Abstract: This paper reviews and discusses research on arithmetical strengths and weaknesses in children with specific developmental cognitive disabilities. It focusses on children with dyslexia, developmental language disorder, attention deficit hyperactivity disorder, autism and Williams syndrome. In general, studies show that arithmetical weaknesses are commoner in children with any of these disorders than in controls. Autism is sometimes associated with specific strengths in arithmetic; but even in autism, it is commoner for arithmetic to be a relative weakness than a relative strength. There may be some genetic reasons why there is an overlap between mathematical difficulties and other developmental learning difficulties; but much of the reason seems to be that specific aspects of arithmetic are often influenced by other factors, including language comprehension, phonological awareness, verbal and spatial working memory and long-term memory, and executive functions. The findings discussed here will be discussed in relation to Pennington's (2006) Multiple Deficit Model.

Keywords: Specific learning difficulties; mathematical difficulties; arithmetic; dyslexia; developmental language disorder; autism; attention deficit hyperactivity disorder; Williams syndrome; children; individual differences.

What this paper adds:

This paper reviews arithmetical weaknesses and in some cases strengths in a variety of developmental cognitive and learning disabilities. It presents some important issues for future research. It proposes that the usual sharp distinction between domain-specific and domain-general abilities is oversimplified, and for example that certain early numerical abilities may not just depend on executive functions but could be seen as particular types of executive function. It also points out that both arithmetical ability and other cognitive abilities are not unitary but are made up of many components; and that more research needs to be done on exactly how the different components of other abilities relate to different components of arithmetic.

Arithmetic in Developmental Cognitive Disabilities **(Research in Developmental Disabilities; 2020; in press)**

Although mathematical difficulties can occur on their own, they are often comorbid with other developmental cognitive disabilities: for example, dyslexia, developmental language disorder, attention deficit hyperactivity disorder, autism and Williams syndrome. This is not an exclusive list of the other cognitive difficulties that are sometimes associated with mathematical difficulties, but these difficulties do seem to have received a relatively large amount of study with regard to their associations with arithmetical performance. Such studies can give useful information about the degree and nature of associations and dissociations between numerical abilities and other cognitive abilities; and can inform more general models of comorbidity of developmental disorders, such as that of Pennington (2006).

The present paper discusses findings concerning arithmetical difficulties in the disorders listed above. The terms ‘arithmetical’ and ‘mathematical’ are used interchangeably, because they are commonly used in this way in the literature being discussed. However, we must remember that there are many aspects of mathematics other than arithmetic – geometry, measurement, algebra, etc; and that these may also be affected by specific learning difficulties.

Arithmetic and dyslexia

Though reading and mathematical disabilities often occur separately, most studies suggest that they occur together more often than would be expected by chance (Gross-Tsur, Manor and Shalev , 1996; Moll, Landerl, Snowling . & Schulte-Korner.2019). Moll et al (2019+ found that children with reading deficits were four times more likely to have deficits in arithmetic than would be expected by chance alone. Dyslexia is commonly found to be associated with two particular deficits: weaknesses in phonological awareness and weaknesses in verbal working memory tasks, especially rapid automatized naming. Both of these may be related to broader phonological weaknesses. It might therefore be expected that children with dyslexia might have particular deficits in areas of arithmetic that depend on, or are facilitated by, either phonological awareness or phonological working memory or both.

Some studies do indeed suggest that phonological awareness contributes not only to reading but to some aspects of arithmetic. Vanbinst, van Bergen, Ghesquiere & De Smedt (2020) found that unselected five-year-olds' phonological awareness predicted their subsequent performance in both reading and arithmetic, even after controlling for letter knowledge, early arithmetic, symbolic and non-symbolic magnitude comparison and numeral recognition. Numeral recognition also predicted both reading and arithmetic. By contrast, symbolic and non-symbolic magnitude comparison were strong predictors of arithmetic but not reading. Thus, it appears that reading and arithmetic have shared as well as unique predictors, and that phonological awareness is a particularly significant predictor of both.

