An overview of dyscalculia

Methods for ascertaining and accommodating dyscalculic children in the classroom

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For many children, mathematics is an inherently difficult subject to learn. Between 5 and 8 percent of children between the ages of 6 and 14 have a particular type of cognitive deficiency that limits their aptitude to acquire knowledge and understanding of fundamental ideas in numeracy (Geary, 2004). Increasingly, researchers in the cognitive sciences are studying this deficiency under the name dyscalculia, a disorder in which normally intelligent children demonstrate specific disabilities in learning mathematics (Ansari & Karmiloff-Smith, 2002). Teachers need to be informed about dyscalculia so that they can implement strategies that intentionally and explicitly accommodate students who have this disorder. The objectives of this paper, therefore, are to define dyscalculia, to consider the origins of dyscalculia in psychological, biological, and pedagogical contexts, to describe the criteria required to diagnose students with dyscalculia, and to delineate practical methods and instructional designs that can be implemented in the classroom to address the specific learning needs of dyscalculic learners.

What is dyscalculia?

In the most general sense, dyscalculia is the inability to obtain a suitable and appropriate competence in mathematics (Butterworth, 2003) and the inability to build mathematical relationships successfully (Beachman & Trott, 2005). Although an etiological understanding of dyscalculia is still undetermined, numerous studies have attempted to find some possible causes. One hypothesis, which claims that dyscalculia is hereditary, is gaining support in the cognitive sciences (Ansari & Karmiloff-Smith, 2002), because the mathematical learning disorder is unusually common in identical twins and, to a lesser degree, fraternal twins and other siblings (Alarcon, Defries, Gillis Light & Pennington, 1997; Shalev, Manor, Kerem, Ayali, Badichi, Friedlander & Gross-Tsur, 2001). Other research has been less successful in formulating whether there is a biological malady within the brain that specifically causes dyscalculia (Dehaene, Spelke, Pinel, Stanescu & Tsivkin, 1999; Kiefer & Dehaene, 1997; Levy, Levy & Grafman, 1999; Spelke & Dehaene, 1999). Although emotional problems caused by environmental deprivation are generally regarded as secondary complications for other learning disorders (Broman, Bien & Shaughnessy, 1985), their effects on the development, sustainability, and treatment of dyscalculia have recently gained reconsideration as a potential primary cause (Shalev & Gross-Tsur, 2001). One team of educational psychologists believes that overall low intelligence contributes to a person's acquisition of dyscalculia (Miller & Mercer, 1997). Another researcher thinks that mathematics anxiety plays a role in the development of symptoms of innumeracy even when psychological intervention can provide a certain degree of remediation (Ashcraft, 1995). At least two publications suggest that ineffective teaching strategies, particularly in the years of early childhood, might promote the development of a mathematical learning disability in vulnerable students (Butterworth, 2003; Shalev & Gross-Tsur, 2001). One last proposition is that poor social skills might contribute to the progression of dyscalculia (Rourke, 1989). In all likelihood, different components of mathematical cognition are influenced by a myriad of causes (Geary, 2004) making it impossible to identify just one that is responsible for the whole of dyscalculia.

The origins of dyscalculia

Even though the cognitive sciences have not yet been able to establish a thorough understanding of the origins of dyscalculia, there have been several discoveries that have helped to develop some important correlations between dyscalculia and other learning and psychological disorders. Many studies have shown that a considerable number of dyscalculic children suffer concurrently from additional ascertained difficulties. For example, one analysis discovered that approximately 17 percent of dyscalculic children are also dyslexic, and another 26 percent experience the effects of attention deficit hyperactivity disorder (Shalev, Manor, & Gross-Tsur, 1997). Two years later, a paper suggested that 4 in 10 people who are diagnosed with dyslexia also have trouble with mathematics to some measurable extent (Butterworth, 1999). Therefore, an independent diagnosis of dyscalculia is often difficult to ascertain (Gross-Tsur & Manor, 1996; Ostad, 1998). Nevertheless, there are some methods that educational psychologists utilise to detect dyscalculia in a child.

Methods for diagnosing dyscalculia

Currently, there are three well-documented methods for diagnosing dyscalculia. The following sections describe each of the three methods in detail.

