Understanding Developmental Dyscalculia: A Math Learning Disability
(Transcript)
Presented by: Daniel Ansari


For technical assistance, please call Mercia at 416-929-4311 ext. 42.

[Image logo LD@school.]

Amy – Hello everyone, we’re going to get started now.

Welcome to LD@school’s second of four webinars for 2014 – 2015 year! My name is Amy Gorecki and I will be your moderator this afternoon.

[SLIDE – Image logo LD@school] Text on slide: Funding for the production of this publication was provided by the Ministry of Education. Please note that the views expressed in this webinar are the views of the Recipient and do not necessarily reflect those of the Ministry of Education.]

Funding for the production of this webinar was provided by the Ministry of Education. Please note that the views expressed in this webinar are the views of the Recipient and do not necessarily reflect those of the Ministry of Education.

[SLIDE – Welcome]

The LD@school team is very pleased to welcome our guest speaker, Dr. Daniel Ansari, who will be speaking to us this afternoon about Understanding Developmental Dyscalculia: A Math Learning Disability.

Just to let everyone know, all webinar participants except for the presenter have now been muted for the remainder of the presentation; once Dr. Ansari has finished his presentation, we will be opening up the floor for questions.

Over the course of the presentation, if you would like to ask any of the LD@school team a question, you may enter your text in the box at the bottom of the control panel and choose to send it to the staff from the dropdown menu underneath.

Amy – After the webinar, we will be sending out presentation SLIDES, as well as a link to a survey to provide us with feedback on the webinar. In approximately three weeks, the webinar recording will be available and we will send out a link to all participants.

[SLIDE – Welcome
Text on slide: Dr. Daniel Ansari. Western University, Canada
Picture of Daniel Ansari.]

That takes care of all of our housekeeping for this afternoon, so let’s get started.

I’d like to introduce our speaker, Dr. Daniel Ansari.

Dr. Daniel Ansari is a Professor and Canada Research Chair in Developmental Cognitive Neuroscience in the Department of Psychology at Western University, where he heads the Numerical Cognition Laboratory. Dr. Ansari and his team explore the developmental trajectory underlying both the typical and atypical development of mathematical skills. Dr. Ansari has received the ‘Early Career Contributions’ Award from the Society for Research in Child Development, the Boyd McCandless Early Researcher Award from the American Psychological Association. In 2014, Dr. Ansari was named as a member of the inaugural cohort of the College of New Scholars, Artists and Scientists of the Royal Society of Canada.

Welcome Dr. Ansari; the cyber floor is now yours.

[Text on slide: Daniel Ansari
Numerical Cognition Laboratory
Department of Psychology & Brain and Mind Institute
University of Western Ontario.

Image logo Brain and Mind, Image logo University of Western Ontario.

LD@school Webinar, Learning Disabilities Association of Ontario, March thirty first two thousand and fifteen.]

Dr. Ansari – Thank you very much. Thank you very much, it’s a great pleasure to be here today and be able to share some of our insights into developmental dyscalculia with you.

[SLIDE – Poll Question Number One
[Text on the slide:
• How important do you think math skills are for educational & life success
• On a Scale from one to four with one being not important at all and four being very important.]

Before I get started, I wanted to ask the audience a poll question, so we can launch that poll question now, which is “how important do you think math skills are for educational and life success?” And please indicate so on a scale from one to four, with one being not being very important at all and four being very important. So if you can respond now, that would be great. And submit your score and we can go ahead and close the poll. Okay, well 68% of you think it’s very important, 29% think it’s important and only 3% think it’s somewhat important.
Well, I want to start my presentation by showing you some data that indicates that math skills are indeed extremely important, not just for educational but also for life success. So here are some statistics to address this question of how important are math skills. Bynner and Parsons in 2005 stated in a report in the U.K. found that low numeracy associated with the probability of negative outcomes such as unemployment, physical illness, depression, and even incarceration. In other words, there’s a correlation between individuals’ numeracy abilities and these negative life outcomes.

Relatedly, the OECD, the Organization for Economic Corporation and Development, that publishes this Program for International Student Assessment, or the PISA study, has shown that improvements in mathematical competence across time are related to economic growth within countries. So there’s a correlation again between improvements in mathematical competence and economic growth.

KPMG, the management consultancy, was commissioned by the U.K. government to estimate the cost of low numeracy, and they estimated that about £2.4 billion per year are lost, 2.4 billion pounds sterling, are lost per year due to low numeracy. So again, suggesting that it’s a high economic cost to low numeracy.

Beyond economics, numeracy also plays a role in other domains of life such as healthcare. There’s a growing field called ‘health numeracy’ where researchers are showing that the ability of patients and healthcare professionals to use healthcare information is influenced by their numerical abilities. Just consider a nurse on the floor of an emergency room having to read off numbers of an instrument very quickly and translate them, maybe even perform some sort of calculation, in order to deliver medication or some other program to the patient. If any mistake is made in those rapid calculations, and the recognition on the screen of the instrument, that’s going to translate into potentially adverse implications for the patient.

So these statistics show how critical it is to know more about why some children struggle so much to acquire basic numerical and mathematical skills.

[SLIDE – How familiar are you with Developmental Dyscalculia?]

On a Scale from one to four with one being not familiar at all and four being very familiar.]

[SLIDE – Poll Question number two

Text on the slide:

• How familiar are you with Developmental Dyscalculia?

• On a Scale from one to four with one being not familiar at all and four being very familiar.]
So I have a second poll question, which is ‘how familiar are you with Developmental Dyscalculia? And we can launch the poll now, and please indicate one a scale from one to four, where one being not familiar at all and four being very familiar. So, if you can indicate that and submit your scores. We can go ahead and show the results. Okay, so the majority of you are either not familiar or somewhat familiar. Okay, that’s very good to know for me to know what the audience knows about what I’m going to be talking about, and hopefully by the end of this webinar, you’ll be much more familiar with developmental dyscalculia.

[SLIDE – Poll Question number three
Text on the slide:
• How familiar are you with Developmental Dyslexia?
• On a Scale from one to four with one being not familiar at all and four being very familiar.]

I have another poll question, which is ‘how familiar are you with Developmental Dyslexia?’ And again please, we can open the poll and let you indicate on a scale of one to four, with one being not familiar at all and four being very familiar. If you can submit those score, and we can go ahead and close that poll and show the results. Great, so here the results clearly indicate that the audience is more familiar with Developmental Dyslexia than Developmental Dyscalculia. So thank you very much for those answers to my poll questions.

[SLIDE – What is Developmental Dyscalculia
Text on the slide:
Image: A student having math struggles.]

So I want to start by defining Developmental Dyscalculia; what is Developmental Dyscalculia?

[SLIDE – Diagnostic Criteria]

I’m going to be reviewing some diagnostic criteria for you that will get us started.

[SLIDE – DSM five.

One of the most commonly used diagnostic criteria, of course, is the DSM – the Diagnostic and Statistical Manual of Mental Disorder. It’s now in its fifth edition, published by the American Psychiatric Association.

[SLIDE – DSM FIVE
Text on the slide:
Specific learning disorder
“A neurodevelopmental disorder of biological origin (highlighted in yellow) manifested in learning difficulty and problems in acquiring academic skills markedly below age level and manifested in the early
school years, lasting for at least 6 months; not attributed to intellectual disabilities, developmental disorders, or neurological or motor disorders].

In the DSM-V, Developmental Dyscalculia falls under an umbrella term, called ‘specific learning disorders’. The definition in the DSM-V states that a specific learning disorder is “a neurodevelopmental disorder of biological origin manifested in learning difficulty and problems in acquiring academic skills markedly below age level and manifested in the early school years, lasting for at least six months; not attributed to intellectual disabilities, developmental disorders, or neurological or motor disorders.” I just want to highlight two things here: one of them is that the DSM-V states it’s of biological origins. We’ll talk a little bit about what we know with regards to the neuroscience of developmental dyscalculia, and importantly as well, something that wasn’t in the DSM-IV is this criterion that it has to last for at least six months. So the direct implication here is that in order to diagnose somebody with a specific learning disorder in mathematics, developmental dyscalculia, one has to look at children repeatedly, and we experience that very much in our research. There are a lot of so-called forces positively, that we only diagnose children using one time points and multiple time points are required in order to be confident that a particular individual has or does not have developmental dyscalculia.

[SLIDE – DSM FIVE.
Text on the slide:
Specific learning disorder
Specify if:
• With impairment in reading;
• With impairment in written expression;
• With impairment in mathematics;
• Number sense, fact and calculation;
• Mathematical reasoning.]