Other studies also show that both phonological awareness and rapid automatized naming are significant correlates and predictors of at least some aspects of mathematics, particularly verbal counting sequence knowledge (Koponen, Eklund & Salmi, 2018; Koponen, Eklund, Salm & Aro, 2013; Koponen, Eklund, Heikkila et al, 2020; Traff, Olsson, Skagerlund & Ostergren, 2020), digit recognition and comparison (Traff et al, 2020) and arithmetical fluency, especially with single-digit arithmetic problems that may be particularly facilitated by memorization (De Smedt, Taylor, Archibald & Ansari, 2010; Koponen et al, 2013; Singer, Strasser & Cuadro, 2019). Some studies suggest that the associations between phonological abilities and arithmetical fluency are largely mediated by counting (e.g. Koponen et al, 2013).

Phonological difficulties are associated with difficulties in arithmetic. For example, Jordan, Wylie & Mulhern (2010) found that poor phonological awareness in 5-year-olds was associated with difficulties in arithmetic, both at the time and late on. About half of the children with poor phonological awareness showed significant difficulties in arithmetic by the age of 7, while most of the rest showed more circumscribed difficulties in tasks that involved factual knowledge.

Relative weaknesses in phonological awareness are also associated with difficulties in memory for arithmetical facts in older dyslexics including adults De Smedt & Boets (2010) compared 25 adults with dyslexia with 25 controls, and found that those with dyslexia had worse phonological awareness and also worse memory for arithmetical facts, and that there was a significant correlation between factual memory and phonological awareness.

.   In particular, people with dyslexia usually experience at least some difficulty in learning number facts such as multiplication tables. Miles 1993) found that 96% of a sample of eighty 9- to-12-year-old dyslexics were unable.to recite the 6×, 7× and 8× tables fluently.

. Some studies suggest that phonological awareness and verbal memory – abilities commonly impaired in dyslexia - may be more associated with factual and procedural difficulties in arithmetic, while semantic comprehension difficulties may be more associated with difficulties with arithmetical word problem solving. Word decoding in reading appears to be particularly associated with fact retrieval in arithmetic, whereas reading comprehension appears to be more associated with word problems and possibly with conceptual knowledge.

. Dyslexia is more often associated with difficulties with short-term and long-term memory for number facts, than with difficulties with arithmetical concepts and principles (Miles & Miles, 1992; Pritchard, Miles, Chinn, & Taggart, 1989; Steeves, 1983).   However, this is not always the case. Children with dyslexia can have strengths and weaknesses in almost any area of arithmetic. For example, Macaruso & Sokol (1998) studied 20 adolescents with both dyslexia and arithmetical difficulties, and found that they had a very heterogenous range of difficulties, which could include factual, procedural or conceptual difficulties or any combination of these, arithmetical difficulties were very heterogeneous, and that factual, procedural and conceptual difficulties were all represented. De Smedt & Boets (2010) found some association between dyslexia and procedural, as well as factual, difficulties in arithmetic. Thus, any assumption that comorbidity between dyslexia and arithmetical difficulties are due *only* to an association between phonological difficulties and weaknesses in factual memory is too simplistic.

Arithmetic and developmental language disorder

Developmental language disorder, formerly called specific language impairment, involves delays and/or deficits in producing and/or understanding spoken language (Bishop, 2017). There is significant comorbidity between developmental language disorder and dyslexia, but they are not just different aspects of the same disorder, and each often occurs on its own. Several studies, to be discussed below, indicate that developmental language disorder is often associated with low attainment in mathematics.

Most studies suggest that phonological awareness, and often other aspects of phonological processing such as phonological memory. are impaired in children with developmental language disorder, to a similar extent as is found in dyslexia (Claessen, Leitao, Kane & Williams, 2013; Spanoudis, Papadopoulos & Spyrou, 2019; Wong, Ho, Au et al, 2015), though McArthur & Castles (2013) did not find any phonological deficits in children with language disorders without reading disability. Kleemans, Segers & Verhoeven (2012) found that phonological awareness, naming speed and all aspects of working memory were worse in children with language disorders than typically developing children. Phonological awareness and working memory predicted arithmetical calculation in both groups, but naming speed did so only in the group with language disorders.

