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MATHEMATICS EDUCATION NETWORK

Dyscalculia: What's new?

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Outline

- Definitions and diagnosis of dyscalculia
- Recent changes in diagnostic criteria/controversies
- Cognitive theories of dyscalculia and the dyscalculic cognitive profile

The broader context

- functional innumeracy can be defined as lacking the necessary numerical skills and competence to deal with everyday situations involving numbers and basic numerical operations (Bynner & Parsons, 1997)

- government statistics suggest that 17 million adults in England (49% of the working age population) have the numeracy level of a primary school pupil, and only 22% of adults are functionally numerate (Smith, 2017)

- by the end of secondary school, the gap between the highest and lowest achieving students in mathematics in England equals around eight years of schooling, which is larger than in most other countries (OECD, 2015)

- the annual cost of poor mathematics skills to the UK economy is estimated to be up to £33bn (National Numeracy, 2019)

- low numeracy is linked not only to poor academic achievement and limited career opportunities, but also to an increased risk of unemployment, mental and physical illness, and higher rates of arrest and incarceration (e.g., Hudson et al., 2009) even in the presence of adequate literacy (Parsons & Bynner, 2005)

DSM-5: Specific Learning Disorder in Mathematics

- persistent, substantial difficulties in mathematics learning and using academic skills
- academic performance should be determined through standardized achievement measures and comprehensive clinical assessment
- a "clinical synthesis" should occur based on the individual's developmental, medical, family, and educational histories, school reports, and psycho-educational assessment
- the difficulties must not be better explained by intellectual disabilities, mental, neurological, sensory (vision or hearing) or motor disorders
- the difficulties must not be better explained by psychosocial adversity, lack of proficiency in language of academic instruction, or inadequate educational instruction
- the deficits must cause significant interference with academic or occupational performance, or with activities of daily living
- severity levels need to be specified

Some other points to note (DSM-5)

- difficulties in learning and using mathematics skills that have persisted for at least 6 months, despite the provision of targeted interventions

- difficulties mastering number sense, number facts or calculation (e.g., poor understanding of numbers, their magnitudes and relationships, using finger counting even for simple calculations instead of fact retrieval, and getting lost in the middle of computations), and problems with mathematical reasoning

British Dyslexia Association/ SpLD Assessment Standards Committee definition

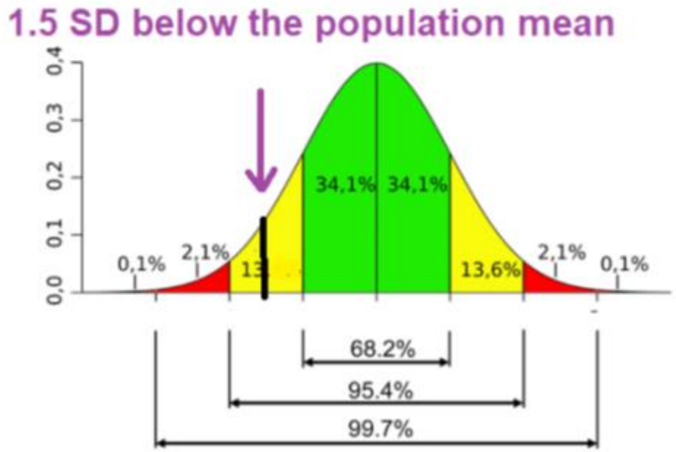
- Dyscalculia is a specific and persistent difficulty in understanding numbers which can lead to a diverse range of difficulties with mathematics. It will be unexpected in relation to age, level of education and experience and occurs across all ages and abilities.
- Mathematics difficulties are best thought of as a continuum, not a distinct category, and they have many causal factors. Dyscalculia falls at one end of the spectrum and will be distinguishable from other maths issues due to the severity of difficulties with number sense, including subitising, symbolic and non-symbolic magnitude comparison, and ordering. It can occur singly but often co-occurs with other specific learning difficulties, mathematics anxiety and medical conditions.

