Dyscalculia in Further and Higher Education

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Abstract

Dyscalculia is one of the newer challenges that face practitioners and researchers, particularly in the post 16 sectors. The focus of this paper is therefore be Further and Higher Education. Dyscalculia is a specific learning difference, which affects the ability to acquire arithmetical skills and an intuitive grasp of numbers. Consideration is given to this and other current definitions, together with a theoretical perspective. The paper also considers the prevalence of dyscalculia, as well as the difficulties dyscalculic students' experience, both in academic life and more generally. The paper highlights DysCalculiUM, a new first-line screening tool for dyscalculia focusing on the understanding of mathematics. The system provides an on-line delivery of the screening tool to identify students at risk with minimal staff input. A Profiler identifies students requiring further investigation. This may take the form of an in-depth interview and referral for further testing. The final section of the paper considers subsequent one-to-one support for students. A case study of a dyscalculic student in Higher Education working with tables of information, percentages and graphs, serves to illustrate some of the ways in which dyscalculic students can be supported on a one-to-one basis.

1. Background

1.1 Towards a Definition

The DSM-IV [1], defines Mathematics Disorder in a person in the following terms: "as measured by a standardised test that is given individually, the person's mathematical ability is substantially less than would be expected from the person's age, intelligence and education. This deficiency materially impedes academic achievement or daily living". One of the key features of this definition is that the mathematical level is significantly lower than expectation. Indeed, Butterworth [2], says: "Most dyscalculic learners will have cognitive and language abilities in the normal range, and may excel in non-mathematical subjects". Another key feature is the impeding of academic achievement and daily living. The National Center for Learning Disabilities [3], says: "Dyscalculia is a term referring to a wide range of life-long learning disabilities involving math… the difficulties vary from person to person and affect people differently in school and throughout life". However, the DSM-IV definition does not expand on what is meant by mathematical ability and this is crucial to our understanding of dyscalculia. The definition is centred on "Mathematics Disorder" and this implies a stable cognitive root, which should not be based on achievement or mastery that is subject to influences of education and environment. Therefore it would seem inappropriate to make assessments through achievement tests, as is often current practice.

The National Numeracy Strategy [4], defines dyscalculia as that which "affects the ability to acquire arithmetical skills. Dyscalculic learners may have difficulty understanding simple number concepts, lack an intuitive grasp of numbers, and have problems learning number facts and procedures. Even if they produce a correct answer or use a correct method, they may do so mechanically and without confidence." The "ability to acquire" is important in that it emphasises acquisition rather than the carrying out of arithmetic procedures. The definition also goes further than the previous one, in that it is more specific about the nature of the mathematical ability: i.e. "difficulty understanding simple number concepts, lack an intuitive grasp of numbers", thus placing understanding at the core of dyscalculia. "A lack of a true comprehension or understanding of maths will be a key characteristic of dyscalculic people" Chinn [5], However, the National Numeracy Strategy [4], continues with the inclusion of "learning number facts and procedures". This would be more indicative of the issues experienced through dyslexia. The dyslexic student is likely to struggle to recall number facts such as times tables and would rely on understanding the mathematics required, rather than well rehearsed procedures learnt by rote or over-learning.

1.2 Prevalence

There is currently no adult data available that gives an estimate of the number identified with dyscalculia. The available data from previous research studies relates to populations of children. Original estimates by Kosc [6] placed this at 6.4% and this is broadly in line with more recent estimates by Butterworth [7], of between 5% and 6%. However, Geary [8], and Desoete [9], both estimate the prevalence of dyscalculia in child populations to be as high as 8%.

1.3 Theoretical Perspectives

Recent advances in neuroscience have greatly increased our understanding of how we conceive number. "An elementary number system is present very early in life in both humans and animals, and constitutes the start-up-tool for the development of symbolic numerical thinking that permeates our western technological societies" [10], Dehaene et al. [11] postulate a triple code theory based on three related neural regions of the brain. The first region is the horizontal segment of the intraperietal sulcus (HIPS) in which numerical quantity is represented and manipulated and which is activated independently of input modality, that is as a digit, word or a collection of items. The second region is the left hemisphere angular gyrus (LAG) in which the verbal processing of numbers takes place and is activated by linguistic rather than quantity processing. It is this area that is responsible for digit naming and learned number facts. The third region is the posterior superior parietal lobule (PSPL) in which visual-spatial processing occurs. The PSPL is activated usually in conjunction with HIPS, during number processing, but is associated with space and time. The PSPL is predominantly within the right hemisphere and the LAG is entirely in the left hemisphere. Thereby, a 3-way system guides and constrains the acquisition of symbolic number skills and, in particular, the HIPS and PSPL are activated during number processing. These are mediated by LAG.