It also states that it’s not actually attributed to intellectual ability, so it’s a market deficit in one particular area. Furthermore, the DSM-V then specifies that one has to specify whether the specific learning disorder is with impairment in reading, which would be developmental dyslexia; with written expression; with impairments in mathematics, and for impairments in mathematics it further specifies that that could encompass difficulties with things such as number sense, and I’ll talk a lot more about number sense, facts and calculation, so the ability to retrieve arithmetic facts and to fluidly calculate, and I’ll unpack what those deficits are, as well as mathematical reasoning, the ability to more broadly understand the meaning, for example, of arithmetic or the inverse relationship between addition and subtraction.

[SLIDE – Ontario Ministry of Education Definitions from the PPM 8
Text on the slide:
From the PPM Eight
“The Ministry of Education defines learning disability as one of a number of neurodevelopmental disorders that persistently and significantly has an impact on the ability to learn and use academic and other skills and that results in difficulties in the development and use of skills in one or more of the following areas: reading, writing, mathematics, and work habits and learning skills.”]
We should also look at the Ontario Ministry of Education definitions for learning disabilities. So “the Ministry of Education defines learning disability as one of a number of neurodevelopmental disorders that persistently and significantly has an impact on the ability to learn and use academic and other skills that results in difficulties in the development and use of skills in one or more of the following areas: reading, writing, mathematics, and work habits and learning skills.” You can see that there’s quite a bit of alignment between DSM-V definition of specific learning disorder and what the Ontario Ministry of Education puts forward as its definition.

[SLIDE – Developmental Dyscalculia Prevalence
Text on the slide:
- Prevalence equivalent to five to seven percent (Shalev, 2007; Butterworth et al., two thousand and eleven);
- Prevalence comparable to dyslexia.
- Other names:
  - Mathematics Learning Disorder (MLD);
  - Mathematics Disorder (MD) - DSM IV.]

What about the prevalence of developmental dyscalculia? There are only a limited number of studies that have estimated the prevalence of developmental dyscalculia, but these have estimated that between 5 and 7% of the population present with a profile that is consistent with the diagnosis of developmental dyscalculia. Therefore the prevalence is actually comparable to developmental dyslexia, but I should note here that we have a lot more prevalent studies of dyslexia than we have of dyscalculia. So I would put more confidence in the presence of rates for dyslexia than I would for dyscalculia. I should also note at this point that there are other names that are being used to describe what I refer to as developmental dyscalculia, a specific learning disorder in the domain of mathematics. Other researchers and practitioners use terms such as ‘mathematics learning disorder’ or MLD, and ‘mathematics disorder’ which was the term previously used by the DSM-IV before the DSM-V switched it to ‘specific learning disorders’ and further categorized it as a reading, writing, or a math disorder. So it’s important to note that these labels are used interchangeably in the research literature.

[SLIDE – Ministry Of Education notes on Terminology from the PPM 8
Text on the slide:
- There are different terms used to describe various learning disabilities, which can be confusing: some are medical, some are used in research, some are used for a clinical diagnosis, and some are used in an educational setting;
- Learning disabilities are all neurologically-based processing problems;
- These processing problems can interfere with learning basic skills such as reading, writing and/or math;
- They can also interfere with higher level skills such as organization, time planning, abstract reasoning, long or short term memory and attention.]

It’s useful here also to consider what the Ontario Ministry of Education says about terminology. They say that there are different terms used to describe various learning disabilities, which can be confusing: some are medical, some are used in research, some are used for a clinical diagnosis, and some are used in an educational setting. Learning disabilities are all neurologically-based processing problems. These
processing problems can interfere with basic skills such as reading, writing or math. They can also interfere with high-level skills such as high-level organization, time-planning, abstract reasoning, long or short-term memory, and attention. We talk about the difference between the basic skills and the high-level skills in the context of dyscalculia as well. But here is also a recognition from the Ministry of Education that there are multiple terms that are often used interchangeably that can be confusing.

[SLIDE – Ministry Of Education notes on Terminology from the PPM 8
[Text on the slide:
- Dyslexia, dysgraphia, dyspraxia and dyscalculia are terms used in the medical and research fields;
- These terms may also be more prevalent in the US and the UK;
- In a school setting, students may be considered to have a specific learning disability (or learning disabilities) that affect academic areas or impact on executive functioning;
- A psychologist might diagnose a math learning disability when the learning difficulties are unexpected.]

Furthermore, the Ministry of Education states that dyslexia, dysgraphia, dyspraxia and dyscalculia are terms used in the medical and research fields. These terms may also be more prevalent in the U.S. and the U.K. In a school setting, students may be considered to have a specific learning disability (or learning disabilities) that affect academic areas or impact on executive function. A psychologist might diagnose a math learning disability when the learning difficulties are unexpected. ‘Unexpected’ here refers to the notion that a learning disability occurs despite otherwise normal functioning, which I also think is consistent with the DSM-V where the definition is that it’s unexpected given the individuals’ other neurological and psychological functioning.

[SLIDE – Understanding the Terms
Text on the slide:
Image of a table comparing terms from medical/research in the U.S. and U.K. and Ontario. Dyslexia, dysgraphia, dyspraxia, and dyscalculia are terms from the medical research U.S./U.K. column. Reading, written expression, speech, and math are terms from the in Ontario column.]

Here’s a table that may help to understand the terms a little bit better. So in medical or research terminology in the U.S. and U.K., people refer to dyslexia in Ontario as ‘reading difficulties’, dysgraphia problems with written expression, dyspraxia problems with speech, and dyscalculia with math.

[SLIDE – Developmental Dyscalculia
Text on the slide:
Ratio of publications on Dyslexia: Dyscalculia. A ratio of fourteen to one is shown. Berch & Mazzocco (two thousand and seven).]

So I hope this overview of the terminology helps you understand how is dyscalculia used and how it’s similar to the other terms that are being used to describe specific learning difficulties in the domain of mathematics.
Now, I've already alluded to this when I talked about the prevalent studies but there really is a big difference between the ratios of publications on dyslexia compared to dyscalculia. For every fourteen publications on dyslexia there's only one on dyscalculia.

So it’s an area that we’re still trying to understand what causes developmental dyscalculia, and what neurological functions are associated with dyscalculia. But we’ve made some progress and I want to review that progress for you.

[SLIDE – What underlies Developmental Dyscalculia?
Image of a student in front of the board.]

So I want to ask the question what underlies developmental dyscalculia? Having provided a definition and having a discussion of terminology and prevalence, it’s now time to examine what might be the causal factors of developmental dyscalculia.

[SLIDE – Symptoms and causes
Image of Geary’s research that is depicted in a flow chart. Published in nineteen ninety-three.

There are four boxes on the left-hand side of the screen that begin the flow chart: counting knowledge; working memory: attentional allocation; working memory: decay rate; and counting speed. Counting knowledge and working memory: attentional allocation both lead to a second box labeled procedural skills. Working memory: decay rate and counting speed lead to a box labeled knowledge base: fact retrieval. There is an arrow connecting procedural skills to knowledge base: fact retrieval. Both of the procedural skills and knowledge base: fact retrieval boxes lead to a third and final box, which is labelled as test performance.]

Until very recently, there was great focus on a particular set of factors that might contribute to test performance that are very well illustrated here in this figure taken from David Geary’s review paper in 1993. David Geary, researcher out of the United States, perhaps the most influential researcher on developmental dyscalculia, or he often refers to it as MLD, math learning disability. When he conducted his early work, he focused very much on high-level functioning, such as counting knowledge, working memory – of course working memory we need not only to do math but we also needed in order to do all sorts of things in our everyday lives, so it’s not math specific. Procedural skills are not math specific and neither are fact retrieval. So all of these were thought to contribute to test performance, and indeed there was very good evidence suggesting that all of these factors are contributing to test performance.

[SLIDE – Table 4.4 Summary of MD children’s Cognitive Deficits in Elementary Mathematics
Table four point four, Summary of MD children’s Cognitive Deficits in Elementary Mathematics.
This table has 2 columns. The column on the left-hand side represents the functional deficit in children with Mathematics Dyscalculia and the column on the right-hand side represents the potential deficits in supporting systems. This table summarizes that children who use immature counting procedures to solve simple arithmetic problem will use an immature conceptual understanding of counting. Frequent procedures errors influence to immature conceptual understanding of counting, and poor working memory (Hicth and McAuley in nineteen ninety, Geary in nineteen ninety, Siegel and Ryan, Nineteen eighty). The last deficit is the arithmetic fact retrieval deficits, which may reflect difficulties in lexical
access and/or difficulties in inhibiting irrelevant associations. (Barrouillet and al., nineteen ninety seven, Coonway and Eagle, nineteen ninety four.)]