Recent updates/inconsistencies in the diagnostic criteria

- DSM-5 (2013): no longer applies a discrepancy criterion between intelligence and mathematics skills (the DSM-IV required at least 1 *SD* difference) – this has important implications for both <u>prevalence</u> and the <u>characteristics</u> of dyscalculic individuals
- the ICD-11 (2022) definition is different from the previous, ICD-10 definition, which emphasized an <u>impairment in arithmetic skills</u> (i.e., basic computations), rather than more abstract mathematical skills.
- Many publications on dyscalculia describe it as a specific disorder of arithmetic skills The ICD-11 (and the BDA/SaSC definition) still includes the maths-IQ discrepancy criterion
- The discrepancy criterion has long been criticised on the basis that it is unreliable/not stable across time (e.g., Johnson et al., 2010; Mazzocco & Myers, 2003), and that learning disability should be defined as achievement that is low for age or grade level, regardless of a child's IQ (e.g., Siegel, 1989; Stanovich, 1991).

Estimates of prevalence

- criterion of 2 years below grade level in *arithmetic* in the presence of normal intelligence: 6% in schoolchildren (e.g., Gross-Tsur, Manor, & Shalev, 1996).



- mathematical learning difficulties: 5-8% (Geary, 2004)

- dyscalculia: 3.6-6.5% (Butterworth, 2010)

- similar to dyslexia, between 3.5-6.5% (von Aster & Shalev, 2007)

- 5.7%, similar across genders (based on the DSM-5 diagnostic criteria; Morsanyi et al., 2018)

Having a closer look at the prevalence of dyscalculia and the discrepancy criterion (Morsanyi et al., 2018)

- **Participants**: 2,421 primary schoolchildren attending years 4-7 of primary school in Northern Ireland (corresponding to Key Stage 2 in England)
- 6% of the children had persistent, severe difficulties with mathematics (an average standard score of 78 or less – 1.5 SD below the population mean), and <u>5.7% had a dyscalculia cognitive profile</u> (after excluding children with neurological and sensory difficulties)
- <u>Prevalence is only 1.1% with discrepancy criterion</u> (it excludes more than 80% of children with persistent, serious maths difficulties)
- The average discrepancy between maths scores and IQ in these children is about half *SD* (7-8 standard points).

Is dyscalculia really "specific"?

- The DSM-5 involves an umbrella term of "Specific Learning Disorders" – acknowledges the likelihood of comorbidity between different SLDs
- Comorbidity between developmental disorders is the rule rather than the exception (e.g., Williams & Lind, 2013)
- Morsanyi et al. (2018): 81% of children with dyscalculia had some kind of comorbid condition

Some <u>examples of comorbid conditions</u>:

