SPECIFIC LEARNING DIFFICULTIES
UNIT 16
DYSCALCULIA

Learning objectives

Trainees will:

- Know and understand how basic mathematical skills develop
- Know how dyscalculia is currently defined
- Know the limitations of current knowledge on identification of dyscalculia
- Know how pupils experiencing difficulties with maths can be supported.

Online Resources

The content and tasks throughout these PDFs are supported by online resources that are designed to facilitate and supplement your training experience.

Links to these are signposted where appropriate. The resources use graphics and interactive elements to:

- Highlight salient points
- Provide at-a-glance content summaries
- Introduce further points of interest
- Offer visual context
- Break down and clearly present the different stages and elements of processes, tasks, practices, and theories

The online resources offer great benefits, both for concurrent use alongside the PDFs, or as post-reading revision and planning aids.

Please note that the resources cannot be used in isolation without referencing the PDFs. Their purpose is to complement and support your training process, rather than lead it.

You should complete any learning or teaching tasks and additional reading detailed in this PDF to make full use of the Advanced training materials for autism; dyslexia; speech, language and communication; emotional, social and behavioural difficulties; moderate learning difficulties.

To find out more about the resources, how they work, and how they can enhance your training, visit the homepage at: www.education.gov.uk/lamb

The first resource for this unit can be found here:
www.education.gov.uk/lamb/spld/dyscalculia/intro

Introduction

There is significantly less research evidence and knowledge about the normal development of mathematical skills than literacy skills, and mathematical development is more complex then reading development. Consequently psychologists are still struggling to indentify exactly what features of mathematical learning are difficult for dyscalculics. There are also some difficulties in the terminology; some researchers refer to mathematical difficulties, others to specific arithmetic difficulties, or arithmetic deficits or developmental dyscalculia (DD) (to distinguish it from acquired dyscalculia that occurs in people with brain injury). In this unit we will use the term dyscalculia to refer to pupils with this specific difficulty, except where research evidence relates specifically to another description.

The development of number concepts, counting and arithmetic

There is no strict hierarchy in mathematical development where one component of understanding or knowledge invariably precedes another. Arithmetic is made of many components, and weaknesses in any of them can occur relatively independently of weakness in the others (Dowker, 2004). There are however some broad areas that can be considered as important in the development of mathematical skills.

- **Preverbal numerical abilities**
  Both babies and animals possess some primitive numerical abilities, suggesting that basic understanding of numerical quantities is 'hard-wired' into the primitive brain. This ability may provide the foundation for development of more complex number skills. Subitising is thought to be an example of a primitive rapid number processing mechanism. This is the ability to look at a display of randomly presented dots and quickly say how many there are. People are also quick to say which digit represents a larger quantity when presented with pairs of unequal digits; the greater the difference, the quicker people are to make their judgement. This suggests the existence of a preverbal magnitude based system. There is some evidence to suggest that pupils with dyscalculia have problems in the non-verbal representation of numerical magnitudes, although the ease with which most people complete these non-verbal tasks contrasts with the marked difficulty many have in mastering basic computation (Hulme and Snowling, 2009). Thus there is no easy predictive relationship between these 'primitive' skills and later computation skills.

- **Counting**

Effective counting depends on the understanding of five principles:

1. The one-to-one principle:
   Each object counted gets only one count word
2. The stable order principle:
   The count words (one two three…) have to be used in a fixed order
3. The cardinality principle:
   The last count word used represents the number of things in the group counted
4. The abstraction principle:
   Any collection of objects can be counted
5. The order irrelevance principle:
   The objects can be counted in any order

See online resource:
www.education.gov.uk/lamb/spld/dyscalculia/counting-principles

These counting principles are thought to develop as a result of many hours of practice using counting procedures (Rittle-Johnson and Siegler, 1998). Counting is possibly the foundation for more advanced arithmetic operations.