2. A first-line screening tool for dyscalculia

2.1 Development

DysCalculiUM [12], is a first-line screening tool for dyscalculia, developed by Trott and Beacham at Loughborough (due to be published by *Iansyst* in conjunction with *Tribal* in November 2010). The screener focuses on mathematical understanding and has an on-line delivery to identify students at risk of dyscalculia. The tool is designed so as to minimise staff input. A profiler report, given after each student has taken the screening test, identifies those students requiring further investigation (which can be an in-depth interview or referral for further testing). The model for the screener is based on 11 categories, 6 of which are about understanding number and the other 5 relate to common applications. Conceptual understanding of both number and operations relate to activities associated with the HIPS region, while comparisons of number on a visual-spatial plane and with symbolic notation are associated with the PSPL region. Making inferences from given operations requires both manipulation within the HIPS region and visual-spatial processing, thus requiring activations in both HIPS and PSPL. Furthermore, comparisons of number quantity through language would employ the LAG region together with the HIPS region. The model for the DysCalculiUM screening tool is shown in Figure 1.

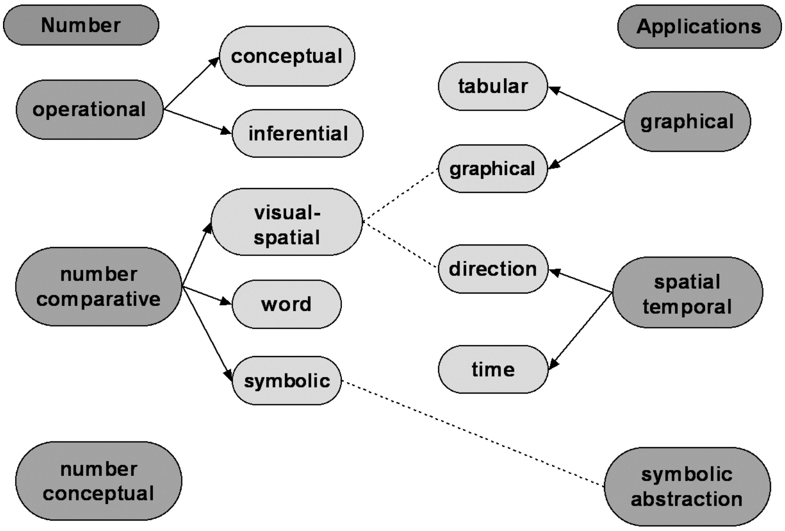

Figure 1: the model for DysCalculiUM, showing the 3 key areas of number, together with their subcategories and the 3 key areas of applications together with their subcategories.

2.2 Trials

The screener has undergone several trials and modifications during its development and the final trials were divided into two parts. In the first, the screener was given to large lecture groups in both Colleges of Further Education and Institutions of Higher Education. The size of each group varied, and the total sample was 504. This provided data for the establishment of "at risk" and "severely at risk" thresholds for the population. The second part involved trials on a one-to-one basis with individuals known to be dyscalculic. This allowed the tool to be verified against a known population. Results from these final trials showed the accuracy of the screener and established reference points for using with future participants. The 8th percentile rank was established as the threshold for "at risk" with the 2nd percentile rank as the threshold for "severely at risk". Of the 51 one-to-one trials with those participants who were known to be dyscalculic, 47 were shown to be "at risk" or "severely at risk" by the DysCalculiUM screening tool. Further information was sought on the four individuals who were not identified by the screener; one assessment report said that the individual was "probably dyscalculic" and the three others were students who were all following science degree courses (biochemistry, physics and computer science). It is likely that these students had developed good coping strategies in order to be able to follow the demands of their courses. These well-developed strategies, that would be frequently repeated during their course, would therefore mediate the score obtained in the screener. This accepted, the screening tool provides a powerful first-line for screening for dyscalculia.

2.3 The Profile

The 11 categories, together with the overall score, are used to create the profile. For each of these, there is an indication of "not at risk", "at risk" and "severely at risk". Guidance is provided on how to interpret the profile and on the subsequent course of action. The procedure is as follows: the learner accesses the DysCalculiUM portal, completes the screener and the results are automatically analysed. The tutor then accesses the portal and reviews the results and profiles, identifying those who are at risk. There can then be a further investigation of the difficulties through an initial tutor-led interview and then by an Educational Psychologist or qualified assessor. A formal identification of dyscalculia can lead to one-to-one support for the learner.

