DIGITAL ACCESS TO SCHOLARSHIP AT HARVARD
DASH.HARVARD.EDU

HARVARD LIBRARY
Office for Scholarly Communication

Exploring Dyscalculia and Its Effects on Math Students

Citation
Cornue, Julia W. 2018. Exploring Dyscalculia and Its Effects on Math Students. Master's thesis, Harvard Extension School.

Permanent link
http://nrs.harvard.edu/urn-3:HUL.InstRepos:42004020

Terms of Use
This article was downloaded from Harvard University's DASH repository, and is made available under the terms and conditions applicable to Other Posted Material, as set forth at http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#LAA

Share Your Story

The Harvard community has made this article openly available.
Please share how this access benefits you. Submit a story .

Accessibility

Exploring Dyscalculia and its Effects on Mathematics Students

Julia Warena Cornue

A Thesis in the Field of Mathematics for Teaching

for the Degree of Master of Liberal Arts in Extension Studies

Harvard University

May 2018

Copyright 2018 [Julia Warena Cornue]

Abstract

This thesis project will provide a detailed analysis of the current state of knowledge about the mathematical learning difficulties of dyscalculia. The project will include information about the much more well known learning disability of dyslexia, and will discuss the relatively high level of responsiveness, including testing and interventions, which have been used for reading and writing development. This thesis project will discuss the definition, history, diagnosis, and characteristics of dyscalculia, as well as describe relevant educational interventions. Information about dyscalculia will be collected through interviews with math educators, students struggling with dyscalculia, psychologists, and skills teachers who focus on the learning profiles of students. Information for this project will also be collected through a careful review of relevant literature and studies on dyscalculia.

A major concern, which will be discussed at length in this thesis, is whether educators have been missing opportunities to provide proper support to students with dyscalculia. It is our hypothesis that much more needs to be done to address the issues that students struggle with who have dyscalculia. Part of the focus of the thesis project will include creating a guide for teachers, to provide them with critical information for them to help support students who struggle with dyscalculia. This guide will incorporate a sample lesson plan, demonstrating potential interventions and support techniques that can be used, as well as highlight what attributes stand out when a student is struggling with dyscalculia.

Dedication

To my husband, family and friends for all of their love and support throughout this process. I could not have gotten through this with out the thoughtful words of encouragement from Jon David; my husband,

Martha; my mother, Dale; my father, and Rebecca; my dear friend.

Acknowledgments

Many thanks to John Wesley Cain

for his positivity, thoughtful advice and thorough feedback

through the development of this thesis project.

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

The term acalculia was coined in 1919 to describe arithmetic disorders, and preceded the term dyscalculia by nearly 50 years (Berch, Mazzocco, 2007, p. 11). Compared to dyslexia, few people are diagnosed or consider themselves to have dyscalculia (Michelle de Almeida Horsae Dias, 2013). When it comes to having trouble with mathematics, students and parents tend to blame their struggles on many different learning deficiencies, but rarely connect these to dyscalculia. What if the student has dyscalculia, but is not recognized? Could we as a teaching community be doing more for these students than we currently are? It is troubling to think that there is a less recognizable learning disability impacting student's ability to learn mathematics. Dyscalculia can be most closely compared to dyslexia and the ability to learn how to read and write. Texts that help clinicians with diagnosis, such as the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), refer to dyscalculia as a "Specific Learning Disorder with impairment in mathematics". The DSM-5 also refers to dyslexia as a "Specific Learning Disorder", but with "impairment in reading". Dyslexia and dyscalculia fall under the same umbrella within the DSM-5, but the prevalence of the dyslexia diagnosis seems far higher.

It has been suggested that when a person states they are bad at math it comes across as a relatively normal statement.

> Dyslexia and dyscalculia can exist in isolation from each other. It is fair to say that of the two disorders, dyslexia is usually more readily

> recognized, and remedied, while mathematical difficulties often seem to go unnoticed. Perhaps this is because mathematics is often seen as an unusually challenging subject, where it is 'normal' and therefore acceptable for otherwise capable pupils to have difficulties (Hannell, 2013 p. 5).

This quote from Hannell's article, *Dyscalculia: action plans for successful learning in mathematics*, shows us a summary of society's view on students struggling in mathematics and these struggles holding less weight relative to struggles with reading and writing. In comparison, when a person states they are a bad reader, society places an increased amount of attention on that person. It is believed that this person needs support in order to move forward in their life. As will be discussed later in this thesis, the initial neglect of students' challenges in mathematics can often lead to significant delay to their mathematical development.

When becoming confident in different school subjects, mathematics holds the reputation of not being comprehensive to the general population. "Several investigators have determined that mathematical learning problems are relatively common" (Dowker, 2008, p. 144). Many students who might be suffering from dyscalculia, and who could potentially be helped, are going through their high school career thinking that they are acceptably bad at math. If a student is not supported properly at an early age in mathematics, learning gaps will develop throughout their school years. As these gaps compound, the end result is an increasingly negative and frustrating situation for the student. "The consequences of dyscalculia for the individual include longstanding disadvantage in education, employment and life skills" (Hannell, 2013 p. 4). As educators, we can work with our students to alleviate these frustrations. The article, "Assessment of the awareness of dyscalculia among educators", shows that 45.2 % of educators who took a questionnaire on dyscalculia reported not to know what dyscalculia is while only 12.9% reported that they can recognize signs of dyscalculia (Michelle de Almeida Horsae Dias, 2013). These percentages show the lack of overall understanding and knowledge amongst the teaching community.

It is quite challenging to define exactly what dyscalculia is. Some have defined it as a "neurologically based disorder of mathematical abilities" developed at an early age (Wadlington and Wadlington, 2008, p. 2). Other studies have found that "developmental dyscalculia cannot yet be identified based on the direct observation of brain functions, but has to be diagnosed based on tests of mathematical abilities in relationship to the child's general IQ" (Dinkel, Willmes, Krinzinger, Konrad, Koten, 2013). See also Chapter 2 regarding definitions and diagnosis. Diagnosing a student with dyscalculia is quite involved. This mathematical disability seems to stem from, and can be mistaken for, multiple other conditions involving issues related to memory, language and anxiety. General math students can have difficulties in one of, or multiple areas listed, but that does not mean they necessarily have dyscalculia. Studies claim that dyscalculia cannot be clearly diagnosed without visual representation of the mathematical deficiency through written tests (Wagner, Karl, personal communication, November 4 2017). Only after a thorough evaluation of a student's overall learning process, can an accurate diagnosis be determined (Wagner, Karl, personal communication, November 4 2017). This is also the case when diagnosing dyslexia. Based on the preceding scholarly references, proper testing should incorporate memory, writing and reading.

When learning mathematics, one has to follow steps and work through examples to understand how certain concepts work. Memory processing, language development and reading skills play a role in understanding and developing mathematical knowledge. Dyscalculia is often undetectable by disorders associated with memory, language, reading, and learning anxiety without proper testing. For example, many students are capable of working through individual problems when notes and examples are present as support, but once the support is removed, they have trouble organizing the steps and information in order to work independently on paper (Hannell, 2013 P. 9). This mostly affects students with certain memory disorders. An analogy can be made to a dry erase board - if someone has notes written all over such a board but then, erases sporadically where some information is still visible, certain students will then lose a sense of how the words are pieced together. This is how some individuals with memory challenges view mathematics when taking an assessment or doing homework without notes. “Pupils with dyscalculia often cannot, or do not, use their own internal language to manage the mathematical tasks they are attempting (Garnett, 1998)” (Hannell, 2013 P. 9). Later in this paper we will evaluate beneficial testing options for young students to identify those who show signs of dyscalculia and should seek further testing.

One of the primary areas of focus for testing dyscalculia is evaluating a student’s memory. Dyscalculia can be broken down into categories that highlight three different types of memory conditions.

1. *Semantic memory:* difficulty retrieving arithmetic facts.
2. *Procedural memory:* difficulty understanding and applying mathematical procedures.
3. *Visuospatial memory:* difficulty understanding spatially represented numerical information such as misalignment of columns, place value errors, or geometry.
   (Wadlington and Wadlington, 2008, p. 3).

These three memory conditions outline one of the underlying difficulties a student faces when struggling with dyscalculia.

In addition to memory, language can cause many obstacles for students when learning mathematics. Not only does mathematics have its own category of language, but it also brings in different symbols that are new and abstract to many students when they see them for the first time.

> Language processing disabilities such as dyslexia (i.e., reading disability) or dysgraphia (i.e., writing disability) can hinder a person's ability to learn vocabulary and concepts and use symbols, signs, and operations. For example, people with language-processing disabilities often have problems with directionality, sequencing, and organization (Wadlington and Wadlington, 2008, p. 3).