Looking at this slightly differently, there is a table in which he summarizes the cognitive deficits in children with MD, mathematics disability or dyscalculia. On the left-hand side of the table you can see the functional deficits and then the potential deficits in supporting systems. So he and his collaborators repeatedly observed that children with developmental dyscalculia use immature counting procedures to solve simple arithmetic problems and this made a rise from immature conceptual understanding of counting, so this emphasis on the understanding of counting. Frequent counting procedure errors, which may reflect immature conceptual understanding of counting, and poor working memory. By counting procedures, what he refers to are the use of counting in order to solve mental arithmetic problems. So it’s not the numeration of sets, but it’s using counting and using one’s fingers to solve mental arithmetic problems and it’s various levels of sophistication of these counting procedures, which I will illustrate on the next SLIDE. The other deficit is the arithmetic fact retrieval deficits, which he attributes to difficulties in lexical access and/or difficulties in inhibiting irrelevant associations. So again, the potential deficit in supporting system arises from general mechanisms, such as lexical access or the ability to exert and exhibit control. That’s thought to be the causal factor in arithmetic fact deficits. At least, in the early years that was the position that people had when they looked at the causes of developmental dyscalculia.

[SLIDE – Strategy Development

Image of a graph that represents decreasing reaction times and cognitive resources. The decreasing reaction times and cognitive resources are shown on the y-axis and the increasing maturity is shown on the x-axis of the graph. The graph is represented by a Venn-diagram. Within the top circle of the Venn-diagram, labelled as ‘counting based’ there is a second Venn-diagram with two intersecting circles. The top circle of the inner Venn-diagram contains the words ‘counting fingers’, ‘sum’, ‘max’, and ‘min’. The lower circle of the inner Venn-diagram contains the words ‘verbal counting’, ‘sum’, ‘max’, and ‘min’. In the outer Venn-diagram, the second and lower circle, labelled as ‘memory-based’ contains a three circle Venn-diagram. The top circle contains the word ‘fingers’, the middle contains the word ‘decomposition’ and the lower contains the word ‘retrieval’.

With regards to fact retrieval and counting, one needs to consider how counting procedures change over developmental time. What we see is that children start out by using their fingers in order to perform elementary calculations, addition problem for example, but there are various types of levels of sophistications, for example if we are adding five plus three we could count out both addends on our fingers, or we could hold up one hand for five and one hand for three, which would be a more sophisticated counting finger-based strategy. And then children more away from using their fingers to using verbal counting, and again they’re at various levels of sophistication. Eventually, they move to a stage where they can decompose problems into multiple parts, or simply retrieve the solutions from memory. Children with developmental dyscalculia typically do not undergo the same developmental trajectory with regards to the strategies that they use. Most commonly, children with developmental dyscalculia fail to encode arithmetic facts into long-term memory. They will rely on count-based strategies using their fingers or verbal counting even when their peers have already moved onto retrieving the solutions to simple problems, such as two plus three from memory. So it seems to be at
the level of encoding arithmetic problems into long-term memory, there’s a fundamental barrier there in children with developmental dyscalculia.

[SLIDE – Key Findings
Text on the slide:
A persistent inability to retrieve arithmetic facts from memory is a hallmark of Developmental Dyscalculia].

So key findings from the earlier literature is that dyscalculia is associated with a persistent inability to retrieve arithmetic facts from memory, and this is a hallmark of developmental dyscalculia.

[SLIDE – What about factors that are specific to number processing?
Text on the slide:
Domain-specific symptoms & causes.
Image: A student having math struggles].

[SLIDE – Domain-specific factors
Text on the slide:
- Analogy: phonological awareness;
- Awareness that language decomposes into units of sounds;
- Foundational competence;
- Readiness skill].

So this early work was very productive in helping us to describe the kinds of problems that children have when they encounter simple math problems. However, this literature didn’t focus very much on factors that might be specific to number processing. They focused on general difficulties, such as working memory, inhibitory control, and not so much what’s domain-specific. Are there maybe some deficits that have to do in which the way children with developmental dyscalculia represent numbers that could lie at the heart of their deficits. More recently, researchers have started to search for domain-specific factors that may account for developmental dyscalculia. And an analogy that we could draw here is phonological awareness in the domain of reading that is thought to be one of the key building blocks of building a reading brain. The awareness that sounds decomposing to units, that that language decomposes into units of sound, as you can measure by example by the rhyming task that I’ve shown there on the right-hand side of your screen, where rhyming is a good way to assess whether children have a good understanding of phonological awareness.

[SLIDE – Foundational Competencies
Image of a graph illustrating the Matthew Effect of Reading. The grade levels K, 1, 2, and 3 are shown on the x-axis and achievement is show on the y-axis. The graph shows two lines: the first is a low, almost straight line that represents achievement without foundational skills, and the second is a line that increases significantly as the grade level increases, and represents achievement with foundational skills].

This is known to be a foundational competence, or what we refer to as a ‘readiness skill’. One way of thinking about foundational skills is to think about them developmentally. This is illustrated on this SLIDE here, which is showing the so-called ‘Matthew Effects in Reading’, which was originally described by
Keith Stanovich at the Ontario Institute for Studies in Education at the University of Toronto, who through looking at the literature, observed that those children who lacked critical foundational skills, such as phonological awareness early on have a more flat developmental trajectory, that is their reading skills don’t grow at the same rate as those who have the foundational skills, suggesting that there are cumulative effects for having these foundational competencies. And I think it can be argued that this was a real breakthrough in understanding dyslexia because it allowed individuals to look for difficulties that might already be in existence before children even encounter print, just their phonological awareness of the spoken language turned out to be a good predictor of their later reading skills.

[SLIDE – Implication
Text on the slide:
Early deficit in core competencies lead to subsequent difficulties in acquiring higher-level skills].

So the implication here is that early deficits in core competencies lead to subsequent difficulties in acquiring high-level skills. It’s the kinds of skills that Geary looked at – arithmetic and even more complex math skills.

[SLIDE – Poll Question Number Four
Text on the slide:
- How clear is the concept of ‘foundational competencies’ to you?
- On a Scale from one to four with one being not clear at all and four being very clear].

So what I want to do now is to look at what are these core competencies in the domain of mathematics and number understanding, but before I do so, I want to ask you a poll question which is just to help me understand whether you’re following along with the vocabulary that I’m using is ‘how clear is the concept of foundational competencies to you?’. Could you please indicate on a scale from one to four where one being not clear at all and four being very clear. So we can open that poll, and if you could please submit your answers. Excellent, I think we can probably close that poll and show the results. Good. So, 59% of you say that it’s very clear, but 22% of you say that it’s clear and 17% of you say that it’s somewhat clear.

[SLIDE – Foundational Competencies
Image of a graph illustrating the Matthew Effect of Reading. The grade levels K, 1, 2, and 3 are shown on the x-axis and achievement is show on the y-axis. The graph shows two lines: the first is a low, almost straight line that represents achievement without foundational skills, and the second is a line that increases significantly as the grade level increases, and represents achievement with foundational skills].

So let me just try to elaborate this just for a few seconds, I’m going to go back. I think this is the best SLIDE to elaborate it. It’s the notion that early competencies that are fundamental to acquiring a particular skill, for example reading, have a cumulative effect on the subsequent learning of high level skills. So having poor phonological awareness means that you’re going to have difficulties linking letters and speech sounds. If you have difficulty linking letters and speech sounds, you’re going to have trouble reading letter by letter, and later on reading by word forms. So it’s the notion that you need to have these building blocks in place in order to set the developmental trajectory in the right way. So I hope that clarifies things a bit more.
So now having illustrated this notion about foundational competencies, or building blocks in developmental dyslexia, what about developmental dyscalculia? We know a lot about their strategy difficulties, about their working memory deficits, but this has something even more deep at the core of the understanding of numbers that is dysfunctional. A breakthrough study was published in 2004 by Karen Landerl, Ana Bevan, and Brian Butterworth at University College London and they really focused in their study on basic numerical capacities.