Developmental language disorder is more frequently associated with semantic language deficits than is dyslexia, and this may also contribute to associations with mathematical difficulties. Several studies indicate that in the general population semantic abilities are particularly associated with word problem solving (Bjork & Bower-Crane, 2013; Pimperton & Nation, 2010; Singer, Stasser & Cuadro, 2019)

Another deficit often found in developmental language disorder is in syntactic abilities . We may note that, Chow & Ekholm (2018) found arithmetic to be much more significantly associated with syntax than with vocabulary.

Early studies by Rourke and colleagues (Rourke, 1978, 1993; Rourke & Conway, 1997; Rourke & Finlayson, 1978) compared numerical performance of children with verbal learning disabilities and nonverbal learning disabilities. In the former, verbal IQ is lower than nonverbal IQ; reading and verbal memory are impaired; but visuospatial ability is preserved. In the latter, nonverbal IQ is lower than verbal IQ, and reading ability is preserved, but visuospatial skills and sometimes social skills are impaired. They found that children with verbal learning difficulties had problems predominantly with fact retrieval and with reading numbers, while those with nonverbal learning difficulties showed difficulties with the spatial representation of numerical information, and with the conceptual understanding of place value.

Most subsequent studies have not, however, shown this sort of dichotomy between children, whose mathematical difficulties are associated with a higher verbal or higher nonverbal IQ, or who have mathematical difficulties that are or are not associated with reading difficulties (Geary, Hoard & Hamson, 1999;

Hanich, Jordan, Kaplan & Dick, 2001; Shalev, Manor, Amir et al, 1997). Most of these studies, however, have started with groups of children already known to have mathematical difficulties, and so might yield different results from one which started with groups with verbal versus nonverbal learning difficulties and then investigated their mathematical characteristics. Another issue is, however, that both verbal and nonverbal learning difficulties are non-unitary and may take a variety of forms, which cannot validly be lumped together. For example, as stated above, both dyslexia and developmental language disorder are verbal learning disabilities but are separable disorders.

Most studies suggest that language impairments are associated with greater difficulties with some aspects of arithmetic than others. Donlan, Bishop & Hitch (1998) found that basic nonverbal magnitude comparison abilities did not seem to be impaired. Fazio (1994, 1996) found that children with language impairments were delayed in counting procedures but not counting principles. They also had difficulty in retrieving arithmetic facts (Fazio, 1996, 1999). Donlan & Gourlay (1999) found that many older primary school children with language impairments were able to compare the magnitudes of written 3-digit numbers successfully, sometimes without being able to read the numbers aloud.

Most studies of children with developmental language disorder have shown that such children tend to have particular difficulties with verbal counting (Arvedson, 2002; Fazio, 1994), fact retrieval (Fazio, 1999) and transcoding, while place value and symbolic magnitude comparison are often relatively well preserved (Cowan, Donlan, Newton & Lloyd, 2005;Donlan & Gourlay, 1999). Overall, it appears that, as with dyslexia, tasks requiring verbal working and long-term memory are affected by language impairments to a greater extent than those involving magnitude comprehension and numerical principles.

However, as with dyslexia, developmental language disorder is not invariably associated with any one specific profile of mathematical strengths and weaknesses. Koponen, Mononen, Rasanen & Ahonen (2006) found that such children in fact have very heterogeneous patterns of mathematical weaknesses, which can include nonverbal as well as verbal aspects of numeracy. In their study, 29 children with developmental language disorder were tested on various aspects of numeracy, and were also tested on the verbal skills vocabulary, sentence comprehension, digit span and rapid automatized naming and on nonverbal reasoning as measured by Raven's Matrices. In this group, rapid automatized naming was a significant predictor of arithmetical fact retrieval, but other verbal skills were not. Nonverbal numerical skills were not predicted by any of the verbal skills measured, or by nonverbal reasoning. It is possible that nonverbal working memory tasks and executive function abilities would have had more explanatory power.

