Dyscalculia Primer and Resource Guide

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by

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The purpose of this primer is to explain the cognitive neuroscience approach to dyscalculia (including the state of research in this area), to answer frequently asked questions, and to point the reader towards further resources on the subject.

Further references include some of the major scientific literature in the field, as well as reading suggestions for teachers and parents.

Note: The term dyscalculia in this document refers to developmental dyscalculia (present from birth or at an early age) and not to acquired dyscalculia (acquired as a result of brain lesion).

What is dyscalculia?

The first neuropsychological definition of developmental dyscalculia was put forward by the researcher Kosc (1974), who defined it as a difficulty in mathematical performance resulting from impairment to those parts of the brain that are involved in mathematical processing, without a concurrent impairment in general mental function. This definition is the same definition that researchers in cognitive neuroscience use today when searching for the causes and features of dyscalculia.

Are there other definitions of dyscalculia?

Yes, there are other definitions of dyscalculia, as well as other similar constructs that are defined in slightly different ways. For instance the DSM-IV (Diagnostic and Statistical Manual of Mental Disorders, 4th Edn, American Psychiatric Association) includes the diagnosis 315.1 "Mathematics Disorder", and in the United States there is an educational definition of "Mathematical Disabilities" linked to the legal definition of learning disabilities given in Public Law 94-142.

What all of these definitions have in common is 1) the presence of difficulties in mathematics, 2) some degree of specificity to these (i.e. the lack of across-the-board academic difficulties) and 3) the assumption that these are caused in some way by brain dysfunction.

What causes dyscalculia?

As mentioned above, it is assumed that developmental dyscalculia is caused by the dysfunction of mathematical processes and areas in the brain. However, it is important to realise that the research establishing this is just in its infancy. The goal of cognitive neuroscience researchers is to fully develop a brain-based diagnosis usable from an early age, as well as brain-based prevention and remediation techniques.

What makes us optimistic about the possibility of achieving this? Firstly, research in the dyslexia field (ahead by a good 30 or so years) has now clearly shown an association with the under-functioning of brain areas in reading, that this is diagnosable from an early age, and that it can be remediated via auditory training programs (Lyytinen et al., in press).

Secondly, the research that we have in the field of dyscalculia points in the right direction. Research on genetic and developmental disorders associated with dyscalculia such asTurner's syndrome, Foetal Alcohol Syndrome, and low birth weight (Isaacs et al., 2001; Kopera-Frye et al., 1996; Molko et al., 2003), shows brain impairment in areas of the brain known to process mathematics (specific parts of the parietal lobes). Developmental dyscalculics also show difficulties on basic cognitive tasks known to activate these areas (Landerl et al., 2004).

Finally, research in the field of acquired dyscalculia (dyscalculia acquired as a result of brain injury) is in line with these findings; damage to the same area of the brain results in dyscalculia that has similarities to developmental dyscalculia (Stanescu-Cosson et al., 2000).

If the cause is in the brain, isn't there nothing that can be done?

Not necessarily! This is a common misconception. The functioning and structure of the brain reflects not only our genes, but also our environment, and finally the interaction between the two. Research over the last 30 or so years has shown that the brain is surprisingly "plastic", i.e. able to be modified by experience. Research on dyslexia has shown that auditory training programs can result in significant improvement in reading (Merzenich et al., 1996; Temple et al., 2003). This discovery is fundamentally driven by brain research; research showing that auditory areas were highly involved in reading (a very non-intuitive finding!) led researchers to try auditory-based training programs.

In the case of mathematics, we do not know yet whether the same type of plasticity is present in the brain, but researchers are actively working on this question.

How is dyscalculia diagnosed?

Because we do not yet have a way to diagnose dyscalculia based on its underlying cause, we have to diagnose it based on its effects, i.e. difficulties in mathematics. This is much more difficult, because there are other factors that may cause the same effects. In other words, "there are many reasons for being bad at maths!". Reasons other than dyscalculia include inadequate instruction, lack of motivation, attentional disorders, anxiety disorders, or mental retardation.

Methods of diagnosis differ widely, but in general include some common aspects: 1) an identification of a difficulty in mathematics that affects academic or everyday life, and 2) an attempt to rule out some of the other factors that could be responsible for the difficulty. The idea is, of course, that once all other factors are ruled out, brain dysfunction is the only explanation left. For an article on diagnosis, see Shalev & Gross-Tsur (2001).