**So to give you one example of what they looked at, but first I need to describe to you the groups that they tested. They compared four groups of individuals. One group of individuals with dyscalculia, so these were students who had specific difficulties in acquiring basic math skills and scored two standard deviations below the mean on the standardized test of math but were fine with their reading abilities. Dyslexics showed disability on standardized test of reading achievement, but not math. A double deficit group, or a dyslexic/dyscalculic group, who had both difficulties in reading and in math. And a group of typically developing children who had no market deficits in either reading or math.**

**Number comparison - which is numerically larger? Size comparison - which is physically larger?**

So their focus on basic number focusing on developing tasks such as this one here. It’s a very simple task; you see two numbers and you can ask two possible questions. You might be asked to compare them on the basis of their numerical magnitude or on the basis of their physical size. So in the case of eight and two you would have to say that eight for numerically larger and two for physically larger. This is an elegant task because you could measure at the same time, using the same numbers on the screen. The ability of children to access the numerical meaning of the numbers, when you ask them to compare them on the basis of numerical magnitude, or the physical size, which doesn’t require you to have a good understanding of the numerical magnitude.
Image of a bar graph illustrating the basic number processing. There are eight bars clustered into four groups: the first group is labelled as control group, the second group is labelled as dyslexia, the third group is labelled as dyscalculia and the last group is labelled as a double deficit group, or a dyslexic/dyscalculic group. Each group contains data graphed on two bars – size comparison and number comparison. For all four groups, the size comparison data is more or less the same, scoring six hundred and fifty. The number comparison data is circled for the dyscalculia and dyscalculia/dyslexia group where both groups scored almost one thousand five hundred compared to the control group and dyslexia group who scored approximately one thousand one hundred.

So, when they ran this task and compared performance in the number comparison and in the size comparison task, this is what they found. What you see on this figure are reaction times. So the access is showing you reaction times in milliseconds, and the various groups, the control group, the dyslexics, the dyscalculics, and the dyscalculia/dyslexic group. What you can see in the green bars is the reaction times for the size comparison task. So this is where children were asked to judge which of two numbers are physically larger, and when you compare across the four groups what you can see is that all of the children were pretty fast at this. There was critically no difference between the dyscalculics and the dyslexics or the controls and the dyscalculics. All groups performed equally well when they simply had to look at which number is physically larger. However, a massive difference emerged when you ask children to compare the two numbers, same stimuli, on the basis of numerical quantity that is represented by the symbols. And what you see here now is that the children with dyscalculia as well as those with dyscalculia and dyslexia, the two groups toward the right-hand side of the graph, they are both significantly slower than both the control group and the dyslexia group.

Findings suggest that: Dyscalculia = deficit to represent and process numerical magnitude in a typical way.

What this study shows is that children with developmental dyscalculia don’t have a problem with number recognition, what they have a problem with is retrieving the meaning of the erratic numerals, and comparing the meaning of two erratic numerals with one another in the context of judging which one is numerically larger.

There is a box that contains the words ‘lack of understanding numerical magnitude’ with an arrow leading to another box that contains the words ‘difficulties in learning numerical expressions and maintaining them in memory’. Under both boxes, there is a long arrow pointing to the right that demonstrates the relationship of these two over developmental time.

- Lack of understanding numerical magnitude;
- Difficulties in learning numerical expressions and maintaining them in memory;
- Developmental time.
This was sort of a breakthrough finding because now we have a candidate for a more basic skill that might lie at the core of developmental dyscalculia. So here’s just showing you that significantly longer reaction time in the number comparison for the dyscalculic and co-morbid group, or double deficit group, compared to the two control groups – the control group who had no deficits and the dyslexic group. So these findings then suggest that dyscalculia is associated or is a deficit to represent and process numerical magnitude in a typical way. Furthermore, this leads to the hypothesis in terms of the foundational competency that lack of understanding numerical magnitude leads to difficulties in learning numerical expressions and maintaining them in memory. So Geary had described these problems using procedures and maintenance and memory, but that model hadn’t really described where those deficits come from.

Now there’s a that if you have poor representations of quantity, and poor representations of the meaning of numerical symbols, then it’s going to be very difficult for you to use those symbols in order to perform, for example calculation problems, and that may then lead to these working memory deficits and the inability to retrieve, to encode arithmetic facts into long-term memory and to retrieve them. And of course, this occurs over developmental time. That the lack of understanding numerical magnitude early, which over developmental time in an accumulative way leads to these high-level difficulties.

[SLIDE – Implication: Dyscalculia is associated with deficits in processing the meaning of numbers]

So the implication from these findings is that dyscalculia is associated with deficits in processing the meaning of numbers.

Another implication is that the risk of dyscalculia can be screened before children learn arithmetic. Early studies were all looking at school-aged children, they were all looking at difficulties they were having with arithmetic. Now we have a candidate mechanism that can be detected much earlier.

[SLIDE – Implication: Risk of Dyscalculia can be screened for before children learn arithmetic.]

[SLIDE – Ministry Of Education

Text on the slide:

Many students enter school having already shown the precursors or early signs of learning disabilities, such as language delays or difficulty with rhyming or counting. PPM eight stresses the importance of early and ongoing screening.]

This is also related to something that the Ontario Ministry of Education emphasized, which is that many students enter school already having shown the precursors or early signs of learning disabilities, such as language delays or difficulty with rhyming or counting. And the Ministry of Education and its memorandum states, or stressed the importance of early and ongoing screening. And early and ongoing screening requires that we know what to screen for. We need to screen for the precursors of school-aged level difficulties. The precursors, for example of calculation deficits, in developmental dyscalculia.

[SLIDE – Non-symbolic number processing]
There are four images. The first is a green square with polka dots, the second one is a monkey counting two tiles of black dots on a blackboard, the third one is an infant smiling and looking at light, and the last one is a brain where certain parts of the left and right hemispheres are highlighted in yellow.

In this context, I want to introduce you to the notion that we share with other animals the basic quantity that the ability that we refer to as non-symbolic number processing. Non-symbolic number processing simply means that you can guess how many dots are in this array, and you can do so very rapidly, you may not be 100% correct, it’s more of an approximate system of number representation. It’s been found that even very young infants are sensitive to the difference between two daughter rays and can measure that looking at their looking times, how much time they spend looking at one ray of dots versus another. And there’s a long line of research showing that non-human primates or even salamanders are sensitive to the differences between non-symbolic quantities. Furthermore, we understand a lot about the brain mechanisms underlying non-symbolic number processing and we know that in the parietal cortex that there are areas in the so-called inter-parietal sulcus that are highlighted here in yellow on this brain figure, that are activated when you engage in non-symbolic number processing.

[SLIDE – Is Developmental Dyscalculia characterized by a core deficit in non-symbolic number processing?]

This, of course, leads to the question whether developmental dyscalculia is characterized by a core deficit in non-symbolic number processing. And this is really a very important question because if indeed developmental dyscalculia is characterized by deficit non-symbolic number processing, then maybe it means that we’re born with developmental dyscalculia. So this is a key question in the field.

[SLIDE – Two possibilities
Text on the slide:
There are two images. The first represents Number Module Deficit where there is a circle with bubbles inside of it with a red X over top. There is also an arrow that points to a number seven with an X over it. The second image is represents Symbolic Access Deficit where there is a circle with bubbles inside, this time without an X over the bubbles. There is also a double-sided arrow with an X over it that points to the number seven with an X over it as well as to the bubbles.]

There are, of course, two possibilities. One of them is that you have impaired non-symbolic number processing, which is indicated by this daughter ray, which leads to deficits in symbolic processing, which is the so-called number module deficit hypothesis. The other hypothesis is that, perhaps, it’s not so much that you’re born with a deficit in non-symbolic number processing, but that children with developmental dyscalculia have difficulties in linking numerical symbols, such as number words and erratic numerals, to these pre-existing, non-symbolic approximate representations in numbers.

[SLIDE – Poll Question Number Five
Text on the slide:
• How clear is the distinction between number module deficit’ and ‘symbolic access deficit to you’?
• On a Scale from one to four with one being not at all and four being very clear.]
I want to briefly explore the evidence for these two hypotheses with you, but first I want to ask you a poll question so that I can get an understanding for how clear my description was and what I want to ask you is how clear is the distinction between ‘number module deficit’ and ‘symbolic access deficit’ to you? Please indicate this on a scale from one to 4, with one being not at all and four being very clear. So if you can go ahead and vote, please. If we could take a look at the results. Okay, so somewhat clear is the majority, so I think I’m just going to briefly go over it, I don’t have much time to fully re-iterate what I just said.