- **Arithmetic**

Single digit addition is the first number operation pupils are taught in school. Even a calculation such as 2+3 demonstrates the complexity of skills involved. Younger children might use objects which they regroup and recount, or count on fingers. A more skilled child might use the count on strategy starting the count with 2, and counting on 3, 4, 5. In both strategies the cardinality principle would have to be used. A more sophisticated user of the count on strategy might start at 3 and count 2 more. This is the min strategy and in order to use it the pupil must understand the commutativity principle (changing the order of numbers in a sum does not alter the result, in some operations). Early addition can be seen as an extension of counting. Later pupils are expected to learn number bonds and retrieve these automatically. It is likely that frequent calculation of addition bonds such as 3+4 encourages storage of these bonds in long-term memory. Therefore pupils who experience difficulties with calculation will struggle more to establish effortless retrieval of number bonds facts. Significantly, effortful and error-prone calculations may lead to incorrect solutions being stored in long-term memory.

See online resource:
www.education.gov.uk/lamb/spld/dyscalculia/arithmetic

What is dyscalculia?

There are many explanations for poor performance on maths activities including inappropriate teaching, behavioural problems, anxiety and missing lessons. This makes identifying a specific condition such as dyscalculia difficult. Additionally, mathematics, even in early years, comprises a wide variety of skills (for instance: counting, estimating, retrieving arithmetic facts, understanding arithmetical operations and laws, knowing procedures in multi-digit tasks, solving novel word problems and so on).

See online resource:
www.education.gov.uk/lamb/spld/dyscalculia/early-maths-skills

As a consequence it has been difficult to develop standardised tests of arithmetic, with the effect that identifying typical and atypical performance in mathematics is problematic. It would also be essential to separate measures of attainment (that could be influenced by quality and quantity of experience/education) from innate capacity.

The DfES (2001) defines dyscalculia as:

> '*a condition that 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*.' (DfES 2001, p2)

Dyscalculics are less accurate and slower at arithmetical operations (Landerl, Bevan and Butterworth, 2004). They also depend more on immature strategies such as counting on their fingers to solve problems. Some pupils may compensate in untimed conditions using strong verbal or conceptual skills so any measure that only takes into account accuracy of performance is likely to miss many dyscalculics. Attention should also be paid to how arithmetic problems are solved, and how quickly.

It is possible that the difficulties faced by dyscalculic pupils stems from the lack of an intuitive grasp of number. The defective 'number module' hypothesis (Butterworth, 1999) postulates a developing brain has a specialised capacity (number module) for recognising and mentally manipulating numerosities (cardinal values). This is probably hardwired into the brain, and in dyscalculia is thought not to develop normally. Evidence is found in the slower performance of dyscalculics in subitising and numerical magnitude tasks (Butterworth, 1999).

Hulme and Snowling (2009) looked at a number of research studies and identified a possible prevalence rate ranging from 1.3% to 11.2% depending on the chosen cut off point. They comment that ‘maths disorder’ occurs quite frequently and that it is quite commonly associated with reading difficulties.

There is evidence of heritability and genetic influences on dyscalculia, and while there are no ‘maths’ genes, genes do seem to effect underlying cognitive processes. However, as for dyslexia, genetic makeup is not deterministic. Multiple sets of genes operate in the context of biological and environmental factors which influence development of specific skills.

There is also emerging evidence of a brain basis for dyscalculia, for instance the horizontal intraparietal sulcus may be implicated in deficient ‘number sense’, and less activation in the parietal areas occurs in dyscalculics during calculation (Hulme and Snowling 2009).

How does dyscalculia relate to dyslexia?

There is a great deal of co-morbidity of dyscalculia with dyslexia. About 60% of dyslexics also have dyscalculia. However this means that 40% of dyslexics don’t have dyscalculia and may even be above average in maths (Butterworth 2007). Pupils with dyscalculia alone might have a specific deficit in the nonverbal ‘number sense’ system and those with both dyslexia and dyscalculia might have additional difficulties with the language aspects of maths (Hulme and Snowling 2009). Pupils with both dyscalculia and dyslexia seem to usually have more severe difficulties with maths, more than those with dyscalculia alone.