Language is one of the factors that is characterized in both dyscalculia and dyslexia. This common characteristic represents an overlap between the two learning deficiencies (LD). Those who struggle with dyslexia or dyscalculia, have somewhere between 20% and 60% chance of struggling with both learning deficiencies (Hannell, 2013, p. 5). In addition to the previously mentioned characteristics there are other factors that can be common with both deficiencies.

The anxiety many students encounter when confronted with mathematics is not a learning disability (Wadlington and Wadlington, 2008, p. 3), but can be caused by LD's such as dyscalculia and dyslexia. Anxiety can have a large impact on a student's ability to successfully retain material and succeed on tests. The notion of not being a "math person" develops an avoidance of the subject due to the anxiety that results from prior struggles in the subject matter. When students perform poorly on examinations as a result of anxiety, it then commonly will lead to increased anxiety for future examinations. This spiraling pattern of anxiety leading to failure produces a continuous obstacle when attempting to learn future material. Once these anxiety triggers are recognized, the student has a better chance of effectively managing their anxiety. Dyscalculia can directly cause anxiety and this can present an additional obstacle for the students to overcome.

Another factor that affects the LD is a student's background outside of the classroom, including their genetics. Developmental success in mathematical skills might be partially due to one's upbringing.

> For instance, Shalev and Gross-Tur (2001) found that about 50% of the siblings of a pupil with dyscalculia could be expected to have similar difficulties. Parents and siblings of a pupil with dyscalculia are ten times more likely to have dyscalculia than members of the general population (Hannell, 2013, p. 5).

Are these statistics due to genetics or are they due to the environment in which the child is developing? This, as well as other confounding factors, will be further evaluated later in this thesis, specifically during the student interview. Additional factors that may lead to signs of mathematical difficulties include a student's lack of motivation, and/or an instructor's lack of teaching experience. Experiencing either of these factors at a young age can potentially obstruct a student's mathematical learning path because gaps in their learning have developed within their prerequisites.

The lack of motivation or proper prior instruction can mask the presence of dyscalculia. This scenario is one of the most challenging situations to overcome, where a student lacks the mathematical background to advance while they are also struggling with an unrecognizable learning disability. This shows why a student needs to be diagnosed through written tests and not by visual representation. Students who do not struggle with dyscalculia should be able to learn the material with proper instruction. A person with dyscalculia will need more support and will show a slower response rate (Hannell, 2013 P. 4).

Due to the various characteristics involved with dyscalculia, the mathematical areas in which the student with dyscalculia is struggling with may vary. When learning mathematics some students may appear to be more skilled with the visual side of the subject, as in the case of learning about geometry. Other students appear to be more comfortable with the magnitude side of mathematics, as in the case of learning algebra. For every learning deficiency, there are different forms of interventions. Usually these different interventions are laid out so educators can use them in particular situations to help students learn certain subjects to their greatest potential. These interventions are lacking when it comes to dyscalculia compared to dyslexia interventions. Later in this thesis there will be an outline of intervention recommendations for students who struggle with dyscalculia.

The subject of mathematics is complex. As this thesis will show, diagnosing dyscalculia is comparably as involved. As stated earlier, there are many other reasons why individuals struggle with the subject, such as math anxiety, lack of motivation, poor instructions, and more. This thesis will explore the current state of knowledge regarding dyscalculia through interviews, surveys and reviews of the literature. Through exploration, a write up of ways to recognize signs of dyscalculia in students of different age groups will be presented. Additionally, plans will be formulated and presented on how to best work with these students one on one and in a group setting. This project will look at memory, language, and reading skills as well as other confounding factors, plus educational interventions, to help close the education gap related to dyscalculia.

Chapter 2

Definition and Diagnosis

Dyscalculia is a learning deficiency that occurs in 5-10% of the population of all ages (Pearson Clinical by Sydney Hemdon and Cheryl Axley, 2017). Since the learning deficiency is not well known throughout education practices, this percentage could potentially be greater. In most cases dyscalculia is developmental where a student is born with the learning disorder (LD). In some rare cases, the LD is acquired through a brain injury such as a concussion. There are a few misconceptions when it comes to dyscalculia, such as a student being able to grow out of it. Additional misconceptions, are that it is gender, ethnic or socio-economic specific, and that it is linked to a persons overall intelligence (Pearson Clinical by Sydney Hemdon and Cheryl Axley, 2017). Many students who struggle with dyscalculia also struggle with other forms of deficiencies such as ADHD, emotional discomfort, dyslexia and dysgraphia, but studies have not proven these directly linked to why a student struggles with dyscalculia. However, there have been studies stating that troubles with math, outside of dyscalculia, can be related to troubles with reading (Wadlington and Wadlington, 2008, p. 3).

Dyscalculia is a learning deficiency that is easier to work with if diagnosed at an early age (Pearson Clinical by Sydney Hemdon and Cheryl Axley). Finding successful ways to work with this mathematical learning deficiency is easier when the student is younger because the brain plasticity decreases after a certain age (Wagner, Karl, personal communication, November 4 2017). Since this learning deficiency is a 'brain-based condition' a diagnosis cannot be made through visual characteristics, but these characteristics assist with an appropriate diagnosis. If a student at a young age shows these signs of dyscalculia and is diagnosed, then the student can learn proper tactics and skills throughout their elementary years to help them succeed. If these signs are ignored, the student will miss opportunities to learn different interventions at a young age to help them through their mathematical courses. Learning about these interventions at a young age allows them to manipulate and develop techniques to best fit their learning needs throughout their earlier years of schooling.

One of the most common indicators of dyscalculia is having trouble with the understanding of quantity and number sense (Pearson Clinical by Sydney Hemdon and Cheryl Axley, 2017). These indicators lead to other issues such as properly estimating values, reading graphs and visual and spatial orientation. Another common characteristic of dyscalculia is trouble with working memory. This indicator leads to many other characteristics of the LD such as matching numbers and symbols with equivalent words. An example of this would be sum as a + sign or product as an × sign. Students struggling with dyscalculia have trouble visualizing how equations and proofs get from point A to point B, so they easily make false assumptions and inferences.

As stated earlier, some students struggling with the learning deficiency may have issues with approximating amounts. For example; if you show a student with dyscalculia two piles of marbles or two images of various objects, at a glance they may not be able to tell which pile or image has more.

Figure 1: Which has more?

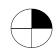
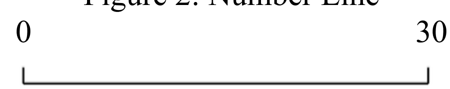
Another struggle a student with dyscalculia has is making connections between different types of equivalents. They can see that 3 = 3, but students at a young age have trouble making the connection that ¼ =  or that 3 = ΔΔΔ. Students in the secondary level of schooling have come up with tactics to help them understand the earlier figure, but may have issues understanding why ½ = 0.5. The struggle of understanding equivalents leads to issues with magnitude and sequencing. A student with dyscalculia may not know if 989 is bigger that 898 when asked right away. The student may also have issues with understanding a number line and where numbers are proportionally to other numbers. For example, if a student with dyscalculia were asked, where on this number line would you place 10?

Figure 2: Number Line



The student would not necessarily know and may put the mark for 10 closer to the 30. The student could know that the marker for 10 goes in between, but the placement of the marker in relationship to the 0 and the 30 is what is most challenging (Pearson Clinical by Sydney Hemdon and Cheryl Axley, 2017).

Lastly, a student with dyscalculia shows signs of the learning deficiency through their difficulties with operations. They can easily add together single digit numbers because they have learned how to use tools such as finger counting. However, they tend to run into a challenge when it comes to adding two digit or three digit numbers together such as 15 + 26. Some with dyscalculia may say the answer is 14 because they added all the numbers in the problem together (1+5+2+6). Others may say the answer is 311 because they did not take into account the fact that they need to carry over the sum of the first place value into the second (1+2 = 3 and 5+6 = 11, so 15+26=311). These questions are more suitable for middle school range of students, but these still may be worth using on high school students.

Signs of dyscalculia are recognizable but, unfortunately, do not indicate that the student necessarily has the LD. Some signs in elementary students that stand out are; finger counting, symbol confusion, anxiety and frustration, skipping numbers, avoiding games with scoring, staying within single digits, and time and money mismanagement (Pearson Clinical by Sydney Hemdon and Cheryl Axley, 2017). Signs that are apparent in secondary school students are; taking longer to complete work, trouble reading charts and graphs, errors in calculations, error in estimation, measurement and time problems, and avoiding games with scoring (Pearson Clinical by Sydney Hemdon and Cheryl Axley, 2017). These signs are quite broad because a student without dyscalculia could potentially have all these signs. This is why testing is very important to ensure that the student receives proper assistance and is introduced to proper tactics to find success in the subject of mathematics.