[SLIDE – Two possibilities
Text on the slide:
There are two images. The first represents Number Module Deficit where there is a circle with bubbles inside of it with a red X over top. There is also an arrow that points to a number seven with an X over it. The second image is represents Symbolic Access Deficit where there is a circle with bubbles inside, this time without an X over the bubbles. There is also a double-sided arrow with an X over it that points to the number seven with an X over it as well as to the bubbles.]

It’s actually a very simple, two simple possibilities. So we share with other animals a basic non-symbolic sense of quantity. Some people refer to this as ‘number sense’. We can discriminate between daughter rays, and so can non-human primates and we can detect that in very young babies. Now it might be that developmental dyscalculia is due to a deficit of this non-symbolic number processing system that then leads to difficulties in acquiring symbols, such as erratic numerals or number words. But it could also be, which is what the symbolic access deficit hypothesizes that the difficulty is not so much that you’re born with impairment in non-symbolic number processing, but that children with developmental dyscalculia have difficulties making symbols meaningful, linking them to representations of quantity. So I hope that’s made it a little bit clearer.

[SLIDE – Evidence for number module deficit in Developmental Dyscalculia]

So I now want to look at evidence for the number module deficit in developmental dyscalculia, and then also evidence for also the symbol access deficit model.

[SLIDE – Child Development image of journal article
Child Development, July/August (two thousand and eleven) Volume eighty two, number four, pages one thousand two-hundred twenty four until one thousand two hundred thirty seven.

Impaired Acuity of the Approximate Number System Underlies Mathematical Learning Disabilities (Dyscalculia). This journal was written by Michèle M.M Mazzocco, from Kennedy Krieger Institute and Johns Hopkins University and Lisa Feigenson and Justin Halberda from Johns Hopkins University.]

There was an influential paper published in 2011 by Michèle Mazzocco, Lisa Feigenson, and Justin Halberda from John Hopkins University entitled ‘Impaired Acuity of the Approximate Number System Underlies Mathematical Learning Disability (Dyscalculia)’. Complicated title but the study’s not as complicated as the title makes it sound.

[SLIDE – Longitudinal Study
Text on the slide:
Data collected over one ten years
Children were tested in grade nine
- Ten MLD/Dyscalculia (tenth percentile or below)
- 9 Low Achieving (LA, tenth – twenty fifth percentile)
- Thirty seven typically achieving (TA, twenty fifth – one hundredth percentile)
- Fifteen high Achieving (HA, ninety fifth percentile and above).

This was based on the longitudinal study conducted by Michèle Mazzocco, and the children were tested when they were in grade nine, but they had scores available for over ten years before then. From this longitudinal study, Michèle Mazzocco and her colleagues were able to identify ten children with math learning disability or dyscalculia who had very profound difficulties in math, and they demonstrated those profound difficulties in math, tenth percentile or below for ten years. Then there’s a group of low-achieving children who are slightly better, not as impaired but still impaired. Thirty-seven typically achieving children, and fifteen high-achieving children. So you’ve got a full range of math performers. The question now is does non-symbolic number processing differentiate between these groups.

[SLIDE – Task
Image of yellow and blue dots. This image helps to indicate whether there are bluer or more yellow dots.]

They use a very simple task. You see a display of yellow and blue dots and you have to indicate whether there are bluer or more yellow dots. And these flash very quickly so you have to make a rough judgement using your intuitive sense of non-symbolic numerical quantities.

[SLIDE – Result
The results from the previous task is graphed on a bar graph and used the Mean Webinar Fraction as a comparison between the four group – MLD, low achieving, typically achieving, and high achieving. The MLD bar graph is highest with a Mean Weber Fraction of approximately 0.38, followed by low achieving with a Mean Weber Fraction of approximately 0.26, summarily the typically achieving group also had a Mean Weber Fraction of approximately 0.26, and lastly the high achieving scored a mean weber fraction of approximately 0.23.]

What they found was; they used a measure called Weber Fraction, which is a measure of how accurate you are at making these discriminations, and a higher Weber Fraction means poorer performance. Now what you can see is that the group with those very specific deficits, the MLD group, did show a higher Weber Fraction. They did show poorer acuity in this non-symbolic number discrimination task than all the other groups.

[SLIDE – Evidence for symbolic access deficit number processing deficit in Developmental Dyscalculia.]
So this is supportive of this notion that math learning disabilities, your dyscalculic, is associated with this core deficit in non-symbolic number processing.

Contents lists available at ScienceDirect.
Defective number module or impaired access? Numerical magnitude processing in first grades with mathematical difficulties.

This journal was written by Bert De Smedt from Centre of Parenting, Child Welfare and Disabilities, Katholieke Universiteit, Leuven, Three thousand Leuven, Belgium and by Camilla Gilmore from learning Science Institute, University of Nottingham, Nottingham, postal code: NG eight, one BB, United Kingdom.

However, there is also evidence for the symbolic access deficit in developmental dyscalculia. I’m just reviewing a selection of the paper because I don’t want to bore you with paper after paper. But here’s a paper by Bert De Smedt and Camilla Gilmore.

Table one: Descriptive statistics of the sample (Numbers of individuals tested = eighty-two)

This table holds 5 columns. The right hand-side of the column represents the group, following by the numbers, sex, age, and the very last is the left hand-side of the column which represents general mathematics achievements.

This table summarizes that twenty children with dyscalculia (eights boys and twelve girls) aged six or under with general mathematics achievement of 71.52. Twenty-one children (seven boys and fourteen girls) aged six or under with low general mathematics achievement of 88.61. Forty-one children aged six or under (nineteen boys and twenty-two) with typically-achieving general mathematics achievement of 108.71.

Note: Standard deviations are in parentheses, MLD, Mathematics Learning disabilities; LA, Typically achieving. Standardized score (M=100, SD=15).

And what they did is they also had various groups of individuals.

Tasks

There are two images. The first image represents non-symbolic number comparison where a dark background that is divided into two equal parts both containing different sized white dots shown on a computer screen. The second image represents symbolic number comparison where a dark background that is divided into two equal parts is shown on a computer screen. The number eight is written on the left-hand side of this screen and the number nine is written on the right-hands side of the same screen. One group of children with MLD or dyscalculia, a low-achieving group, and a typically-achieving group and they tested these individuals’ ability to both perform symbolic, so comparing which of two numbers is larger, digits is larger, or which of two dot arrays is larger, which would be the non-symbolic task.

Bar graph of Numerical Magnitude Comparison.

There are six bars clustered into two groups: the first one group is labelled as ‘symbolic’ and the other is labeled as ‘nonsymbolic’. Each cluster has three bars that represent the dyscalculia group, the low-achieving group and the typically achieving group.
The first cluster compares children’s reaction times in identifying symbolic numerical magnitudes of the three groups. The dyscalculia group scored the highest mean reaction time at approximately one thousand seven hundred milliseconds; the typically achieving group scored the lowest mean reaction time at approximately one thousand four hundred milliseconds; and the low-achieving group scored in between the other two groups with a mean reaction time of approximately one thousand five hundred milliseconds.

The second cluster compares children’s reaction times for identifying nonsymbolic numerical magnitudes of the three groups. All groups had similar reaction times. The dyscalculia group had a mean reaction time of approximately one thousand two hundred fifty, and the low-achieving and typically achieving groups both had the same mean reaction times of approximately one thousand two hundred.

And what they found was that when you looked at the symbolic comparison performance that’s on the left-hand side of your screen; the three bars representing in white the dyscalculia group, in the light grey, the low-achieving group, and the slightly darker grey, the typically achieving group. This is reaction time and what you can see is there are group differences for symbolic, but not for non-symbolic.

So this is evidence in support of this notion that it’s not so much the difficulties with dot discrimination but it’s the difficulty with discriminating between Arabic numerals that lies at the core of developmental dyscalculia. The implication is, and I told you at the very beginning of my webinar, that we’re still very much in the beginning of understanding developmental dyscalculia, that the data are controversial. It’s unclear whether it’s a deficit in symbolic or non-symbolic number processing.

At this point I would say that I believe it’s very much possible that you have various types of dyscalculia with some being associated with non-symbolic number processing and some being associated with symbolic number processing and in future, we need to probably differentiate more between these various sub-types, and I’ll talk about this notion at the end as well.
So to give you an interim summary, developmental dyscalculia is associated with impairments of domain-general competencies – working memory, processing speed, the kinds of things that David Geary investigated in the early ’90s. Looking at what are the arithmetic deficits. Working memory, it’s been found that especially visuo-spatial working memory is impaired, retrieval of arithmetic facts or the difficulty in retrieving or encoding and subsequently retrieving arithmetic facts is a hallmark of developmental dyscalculia. But more recently, work that I’ve just reviewed for you also show there are main specific deficits in foundational competencies – symbolic and non-symbolic number seems to be impaired. It’s unclear which are stronger, but in general, when one looks across the evidence, most of the evidence is in support of the access deficit hypothesis, but as I’ve just said, it might be that there are multiple sub-types of developmental dyscalculia.