While this may sound fine in theory, it is not so easy in practice. Which tests should be used to show difficulty in mathematics, and where should the cut-off point be? How should other factors be ruled out, and which other factors should be ruled out? For instance, if a pupil has difficulties in mathematics because of a difficulty in memorising verbal information – which means she cannot remember her times tables – is she dyscalculic? Currently, there is little agreement on these questions, but as more research is conducted, consensus is likely to increase.

How prevalent is dyscalculia?

The percentage of the population suffering from developmental dyscalculia is difficult to establish, because of the different criteria used for diagnosis. However, the prevalence studies that have been conducted allow at least a rough idea. In these studies, prevalence is estimated to be between 3-6 percent of the population (Badian, 1999; Gross-Tsur et al., 1996; Lewis et al., 1994).

What is the relationship between dyscalculia and dyslexia?

The relationship between dyscalculia and dyslexia is not clear. Studies looking at the percentage of dyscalculics who are also dyslexic differ wildly in their estimates from 17% to 64% (Badian, 1999; Gross-Tsur et al., 1996; Lewis et al., 1994). It is unknown whether there is a common cause for those children with both disorders and, if so, at which level it could be, for example a brain area in common, or a general brain development factor. Researchers are currently investigating this question.

What is the relationship between dyscalculia and "math anxiety"?

"Math anxiety" is the name given to the feeling of tension and fear that some children and adults experience, and which is often specifically associated with mathematical activity(Ashcraft, 2002). There is very little research on the overlap between this and dyscalculia. It is a reasonable hypothesis that dyscalculia may increase the chances of having math anxiety, and preliminary work by Butterworth and colleagues, based on focus groups of dyscalculic children, supports this idea. It is also possible that math anxiety could cause dyscalculia, although this is less likely.

What is the relationship between dyscalculia and attention deficit and hyperactivity disorder?

Dyscalculia also appears to be associated with behavioural disorders such as Attention Deficit Disorder (if diagnosis does not exclude cases with this disorder present). Estimates of the percentage of dyscalculic children who also have ADHD are between 15-26% (Lindsay et al., 2001). As with dyslexia, it is not clear whether these children have a "double deficit", or if their difficulties in mathematics are caused by their difficulty in maintaining sustained attention.

Are there any other disorders that dyscalculia is related to?
Dyscalculia is associated with both genetic and foetal disorders, including Turner's syndrome, William's syndrome (Ansari & Karmiloff-Smith, 2002), and Foetal Alcohol syndrome.

Are there different types of dyscalculia?

This is a question that has been much debated, and is still a point of controversy. It is important because it is part of the process of identifying causes of dyscalculia, and also because different types of dyscalculia should probably be diagnosed and treated in different ways.

Some researchers have argued that children who have dyscalculia as well as dyslexia show a different pattern of difficulties to those who just have dyscalculia. In early research, Rourke (e.g., 1993) argued that the dyscalculia/dyslexia group had left hemisphere impairments that caused difficulties with verbal processing, and that the dyscalculia only group had right hemisphere impairments that caused difficulties with non-verbal processing. However, this distinction has not been supported by subsequent research and appears to be too simplistic.

More recent research by Jordan and colleagues (Jordan et al., 2003) and Shalev and colleagues (Shalev et al., 1997) suggests that the dyscalculia/dyslexia group simply have more difficulties in maths, and difficulties particularly in more verbal tasks. However they still present the same difficulties in more non-verbal tasks. From this research it seems that this group really does have two deficits that combine together to produce even more problems than a single deficit.

Another researcher, Geary (1993), has argued for three different subtypes of dyscalculia, one based on difficulties in fact retrieval (ie. learning simple addition sums, and times tables), one based on difficulties in learning procedures and strategies, and one based on visuo-spatial difficulties.

As you can see, there is little consensus in this area, and more research to be done. Part of the problem is that each group of researchers uses different tests, and the types of dyscalculia found then seem to be related to this factor! Many researchers are actively working on this question, so we will all stay tuned to see what emerges…

How can I tell if my child has dyscalculia?

If your child has persistent difficulties with mathematics, you should suspect dyscalculia, even if your child also has reading problems. You should have your child referred to a school psychologist for evaluation. Diagnosis should include interviews with you and your child, an IQ test, and mathematics achievement tests; as well as a more detailed examination of mathematics abilities.