See online resource:

www.education.gov.uk/lamb/spld/dyscalculia/dyslexia-data

Identifying pupils with maths difficulties and dyscalculia

Dowker (2004) suggests that pupils who are at national curriculum level 1 at age 7 and level 3 at age 11 can be considered to have maths difficulties, whilst pupils achieving below these levels should be considered to have ‘quite marked mathematical difficulties’.

There are currently no agreed criteria for diagnosing dyscalculia. Tests of attainment must be separated from tests of capacity since attainment can be affected by teaching, attendance and so on. Maths ‘capacity’ implies innate skills that underpin learning and might be immune to teaching (for example Butterworth's (1999) 'number module'). Difficulties with identification are further compounded by the finding that any component in arithmetic functioning can be selectively impaired, for instance a pupil may be able to carry out arithmetical calculation, but unable to remember number facts, another pupil may be able to remember the facts but unable to carry out procedures. Pupils both with and without mathematical difficulties can have strengths and weaknesses in almost any area of mathematics, and pupils often show random variations in performance from day to day (Dowker 2009). Thus the profile of each pupil with dyscalculia will be unique.

One fairly consistent finding is that many pupils with dyscalculia use counting strategies to solve arithmetic problems well beyond the point at which their peers have begun to use number fact retrieval and more sophisticated 'min' strategies for instance. The outcome of this is usually in the much slower speed at which arithmetic problems are performed. Thus it would be useful alongside considerations of attainment and accuracy to make observations of *how* pupils solve problems and *how long* it takes them.

Many good intervention programmes include a diagnostic assessment to guide planning for teaching.

Dyscalculia and math difficulties are likely to form part of a continuum of maths ability, with a few individuals having severe specific difficulties with arithmetic (Dowker, 2004) and therefore others with milder difficulties.

Butterworth (2003) has devised a computer-based screener intended to screen for pupils who might be experiencing dyscalculia. It incorporates recognition of small numerosities, estimation of larger numerosities, and comparisons of number size, and performance speed is measured. This assessment has been standardised with ages 6 to 14. It is intended that teachers would use this as a starting point for more individualised assessment of strengths and difficulties. It does *not diagnose* dyscalculia.

Activity 1

Go through the list of pupils with SEN in your school.

- How many of them are identified with maths difficulties?
- How many are identified with both dyslexia and dyscalculia/maths difficulties?
- How many of them might have difficulties only in maths, or subjects that are in part dependent on maths such as physics?

Given a prevalence rate of 1.3 – 11.2% do you think your school is doing enough to identify pupils who are struggling with maths? Discuss these issues with the SENCo and other colleagues, focus on how you might improve/refine identification of these pupils. Consider making observations of pupils whilst working on arithmetic activities, and analysis of end of key stage or unit test papers or use of ‘assessing pupil progress’ (APP) tools. Remember that identifying the unique strengths and difficulties of the individual is important.

In your learning log make notes about your discussion, and any actions to support improved identification that you agree on with your colleague.

Memory and dyscalculia

Mental arithmetic tasks clearly involve working memory since to solve a problem you need to remember each number in it and each stage of the calculation, retrieve the correct procedures for calculation, apply them, and then give the answer. However, in a review of studies Hulme and Snowling (2009) found that although there was some evidence of working memory deficits in pupils with dyscalculia, it is difficult to say exactly how these deficits could explain dyscalculia since the deficits in working memory were complex and may be mediated by factors such as IQ or processing speed.

It is possible that working memory difficulties in dyscalculia are specific to numerical information, but at present there is no evidence that working memory difficulties are a *causal* feature of dyscalculia (Butterworth 2007).

Maths anxiety

Maths anxiety can lead pupils (rarely in young pupils, Dowker, 2004) and adults to avoid situations which necessitate the use of maths skills. Thus they avoid maths education, resulting in less opportunity to develop skills and less experience of applying maths knowledge. For those with the worst symptoms any attempt to engage in maths activities may result in overwhelming anxiety and panic. This anxiety is likely to be particularly severe in test situations.