[SLIDE – Implication
Text on the slide:
Need to consider both domain-general and domain-specific deficits and how they interact over developmental time.]

So the implication from this is I think we need to consider both domain-general and domain-specific deficits and critically, we need to understand how they interact over developmental time. It’s not either/or maybe, it’s more how are they related? If you have a poor representation of number and if you cannot easily the semantic meaning of numerical symbols, that’s going to impair your ability to calculate and that is subsequently going to impair your ability to perform higher-level problem solving, algebra, and so forth. So we need to think about this developmentally – the early origins and how they cumulatively lead to deficits.

[SLIDE – The Ministry of Education encourages school boards to use a multidisciplinary approach to assessing and identifying learning disabilities.]

Relating this back to the recommendations by the Ontario Ministry of Education, in their memorandum eight they encourage to school boards to use a multidisciplinary approach to assessing and identifying learning disabilities, and I believe that’s fundamental, that one uses both domain-specific and domain-general measures. The domain-specific measures are not yet commonly available but we have a free screening tool at www.numeracyscreener.org that you might want to look at. It’s not a diagnostic tool but at least it provides perhaps some indication of difficulties, which may need to be more thoroughly followed up.

[SLIDE – Historical model of Developmental Dyscalculia
Text on the slide:
Image that contrast the historical model of developmental dyscalculia
There are four boxes on the left-hand side of the screen that begin the flow chart: counting knowledge; working memory: attentional allocation; working memory: decay rate; and counting speed. Counting knowledge and working memory: attentional allocation both lead to a second box labeled procedural skills. Working memory: decay rate and counting speed lead to a box labeled knowledge base: fact retrieval. There is an arrow connecting procedural skills to knowledge base: fact retrieval. Both of the procedural skills and knowledge base: fact retrieval boxes lead to a third and final box, which is labelled as test performance.]
So, to sort of review where we’ve been, where we’ve come from, and where we are now, I want to contrast the historical model of developmental dyscalculia, which is this one, which is very much emphasizing these domain-general competencies to a more modern model of developmental dyscalculia, published by Brian Butterworth and colleagues in Science.

**[SLIDE – Today`s model of Developmental Dyscalculia](image)**

*Image from Butterworth et al (2011)*

The image is representational of three tiers: biological at the bottom, cognitive shown in the middle, and behavioural at the top. In the biological tier, there is a flow chart that shows the relationship between the occipitotemporal, the parietal lobe, and the frontal lobe, which are all classified as genetics in this chart. Fusiform gyrus is in the occipito-temporal box with a double-sided arrow to intraparietal suicus, in the parietal lob box. Intraparietal suicus has a double-sided arrow pointing to angular gyrus, also in the parietal lobe, which then points to the prefrontal cortex with a double-sided arrow, which is in the frontal lobe box.

In the cognitive tier, there is a flow chart where numerosity representation manipulation has two arrows that breakoff and point upward to number symbols and arithmetic fact retrieval. Spacial abilities has an arrow that points back down to numerosity representation manipulation, and another arrow that points upward to concepts, principals, and procedures.

In the behavioural tier, number symbols, arithmetic fact retrieval, simple number tasks from numerosity representation manipulation, and concepts, principals and procedures all have arrows that point to ‘arithmetic’ to show this relationship.

Where now you’re seeing that we are looking at developmental dyscalculia at multiple levels of analysis. We consider the behavioral levels, but then we consider the cognitive levels that include such things as concepts, principles, procedures, spatial abilities, but also, the critical role of numerosity or numerical magnitude representation.

**[SLIDE – No single cause!](image)**

*Image of a journal with: Trends in Neuroscience and Education.*

Trends in Neuroscience and Education Contents lists available at Sciverse ScienceDirect;

Trends in Neuroscience and Education

Journal homepage: www.elsevier.com/locate/tine

Multiple components of developmental dyscalculia

This journal was right by Wim Fias from the department of experimental psychology, Gherst University, H.Dunman 2, B nine thousand Ghent, Belgium, Vinod Menon from School of Medicine, Stanford University, California, United States and Denes Szucs from the department of psychology, University of Cambridge, Cambridge, United Kingdom.

And then even at the biological level and the genetic level; the biological level, the brain level, and the genetics level; I haven’t included too much about that in this talk, but if you’re interested in learning more about that, you can send me an email and I can send you some papers on the more
neurobiological basis of developmental dyscalculia. But we’ve certainly come a long way and we’re starting to understand how all these different sub-components interact with one another.

[SLIDE – Developmental Dyscalculia is a heterogeneous specific learning disorder.]

Related to this, it’s important to recognize, and I think I have emphasized it before, that there’s no single cause of developmental dyscalculia, but there are multiple components. It’s a highly complex specific learning disorder.

[SLIDE – No single cause!]

Image of a journal: Research in Developmental Disabilities.

Research in developmental Disabilities thirty five, two thousand and fourteen, page six fifty seven until six fix seventy.;

Contents lists available at ScienceDirect
Research in developmental Disabilities
Cognitive subtypes of mathematics learning difficulties in primary education.
This journal was written by Dimon Barlet, Daniel Ansari, Anniel Vaessen, and Leo Blomert].

Developmental dyscalculia therefore is a heterogeneous specific learning disorder, and indeed, in a recent analysis, together with colleagues at the University of Maastricht, we used cluster analyses in a relatively large group of children with developmental dyscalculia to differentiate between different subgroups, and we count six different clusters; some children who show very strong impairment in symbolic number processing, that was actually the strongest impairment; but other children who had more working memory impairments; some children who found it very difficult to place numbers on a number line, maybe having a spatial representational problem there as well. So there’s no single cause. The hope for the future is that we can empirically use these cluster analyses and use them to tailor specific diagnostic approaches and intervention approaches to sub-groups. I think that is very much the way that research is moving now, but we need to take individual differences into account.

[SLIDE – Implication: There is not one Developmental Dyscalculia but many.]

So the implication there is there is not one developmental dyscalculia but many and there are many different causes.

[SLIDE – Comorbidity.]

Text on the slide:
Developmental Dyscalculia often not isolated.
Often comorbidity with
  •  Developmental Dyslexia;
  •  ADHD;

No clear evidence for a common cause
Most studies point to disorders with separate causes.]

This also leads me to an important topic which is the topic of comorbidity. So developmental dyscalculia is often not isolated, so you do find some children who only have that math deficit but many have other difficulties, such as developmental dyslexia. Many studies have shown that children who have
developmental dyscalculia often also have reading difficulties or they have attention/hyperactivity disorders, or other generalized problems with executive functioning, for example. Interestingly, there is yet to be any clear evidence for a common cause when it comes to the relationship between developmental dyslexia and developmental dyscalculia. That has not been found yet. People have looked for common causes such as a general symbol processing deficit, does not turn out to explain the comorbidity. So more studies currently point to disorders that exist within the same individuals but have separate causes, but I would say watch this space – there’s a lot more research to be done on this, and I think neuro-scientific research can be very informative here.

[SLIDE – Implication: Multiple specific learning difficulties may exist within the same child, but they are not necessarily linked.]

But we do know from neuroscience that the networks that are engaged by math and reading, some nodes are overlapping, but many are quite different as well. So it is possible that you can have two specific learning disorders that actually have different causal pathways. So the implication here is that multiple specific learning difficulties may exist within the same child, but they are not necessarily linked. I think that’s very important. One interesting question that we want to pursue, for example, does reading intervention improve math, and does math intervention improve reading. So that’s a question we’re looking to pursue in the future, because perhaps through examining the intervention effects, we get to understand more about the commonality and the differences between the disorders.

[SLIDE – Practical Suggestions.
Text on the slide:
When thinking about how to help children with Developmental Dyscalculia it is critical to think developmentally
  • What foundational skills might be lacking?
  • What building blocks need to be built?]

[SLIDE – Practical suggestions.
Text on the slide:
A developmental perspective also means
  • That we can detect risk factors earlier;
  • No need to wait until children learn arithmetic;
  • Test the foundational skills;
  • Train children on foundational skills BEFORE they learn arithmetic.]