Testing and Diagnosis

To obtain an accurate understanding of the diagnosing process of dyscalculia, as well as other learning disabilities, the researcher interviewed Karl Wagner, PsyD. Wagner is a licensed psychologist with over 20 years of experience working with schools, families, adolescents and adults. He specializes in neuropsychological, academic, personality and vocational assessment, consultation, follow-up support and therapy (Wagner, 2016). Wagner currently practices at Powell and Wagner Associates in Westborough, Massachusetts.

During the interview, Karl Wagner, personal communication, November 4 2017 shared that out of a group of children being tested for learning deficiencies, 80% do not neatly fit into a category. These categories include LD's such as ADHD, dyslexia, and dyscalculia. These 80% of children are sent home from being tested through interviews, neuropsychology tests, and IQ tests with a list of accommodations. These accommodations are put together for their classroom teacher and standardize testing. The practices don't necessarily cure dyscalculia, but they will help the student find a comfortable way to learn mathematics. Each of these children is a special case that has to be looked at one at a time. They all don't fit into just one category.

General testing for learning deficiencies begin with an interview to understand the child's academic background, as well as their medical history from prenatal to present time. After the psychiatrist has gotten to know the child, the testing begins. The first test is the Wexler Cognitive Test, which looks into neuropsychology of the child's brain (Wagner, Karl, personal communication, November 4 2017). After the doctor gets a sense of the relationship between the child's brain and their behavior, the child takes an

IQ test. This IQ test gives a read of the child's overall intelligence, which is the base line for future testing. The future tests given to the child by the psychiatrist are then compared to their IQ score. If their future English and math scores line up with their IQ score then their problem is not subject related. However, if one drops below their IQ score, then a red flag is raised.

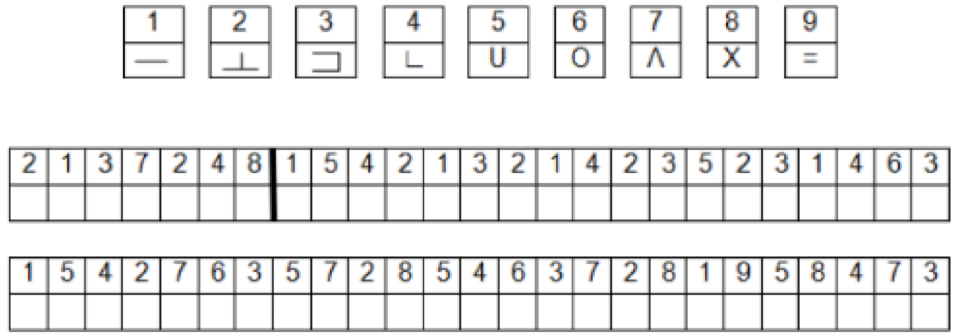
A mathematical learning deficiency (MLD) is detected through diagnostic tests and evaluations with assistance from Diagnostic and Statistical Manual of Mental Disorders (DSM-5). The American Psychiatric Association states that the DSM-5 is a "handbook used by health care professionals in the United States and much of the world as the authoritative guide to the diagnosis of mental disorders" (American Psychiatric Association, DSM-5: Frequently Asked Questions). Included in this handbook are descriptions and symptoms of mental disorders as well as medications and other interventions to aid these disorders.

The diagnostic tests and evaluations focus on the following functions.

- Visual Spatial Scoring
- Applied Problems: These problems are in story form where the child reads the problem out loud and then reads problem to themselves before making computations
- Calculations: Starting with problems as easy as 2+2 and finishing with college level problems
- Timed Math Facts: Do as many quick computation problems in three minutes (Wagner, Karl, personal communication, November 4 2017)

These tests also consist of decoding problems as shown in the next figure.

Figure 3: WISC-IV Coding

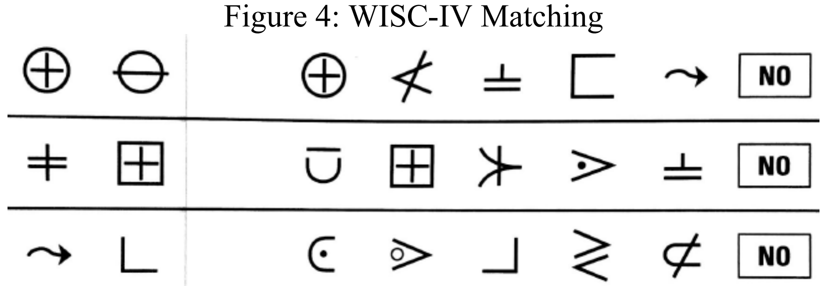


(Hadweh Briceño, Marcelo & Maureira Cid, Fernando, 2017, P. 35)

Here a student is timed to see how quickly they can match each number in the lower boxes with a figure within the given coding. The students that move through this task quicker are the students with better memory. Those who can memorize all the coding can quickly link the number with the given coding, while those who have poor memory, have to keep checking the coding box to make the connection with the number (Wagner, Karl, personal communication, November 4 2017).

Another example of testing that students experience while being examined for different learning struggles is shown below.

Figure 4: WISC-IV Matching



(Wechsler, 2003)

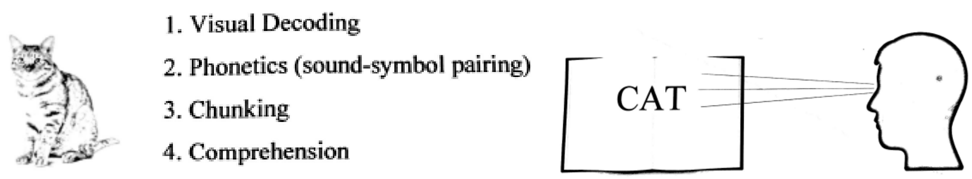
For this part of the testing students are asked to recognize if the figures in the left-hand column appear with in their row on the right. If they do, they circle the matched figure and, if they don't, they circle the box containing the word "NO" (Wagner, Karl, personal communication, November 4 2017).

This symbolic form of testing signifies how a student can potentially view mathematics since mathematics is made up of an assortment of different symbols. "Mathematics is a symbolic language which encompasses numbers, form, chance, algorithm and change (Van De Walle, 2004)" (Zerafa, p. 1179). Most mathematical symbols tend to stay the same throughout time, but some do evolve or have different forms. For example; the division of two terms can look like $x \div y$ or it can look like $\frac{x}{y}$. Another example is the different symbols for multiplication, which can take the form of an ex (×) or a dot (·). Students with dyscalculia or dyslexia are ones who stand out while taking these types of tests because they have trouble making connections with the symbols. If the student is having trouble with these tests, then they are most likely having trouble on other forms of learning in school. Due to poor scores on these types of tests, students are evaluated more closely to obtain recommended accommodations. These accommodations are different for every student showing the importance of these evaluations.

Dyslexia

A much better known learning deficiency compared to dyscalculia, which affects reading and writing skills, is called dyslexia. Dyscalculia is at times thought of as the dyslexia of mathematics. The main operative difference between the two LD's is the fact that dyslexia has been studied more than dyscalculia. The figure below is helpful in understanding what dyslexia is.

Figure 5: Defining Dyslexia



(Wagner, Karl, personal communication, November 4 2017)

This figure shows how a person without dyslexia sees a word and immediately can associate an image to the word (visual decoding), the sounds each letter makes (phonetics), what the letters sound like when put together (chunking), and the overall meaning of the word (comprehension) (Wagner, Karl, personal communication, November 4 2017). A student with dyslexia has trouble putting these four steps together, in an instant, while reading. This lack of instant comprehension, leads to many issues with writing as well.

When learning mathematics there is usually some kind of reading involved. Word problems are common in mathematics, as well as when a teacher asks students to read a textbook chapter on their own. At an older age, it is important to have developed the ability to take valuable notes as well as know how to use the textbook as an aid, to read and work through individual problems. If a student has dyslexia and/or dysgraphia, taking notes and reading math books independently may seem like an unreachable task. Both language development and reading impact the learning of mathematics.

Breaking down dyscalculia the same way as dyslexia is quite challenging because the study of dyscalculia is much more involved. As seen in the preceding paragraph, dyslexia can be broken down into four challenging factors that cause complications. These four challenging factors include visual decoding, phonetics, chunking, and comprehension. Various outliers cause the complications students have with mathematics. In comparison, dyscalculia has many more outlying factors including complications with reading and writing math, language, spatial reasoning, memory, anxiety and more. If a student struggles with one of these confounding factors, then they are at a greater disadvantage compared to their classmates.