The kind of diagnosis that is carried out will vary depending on where you live and who you see. However, do not forget though that you have the right to be informed of results, and that you know your child best. Always ask for a second opinion if in doubt. You should be aware that dyscalculia is less well known than dyslexia, so this makes it hard to diagnose. You may need to be persistent!

Will my child "grow out of" dyscalculia?

While it is possible that children may grow out of some types of dyscalculia (especially a proposed

type involving difficulty learning sequences and strategies; Geary, 1993), in most cases your child will NOT grow out of dyscalculia. It is important therefore to seek help; your child needs special assistance in order to catch up on maths.

Can dyscalculia be prevented?

At the moment, no; apart from avoiding drinking alcohol during pregnancy, as drinking alcohol during pregnancy appears to be one cause. In the future, we hope that all types of dyscalculia might be able to be diagnosed at a very young age, so that children could receive extra assistance with mathematics before starting school or during the first years of learning maths. If this type of assistance worked, we could then hope to be able to "restore" mathematical learning to normal levels, thus avoiding any later learning difficulties.

How can dyscalculia be remediated?

There has been much work on this question in the educational field, and there are many curricula designed for children with difficulties in mathematics. However very few of these curricula have been rigorously tested for their efficacy, and the studies that do exist include children who have difficulties in mathematics for all sorts of reasons, not just those with dyscalculia.

So in a way, research on this is just beginning. I personally am involved in a project to test a remediation designed for dyscalculic children, and there are other such projects underway. We hope that in the next 5 to 10 years, some clear and solid answers to this question will emerge.

What are the consequences of untreated dyscalculia?

While dyscalculia is less debilitating than dyslexia, it still has a negative effect on the lives of sufferers. Many dyscalculics find ways to compensate for their dyscalculia, such as using a calculator wherever possible, however this can only help to some extent. Others simply do their best to avoid maths. Having dyscalculia limits academic and career possibilities for children and adults (Rivera-Batiz, 1992), as well as affecting everyday life (for example management of finances).

I am a teacher, what should I look out for in the classroom?

Look out for children who are struggling in maths even though they seem to be bright enough, and do well in other school subjects (although they may not do well in reading). The following is a non-exhaustive list of possible "symptoms" to look for:

- seeming to have no "sense of number"
- having trouble learning error-free counting, memorising arithmetical facts, following procedures, or executing strategies
- can do the above task(s), but very slowly
- exhibiting dislike of or anxiety towards maths, or avoidance behaviours

How should I teach maths to a child with dyscalculia?

Firstly, a child with dyscalculia needs extra help with mathematics from someone. You should be aware that there are many different points of view about how dyscalculia is best remediated, and few of them are based on research. Thus you need to "shop around" a bit. There are some starting materials referenced below that could help.

At the end of the day, the best approach is probably to a) identify the areas where the child has a difficulty, and b) try and target an intervention at these areas. It is important to realise that difficulties might result from a very low level ability, such as understanding the meaning of numbers, or verbal memory. The former is possibly most helped by interventions emphasising understanding, and the latter may be by drill-type interventions.

Further Resources for Teachers and Parents

Books

- Brian Butterworth. (1999). The Mathematical Brain. MacMillan, London. General Introduction to numerical cognition for the public.

- Stanislas Dehaene (1997). The Number Sense. Oxford University Press, Oxford. General

Introduction to numerical cognition for the public.

• Brian Butterworth & Dorian Yeo. (2004). Dyscalculia Guidance: Helping Pupils with Specific Learning Difficulties in Maths. Nfer Nelson, London. Teacher's guidebook, complete with exercises.

Websites

• United States National Center for Learning Disabilities. http://www.ncld.org/ . Has fact-sheets on dyscalculia, and links to local resources

• LDOnline. http://www.ldonline.org/. US site with links to many resources, including further reading on mathematical disabilities.

• The OECD's Brain and Learning site. http://www.oecd.org/edu/brain. An OECD project funded by NSF to develop an information network for dyslexia and dyscalculia and remediation tools.

• Brian Butterworth's Website (University College, London) http://www.mathematicalbrain.com. Updates on the latest research, and links to resources.

• Stanislas Dehaene's Website (INSERM U562, Paris) http://www.unicog.org, see the "Numbers" page. Updates on the latest research, and lists of further academic articles to read.