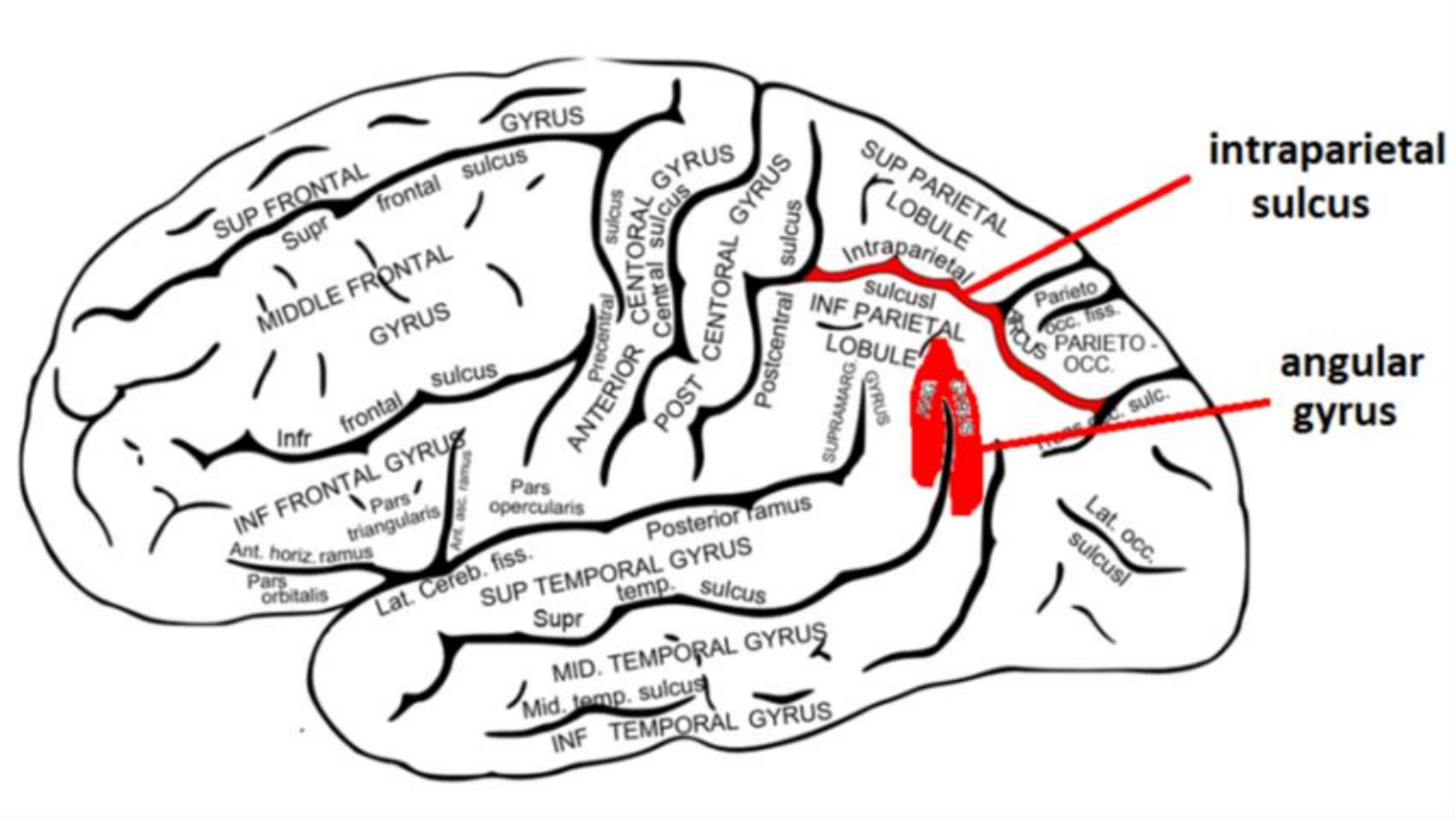
- 45.3% had general cognitive and learning difficulties (7 times more likely than in children without dyscalculia)
- 11.5% had speech and language difficulties (5 times more likely than in children without dyscalculia)
- 5.6% had dyslexia (1.3 times higher than in children without dyscalculia)

Does dyscalculia only affect number skills?

The defective number module hypothesis of dyscalculia (e.g., Butterworth, 1999):

- Selective deficits in magnitude processing arise when the specialised number module fails to develop normally
- We are born with a capacity for recognizing and mentally manipulating *discrete quantities*
- Understanding numbers is largely independent of language

Dyscalculia and the brain: The role of the intraparietal sulcus (IPS) and the angular gyrus



sulcus = depression or fissure
gyrus = ridge

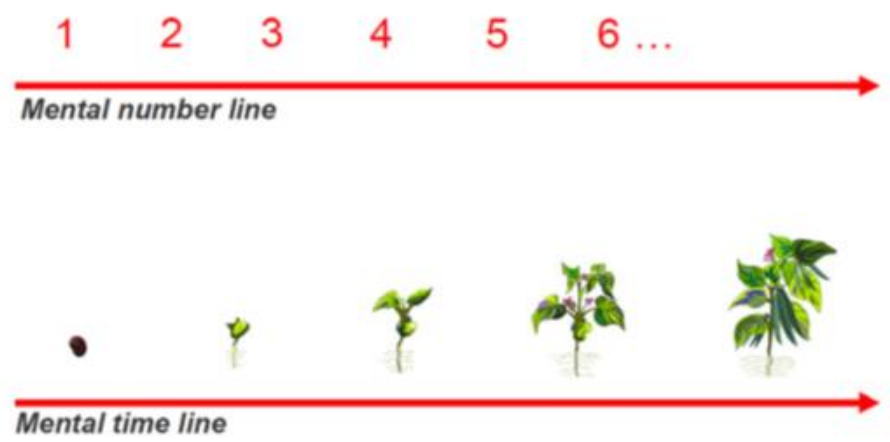
What does the IPS do?