> Teaching mathematics to mainstream classes in primary schools can be a challenging endeavor. One challenge can be catering for pupils who would have yet not grasped the basic skills and concepts usually acquired in the lower grades (Zerafa, 2014, P. 1).

Students struggling with dyscalculia do not grasp these concepts in lower grades because of the traditional practices teachers follow in mainstream classes. These practices reach some students, but do not help the students who need certain additional accommodations. One finds these accommodations in reading and writing courses due to the development of interventions for students struggling with dyslexia. “Literacy difficulties account for over 90% of the research literature on learning disorders, and yet in every classroom there are an equal number of children struggling with mathematics” (Hannell, 2013 p. 1). These numbers indicate that dyslexia has been researched much more fluently compared to dyscalculia and there seems to be a lack of knowledge of dyscalculia showing the educational gap within the system.

Dyscalculia has many common characteristics that are recognizable. These characteristics include struggles with quantity and number sense, estimating values, reading graphs and visual and spatial orientation. These characteristics are recognizable through a few practices such as finger counting, symbol confusion, anxiety and frustration, skipping numbers, avoiding games with scoring, staying within single digits, and time and money mismanagement. Though these characteristics are apparent, a student cannot be diagnosed through these visual components. A student that shows these signs at an early age should be tested as soon as possible. Testing is vital to ensure the proper accommodations can be put in place to help the student learn mathematics at the best of their ability. If a student that shows these characteristics is overlooked and not tested then the student is missing an opportunity to learn mathematics more fluently throughout their middle school and high school years.

Chapter 3

Confounding Factors

Learning deficiencies can easily be confused with one another. Sometimes a student may appear to have issues with executive functioning skills, but the learning complications may stem from another LD such as memory or language. In comparison, one may have a student who has difficulty with copying down various words from memory. This issue may appear to be because of poor retention, but is actually due to a reading and writing deficiency (Thompson-Grove, G., All Kinds of Minds Conference, (personal communication, July 20 2016)). Similar misinterpretations can occur when it comes to the difficulties that arise when learning mathematics. “Calculation is a complex skill that activates both visual and spatial and visual and verbal networks” (Rapin, 2016, p. 11). A student may appear to have a LD such as dyscalculia, but there are confounding factors outside of the LD that may cause challenges within the subject. Four confounding factors that will be explored in this chapter are memory, language, anxiety and student background. These four factors are all seen within dyscalculia and intensify the LD’s characteristics. They also can be looked at separately, where a student without dyscalculia may need support in one or more of these factors in order to succeed in mathematics. When one of these factors becomes apparent, support and testing need to be established so that the student is properly assisted and diagnosed.

Memory

Students work in various ways when learning mathematics. Some students are inclined to memorize processes, to help them work through steps within a single mathematics problem. Others, may not necessarily memorize, but understand why and how the mathematical themes work and use this to guide them through a math problem. A student who has a hard time with understanding mathematics, coupled with difficulty in memory, will in turn have difficulty finding strategies to progress in the subject through their educational years. Students with dyscalculia will commonly struggle with memorizing facts, process and visual representations within the subject. As stated in Chapter 1, there are three different types of memory conditions seen within a student struggle with dyscalculia.

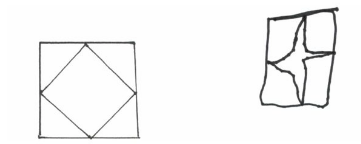
1. *Semantic memory:* difficulty retrieving arithmetic facts.
2. *Procedural memory:* difficulty understanding and applying mathematical procedures.
3. *Visuospatial memory:* difficulty understanding spatially represented numerical information such as misalignment of columns, place value errors, or geometry.
   (Wadlington and Wadlington, 2008, p. 3).

These categories are broken down to specific areas that expand on the generalization of memory. The first condition works with the connections involved within mathematical criteria. *Semantic memory* does not seem to only relate to difficulties with retention, but with the idea of making connections to arithmetic facts. Students who struggle with memory, but do not have dyscalculia, use relevance in order to make a connection with the content they are trying to memorize. Students with dyscalculia have difficulty making this connection to the subject and therefore cannot retrieve certain facts to guide them through mathematical problems. Whether someone struggles with memory or has dyscalculia, assistance is required in order for these students to succeed. The student with dyscalculia will require more support since they have more difficulty in discovering relevance within mathematics.

The next condition expands on semantic memory and involves the application of the arithmetic facts to mathematical problems. *Procedural memory* deficiency is when a student cannot memorize the process at which a certain problem is done. In other words, the student is not able to remember each step required to work through the problem. By lacking the arithmetic facts, as well as the mathematical process, the student is not able to make the connection between these facts and applications. Since the student cannot make this connection, they will have a hard time recognizing how and why the computations actually work together. If a student had a weak memory, but understood why an arithmetic fact is true, then they might use this connection in order to guide them. Clearly, semantic memory and procedural memory are relatable. To ensure a student with dyscalculia is able to succeed, they need a strong foundation in place to confirm they are supported in the areas of semantic and procedural memory. Only with this support, the student will be able to make successful computations on their own. The final condition deals with the visual side of memory.

Visuospatial memory can be compared to visual spatial skills. “Mental manipulation of graphic images may be difficult for the pupil with dyscalculia, so symmetry, tessellation and geometry may all prove to be real challenges” (Hannell, 2013 p. 7). Trying to properly sketch an image, with some symmetry, from a figure that a teacher put on the board, could challenge a student with a lack of visual spatial skills. Not only could their sketch be misconstrued, but also the student may misplace lines while duplicating the image. Here is an example of a student's sketch with poor visual spatial skills due to dyscalculia.

Figure 6: Visual Spatial Sketch



(Hennell, 2013 p. 7)

The student can clearly make straight lines for the outer square, but has trouble inscribing the other inner figure as a square. When a student is challenged with drawing a figure, as shown above, assistance needs to be offered to support their visual spatial memory challenges.

As seen in chapter 2, there are various tests that a student has to take when being diagnosed with dyscalculia. These diagnostic tests look at *Visual Spatial Scoring, Applied Problems*, *Computational Problems*, and *Timed Math Facts*. These tests look into more than a student's math skills by observing their visual spatial skills in *Visual Spatial Scoring*, reading and language comprehension in *Applied Problems*, and memory in *Timed Math Facts*. These three different types of testing break down the parts of the brain needed in order to excel in mathematics.

Language

Mathematics has its own unique language. There are many different forms of notation, lettering, words, phrases and more that make up the subject. Students who struggle with dyscalculia have primary difficulties connecting with the language involved in mathematics. “Some students with dyscalculia have particular difficulty in linking the actions that they are supposed to perform with meaningful language” (Hannell, 2013 P. 9). The mathematical language that the student uses to ask questions or explain where they are perplexed is not from their own perception. Therefore, it is difficult for the student with dyscalculia to form questions or sentences in order to voice where the confusion has appeared. When a student with the LD is working through a particular problem, they may not necessarily have language skills to work through the process in their own mind. For example, a student with dyscalculia will have trouble forming a mathematical sentence into an equation that is then solved. They may be able to mimic what their teacher does on the board, but have no connection to the meaning behind the process.

In order to explain what you are struggling with or why you are struggling in mathematics, you need to be able to communicate words and terminology within this unique language. Students with, and some without, dyscalculia show their lack of understanding through statements such as “I’m confused” or “I don’t understand”. These vague statements give a teacher an opportunity to help the student elaborate and be more specific on what part of the material is not connecting with them. These teachers must make the effort to close the confusion gap or the student will not be able to properly move forward. Assisting the student, by showing them ways to explain their confusion, is strengthening not only their verbal skills in the subject, but also their self-advocacy skills and confidence.

One type of problem that a majority of students struggle with or skip in mathematics, are word problems (Wadlington and Wadlington, 2008, p. 3). Not only is the use of the unique language put into real life examples, but also there is vocabulary that needs to be translated into an equation. A student who does not struggle with dyscalculia might skip the problem because they recognize the effort that would be involved. The difficulty is not that the student is unable to solve the problem, but the inclination to make the connection between the math vocabulary and the real world vocabulary may not be there. A student with dyscalculia, on the other hand, may skip the problem because they are unable to begin the translation of the real world vocabulary into a mathematical equation. Connecting words to symbols, such as greater than (>) or equal to (=), is one challenging task. Another challenge is organizing what the problem is asking of them. The combinations of language challenges are exemplified with those with dyscalculia. Assistance is necessary in order to make them comfortable with various aspects of the mathematical language, specifically within word problems.