There is no evidence that dyscalculia is *caused* by anxiety about mathematics, though anxiety in any context is likely to interfere with learning and performance. It is important to remember that although it is likely there will be some overlap between these groups of children, maths anxiety is not the same thing as children having specific difficulties with number concepts which may require specialist interventions.

Anxiety specifically related to maths is common (research evidence is in adults, Hulme and Sowling 2009) and seems to operate at least in part by interfering with working memory operations (which may be normal without any anxiety present). Maths anxiety will therefore have a significant impact on performance. It seems likely that early difficulties with maths lead to maths anxiety, which serves to further reduce opportunities for efficient maths learning. Early and sympathetic intervention is likely to be particularly useful in prevention of maths anxiety.

See online resource:
www.education.gov.uk/lamb/spld/dyscalculia/maths-anxiety

Activity 2
Perhaps the best way to find out if individual pupils are experiencing maths anxiety is a combination of observation of pupils in class and interview with pupil and parents.

- Use the Maths Anxiety Questionnaire as a guided interview with a pupil who finds maths difficult and you think may be experiencing maths anxiety, adjust the questions as necessary for the age group you work with.
- Make careful note of their responses and make a judgment about their level of anxiety.
- Share this approach with a colleague and encourage them to carry out a similar interview with a pupil.
- Now look through the suggested support for pupils with dyscalculia (below) and identify approaches that may prove supportive with the pupils you identified.

Supporting pupils who find maths difficult
Since arithmetic is componential, interventions that focus on the particular numerical and arithmetic components with which an individual pupil has difficulty are more effective than those which assume that all children's arithmetical difficulties are similar (Dowker, 2009). Furthermore, since individual arithmetical difficulties respond well to intervention, individualised work with children who are falling behind has a significant impact on their performance. The amount of time spent on intervention does not, in many cases, need to be great.

Many schools set pupils for maths, and others prefer mixed ability teaching, which may include working in differentiated groups. Evidence regarding the effectiveness of these approaches is as follows (see Dowker, 2004):

- Ability grouping/setting: this seems to have a mixed effect, and in many cases a particularly negative effect on the lowest ability group. This is likely to be as a result of teachers assuming homogeneity in the group/set and making insufficient account of individual differences.
- Individualised and small group work in class: within class provision of appropriate resources and activities seems to have a positive effect on the performance of low achievers.

The following approaches are useful:

- Analyse exactly what the pupil finds difficult and intervene directly in areas of difficulties
- Use concrete materials and visual representations to help link mathematical symbols to quantity (schemes such as Addacus, Numicon and Stern have specific equipment for this)
- Use multisensory teaching methods
- Start at a level which the pupil is comfortable, plan for them to experience success, and slowly increase the challenge
- Provide a lot of practice for any new skills/concepts
- Monitor activities to make sure no pupil is under undue pressure.
- Do not use competitive games unless you are sure all pupils involved have a reasonable chance of succeeding, even games such as ‘fizz buzz’ which are fun for many can be a source of anxiety for some.
- Make use of cooperative learning activities.
- Set up open ended problem solving activities that might have a variety of routes to a solution, encourage discussion and experimentation.
- Avoid situations in which anxious pupils will have to perform in front of large groups.
- Allow all pupils including those who are anxious to ‘phone a friend’ or ‘go 50/50’ for example when dealing with maths problems.
- Make sure all instructions are clear.
- Check with pupils to make sure they understand. Ask several pupils how they would do the first question of an exercise or a sample question on a test. Correct any misconceptions.
- Give worked examples or models to show how a problem might be solved.
- Allow pupils extra time - even when given work at their level dyscalculic children often work slowly. Allow those who are anxious or slow workers extra time in tests and examinations.
- Teach test-taking skills; give practice tests; provide study guides.
- Have pupils do projects, organize portfolios of their work, make oral presentations, or create a finished product, rather than sit a test.
- Encourage an appropriate classroom ethos. Do not allow pupils to make statements such as "This is easy." What may be easy for one may not be for another.
- Use written rather than verbal instructions and questions. Dyscalculic pupils may already be experiencing cognitive overload trying to understand the maths, reduce the memory burden of having to remember instructions too.
- Focus on understanding, rather than rote memory. Avoid drilling and recitation of number bonds and times tables without first achieving

understanding. Where this is necessary try to use a fun method such as computer or card games. While facts are important for maths, drilling alone is ineffective for dyscalculic pupils. Calculators and number fact grids and so on can make up for memorisation. Pupils who have not memorised arithmetic facts can often manage other aspects of maths well, given the right supports.