Cowan, Donlan, Newton & Lloyd also (2007) found that a group of 7-to 9-year-old children with language impairments performed worse on a wide variety of number skills. They also performed worse on working memory tasks and had received lower levels of instruction. Nonverbal reasoning, working memory functioning, instruction, and especially language comprehension instruction all contributed to individual differences in number skills, but did not fully explain group differences.

Fyfe, Matz, Hunt & Alibali (2019) found that mathematical skills in children with developmental language disorder were predicted both by verbal working memory and by visual pattern extension. The importance of pattern recognition and extension to mathematical development is becoming increasingly recognized with regard to typically developing children,(e.g. Burgoyne, Witteveen, Tolan et al, 2017) and the study by Fyfe et al (2019) indicates that it may be one of the factors that explains individual differences in mathematics in children with language disorders. This may because nonverbal patterning ability is compensatory in those with language disorders; or it may be that a subgroup of children with developmental language disorder have difficulties with pattern that affect both language patterns and other patterns.

Arithmetic and autism

While there sometimes appears to be a stereotype that autistic individuals are likely to be savant calculators or even mathematicians, most do not have mathematical skills disproportionate to their overall IQ. Indeed, most studies suggest that the reverse is true overall, though it is true that a small minority are savant calculators (Heavey, 2003; Hermelin & O'Connor, 1991).

It is true that a few studies have even suggested that people with autism are better at some aspects of mathematics than typically developing individuals (Iuculano, Rosenberg-Lee, Supekar et al, 2014). However, this is not found in most studies, and, where it has been found, is limited to computational ability and does not extend to problem-solving.

Mathematical difficulties seem to be commoner in autistic than non-autistic individuals, though not nearly to the same extent as is the case for language disorders. Mayes & Calhoun (2006) found that 23% of autistic children had a mathematical learning disability, which is about four times the rate found in non-autistic children, but much lower than the 60% found for disorders of written expression. Chiang & Lin (2007) reviewed 18 studies of mathematical performance in 837 individuals between 3 and 51 years, diagnosed with high functioning autism or Asperger syndrome. The majority performed at an average level on standardized mathematics tests. Their scores on the Arithmetic subtest of the WISC were, in most studies, slightly but significantly lower than would be predicted from their full-scale IQ. However, a few did obtain extremely high scores on WISC Arithmetic and/or other standardized arithmetic tests, indicating that high-functioning autism is compatible with mathematical giftedness.

Indeed, it appears that autism can be associated with discrepancies in both directions between full-scale IQ and arithmetical performance. Jones, Happe, Golden et al (2009) found that a sample of autistic adolescents included a group with significantly higher performance in arithmetic than would be expected from their full-scale IQ, and another with significantly lower performance in arithmetic than would be expected from their full-scale IQ. There were similar groups for reading performance, but interestingly the groups with discrepantly high or low arithmetical performance were not the same as those with discrepantly high or low reading performance. Those with discrepantly high arithmetical performance tended also to do well in mathematical reasoning tasks, but not to the extent that would be predicted from their arithmetic scores.

There are somewhat conflicting findings regarding the existence of differences between autistic and non-autistic children with regard to basic, early-developing numerical abilities,

such as magnitude comparison and estimation, Titeca, Roeyers & Desoete (2018) compared 20 high-functioning four-and five-year-olds with autistic spectrum disorder and 20 age-matched typically developing controls on five early numerical-abilities: verbal subitizing, counting, magnitude comparison, estimation, and arithmetic operations. No significant group differences were found. This would suggest that any differences found in the mathematical performance of autistic and non-autistic children at an older age are unlikely to be due to differences in foundational numerical abilities. However, somewhat different results were obtained by Aagten-Murphy, Attucci, Daniel et al (2015). They investigated 8-to 13-year-old autistic children's performance on tasks involving nonsymbolic estimation (comparing sets of dots outside the subitizing range and presented too quickly for counting) and symbolic estimation (spatial representation of numerals on a 1 -1000 number line). Autistic individuals performed less well than typically developing individuals on both types of estimation, though they used similar strategies. In both the autistic group and the typically developing control group, symbolic estimation was correlated with mathematical performance, but nonsymbolic estimation was not.