[SLIDE – Practical suggestions.
Text on the slide:
Research on basic number processing deficits; suggest that the following are important:
  • Working on symbolic-non-symbolic mappings;
  • Developing fluency with the use of numerals;
  • Working with number lines;
  • Making number salient.]
For arithmetic:

- Work on improving counting strategies;
- Teach more efficient strategies;
- Use of both manipulative and symbols to aid understanding of arithmetic.

I now want to finally turn to some practical suggestions. I have to preface this with saying that I am a scientist and my expertise is in basic research but I do of course think about how we can translate the work that we do on dyscalculia, and math learning more generally, into concrete strategies. So, one of the things that I would like to emphasize is that when thinking about how to help children with developmental dyscalculia, it is critical to think developmentally. That may sound very straightforward but it does require one to ask questions about ‘What might be some of the foundational skills that this child is lacking?’ So, if they show poor attention skills in math, maybe it’s not because they’ve got attention problems, but maybe it’s because they cannot deal with the representation of numbers. And, ‘What building blocks need to be rebuilt?’ So, thinking developmentally and thinking about how a given mathematical competency that one is trying to teach is reliant on processes that were required earlier can be very helpful. A developmental perspective also means that we can detect risk factors earlier. There’s really no need to wait until children learn arithmetic. In order to understand who might be at risk of acquiring difficulties in arithmetic and who might be just fine. And we can test the foundational skills, such as the ability to perform number comparison or the ability to match numerals to sets. And we can train children on foundational skills before they learn arithmetic. We are running some pilot studies on some potential tools to train foundational skills in senior kindergarten before children enter the formal classroom and before they acquire, or before they are introduced very formally, to arithmetic. So, much like in reading, where we can emphasize phonological awareness skills in prereaders, we can emphasize these foundational skills in math learners as well.

Research on basic number processing deficits suggests that the following are important: working on symbolic and non-symbolic mappings. So what I mean by that is helping children understand that three dots is the same as the number word three or the Arabic numeral 3; three forks on the table is three fish in an aquarium. Being able to understand these multiple representations of the same numerical quantity is something quite challenging. We, as adults, think it’s quite easy, but developmentally it’s quite an abstract understanding that we need to develop because number is an abstract quality of sets. Developing fluency with the use of numerals through exercises such as numeral naming, but also numeral comparison. Working with number lines has been found to be extremely beneficial. Robert Siegler, at Carnegie Mellon University, has done some beautiful work showing how playing simple board games helps children in their spatial understanding of number and in numerical relationships between numbers. Making numbers salient through number talk, through helping children to carve out the worlds that they’re in in terms of numerical quantities and the relationships between them I think can be very important as well.

Text on the slide:

Developmental Dyscalculia
- Is a specific learning disability;
- Affecting numerical & mathematical skills;

Text on the slide – Summary & Conclusions.

Developmental Dyscalculia
- Is a specific learning disability;
- Affecting numerical & mathematical skills;
Prevalence between five to seven percent.

For arithmetic, I would say one of the things that we have really understood well about developmental dyscalculia is that very few of them get to a stage where they can recall arithmetic facts. So, perhaps it’s more about working on improving the counting strategies that they use, working to move away from finger counting to verbal counting, but gradually, teaching more efficient strategies that do not require retrieval, and using both manipulatives and symbols to aid the understanding of arithmetic.

So I want to summarize and conclude and then I look forward to taking your questions. I hope that I’ve shown you that developmental dyscalculia is a specific learning disability that affects numerical and mathematical skills. The prevalence is between five and seven percent; however, take into account my caveat about the number of good prevalent studies to date. With regards to the causes and symptoms of developmental dyscalculia, what we know is that they have persistent difficulties in encoding arithmetic facts into memory; they use non-retrieval strategies when other children have started retrieving; they also have, and this the revelation of more recent research, problems with basic number processing foundational skills; with their basic symbols and their understanding of non-symbolic quantities, such as dot arrays or groups of objects, or numbers of sounds is typical, suggesting perhaps that there is a component, a very biologically basic component to this deficit in some individuals.

In our research, we’re finding that what they struggle with most is understanding numerical symbols and using these fluently. Intervention strategies, I believe, need to be developmentally appropriate and they need to build on foundational skills and recognize that math is a cumulative skill and that dyscalculics have become arrested at some point in their development and therefore couldn’t pick up the subsequent high-level skills.

And that brings me to the end of my presentation. I thought I had a thank you very much for your attention SLIDE here, but I don’t so I’ll just say, thank you very much for your attention and I look forward to interacting with you in the Q&A section. Thank you.
Amy: Thank you so much Dr. Ansari for presenting such an interesting and important topic to all of our participants today. If anyone has any questions, you can click the raise hand on your control panel and you will be unmuted to ask a live question to Dr. Ansari. Or, you’re also welcome to type your question into the chat box on your dashboard and I will read the question out loud.

Before we get started with the Q&A session, I just wanted to make a quick note that a couple of you had requested the web address that Dr. Ansari referenced over the course of his presentation and we will make sure that this gets sent out to you with the post-webinar email.

So, I have a couple of questions lined up for you Dr. Ansari.

Dr. Ansari: Mmmhmmmm.

Amy: So the first one is asking if you might have any suggestions for educational apps or software other than a calculator or MathPad Plus that could be purchased as assistive technology for math through school board funds.

Dr. Ansari: So this would be actual electronic applications? Is that what the question is referring to?

Amy: Yes, like something for an iPad or a tablet device.

Dr. Ansari: So one of the issues...I have some recommendations. First of all, I have to say that one of the really unfortunate things is that there are very few programs for helping children with developmental dyscalculia that have been rigorously evaluated using, you know, randomized control trials, so what I’m going to say are just some tools that I have found to be interesting, but I cannot yet say that there is good evidence in support of their efficacy. So one of them is actually a free tool called Native Numbers that’s available in the App Store that’s currently only available for iPad, and we are currently working with the Hamilton Wentworth District School Board in a small pilot study to examine the efficacy of this application. It’s a program that I like because it builds very much on foundational skills and tries to help children get a more fluid understanding of quantities and their relations and their orders. It also works on counting. So I like it but the researcher in me says be cautious because we don’t yet have good evidence that it works. But, hopefully in the next few months we’ll be able to report more on that; whether it indeed is of benefit or not.

Amy: Okay, great. Is that designed for a specific age group, just to clarify?

Dr. Ansari: Yes. That would be for JK, K, and maybe grade 1.

Amy: Okay, perfect. I have a couple of questions that sort of tie together, so I’m going to ask this as a two-part question. The first part of the question is do children with developmental dyscalculia have a lower ability to succeed in math. So for example, should they be enrolled in applied level math versus university of college level math?

Dr. Ansari: That’s a tricky question. I think it depends on a case-by-case basis. So, some dyscalculics struggle with arithmetic but are actually very good with things like geometry. Math is such a, you know, there are so many components to math, that I think that it would be important to make sure to assess not just arithmetic, but other skills, in order to determine what a dyscalculic may struggle with and what they may not struggle with. So I think it’s difficult to a priori without having looked at the individual and...
their profile of strengths and weaknesses to make that decision. But many dyscalculics will continue to have problems in university math and one of the things that I find really surprising in this day and age is that at universities, you know, we don’t have special provisions or accommodations for individuals with developmental dyscalculia. We have them for dyslexia, but not for math problems.

Amy – So, the second part of the question kind of leads into that. And it’s a question that asks if you have any specific advice for the parent of a child or even for the child themselves who has interest in pursuing the sciences in university but their math difficulties may pose a hindrance to succeeding with the required math courses in high school.

Dr. Ansari – I would say you’ve got to talk to your academic counsellor. I don’t know how it works in high school compared to the university level and seek accommodations. I think academic counsellors are maybe not so familiar with developmental dyscalculia so bringing them research literature on that, making that clear and finding ways to work around that. I don’t think that developmental dyscalculia is an absolute barrier to science, technology, engineering, and mathematics area. I believe that some dyscalculics just have real difficulties in learning how to calculate but other skills will be fine and they can use technology such as calculators to overcome that. We just need more societal awareness of it, just like we now have for dyslexia and then I think all of these things will fall into place and we will get more recognition of these individuals and their needs. So I’m afraid I can’t give very specific practical suggestions, but I think coming armed with a research body on it and demonstrating that it is real, because some people you know, maybe don’t think it’s real, is going to be very important.