Child's attainment of age-appropriate mathematical skills

The first method for determining whether or not a child is likely to have dyscalculia can be implemented easily in schools using existing student data and resources. Through the administration of a standardised assessment designed to measure the child's attainment of age-appropriate mathematical skills (Shalev & Gross-Tsur, 2001), educators might be able to form a diagnosis of dyscalculia if at least one of the following two circumstances is revealed:

- an inconsistency between the intellectual capability of the child and the results of the assessment (Geary, 2004; Reynolds, 1984); or,
- a significant disparity, usually of at least two year levels, between the

child's ordinal year of study and his or her arithmetic aptitude (Semrud-Clikeman, Biederman, Sprich-Buckminster, Krifcher-Lehman, Faraone, & Norman, 1992).

However, both circumstances are too general to assess accurately the specific extent to which a child may have dyscalculia. Therefore, some students might be incorrectly ascertained as dyscalculic when they might actually be affected by other more predominant learning difficulties.

Direct observation of dyscalculic tendencies

Another way to detect the signs of dyscalculia involves the direct observation of a majority of the following behaviours:

- undeveloped strategies for problem solving (Geary, 1990);
- computational errors caused by a poor working memory span (Siegel & Ryan, 1989);
- deficiencies in the long-term recall of arithmetic facts (Geary, Hamson, & Hoard, 2000; Jordan & Montani, 1997);
- slow rate of processing of basic mathematical skills (Geary & Brown, 1991);
- inability to recognise the commutativity of addition and multiplication (Kaufmann, Handl, & Thony, 2003);
- high rates of errors, particularly those that appear careless (Geary, 1993); and,
- troubles with visual and spatial functioning (Rourke & Finlayson, 1978).

However, any student who is struggling with mathematics would routinely demonstrate one or more of these performance indicators. Just like the assessment of a child's attainment of age-appropriate mathematical skills, this method may incorrectly assess non-dyscalculic children as dyscalculic. Therefore, a comprehensive and unambiguous approach is needed to correctly identify dyscalculia in students so that instructional designs can be modified to accommodate them in the classroom.

The Dyscalculia Screener

One solution could be the Dyscalculia Screener developed by Butterworth (2003). The Dyscalculia Screener consists of a series of item-timed tests that quickly and reliably identify dyscalculia without influences from other potential causes of an inadequate achievement in numeracy. Its primary objective is to measure the instinctive numerical proficiency of children between the ages of 6 and 14. Because human beings possess a biological inclination to gain a foundation level of understanding of numerical concepts, certain basic mathematical skills develop naturally without formalised education (Ginsburg, 1997). For example, a person can conceptualise size (that six is bigger than five), number (that a set of objects has a numerical value), and counting (that four comes after three). The Dyscalculia Screener, therefore, is designed to measure a child's level of inherent numeracy through simple tests involving counting dots and comparing numbers. Because the essential aspect of the tests is the speed with which the subject responds to the questions, Butterworth (2003) developed the Dyscalculia Screener as a software program to administer the testing procedure. The programs will also collate the subject's responses, automatically analyse the aggregated results, and finally calculate a standardised score. This score correlates median reaction time with correctness of responses to generate composite scores in each of the three categories:

(1) dot enumeration; (2) number comparison; and, (3) arithmetic achievement (age-appropriate addition and multiplication). Table 1 summarises the three diagnoses that can be ascertained given the combination of qualitative scores in each category:

Table 1. How results from the Dyscalculia Screener tests lead to a diagnosis of dyscalculia.

Diagnosis	Dot Enumeration	Number Comparison	Arithmetic Achievement
Has poor arithmetic skills but does not have dyscalculia	High	High	Low
Has dyscalculia	Low	Low	Medium
Performs normally	High	High	High

Therefore, a child who has dyscalculia will perform at a low level in the dot enumeration and number comparison tests but at a medium level in the arithmetic achievement test. On the other hand, a child who has poor arithmetic skills but does not have dyscalculia will perform at a high level on the dot enumeration and number comparison tests but give a low level performance in the arithmetic achievement test. Different degrees of diagnoses of dyscalculia can be interpolated based on the actual stanine scores.