Other Confounding Factors

One confounding factor discussed within the first chapter of this thesis is anxiety. Students who struggle with dyscalculia, and have not been previously diagnosed and assisted, have likely encountered mathematical struggles in their prior courses. Math anxiety can develop when past experiences impact the current confidence level within the subject. Without confidence in the subject matter, the likelihood of current failure increases. After a student loses confidence in the subject, then they tend to show lack of motivation to succeed (Hannell, 2013 P. 12). One way to counteract a lack of motivation is to help set an environment that will allow those with dyscalculia to perform at the best of their ability. When working through problems on math assessments, students tend to perform successfully when they have steady concentration. Accommodations need to be established to encourage a student's ability to focus while struggling with dyscalculia.

Student background is another confounding factor, which separates a student with dyscalculia from a student without dyscalculia. The majority of students who lack skills in mathematics come from poor teaching practices, negative learning experiences and families who do not value the subject (Hannell, 2013, p 5). For the students who are not struggling with dyscalculia, but have an improper mathematical background, once these students are provided proper instruction improvement in the subject will be apparent. "Poor response to appropriate instruction is one of the hallmarks of dyscalculia" (Hannell, 2013 p. 4). Therefore, students with dyscalculia, will require more thorough assistance if they are to rebound in the subject as their response rate will be much slower. Both of the confounding factors, anxiety and poor student background, are not necessarily caused by dyscalculia. Though, if dyscalculia is present, these confounding factors are harder to recover from.

As seen in this chapter, dyscalculia can be quite intricate due to its confounding factors. The LD is made up of various complications that involve difficulties with prominently memory and language. The complications with working memory can be broken down neatly into three categories including memory of mathematical facts, memory of procedures, and memory of visual placement. The difficulties a student with dyscalculia experiences with language are not typically misunderstanding the English language, but misinterpreting the unique mathematical language. “Deficits in language and working memory may well create problems in the acquisition of both mathematics and literacy skills” (Hannell, 2013 p. 5). Other confounding factors including anxiety and student background are ones that affect the progress made while growing up with dyscalculia. In the next chapter, the progress that dyscalculia students have encountered will be reviewed. The support that assisted in creating this progress will be outlined to adequately support future students through a life of working with dyscalculia.

Chapter 4

Effective Teaching Leads to Effective Learning

In education, teachers have the goal of giving each student in their class the same opportunities and direction. However, when teachers come across students who are academically weaker compared to their classmates, the teacher must make certain accommodations in order to give the student equal opportunities while maintaining the direction of the course. These accommodations are not always instinctual to teachers and are more thorough when a professional is involved. In the diagnosis of students with dyscalculia and other learning deficiencies, neuropsychologist suggestions can be beneficial for their development. Suggestions from a professional are made after a student goes through comprehensive testing, as discussed in chapter 2. For this chapter, a student participant was studied and interviewed who was diagnosed with dyscalculia at the age of 16. The goal of this study was to research what the student experienced during neuropsychological evaluation and testing, as well as the outcomes following testing and diagnosis. These outcomes include write-ups from a professional neuropsychologist, interventions and classroom experiences.

Participant Background

The student participant was evaluated twice throughout their life by a neuropsychologist. The first time the participant was tested and evaluated was when they were in 5th grade. The purpose of the first evaluation was to gain an understanding about the participant's neuropsychological functioning with concentration in mathematics. Prior to this testing, the participant showed strength academically except for areas of math and sciences. The first evaluation did not lead to a diagnosis of dyscalculia. The participant would struggle for five years before testing was revisited. The second round of testing came about when the participant was intending on taking the SAT/ACT. These forms of standardized testing give students, with certain learning deficiencies, additional challenges relative to their peers without accommodations being put in place. After five years had passed since the participant had their last neuropsychological evaluation, with no improvement in their math classes, the student and their family felt they needed additional resources leading up to the standardized examinations.

During the second evaluation, the participant showed strength in reading and writing. Unfortunately, the participant scored poorly on the majority of math sections, which includes mathematical operations, applications, applied problems, calculations, math fluency, and arithmetic. The Neuropsychological Evaluation written for the participant stated the following in response to the participant's test scores.

> Despite superior verbal skills, the participant appears to be struggling with the unique language of mathematics – their fluency slows considerably on math tasks, and the participant demonstrated impaired ability to interpret data in word problems. While the participant appears to have learned the very basic concepts of mathematics, as the procedures and logic required become more complex, their abilities deteriorate significantly and fall below what would be expected given their cognitive profile or age. Based on these, the participant meets criteria for **Specific Learning Disorder With Impairment In Mathematics**, also known as dyscalculia. Children with learning difficulties such as dyscalculia may have difficulty in monitoring their own learning through internal, language related thinking.

(Participant's Confidential Neuropsychological Report)

Below shows the percentile in which the participant falls in based on their test results. The types of tests that were reviewed for this study was the Nelson Denny Reading Test, Woodcock Johnson IV – Tests of Achievement (TA), Woodcock Johnson IV – Tests of Cognitive Abilities (TC), and Wechsler Adult Intelligence Scale – Fourth Edition. The above tests are a portion of the standard neuropsychological examinations, conducted by these professionals, to give a thorough evaluation of students.

Table 1: Participant's Percentile Rank

Test	**Academic Functioning**	**Percentile**
Nelson Denny Reading Test	Reading Comprehension (Standard Time)	43
	Reading Comprehension (Extended Time)	78
	Vocabulary (Standard Time)	87
	Vocabulary (Extended Time)	98
Woodcock Johnson IV – (TA)	Broad Mathematics	14
	Math Fluency	12
	Math Problem Solving	39
	Applied Problem Solving	34
	Calculation	14
Woodcock Johnson IV – (TC)	Number Series	18
	Letter Pattern Matching	21
	Number Pattern Matching	14
	Visualizing	18
W. Adult Intelligence Scale	Arithmetic (Standard Time)	5
	Arithmetic (Untimed)	16

(Participant's Confidential Neuropsychological Report)

From the table above, you can see that the participant does not lack in strength in the areas of reading comprehension and vocabulary. The test results corresponding with reading and vocabulary are from the Nelson Denny Reading Test, which assesses student achievement in vocabulary, comprehension and reading rate (Coleman, Lindstrom, Nelson, Lindstrom, Noel, 2010, p 1). This reading test is available in a few different levels depending on the student's age and level of education. The participant in this study took the reading test that corresponded with their grade level. The participant scored quite well on this test falling in the 42nd, 78th, 87th, and 98th percentile. The Woodcock-Johnson Tests of Achievement provides an explanation of statistics. Within this explanation, they describe the percentile rank (PR) as a student's relative standing compared to their peers on a scale of 1 - 100. For example, if a student received a PR of 6, then this score would convey that six students (of similar age and education level) out of a hundred would score at the same level of lower. "For most percentile scores, the interpretive ranges are as follows:

Table 2: Ranges of PR Scores

98 – 99	Very Superior
91 – 97	Superior
76 – 90	High Average
25 – 75	Average
9 – 24	Low Average
2 – 8	Borderline
< 2	Extremely Low

Percentiles indicated as > 16 indicate normal performance" (Participant's Confidential Neuropsychological Report). From the four different percentiles under the reading and vocabulary section in the above table, the participant scored within a high average compared to peers, especially when extended time was given.

The above table also breaks down the participant's scores from different tests on various mathematical skills such as calculations, problem solving, and applied problems. These skills were tested through the Woodcock Johnson IV – Tests of Achievement. The participant fell between the 12th and 39th percentile within their scores on this test. The high percentiles of 34 and 39 are from the *Math Problem Solving* and *Applied Problem*

Solving sections of the Woodcock Johnson Test. These portions of the test were untimed and consisted of oral math word problems, where the participant was able to work with pencil and paper, as well as visual cues. These accommodations show that the participant performs well with applicable problems and visuals without the pressure of time. The Neuropsychologists behind this evaluation stated that they witnessed other difficulties as well.

> However, when asked to solve increasingly difficult arithmetic computations, the participant decreased to Low Average (Woodcock Johnson IV, Calculation = 14th percentile). When asked to compute simple addition, subtraction, and multiplication computations in three minutes, the participant scored within Low Average (Woodcock Johnson IV, Math Fluency = 12th percentile).

(Participant's Confidential Neuropsychological Report)

This grouping of results shows that the participant experienced functional impairment while working in areas of multiplication, division, and mental math.