Amy – Thanks Daniel, I think that’s a great answer. We see people with dyslexia who are writers all the time, so I think that’s great to hear.

Dr. Ansari – Exactly.

Amy – We do actually have a live question, so I’m going to ask Jason, are you there? Can you hear me?

Jason – Yes. Yes I can hear you.

Amy – Okay, go ahead.

Jason – Okay great. Hi Daniel. Do you mentioned there’s a screening tool. The screening tool: is it going to ask specific questions geared toward the deficit areas you mentioned or is it more just for the foundational skills that they might be lacking as an overview of what we might need to kind of provide for the student if they’re struggling in math?

Dr. Ansari – Thank you Jason for that question. So it’s kind of both. So the screening tool that we’ve developed, first of all, I really have to preface that it’s not a diagnostic tool at all. It’s just a screener. It asks children to perform as quickly and as accurately as they can a series of number comparisons, both symbolically and non-symbolically. So, you will get, and then you can enter the scores into our website and get a percentile rank. This is all completely free and you get a percentile rank for both symbolic and non-symbolic. So, you could differentiate between somebody who screens at having more difficulties with symbolic than non-symbolic, but we are also developing a number of other screeners and hopefully, eventually, diagnostic tools that will be more comprehensive, because this screener really just assesses that one skill: the comparison skill, and we’re now also discovering that things such as
understanding the order, the sequence of numbers, is very important. So we’re working on more screening tools which we’ll also release through that website when we have enough data to do so.

Amy – Okay, great. Jason, I hope that answered your question. Our next question is coming from Rob and he would like to know if, Dr. Ansari, he wants to know if you feel that dyslexia, dysgraphia, dyspraxia and dyscalculia should be viewed as a spectrum of learning disabilities.

Dr. Ansari – That’s an excellent question. You know, this is the sort of debate in psychiatry is categorical, spectrum-based, Hans Eysenck, the famous psychologist, argued for what I think you are referring to, more spectrum-based. I do believe that there is a spectrum given the high co-morbidity for of course diagnostic purposes, it can be more useful to refer to specific learning disabilities, but we need to continually to work on understanding the relationships between these various disorders, not just co-relationally, but causally; that is very important, I think.

Amy – Okay, great. Thank you. Our next question is from Monica. She wants to know if there is a scope and sequence chart available for the foundation skills.

Dr. Ansari – Yes, there are various literature reviews. You know people are still differing on the sequence of acquisition, but if you want to send me an email: daniel.ansari@uwo.ca, I can send you some of the research review papers that we have. I wouldn’t say there’s one consensus view on that yet.

Amy – So Monica, hopefully you got his email address, but you can email us as well if you have any additional questions if you missed that.

Just a few more questions. This question is from Alison. She would like to know if you have any suggestions for how you intervene with high school students, say grade nine or ten, who don’t have the foundational skills that you were talking about. So, for example, she’s wondering about if JUMP Math might be a good program to make use of.

Dr. Ansari – I get asked this question all the time and it’s such an important question. I don’t have a very good answer for it. I do believe that going back to some of the foundational skills and just making sure that children at that level have them is important. Working on alternative strategies is important. With regards to JUMP Math, that could be interesting, but again, we have to recognize that, as of today, there is no empirical evidence that unequivocally shows the efficacy of JUMP Math, so we have to weight that, and we also have to weight whether it’s very good for children with specific learning profiles. It’s a possibility. I have, you know, my work concentrates on early grades, so I haven’t worked very much with children in the upper grades but that is a very important topic I think for future research. And that research, in and of itself, will hopefully also inform the kind of remediation strategies that one might adopt.

I think, in those upper grades, there’s one topic that I didn’t have the time to speak about, but maybe I can speak about it just very briefly, is that we also need to work on the emotional side; the math anxiety side. And how children view themselves as math learners; what kind of mindset they have about math. And I think especially in the higher grades, you know, work by Carol Dweck and others has shown that math skills start to decline as some students start to adopt a very fixed mindset about their math abilities. So I think in the adolescent years we need to not just only work at the cognitive level, but also at the emotional levels and how learners appraise themselves.
Amy – Okay, great. I think we’ll just go with the one last question that I have right in front of me here, and this question comes from Jennifer, and she would like to know if there are any strengths that students could access, such as spatial reasoning, and I think, to add a little bit of clarity to the question, I think she’s meaning in order to compensate for some of the math difficulties that they might be experiencing.

Dr. Ansari – Great question. Spatial skills tend to be quite impaired in children with developmental dyscalculia, spatial working skills, so I would argue that it’s more at the verbal side where children can use compensatory mechanisms, I think. And I think, you know, recognizing as well that the development of strategies is more important than the development of encoding facts into memory for these students can be important and using that as a compensatory strategy for this clear deficit, the inability to encode and retrieve arithmetic facts. I think you raise a really important point that we need to look at what do they perform poorly at, but what other skills might they be using to overcome their difficulties. For my Ph.D., I worked with Williams Syndrome, a genetic developmental disorder, and they also have math difficulties, but they have a relative strength in language, and I found some evidence that they could use some of their language strength to overcome their non-verbal difficulties, so, thank you for that question. That’s a very important future frontier.

[SLIDE – Other Questions?]
Text on slide:
Image logo LD@school
Email: info@LDatSchool.ca.

Amy – Okay. So, I think that that’s all the time that we have for today. So we’re going to end our question and answer session at this time but if you have any further questions, you can email us at info@LDatSchool.ca and Daniel, I also believe that you said that they could email you directly at daniel.ansari@uwo.ca. Is that right? We will ensure either way that all of your questions get answered.

[SLIDE – LD@school Educators’ Institute]
Text on slide:
LD@school is proud to present the two-day 2nd annual and bilingual Educators’ Institute
Save the date: Tuesday, August 25th and Wednesday, August 26th, 2015
Hilton Mississauga/Meadowvale
Mississauga, ON.
For more information, visit: www.LDatSchool.ca/educators-institute/2015.

Just a couple of notes before we sign off for the afternoon; we hope you enjoyed today’s presentation, and we would also love it if you would come out and see him as our keynote speaker at LD@school’s Educators’ Institute in August. This event is a bilingual conference that focuses on the teaching and learning of students with learning disabilities and this year will be held on August 25th and 26th at the Hilton Mississauga/Meadowvale in Mississauga. Presenters will include experts and educators in the field of LDs from across Canada, including Dr. Ansari and he will be giving our opening keynote on August 25th. As a delegate attending the Educators’ Institute, you will be provided with new perspectives and knowledge in the field of learning disabilities, which is based on current research and practical information on effective assessment and instructional strategies, including technology. All Ontario
educators who work with students with LDs are encouraged to attend! If you would like more information about the event, you can visit the LD@school website or type in the link shown at the bottom of the screen.

[SLIDE–Upcoming Webinar
Text on slide: 
Supporting Social and Emotional Development of Students with LDs. 
Tuesday, May 12th
Guest Speaker: Dr. Colin King 
Registration Open Soon!]}

We’d also like to invite you to join us at our upcoming webinar on Tuesday, May 12th. Dr. Colin King, a psychologist and the Acting Coordinator of Psychological Services in the Thames Valley District School Board will be presenting a webinar on the topic of supporting the social and emotional development of students with LDs. More registration information will be available on the LD@school website next week.

[SLIDE– Join our online community by signing up to receive LD@school’s bi-weekly newsletter on the LD@school homepage. Text on slide: Image on the slide of three boxes from LD@school’s homepage with an arrow pointing to the purple sign-up box for the LD@school newsletter.]

And if you would like to be kept up to date with other upcoming events such as our free webinars, please subscribe to LD@school’s biweekly newsletter, and you can do this on the LD@school homepage by entering your email in the sign-up box located on the bottom of the page.

[SLIDE– Follow us on Twitter. Text on slide: @LDatSchool]

You can also be kept up to date on what’s happening with us by following LD@school on Twitter, and our Twitter handle is @LDatSchool.

[SLIDE– image of the word ‘thank you!’ as well as the LD@school logo and website address www.LDatSchool.ca.]

And, finally, on behalf of the LD@school Team, I would once again like to thank Dr. Ansari for his presentation and to thank all of our participants for joining us. Please remember that we will be sending out presentation SLIDEs, as well as a short survey following today’s webinar. The feedback we receive through this survey provides us with important information for producing future webinars. Also remember that we will be sending out an AODA-compliant link to this recorded webinar in approximately three weeks. Thank you again for participating and we hope you have a wonderful afternoon!