Although the Dyscalculia Screener is likely to be the best tool available for identifying dyscalculia in children, some schools may be discouraged from using it because of financial and social reasons. According to one vendor, the price for one school site license of the Dyscalculia Screener is US$399.95 (A$471.53) plus annual renewals of US$99.95 (A$117.84, at the time of writing) (Felix, 2005). For many schools, especially those which rely exclusively on public funding, the cost of the Dyscalculia Screener may simply exceed budget limitations. Other schools, on the other hand, may be influenced by the societal disposition that mathematical learning difficulties are normal (Vaidya, 2004). These schools, therefore, may not fully appreciate the multitude of benefits available in the Dyscalculia Screener despite increasing numbers of suggestions that dyscalculia may be more common than dyslexia (Gross-Tsur & Manor, 1996; Ostad, 1998), which has been investigated much more thoroughly and has had a significantly longer history.

The latest work in mathematical learning disorders has revealed that dyscalculic learners are indeed affected by this condition in significant ways both academically and socially (Ackerman & Dykman, 1995). Because general life skills require a certain degree of numerical aptitude, dyscalculic children become adults who are severely impeded by their inabilities to reason quantitatively thereby affecting their fundamental understandings of time, money, direction, and space (Beacham & Trott, 2005). Poor numeracy skills have been proven to be more detrimental to a person's employability than poor literacy skills (Bynner & Parsons, 1997). Thus, it is vitally important that educators, particularly mathematics educators, take a genuine interest in the problems caused by dyscalculia.

Instructional modifications designed to accommodate dyscalculic learners

Once a student has been ascertained as having dyscalculia, there are practical methods and instructional designs that can be incorporated into the classroom. Trott (2003) has provided a list of strategies that have been proven to help students who suffer from dyscalculia. This list is categorised into strategies for improving reading skills, improving mathematical problem solving skills, and general instructional design:

Improving reading skills

- Break up large sections of text with page breaks and bullet points.
- Use a sans serif font (i.e., without heads and tails, such as Arial or Tahoma) which is easier for dyscalculic students to read.
- Do not justify the text (as this paper does), because the extra spacing required for justification makes it more difficult to read.
- Use coloured overlays to reduce the glare from black type on white paper, which is often a problem for students who have difficulties with visual perception.

Improving mathematical problem solving skills

- Photocopy mathematics books, which are generally difficult to read because of the interspersement of diagrams, tables, and charts, with the relevant sections placed in a more sequential order.
- Separate multi-step problems into small, manageable steps.
- Use a line reader, if available, to highlight a line of work and fade the other lines into the background.
- Use coloured pens or markers to highlight various parts of a question.
- Use colour in spreadsheets to delineate the different columns and rows.
- Edit down the output tables of statistical analyses so that the student can focus on the relevant sections.

General instructional design

- Supplement missing or incomplete notes.
- Put up large wall posters to remind students of various basic concepts that cannot be easily recalled in short-term memory.
- Use system cards to aid in memorisation.
- Provide flow diagrams or tree diagrams to clarify procedures.
- Provide mind map diagrams to help with the development of a long-term project.
- Employ typical strategies for engaging visual learners to a greater degree.
- Move through a lesson at the student's own pace so that he or she does not become bogged down by the material.
- Teach skills in organisation, studying, and time management.
- Focus on revision prior to an examination.

This list is not exhaustive of all the ways in which to cater for a dyscalculic student. However, using these approaches in mathematics education would facilitate the learning of all students, regardless of whether or not they have been ascertained as having a learning disorder.

Conclusion

Dyscalculia is a debilitating disorder that affects a person's ability to conceptualise the operations and processes of fundamental mathematics. Although its origins are still not entirely clear, there are strategies that have been proven to ascertain dyscalculia correctly as a discrete learning disorder. In all likelihood, the Dyscalculia Screener is the best tool currently available to accurately quantify the degree to which a child suffers from the learning disorder. Because numeracy is a significant part of daily life, it is vital that dyscalculic students be given special consideration to develop their own capacities of mathematical cognition. Instructional methods, such as those outlined earlier, can be integrated into a mainstream classroom to assist students with mathematical learning disabilities.

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