While autism is a highly heterogeneous condition with regard to the impairment and preservation of specific cognitive abilities, it is often associated with relatively preserved spatial abilities. Some studies have suggested that autistic individuals often have exceptional strengths in spatial reasoning Baron-Cohen 2002; Shah & Frith, 1993); though Bullen, Swain-Lerra, Zajic et al (2020) found that, as a group, autistic children without intellectual impairment performed less well on the Block Design task than typically developing children.

Impairments in social cognition are of course among the defining features of the condition, but do not appear to affect mathematics directly, though they may affect it indirectly through problems in teacher-pupil communication. Mathematics is more likely to be directly affected by another common deficit in autism: difficulties with executive functions. Autism is particularly associated with difficulties in planning and lack of cognitive flexibility, which may lead to procedural and conceptual difficulties with arithmetic (Kim & Cameron, 2016; Whitby & Mancil, 2009). Inhibitory control tends to be relatively preserved, and Kim & Cameron (2016) suggest that this, in combination with preserved visual-spatial abilities, may explain why mathematical abilities often escape severe impairment in autism.

Among individuals with autism, verbal IQ and working memory appear to predict performance in mathematics (Assouline, Nicpon & Dockery, 2012; Chen, Abrams, Rosenberg-Lee et al, 2018). Although these are significant predictors in all groups, Bullen et al (2020) found them to be stronger predictors in children with autism than in typically developing children or those with ADHD. This may be because they tend to vary more in children with autism than in typically developing children, or because autistic individuals tend to use different strategies from typically developing children.

If there are indeed such strategy differences, it is still unclear what form they may take, and much more research needs to be carried out in this area. However, there is some evidence that individuals with autism may obtain similar scores on numerical tasks to typically developing individuals, while using different strategies. Gagnon, Mottron, Bherer & Joanette (2004) compared fourteen adolescents with high functioning autism with controls matched for age, gender and full-scale IQ on a task involving rapid quantification of sets of 2 to 9 squares arranged in random configurations. There were no group differences in accuracy, but strategy analysis suggested that the autistic participants may have been more likely than the controls to use rapid counting strategies, and the controls more likely to use subitizing. However, before assuming that there must be a basic difference in strategy use by people with and without autism, it is important to consider the possibility of differences in their interpretations of instructions.

Arithmetic and ADHD

Most studies indicate a significant relationship between attention deficit hyperactivity disorder and mathematical difficulties (e.g. Capano, Minden, Chen et al, 2008). Children with mathematical disabilities are more likely than those without mathematical disabilities to have attentional problems, and children with ADHD are more likely than those without ADHD to have difficulties in arithmetic.

Some studies suggest that it is specifically the attentional component of ADHD, rather than hyperactivity or impulsivity, that contributes to reduced performance in arithmetic . Even in children without an ADHD diagnosis, teacher ratings of attentional problems appear to predict low performance in arithmetic, whereas teacher ratings of hyperactivity and impulsivity do not (Oner, Vanaritran and Kardadniz, 2019; Salla, Michel, Pingault et al, 2016; Tymms & Merrell, 2011).

It appears that some components of arithmetic are more affected than others by ADHD. In particular, those aspects of arithmetic that rely on working memory appear to be the most affected. Ganor-Stern & Steinhorn (2018) looked at exact calculation and estimation of multiplication problems in adults with and without ADHD. Those with ADHD were slower (though not less accurate) on exact calculation tasks and on estimation tasks for which they used approximate calculation strategies, but not on estimation tasks for which they used strategies involving sense of magnitude. This is likely to be because both exact and approximate calculation strategies involve working memory, whereas sense of magnitude does not.