Academic References

Ansari, D., & Karmiloff-Smith, A. (2002). Atypical trajectories of number development: A neuroconstructivist perspective. Trends in Cognitive Sciences, 6(12), 511-516.

Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. Current Directions in Psychological Science, 11(5), 181-185.

Badian, N. A. (1999). Persistent arithmetic, reading, or arithmetic and reading disability. Annals of Dyslexia, 49, 45-70.

Geary, D. C. (1993). Mathematical disabilities: Cognitive, neuropsychological and genetic components. Psychological Bulletin, 114(2), 345-362.

Gross-Tsur, V., Manor, O., & Shalev, R. S. (1996). Developmental dyscalculia: Prevalence and demographic features. Dev Med Child Neurol, 38(1), 25-33.

Isaacs, E. B., Edmonds, C. J., Lucas, A., & Gadian, D. G. (2001). Calculation difficulties in children of very low birthweight: A neural correlate. Brain, 124(9), 1701-1707.

Jordan, N. C., Hanich, L. B., & Kaplan, D. (2003). A longitudinal study of mathematical competencies in children with specific mathematics difficulties versus children with comorbid mathematics and reading difficulties. Child Development, 74(3), 834-850.

Kopera-Frye, K., Dehaene, S., & Streissguth, A. P. (1996). Impairments of number processing induced by prenatal alcohol exposure. Neuropsychologia, 34(12), 1187-1196.

Kosc, L. (1974). Developmental dyscalculia. Journal of Learning Disabilities, 7(3), 164-177.

Landerl, K., Bevan, A., & Butterworth, B. (2004). Developmental dyscalculia and basic numerical capacities: A study of 8-9-year-old students. Cognition, 93(2), 99-125.

Lewis, C., Hitch, G. J., & Walker, P. (1994). The prevalence of specific arithmetic difficulties and

specific reading difficulties in 9- to 10-year old boys and girls. Journal of Child Psychology & Psychiatry & Allied Disciplines, 35(2), 283-292.

Lindsay, Rl, Tomazic, Levine, Md, Accardo, et al. (2001). Attentional function as measured by a continuous performance task in children with dyscalculia. J Dev Behav Pediatr, 22(5), 287-292.

Lyytinen, H., Guttorm, T. K., Huttunen, T., Hamalainen, J., Leppanen, P. H. T., & Vesterinen, M. (in press). Psychophysiology of developmental dyslexia: A review of findings including studies of children at risk for dyslexia. Journal of Neurolinguistics, In Press, Corrected Proof.

Merzenich, M. M., Jenkins, W. M., Johnston, P., Schreiner, C., Miller, S. L., & Tallal, P. (1996). Temporal processing deficits of language-learning impaired children ameliorated by training. Science, 271(5245), 77-81.

Molko, N., Cachia, A., Riviere, D., Mangin, J. F., Bruandet, M., Le Bihan, D., et al. (2003). Functional and structural alterations of the intraparietal sulcus in a developmental dyscalculia of genetic origin. Neuron, 40(4), 847-858.

Rivera-Batiz, F. L. (1992). Quantitative literacy and the likelihood of employment among young adults in the united states. The Journal of human resources, 27(2), 313-328.

Rourke, B. P. (1993). Arithmetic disabilities, specific and otherwise: A neuropsychological perspective. Journal of Learning Disabilities, 26(4), 214-226.

Shalev, R. S., & Gross-Tsur, V. (2001). Developmental dyscalculia. Pediatr Neurol, 24(5), 337-342.

Shalev, R. S., Manor, O., & Gross-Tsur, V. (1997). Neuropsychological aspects of developmental dyscalculia. Mathematical Cognition, 3(2), 105-120.

Stanescu-Cosson, R., Pinel, P., Moortele, P.-F. v. d., Le Bihan, D., Cohen, L., & Dehaene, S. (2000). Understanding dissociations in dyscalculia: A brain imaging study of the impact of number size on the cerebral networks for exact and approximate calculation. Brain, 123(11), 2240-2255.

Temple, E., Deutsch, G. K., Poldrack, R. A., Miller, S. L., Tallal, P., Merzenich, M. M., et al. (2003). Neural deficits in children with dyslexia ameliorated by behavioral remediation: Evidence from functional mri. Proc Natl Acad Sci U S A, 100(5), 2860-2865.

Top of page