There are an increasing number of mathematics intervention programmes. Four examples are listed here, though there are many more and there is no evidence that any one programme is best for most or all pupils. Mention of programmes in this unit should not be seen as particular endorsement.

- Mathematics recovery is designed for 6-7 year olds and achieves extremely good gains for most pupils (Willey, Holliday and Hartland 2007).
- Catch up Numeracy, developed by Ann Dowker and targets pupils in Years 2 to 9 who have numeracy difficulties. The amount of time that individual pupils receive Catch up Numeracy support depends on their progress, which is usually substantial.
- Numbers count: developed and run by Edge Hill University. Pupils make and maintain impressive gains. Designed for the lowest achievers in year 2. It is teacher led and requires specialist training.
- Primary national strategy wave 3 materials ‘Supporting children with gaps in their mathematical understanding’. Various intervention projects have been produced that are based on these materials and although the national strategies no longer exist, the materials do remain widely available on the internet.

Trainees should consult the document ‘What works for pupils with mathematical difficulties?’ Dowker (2009) regarding the effectiveness of these and other intervention programmes. In general the most effective programmes include specific training for those who run them. Additionally, outcomes for pupils are better when interventions are well managed.

Activity 3

Investigate and answer the following questions in your learning log:

- What maths interventions are available in your school for pupils with the greatest needs?
- Are the interventions targeted at individual needs of pupils?
- Are the outcomes of these interventions monitored? How?
- Do pupils make sufficient progress?
- Are those who deliver the interventions well trained and supported?
- Are the interventions well managed?

- What action might you need to take regarding maths interventions? Discuss your findings with a colleague and/or the SENCo and create an action plan.

References

Butterworth, B. (1999) The mathematical brain. London: Macmillan

Butterworth, B. (2003) The Dyscalculia Screener GL Assessment UK

Butterworth, B. (2007) Developmental Dyscalculia. In: Handbook of mathematical cognition Jamie I D Campbell Psychological Press

Dowker, A. (2004) What works for pupils with mathematical difficulties? Ref: RR554

Dowker, A. (2009) What works for pupils with mathematical difficulties? Ref: 00086-2009BKT-EN

Hulme, C. and Snowling, M. (2009) Developmental disorders of language learning and cognition. Wiley-Blackwell, UK
See chapter 5 for a good review of available evidence regarding maths disorders.

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

DfES (2001) Guidance to support pupils with dyslexia and dyscalculia DFES 0512/2001

Rittle-Johnson, B. and Siegler, RS. (1998). The relation between conceptual and procedural knowledge in learning mathematics: a review. In, The development of mathematical skills. Donlan C. Psychology press UK

Willey, R., Holliday, A., & Martland, J. (2007) Achieving new heights in Cumbria: Raising standards in early numeracy through mathematics recovery. Educational & Child Psychology, Vol. 24, No 2, The British Psychological Society.

Websites

http://www.mathematicalbrain.com/

http://www.aboutdyscalculia.org/

http://www.mathsrecovery.org.uk/ for more information regarding Mathematics Recovery

www.catchup.org.uk for more information regarding catch up numeracy and to download Dowker (2009).

http://www.teachfind.com/national-strategies/mathematics-intervention-materials-wave-3 for the wave 3 mathematics materials

http://webarchive.nationalarchives.gov.uk/20110202093118/http://nationalstrategies.standards.dcsf.gov.uk/search/primary/results/nav:81327 for springboard materials

http://www.edgehill.ac.uk/everychildcounts/ for more details regarding every child counts and numbers count projects, training and resources.