Figure 2 shows an exemplar profile. This profile, for 'Thomas', shows that he is "severely at risk of dyscalculia". This is given, primarily by the overall score indicator, but this is also backed up by the seven categories highlighted as "at risk" or "severely at risk of dyscalculia". The profile further suggested that Thomas had difficulty understanding number concepts and struggled to make numerical comparisons between numbers. It follows that he also had problems with understanding the concept of number operations and in making inferences from them. However, Thomas did not have difficulty with graphical and tabular information, time and spatial directions, which are more visual areas and suggest that Thomas is a visual learner. During the in-depth interview, Thomas revealed that he had

	Severely at risk	At risk	Not at risk
Overall Score:			
1 Number Conceptual			
2 Number Comparative: Word			
3 Number Comparative: Symbol			
4 Number Comparative: Visual Spatial			
5 Graphical			
6 Tabular			
7 Symbolic Abstraction			
8 Spatial Direction			
9 Time			
10 Operational: Conceptual			
11 Operational: Inferential			

Figure 2: DysCalculiUM profile for “Thomas”, showing areas of strength, “at risk of dyscalculia” and “severely at risk at dyscalculia”

always had particular difficulties with mathematics, and in school had been placed in the lowest mathematics group. He had achieved outstanding results in many other areas, but had failed to overcome his mathematical difficulties. Consequently, he was very low in confidence and was concerned about the numerical aspects of his course.

3. Dyscalculia: The Social Affects

Although there is still a lack of awareness of dyscalculia as a specific learning difference, number and numerical understanding underpin many of our daily routines, including household budgeting, checking change or telling the time. Thus, dyscalculics face challenges each day. Anxiety, frustration and low self-esteem often result. One dyscalculic student recently said that she always paid with “a purple”, meaning a £20 note, thereby ensuring that she had given enough money to cover the cost of her purchases. She could not tender the correct amount nor check her change. She also found it difficult to remember numerous orders when she and her peers went to the cafe. Her embarrassment in this situation led her to stop socialising with her peers and she became increasingly socially isolated. It is therefore important that dyscalculia can be identified effectively so that support can be put in place to enable dyscalculics to reach their full potential and feel more confident in everyday numerical situations. The DysCalculiUM screening tool is a first step in this process.

4. One-to-one Support for Dyscalculia

4.1 Case Study

Following identification, it is important to support the learner in an appropriate way. The following case study will serve to illustrate the ways in which a student with dyscalculia can be supported on a one-to-one basis with the mathematical elements of a course.

‘Liam’ was a first year student studying transport management and was identified as dyscalculic following initial screening with the DysCalculiUM tool, during his first year at university. Liam had always struggled with understanding basic mathematical concepts and had been placed in the lowest set for mathematics in school. However, he had excelled at other subjects, particularly languages. The initial screening and assessment revealed that he had strengths in several areas, especially verbal reasoning, expressive writing and reading comprehension. At the same time, his dyscalculia resulted in difficulties with conceptual understanding of number and operations as well as the ability to tell the time and understand graphical information. Furthermore, he had particular difficulty with sequencing numbers in the correct order and relating them to a number line and problems with carrying out basic numerical calculations. His work showed that he was unsure of basic operations and frequently used inappropriate strategies.

4.2 Tables of Information

One of the first issues that Liam faced in his course was his difficulty with tables of information. He had to follow a 4 X 4 table showing plane flights to four cities and the number of minutes late arriving. Firstly, he was unsure of the distinction between rows and columns. This was addressed by the use of a picture of a rowing boat that moved in a horizontal direction across the page, while a picture of a Greek architectural column served to indicate the vertical direction implied by the word column. Liam found reference to these images helpful and this also emphasised that he was a visual learner. One of the other issues with the table was that he frequently mixed up the numbers required for any particular calculation (see Table 3a). One example was to calculate the percentage of flights to Brussels that were more than 5 minutes late. In order to identify and focus on the appropriate information, pieces of card were used to cover over the irrelevant information, leaving only the required data visible (see Table 3b). Support sessions then focused on the ideas of fractions and percentages, so that, after some time, he was able to see that 3 out of 12 was a quarter or 25%. Visual representations were also utilised during this process.