- The IPS is active in numerical processing, arithmetic (e.g., Dehaene et al., 2003) and numerical magnitude judgments (Ansari, 2007)
- The right IPS is specialised in simple numerical tasks, such as the estimation of the numerosity of small sets (e.g., Piazza et al., 2002)
- Studies of brain-lesioned patients have found the left IPS and the angular gyrus to be critical in normal numerical performance (Cipolotti & van Harskamp, 2001)
- The IPS is part of the dorsal visual pathway (the "where" system), and has a role in spatial perception and visually guided action (e.g., Freud et al., 2016).
- It is also involved in orienting attention, sustained attention and in suppressing task-irrelevant information (e.g., Lee et al., 2013)
- It is also part of a parieto-frontal network, associated with intelligence and reasoning (Jung et al., 2006)

The "number sense" approach
(e.g., Dehaene, 1997)

- We are born with a capacity for representing *continuous quantities*
- Close links between the representations of *numbers, space and time* in the brain
- Also *important links with language*: we need the knowledge of the integer list (number words) – e.g., Gallistel and Gelman (2000)
- The access deficit hypothesis of dyscalculia: dyscalculic learners struggle to link magnitudes to symbolic numbers (e.g.,De Smedt & Gilmore, 2011; Rouselle & Noel, 2007)