The next portion of the above table includes testing results on other mathematical skills including number series, pattern matching and visualizing, where the participant fell between the 14th and 21st percentile. These tests results also correspond with the Woodcock Johnson IV, but show the evaluation of the participant's cognitive ability. The pattern-matching section of the evaluation was broken down into two parts, letter pattern matching and number pattern matching. The participant fell within a higher percentile in letter pattern matching compared to number pattern matching, which shows that the participant has a more thorough connection with letters compared to numbers. The last section of the table focuses on *Arithmetic* through the Wechsler Adult Intelligence Scale – Fourth Edition. In the timed portion of the evaluation, the participant scored within the 5th percentile. When the time restraint was lifted, they scored in the 16th percentile, showing that they perform much more fluently without the pressure of time. The Neuropsychological report summarized the participant's errors in the following statement.

> Across all of these tasks of mathematics, the participant demonstrated simple errors (e.g. reversed signs, incorrect decimal point placements) that indicated a lack of attention to detail. Their errors also demonstrated functional impairments in basic math skill areas (e.g. multiplication, money, and mental math).

(Participant's Confidential Neuropsychological Report)

The researcher's subsequent interview with the participant, allowed for further understanding of the participant's experience with the neuropsychological testing and what the resulting outcomes were.

Interview with Participant

During this study, the researcher interviewed the participant to review their past experiences with mathematics (e.g. school, teachers, testing, etc.) in order to comprehend their overall relationship with the subject. At the beginning of the interview, the participant shared that they had always disliked mathematics and that it is their least favorite subject. The participant's math grades were always much lower than their other grades. Even though they studied very hard for math tests, they felt like they never even studied while taking the test and their grades never reflected the full effort put in. The participant had not heard of dyscalculia until they were diagnosed at the age of 16, which was unfortunately after the participant was finished with the required math courses needed to graduate from high school. The participant stated that they are hopeful that their classes would have been more successful if they were diagnosed at an earlier age.

The participant's mathematical success could have improved if there were accommodations, as well as interventions in place to support them through their courses. When the participant figured out that they had dyscalculia, it was a relief because there was validation on why math had always been a struggle.

The participant's first memory of mathematics was when they were learning how to tell time on an analogue clock. They shared that they could not grasp the concept, due to their poor visual spatial and sequential skills. The participant stated that they remember working on this task with the parent who consistently assisted them with their math courses growing up. They explained that the family has one parent who is skillful in the subject, while the other parent showed little interest in mathematics. The Neuropsychological Evaluation write up mentions that one of the participant's aunt/uncle may have an undiagnosed learning disorder, which resulted in their struggles in school, particularly in the areas of math and science. When learning challenges are present in other family members, even aunts/uncles, the disorder can commonly get passed to the next generation (Hannell, 2013, p 5).

During the interview, the participant also shared what they experienced during their last evaluation with the Neuropsychologist. The first round of testing that the participant acknowledged during their most recent neuropsychological evaluation was when they had to draw a picture of a physical arrangement of three-dimensional blocks. The participant shared that this was very difficult for them, since they had to take a three-dimensional figure and draw it in a two-dimensional space on a piece of paper. Like the analogue clock from their first mathematical memory, this suggests that the participant lacks the visual spatial skills to perform said task. The next evaluation procedure that the participant shared was the assortment of math tests. The participant remembered that the tests were made up of written math problems that they had complete mentally, followed by similar problems to be completed with pencil and paper. The participant recognized that doing problems in their head was much more challenging than doing them on a piece of paper. This aligns with the test results shared earlier in this chapter. The last recollection that the participant shared from testing was when they were asked to memorize a list of numbers and a list of letters in two separate questions. The testing analyzed the participant's ability to take these two lists and write them down from memory. They shared that they were able to remember a lot more letters than numbers, which also supports the evaluation results previously stated. The participant then explained details of their experiences in their lower level math courses.

The participant began by sharing memories from their mathematics classes in middle school, when they believe signs of challenges in the subject were recognizable. They shared that their middle school work in mathematics was more independent than they experienced in high school. Their teacher had them work through tutorial videos at home, and answer problems electronically, where little feedback was given to students if they did a problem incorrectly. The participant felt as though the class and these problem sets were always a competition. When these electronic problems were completed, they were then projected for the whole class to see. The participant remembers always being the lowest scoring student in the class. This projection of the participant's progress, compared to their classmates, diminished their confidence and this added another obstacle in their future development. Since the participant's confidence was so low, they felt intimidated to ask for help in future math courses. They knew working one-on-one with a teacher or a peer would be helpful, but they felt embarrassed to reach out for assistance. The Neuropsychological Evaluation report shared that the participant may not ask for help because they cannot put into words what it is they do not know or understand. This mixed with lack of confidence is the reason why the participant would keep their struggles with mathematics to themselves. By not voicing their struggles to their teachers, the participant hindered their future academic development in the subject. Though they had many poor experiences with the subject, they also mentioned some learning techniques that they found helpful.

At the end of the interview, the participant shared some aspects of math classes that they felt were beneficial for themselves. The participant enjoyed math classes that were more interactive/project based and did not enjoy classes that were based around lectures, home works and tests. The latter class structure lost the attention of the participant and they would eventually fall behind. Additionally, the participant stated that they never found tests or quizzes helpful for them because of the pressure they produced on getting a good grade, rather than actually understanding the material. They felt that examinations were a way of forcing students to only worry about their test results, which felt like the wrong reasons to the participant. In their opinion, a students actual understanding of the material, was much more important than the test grades themselves. They felt that there were other ways of representing the true learning of the subject matter. Exiting the interview, the participant was asked how they see mathematics in their future. They shared that they hope not see too much of the subject in their college and professional careers. They would like to work in communications or media where they understand that they may have to work with statistics, but they hope that the relevance of the work will help them perform well. From working with the participant, the researcher noticed that the student might have been more successful in the subject with certain interventions put in place. Some of the participant's teachers used certain teaching practices, also known as interventions, to help them succeed in their courses. Some of these interventions include applications and repetition in order to successfully engage the participant.

Participant Grades and Comments

To achieve further insights regarding the participant's dyscalculia diagnosis, their comments and grades from Algebra 2 and Geometry were reviewed. The participant took these classes before they were diagnosed with dyscalculia, but these comments and grades show the participant's successes and failures between the two subjects.

Table 3: Teacher Comments

Class:	**Grade:**	**Comment Written to Participant from Teacher:**
Geometry	B	Your peers respect you and I highly value your presence in class. Your energy and personality contributed greatly to class discussions that enriched the material presented. This module your questions were well thought out and accurate to the material being learned, I only hope that the upcoming mods you are more vocal without me calling for your perspective. Your performance on homework quizzes and on tests showed an improvement as the module progressed.
	C+	You are hardworking, relentless and motivated. I know that at times the content seems difficult, I would advise that when this occurs that you attend extra help sessions to overcome confusion. You do an outstanding job presenting material when I call on you. But I have also noticed that you avoid asking questions in class. I feel you will learn more if you allow yourself to ask for clarification if the content is unclear.

	D+	I enjoyed having you in class these last three modules in Geometry. I like how you did not avoid a challenge, but rather accepted the challenge and did your best to overcome it. You were not afraid and I admire that about you. I know at times the material was challenging for you, but I noticed your most successful moments arrived when you had to explain/teach to the class. My regret, as I reflect on the last three mods is that I did not capitalize on this. In your future math classes I hope that you become more willing to share your answers, to seek assistance and to be willing to challenge misconceptions when they arrive. As you enroll in Algebra 2 next year, it will be imperative that you attack the course with a vigorous commitment to complete all assignments to the best of your ability and then be present during extra help sessions to reinforce those skills. You have the ability to blossom in mathematics, but you must be willing to sacrifice additional time and energy to reach your potential.
Algebra 2	C	You are a fantastic student to have in class. I appreciate your great enthusiasm, joy and energy. I was not surprised when you helped lead the homework review, and admire your openness and ease of collaboration with peers. You have been dedicated in doing the homework. However, it has been at time incomplete, reflecting your conceptual struggles with the material. Remember to always check your odd number answers in the back of the book, read the chapter explanations if you gets stuck, or watch the online tutorials. You can also do your homework in extra help sessions. Your mastery of the material is spotty, and you are trying to cope with gaps in your understanding. I would suggest trying to go back to basics and drill through topics like working with fractions and negatives, graphing lines, and solving equations. As we move onto more complicated materials, these skills will be the building blocks that you will need to succeed.
	B+	You continued to do good work this module. You turned in all of your assignments and worked well with your peers when you struggled with a concept. You had difficulty on the first unit evaluation, a test on quadratics on which you earned a 47% but did a good job on the second unit where you chose to do a mini-textbook about polynomial functions. You had difficulty initially on the third unit evaluation, a test on rational exponents, but took full advantage of the unlimited retakes option for this particular test and kept reviewing your errors and taking different versions until you scored an 89%. Overall, you are a fully engaged in class, a highly sought after partner, and a persistent and diligent student.