Birmingham to	Minutes late (to nearest minute)			
	On time	1 to 5	6 to 10	Over 10
Paris	8	3	1	0
Brussels	6	3	1	2
Munich	4	1	0	0
Dublin	7	1	1	1

Table 3a: showing the frequency of flights from Birmingham to 4 cities, together with the number of minutes late arriving

Birmingham to	Minutes late (to nearest minute)			
	[redacted]		6 to 10	Over 10
[redacted]				
Brussels	[redacted]		1	2
[redacted]				

Table 3b: with covered cells showing only the frequency of flights from Birmingham to Brussels that were more than 5 minutes late.

4.2 Graphical Representations

Another section of his course required understanding of graphical representations. This was particularly difficult for Liam. The first issue was that he struggled with ordering a sequence of numbers and relating them to a number line. Numbers were written on post-its, one number on each, and Liam was encouraged to put them in order. He also worked on placing them on a number line. When this process was secure, he was able to transfer this to the horizontal axis of a simple linear distance/time graph. Thus, he was able to conclude that time was going forward. However, he was unable to see that the distance was also changing (in this case increasing) simultaneously. The graphs were re-drawn many times without the understanding being present. It was only by chance, that on one occasion he drew the graph with the vertical axis on the right hand side, and he had a "eureka moment". He said: "it's climbing up the wall!" This was a pivotal moment for Liam and, although he often resorted to drawing his graphs "backwards", he was able to move ahead to other aspects of his course with greater confidence. This included correlation and sales forecasting.

Although Liam continued to struggle with the mathematical aspects of his course, he was highly successful in other areas and was able to complete the course.

5. Conclusion

Dyscalculia is one of the newer challenges that face the community of practice. While dyslexia has been the subject of numerous studies and dyslexia support is well established throughout education, dyscalculia is often not recognised or supported. Recent developments in neuroscience have provided an insight into how we conceive and process number; this is invaluable in informing our practice enabling the development of effective screening and support.

References

1. DSM-IV (2000) *Diagnostic and Statistical Manual of Mental Disorders*, Fourth Edition, Text Revision (DSM-IV-TR), American Psychiatric Association

2. Butterworth B. (2001) *Educational Leadership Interview* http://www.mathematicalbrain.com/int06.html (accessed 26/11/07)

3. National Center for Learning Disabilities (2009) *Dyscalculia* http://www.ncld.org/content/view/463/456174 (accessed 26/11/09)

4. DfES (2001) The National Numeracy Strategy. *Guidance to support pupils with dyslexia and dyscalculia*. DfES 0512/2001 http://publications.teachernet.gov.uk/eOrderingDownload/DfES-0512-2001.pdf (accessed 26/11/07)

5. Chinn S. (2006) *What Dyslexia can tell us about Dyscalculia*, Dyslexia Review Vol. 18 (1), pp 15-17

6. Kosc, L. (1974) *Developmental Dyscalculia* Journal of Learning Disabilities, 7(3), p164-177

7. Butterworth B (2002) *Mathematics and the Brain*, Opening address to The Mathematical Association, Reading 2002, http://www.mathematical brain.com/pdf (accessed 26/11/07)

8. Geary D.C. (2004) *Mathematics and Learning Disabilities*, Journal of Learning Disabilities vol 37 (1) pp4-15

9. Desoete A., Roeyers H. and De Clercq A. (2004) *Children with Mathematics Learning Disabilities in Belgium* Journal of Learning Disabilities, Volume 37 (1) pp 50-61 DfES (2001)

10. Piazza M. and Dehaene S.(2004) *From number neurons to mental arithmetic: the cognitive neuroscience of number sense*. In The Cognitive Neurosciences. Michael Gazzaniga, 3rd edition http://www.unicog.org/publications/PiazzaDehaene_ChapGazzaniga.pdf (accessed 2/2/2010)

11. Dehaene D., Piazza M., Pinel P. and Cohen L. (2003) *Three parietal circuits for number processing*, Cognitive Neuropsychology, 20 pp 487--506 http://www.unicog.org/publications/DehaeneEtAl_3parietalCircuits_CogNeuropsy2003.pdf (accessed 2/2/2010)

12. Trott C and Beacham N (2010) DysCalculiUM: a first-line screening tool for dyscalculia, Iansyst/Tribal https://dyscalculia.advancelearningzone.com (accessed 18/2/11)