with dyscalculia can rival a non-dyscalculic peer. That same evidence cuts across all levels of student math ability giving support to using the same interventions as a tool for early math intervention for students not showing the same degree of risk factors or only showing signs of struggle in the four foundational areas.

For that reason we developed a screener and support documents that are easy to use by educators or parents and indicate the presence of the risk factors that would prevent mastery of the key foundational numeracy areas. We also provided suggestions for evidence-based activities that can be used immediately as interventions and have been shown to be effective. This allows additional time for adults to discuss the long-term plan for support withhout losing the opportunity to have an impact on the problem at hand. Regardless of whether there is a diagnosis of dyscalculia or the child is temporarily struggling, successful mastery of the early numeracy skills is the goal as we all master math by following the same path for the mathematics progressions.

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