	C	You continue to work hard at mastering the concepts. You regularly facilitate homework review. I would encourage you to show more of your work on homework. You have done very well with the new iterative tests we have and it has given you an opportunity to raise your test grades. As always, you are a delight in class, a positive and mature influence to all.
	D	You became a leader in the class even as you struggled with the concepts we were covering. Thank you for leading homework review sessions and for maintaining such a positive attitude. Moving forward I suggest you consider math electives such as entrepreneurship and reordering chaos.

When comparing the participant's lack of development between Algebra and Geometry, the regression follows a similar pattern between the two subjects. In both classes, the participant started out with an average score before finishing each course with a D. The participant's teachers both made comments encouraging them to seek extra help in order to obtain a solid grasp on certain material. As stated earlier in chapter 3, reaching out for extra help is one learning technique students with dyscalculia have trouble with. Some students, like the participant, have trouble putting into words what exactly they don't understand or need help with. These students lack confidence in their mathematical vocabulary, which limits their ability to ask the necessary questions to allow them to move forward. Instead, they shelter themselves and eliminate their chances of improving. As seen by the above comments, the material reduced a generally outgoing student, to one who is more introverted.

In each class, from the above table, the participant's teachers put strategies in place to help them succeed in the subject. In Geometry, the teacher noticed that the participant did well when taking lead of the class. Even though the participant didn't contribute to the class regularly, they seemed to display confidence when presenting in front of their classmates. This shows that the participant is confident in front of others, but the mathematical material seemed to reduce their desire to speak out. As will be discussed later in the study, students with dyscalculia need to be encouraged to reach out for additional support, or they might limit their ability to continuously improve in the subject.

In Algebra 2, the teacher found one accommodation that was particularly helpful for the participant. The teacher gave the participant an unlimited amount of chances to retake tests to get them to a point of “mastery”. This idea of repetition seemed to help the participant and resulted in them receiving their highest grade, of a B+, in the course. Even though the participant was not diagnosed during the time of these two classes, the teachers were able to notice that their student needed some special guidance. The interventions, shared below, overlap with the accommodations that the participant’s teachers put in place.

Interventions

Interventions are tactics that help individuals overcome or alleviate a particular deficiency. Interventions for dyscalculia, or any other learning deficiency, are centered on various strategies a teacher could use to help the student, or the students could use to help themself. The first intervention step is recognizing what the student is struggling with. Once this has been established, immediate testing should be performed, to obtain a diagnosis for the individual. The second step involves applying the appropriate support based on the findings from the neuropsychological testing. The interventions are most beneficial when there are put in place early in their adolescent years.

After the above participant was diagnosed with dyscalculia, they received the following suggestions and accommodations from their neuropsychological evaluation write-up. The head of skills personnel, from the participant's school, has modified these guidelines to adjust to the school's level of available support. Some of these guidelines are versatile and can be used for academic growth in a variety of subjects.

Table 4: Suggestions for Student

• Learn self-advocacy skills: Ask questions when you do not know, explain to teachers and advisors what is hard for you
• Attend math support classes, tutoring sessions and/or coaching for executive functioning support
• Frequent check-ins with advisor, Skills Center, and teachers
• Use technology to help executive functions skills
• Rely on written information: Not on what you "think" you remember or what you heard
• Careful schedule planning with advisor

The diagnosed student's teachers also received the following suggestions and accommodations after their evaluation was completed. These guidelines include general recommendations on how to present the material, the most effective way to deliver in class testing, as well as structural guidance in classwork, homework and other assignments.

Table 5: Suggestions for Teachers

• Allow use of computer for written work
• Help student break assignments down into steps
• Preview/review concepts as often as possible
• Use verbal aids when presenting material visually
• Present new material with contextual framework
• Ask leading questions to help student formulate their thoughts
• Provide very clear feedback
• Teach procedures explicitly and provide explicit instructions for all tasks
• Multi-modal teaching: Student needs to see it and hear it
• Use graphic organizers and other visual aids whenever possible
• Provide visual aids, such as handouts, to supplement oral material
• Do not assume that the student is simply "bored" or "uninterested"
• Provide as much structure on assignments as possible: Clarifying, prompting, providing information in context, limiting choices for task, etc.

Table 6: Classroom Accommodations

• Extended time on tests including standardized tests such as the SAT/ACT
• Use repetition as often as possible: Overlearning material is a good strategy
• Provide "retrieval" practice
• Help student develop self monitoring skills
• Allow short and structured breaks during class
• Provide outlines, study guides, and graphic organizers whenever possible
• Provide models to ensure clarity of expectations
• Provide as much guidance and structure as possible
• Help student break down long term assignments
• Provide visual cues, clear guidelines, and hands-on activities whenever possible
• Allow test corrections and revisions when appropriate

Some suggestions for teachers can be regarded as "Action Plans", which promote successful learning. In *Dyscalculia: action plans for successful learning in mathematics*, Hannell broke down these "Action Plans" to help teachers get to the core of the problem when they encounter a student struggling with mathematics and dyscalculia.

Table 7: Action Plans

• Allocate a lot of time to developing core number sense.
• Ensure that mathematical learning experiences are introduced in stages, building on existing learning. This allows the brain to acclimatize to new demands. Never move on to a new topic or an increased level of difficulty before the pupil has mastered the easier levels of the task.
• Use guided practice (they practice, you guide) to help the pupil acquire new understanding of skills.
• Use directed questioning to probe the pupils understanding and to stimulate the development of the connections that are needed for successful learning.
• Set up activities that the pupil can do with a little help, and then provide that help to promote real growth in the child's understanding.
• Recognize individual differences in the way in which your pupils can process different types of information and perform different tasks.
• Accept that pupils with dyscalculia may have extreme difficulty with some types of thinking (such as mental calculation) and offer alternatives (for example, a calculator).
• Provide enough time for practice and consolidation at each stage. This gives the brain time to get its wiring established and operating correctly before moving on to a more advanced or different topic.
• Revisit previously mastered skills often. This makes sure that the neurological circuits that underpin the skills keep in good shape.
• Work towards developing pupils' genuine understanding of mathematical concepts and procedures.
• Avoid teaching meaningless mechanical skills without developing understanding.
• Ensure that you use both verbal and non-verbal learning activities in your teaching.
• Modify how you teach to reflect the relative strengths and weaknesses that an individual pupil may have in the way in which they process information.
• Pupils with dyscalculia may excel in one area of mathematics and have difficulties in another, so always make sure that any mathematics assessment is segmented so that you and the pupil can see the pattern of successes and failures.
• Allow pupils with dyscalculia to use their own strategies if this works for them.
• Make sure the student understands that 'not knowing' is an inevitable part of learning.
• Use the student's errors as an important source of information.

(Hannell, 2013 P. 21 & 33)

In the above guidelines, there are a few similarities between the suggestions and accommodations, processed by the participant's school, and Hannell's "Action Plans". One recommendation that appeared a few times was the concept of "multi-modal" teaching. This teaching practice involves both verbal and non-verbal approaches. These approaches are best used when explaining a new concept or assigning a project. Another overlap between the two references is the accommodation of extra time on tests. This extension of time relieves pressure off of the student so that they can focus on each individual problem on tests and other assignments. The next reiteration is the suggestion to ask the student directed questions. This teaching practice allows for the student to feel encouraged rather than confused by what the question is asking. Another overlapping guideline is to reformat tests and test taking policies to not only keep track of what the students weaknesses are, but to give the student a chance to see what they know and what they need to work on more. The reformatting of test taking policies may include allowing the student to do corrections or to take the test in a more comfortable environment. Lastly, the revisit and overlapping of skills is seen throughout the suggestions and action plans. The review of skills is important when learning mathematics because most math courses are cumulative.

The overlapping skills are quite important when a student with dyscalculia is learning mathematics, but a few important teaching practices came up in Hannell's "Action Plans". One of these teaching practices is the idea of letting the students learn from their mistakes. When learning mathematics, discomfort can arise quite easily due to the anxiety of not understanding a problem at first. The notion of leaning into discomfort allows for a student to take ownership of their mistakes and allow for growth to occur. Even though the above suggestions seem to be independent, they can also be used within a group setting. This group setting can contain a collection of struggling math students or even a group of students with mixed skills. Working in a group allows for different learning habits to be passed along from one student to another. If one student has good learning habits in the subject of mathematics they can share it with a student who is on the other end of the spectrum. As for a group who share the same bad perception of mathematics, they can learn new practices together and inspire one another.