A theory of magnitude…



Bonato et al., 2012

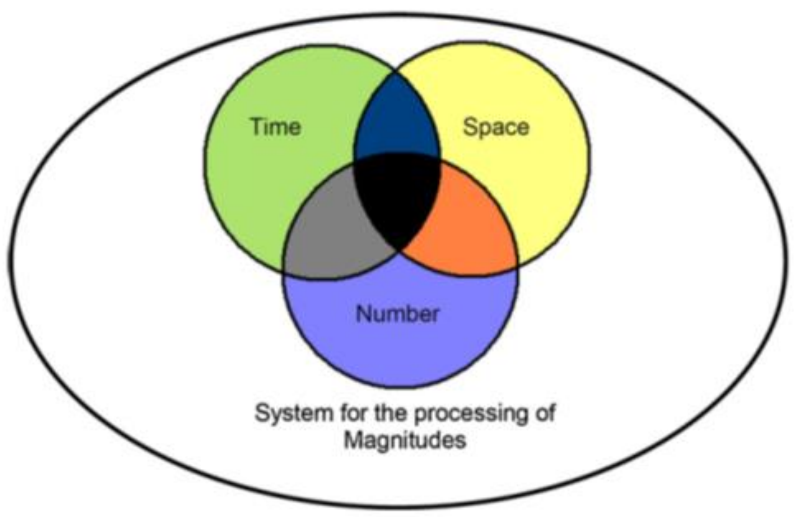
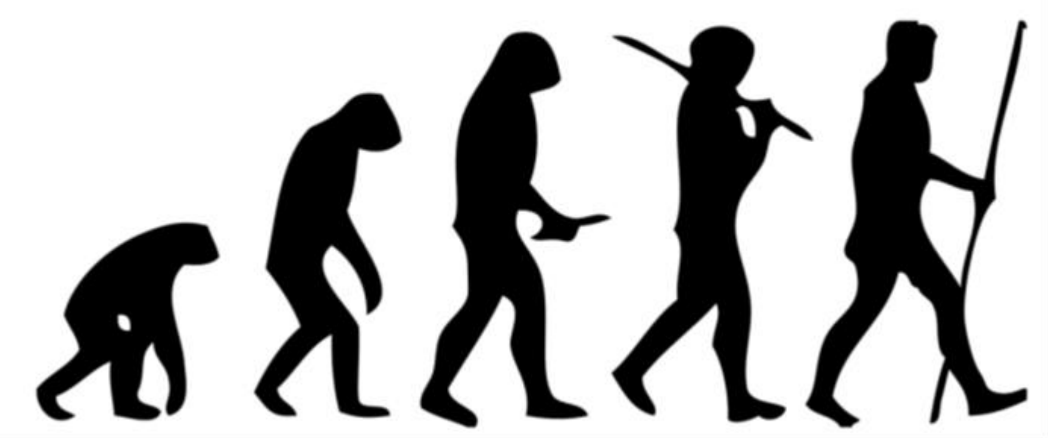
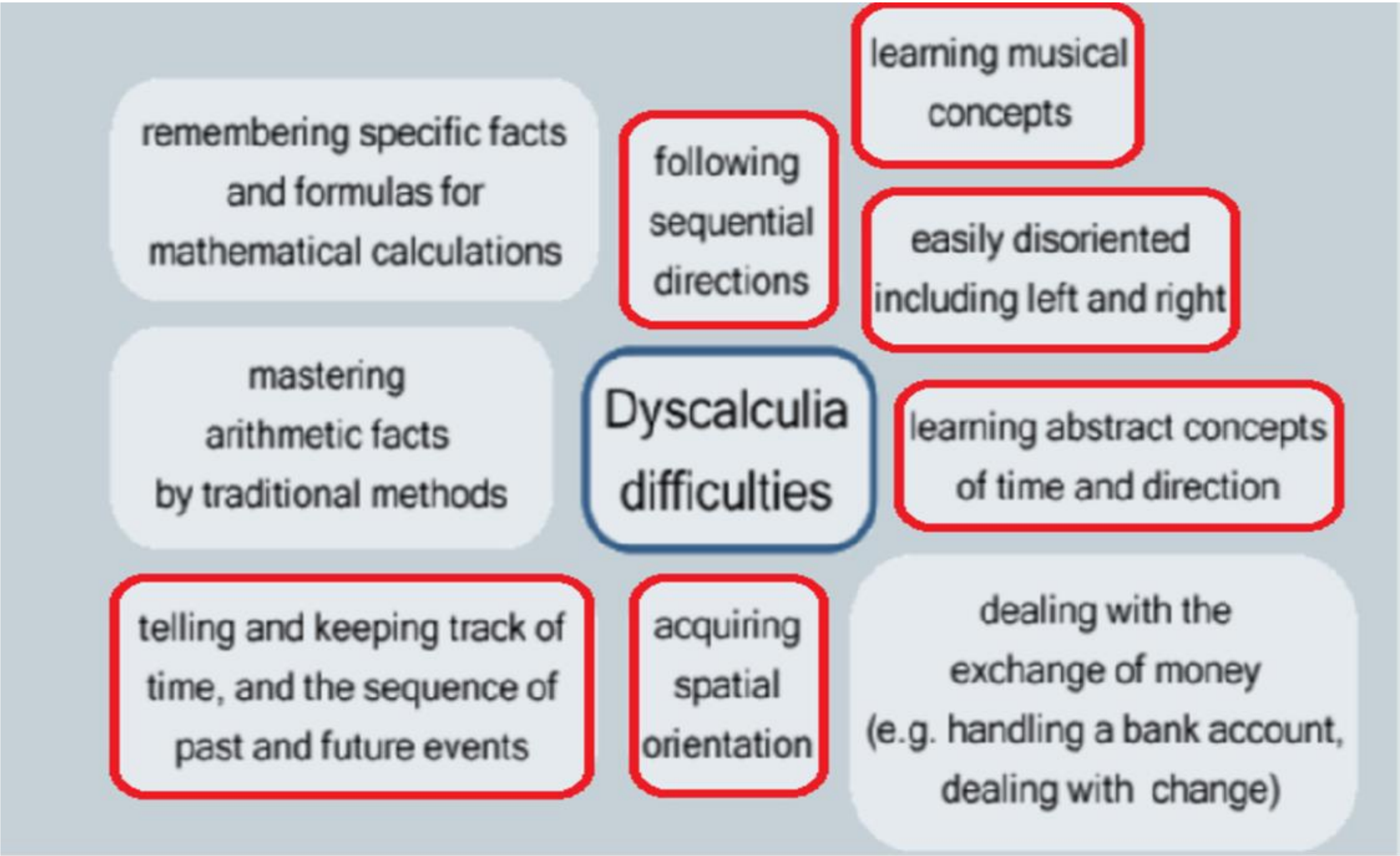


Fig. 3. A schematic representation of the ATOM theory. Adapted from Walsh (2003).