Friedman, Rapport, Orban et al (2018) found that 8-to-12-year-olds with ADHD performed less well on applied arithmetic problems than those without ADHD and that, even after controlling for IQ, both central executive abilities and mathematical calculation skills predicted performance on such problems. Central executive abilities fully mediated the group differences. Phonological and visual-spatial short-term memory did not have independent effects on children’s performance on these problems.

It is also possible that some of the factors that link ADHD to mathematical difficulties are related to emotional rather than cognitive issues. Canu, Elizondo & Broman-Fulks (2017) found that college students with ADHD showed higher specific mathematics anxiety than those without ADHD, even after controlling for general anxiety. Burr & LeFevre (2020) gave 425 undergraduates three measures of mathematical performance (arithmetic, computational skills, and word problem solving) and self-report measures of ADHD symptoms, state anxiety, and confidence about mathematics and literacy. ADHD symptoms were related to low confidence in both mathematics and literacy. Links between ADHD symptoms and mathematical performance were mediated through confidence in mathematics. There were no specific links between attentional symptoms and mathematical performance. It should be noted that the participants were not clinically diagnosed with ADHD, and that it is possible that students with lower academic self-confidence were more likely also to lack confidence in their attentional and executive abilities: thus, the higher self-reported ADHD symptoms might be one aspect rather than a cause, of lower academic self-confidence. However, it is also possible that ADHD symptoms do contribute significantly to academic anxiety, including mathematics anxiety, either by enhancing the impact that anxiety has on working memory and its use in academic activities, and thus creating a vicious circle, or by increasing the likelihood of school experiences of criticism and failure, which contribute to the establishment of mathematics anxiety well before pupils reach university age.

Arithmetic and Williams syndrome

Most studies of individual differences in mathematical ability show a significant relationship between spatial and mathematical abilities (Casey, Pezaris & Nuttall, 1995; Cipora, Hohol, Nuerk et al, 2016; Hermelin & O'Connor, 1986; Sella, Sader, Lolliot & Cohen Kadosh, 2016; Van Garderen, 2016), though not all such studies differentiate clearly between arithmetic and other aspects of mathematics. There have been rather fewer studies of the effects of specific spatial difficulties on mathematics. The early studies by Rourke and colleagues proposing broad differences between verbal and nonverbal learning difficulties and their associated mathematical deficits have already been discussed above in the section on 'Developmental language disorder'. There have also been numerous studies of specific genetic disorders, which are associated with both spatial and mathematical difficulties, such as Turner syndrome (Mazzocco, 2001; Molko, Cachia, Riviere et al, 2004; Murphy & Mazzocco, 2010), the 22q11.2 deletion syndrome (De Smedt, Swillen, Verschaffel & Ghesquere, 2009; Moss, Batshaw, Sotot et al, 1999) and Williams syndrome. As the largest number of studies in the area concern Williams syndrome, this review will focus on that condition.

This disorder is associated with general learning difficulties, with particular deficits in spatial abilities and relative strengths in verbal abilities. Mathematics usually appears to be severely impaired. However, studies indicate that there are significant discrepancies between different mathematical abilities, with some being much more markedly impaired than others. In particular, individuals with Williams syndrome show severe impairments in approximate numerical magnitude recognition and comparison (Ansari, Donlan, Thomas et al, 2003; Kim & Cameron, 2016; O'Hearn & Landau, 2016 while showing relatively preserved abilities in number familiarity (Simms, Karmiloff-Smith, Ranzato & Van Herwegen, 2020), small exact number recognition (Ansari et al, 2003; O'Hearn & Landau 2016) and factual knowledge relating to addition and multiplication (Kim & Cameron, 2016). Thus, Williams syndrome seems to be associated with particular difficulties in those aspects of numerical ability which have been proposed to relate to a spatially-represented 'mental number line' (Dehaene, 1997) while sparing subitizing of small numbers, and those aspects of mathematics that might be more dependent on verbal recall, such as the retrieval of arithmetical facts (Kim & Cameron, 2016).