As seen in this chapter, learning mathematics while struggling with dyscalculia is quite involved. The various accommodations and suggestions previously discussed can help students, but they are most effective when introduced at an adolescent age. The above participant was tested at an early age, but was not diagnosed until their second evaluation. During the first evaluation, there might have not been clear indicators showing that the participant was struggling with dyscalculia. Though these indicators were possibly unclear, they potentially delayed the introduction of additional resources, strategies and guidelines, for the teachers and themselves, needed for successful development in mathematics. If they had these materials, then they might have adapted to practices that would help them learn the subject more confidently. The progression in mathematics could have been affected by other confounding factors, such as memory or attention deficit disorder, but the unidentified problem for the participant was dyscalculia.

Chapter 5

Conclusion and Future Research

Throughout the research process of this study, there were many realizations on the learning deficiency of dyscalculia. These realizations were made by researching the diagnosing process of dyscalculia and other learning deficiencies, analyzing confounding factors affecting dyscalculia, reviewing interventions to support students with dyscalculia and completing a full evaluation of a participant struggling with dyscalculia. The main conclusion resulting from this study is the importance of implementing specific interventions and accommodations at an early age. In order to implement the most effective form of interventions, testing needs to be done during a student's adolescent years, to obtain a proper diagnosis. Following a diagnosis, a clear foundation of resources, strategies and guidelines need to be provided so they can be successfully implemented. However, as seen through the participant in chapter 4, there are certain barriers in the way of students receiving the proper diagnosis. These barriers include unclear indicators, confounding factors, demographics, and family financial stability.

As seen in chapter 2, the process for diagnosing any learning deficiency is quite time consuming for a student, as well as expensive for the family (Wagner, Karl, personal communication, November 4 2017). These two factors can hold back a family from feeling motivated or able to move forward with appropriate steps to properly assist the child. Many families with a lack of resources may have an extremely difficult time affording the first round of testing, let alone a second. Government assistance in the form of funding, grants or scholarships for students with potential deficiencies, could be an option for students whose families cannot afford an appropriate evaluation. Awareness of the learning deficiency may encourage an expanded population of municipalities and individuals backing support for the importance of the proper diagnosis for our youth.

Many families may be hesitant to enter their child in testing due to the lack of awareness of dyscalculia. They may question the rationality of the deficiency and the impact it can have on the student in their educational development. If this research were to be extended, one primary goal would be to raise awareness of dyscalculia throughout school districts and communities. Once awareness is raised in specific areas, a study would be performed to see if additional students are consequently being evaluated in those communities. In chapter 2, we discussed the intricate and involved procedure necessary to diagnose subjects. Another expansion on this study could evaluate the success of the current diagnosing method and explore other formats of testing, with potentially higher success rates. As shown in chapter 4, the participant analyzed was not diagnosed until their second round of testing.

Confounding factors make it difficult to work with students appropriately without a proper diagnosis. As seen in chapter 3, there are many different learning deficiencies that make learning mathematics difficult and only proper testing and evaluations of a student can accurately point out the cause of these difficulties. Dyscalculia is made up of multiple factors including poor working memory, lack of visual spatial skills, and poor mathematical language and number sense. The learning deficiency could be categorized into more outlying factors, but from the research done, these three seem to be the catalyst of the learning deficiency.

An expanded version of this study would involve (i) a more comprehensive literature review; (ii) more study participants from a broad spectrum of disability types connected to dyscalculia; and perhaps even (iii) attempts to report quantitative, as oppose to qualitative, information regarding diagnosis of dyscalculia. As seen in Chapter 4, only one participant was researched. This participant showed that living life with dyscalculia, unknowingly, affected their overall progression in the subject. This research offered one representation of how a student struggles with dyscalculia without proper accommodations and suggestions put in place. Studying multiple students diagnosed at a young age would provide an enlightening comparison to the above participant, as well as to any other subjects not diagnosed as adolescents. The criteria researched would include, age of diagnosis, as well as areas of success and failures. The final area of evaluation would be the self-awareness of the individual and their knowledge level relative to their fellow peers. This would look at the ability of each participant to recognize what they struggle or thrive in within mathematics, as well as the forms of guidance that help them succeed.

Practices within different learning deficiencies change between different school districts, states and countries. If this research were to be expanded, the researcher would explore different types of learning strategies between strong and weak school districts within the United States. This research would include demographical successes and failures in education, and why they occur. These reasons could include subject-focused schools, poverty, and lack of knowledge or significance. Dyscalculia would also be researched by comparing states within the United States to other countries with comparative educational development. Examples could include Germany, China and

England. For each country, the primary learning deficiency of recognition and focus would be identified for each and reviewed. This would give an idea of how ahead or behind the United States is working with the various learning deficiencies. It could also provide insight into ways other countries may be providing more expanded guidance to those diagnosed.

Lastly, this wider range of research would end with a Policy Recommendation for Math Teachers. The recommendation would include math tests for individual teachers to give to young students to learn whether or not they need further evaluation. This policy would not only give the teacher an understanding of what a student's strengths and weakness are while learning mathematics, but where they need more attention. This extra attention could include an evaluation from a Neuropsychologist, so that the student receives suggestions and accommodations at an early age. As stated earlier in this study, the sooner these interventions are put in place for a student with dyscalculia, the sooner the student can adapt and learn the subject without pitfalls or holes within their learning.

References

American Psychiatric Association. (2013). *DSM–5: Frequently Asked Questions*. Retrieved February 15, 2018, from https://www.psychiatry.org/psychiatrists/practice/dsm/feedback-and-questions/frequently-asked-questions

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Axley, C.; Hemdon, S. (Presenters). (2017, November 14). Dyscalculia overview [Audio webinar]. Lokken S. (Host), *Pearson Clinical*. Retrieved from https://cc.readytalk.com/cc/s/meetingArchive?eventId=n3cbmn983wqw

Berch, D. B., Mazzocco, M. M. M. (2007). *Why is math so hard for some children? : the nature and origins of mathematical learning difficulties and disabilities.* Baltimore: Paul H. Brookes Pub. Co.

Coleman, Chris, Lindstrom, Jennifer, Nelson, Jason, Lindstrom, William, & Gregg, K. Noel. (2010). Passageless Comprehension on the "Nelson-Denny Reading Test": Well above Chance for University Students. *Journal of Learning Disabilities, 43*(3), 244-249.

Dinkel, P. J. ; Willmes, K. ; Krinzinger, H. ; Konrad, K. ;Koten Jr, J. W.. Diagnosing Developmental Dyscalculia on the Basis of Reliable Single Case FMRI Methods: Promises and Limitations (FMRI for the Diagnosis of Dyscalculia). 8300 defect for UNSW 2013, Vol.8(12), p.e83722 http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0083722

Dowker, Ann (2008). *Mathematical difficulties: psychology and intervention.* Amsterdam; Boston: Elsevier/Academic Press. C2008. 1st ed.

Michelle de Almeida Horsae Dias, M. d. (2013). Assessment of the awareness of dyscalculia among educators. *Audiology - Communication Research* , 93-100.

Hadweh Briceño, Marcelo & Maureira Cid, Fernando. (2017). Modelos jerárquicos y multifactoriales de la inteligencia I. 29-40.

Hannell, G. (2013). *Dyscalculia: action plans for successful learning in mathematics.* New York: Routledge.

Rapin, I. (2016). Dyscalculia and the Calculating Brain. *Pediatric Neurology, 61*, 11-20.

Schrank, F. A., Mather, N., & McGrew, K. S. (2014). Woodcock-Johnson IV Tests of Achievement. Rolling Meadows, IL: Riverside.

Wadlington, E. ,. (2008). Helping Students with Mathematical Disabilities to Succeed. *Preventing School Failure , 53*, 2-7.

Wagner, K. PsyD. (2017, November 4). Interview type [personal interview].

Wagner, K. PsyD. (2016, July 20). Psychology today: About Karl Wagner, Psychologist, PsyD. Retrieved from https://www.psychologytoday.com/us/therapists/karl-wagner-westborough-ma/69919

Wechsler, D., Kaplan, E., Fein, D., Kramer, J., Morris, R., Delis, D., & Maelender, A. (2003). Wechsler intelligence scale for children: Fourth edition (WISC-IV) [Coding]. San Antonio, TX; Pearson.

Zerafa, Esmeralda (2015). Helping Children With Dyscalculia: A Teaching Programme With Three Primary School Children