[43) Living With Dyscalculia (It’s Not Just "Number Dyslexia") - YouTube]()

Evidence for the role of domain-general skills in dyscalculia

<u>Problems with:</u>

- verbal and visual working memory (e.g., Attout & Majerus, 2015; Bull & Scerif, 2001; Swanson, 2011; Szucs et al., 2013)
- inhibitory function (e.g., Blair & Razza, 2007; Szucs et al., 2013)
- attentional function (Ashkenazi et al., 2009)
- ordering/sequencing skills, including temporal order and learning movement sequences (Morsanyi et al., 2018)
- reasoning skills/transitive inferences (Morsanyi et al., 2013)

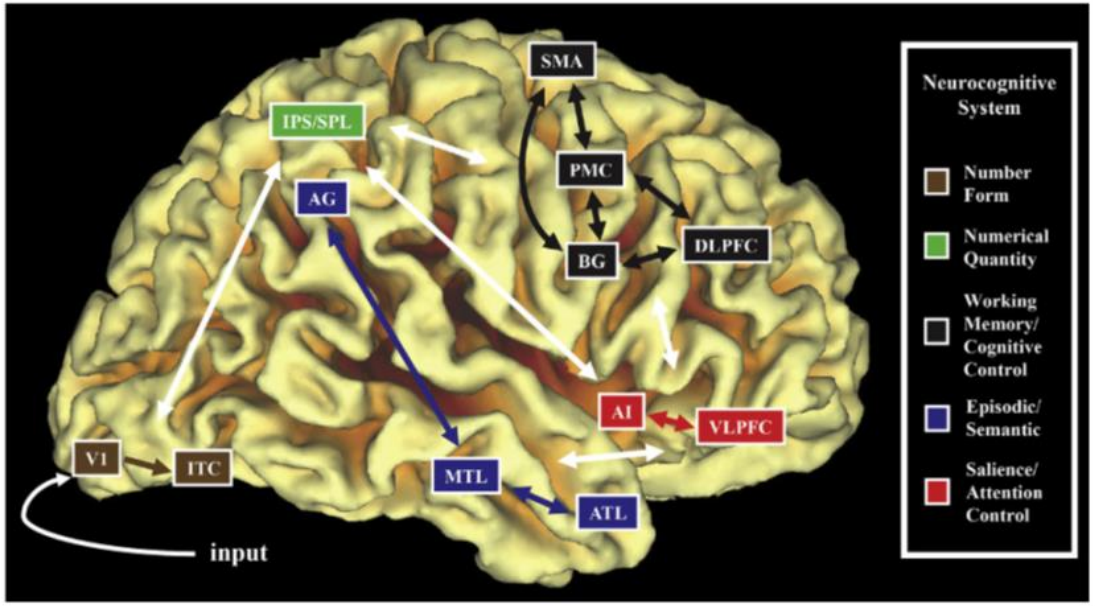
Dogs are stronger than gorillas.

Rabbits are stronger than dogs.

Are rabbits stronger than gorillas?

Multiple neural components of dyscalculia
(Fias et al., 2013)

- Mathematical problem solving is built on multiple neurocognitive components that are implemented by distinct and overlapping brain systems.
- Heterogeneity and comorbidities observed in dyscalculia are a natural consequence of such a multicomponent system



Is dyscalculia resistant to interventions?

- Some researchers suggested that resistance to interventions may be a hallmark of dyscalculia (e.g., Re et al., 2014)
- This is in line with the concept that neurodevelopmental disorders are lifelong conditions
- The DSM-5 describes dyscalculia as persistent difficulties with mathematics, but gives different estimates for the overall prevalence of SLDs in children and adults (about 5-15% in children and 4% in adults)
- The prevalence of a dyscalculia profile markedly decreases across year groups between years 4 to 7 (with proportions of 7.4%, 6.4%, 5.8% and 3.8%, respectively – Morsanyi et al., 2018).
- Dyscalculia is the very low end of the mathematics skills continuum: no evidence that interventions for dyscalculic pupils should be different from interventions for other pupils (Peters & Ansari, 2019)

Concluding comments

- Dyscalculia can be a debilitating condition that seriously affects people’s life chances
- It does not only affect numerical skills, but also spatial and temporal processing, and some general cognitive skills as well
- Co-morbidity and heterogeneity in dyscalculia are the rule, rather than the exception

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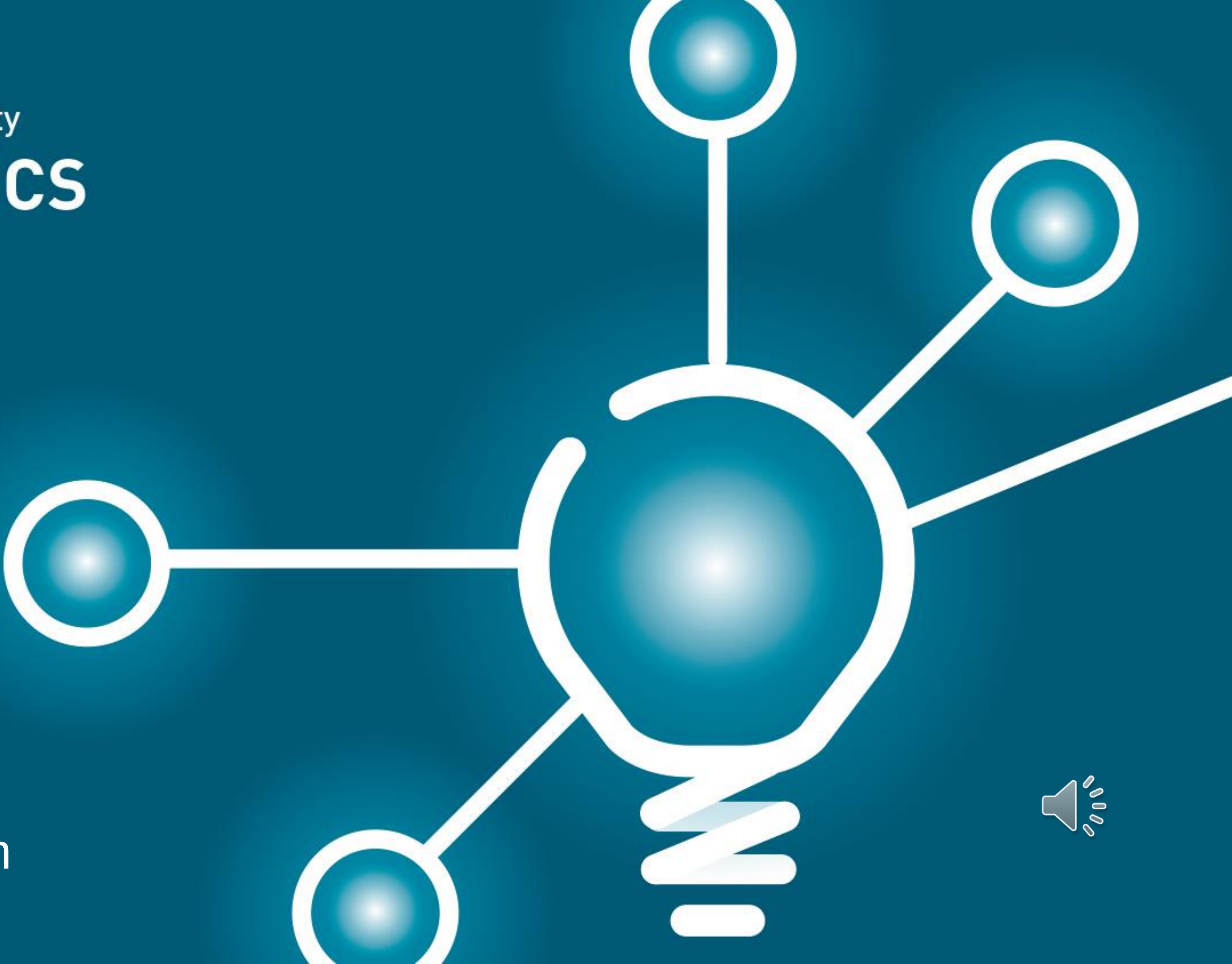

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