It should be noted that Williams syndrome is associated not only with spatial difficulties but with deficits in executive function, and it has been suggested that this too may contribute to their mathematical difficulties (Kim & Cameron, 2016). Also, it is difficult, in a condition which involves both mathematical and spatial difficulties, to come to a firm conclusion as to which one causes the other, or whether both are caused independently by other effects of the genetic condition, or to involvement of adjacent or overlapping areas of the brain: e.g. in the parietal lobes. Very much the same issues apply to the other genetic conditions that affect both spatial and mathematical abilities (e.g. De Smedt et al, 2009; Mazzocco & Murphy, 2010). Nevertheless, the fact that spatial and mathematical abilities are both correlated in the general population, and impaired together in several genetic disorders, gives some support to the view that spatial abilities are important to mathematics.

Implications:

The studies of mathematical skills of children with the developmental disorders reviewed here are consistent with Pennington's (2006; McGrath, Peterson & Pennington, 2020)) comorbidity model, and in particular with his emphasis on the involvement of multiple factors in disorders; on few such factors being necessary or sufficient; and on some factors contributing independently to specific disorders, while some are common factors in several disorders. . Mathematical difficulties are commoner in all the disorders reviewed here than in the general population. However, they are not universal in any of these disorders, with the possible exception of Williams syndrome, which is associated with generally reduced IQ.

These findings with regard to disorders and comorbidity are consistent with earlier findings that arithmetical ability is not unitary in typically developing children and adults (Dowker, 2008, 2015, 2019), but is made up of many different components: e.g. counting procedures; counting principles; calculation; memory for arithmetical facts; word problem solving; There can be strong discrepancies, in either direction, between almost any two subcomponents. Other cognitive and academic abilities also seem to be divisible into different components. For example, reading may be broadly divisible into decoding (in turn dependent on phonological abilities) and comprehension. Working memory also has several different components; as does executive function (Best, Miller, Jones et al, 2009; Miyake, Friedman, Emerson et al, 2000), though some studies suggest that executive function may be more unitary in early childhood than later on (Wiebe, Sheffield, Nelson et al, 2011).

Thus, different aspects of arithmetic are likely to be developmentally related to different aspects of other abilities. More research needs to be done on exactly how the different components of other abilities relate to different components of arithmetic, but it has indeed been found, as described above, that phonological abilities are more related to number fact knowledge and semantic language abilities to word problem solving. .Also different aspects of working memory appear to be related to different aspects of arithmetic (Simmons, Willis & Adams, 2012).

Also, some mathematical characteristics seem to be differentially associated with different types of disorder. On the whole, individuals with predominantly verbal disorders, such as developmental dyslexia and specific language impairment tend to have difficulties in factual and sometimes procedural knowledge in mathematics, while having preserved abilities in magnitude estimation and comparison. Those with disorders such as Williams syndrome, which are associated with impairments in spatial ability, tend to show the reverse pattern. Thus far, the findings seem consistent with the distinction between the effects on mathematics of verbal and nonverbal learning difficulties, put forward by Rourke (1978, 1993) and colleagues. However, most studies show that there is no sharp or universal distinction between the mathematical profiles associated with different disorders. Mathematical strengths and difficulties may be very heterogeneous in any developmental disorder. In particular, both dyslexia and developmental language disorder can be associated with a wide variety of mathematical difficulties, not just those involving memory for facts or procedures.

It is plausible that there are some common genetic influences on mathematics and other cognitive abilities (Salla et al, 2016; Willcutt, Pennington, Duncan et al, 2010) and also that unusual neurodevelopmental patterns may form a common pathway to several different disorders. However, most disorders can occur without mathematical difficulties, and many children with dyscalculia have no other learning difficulties. Once again, findings appear much more consistent with Pennington's (2006) multiple deficits model than with single deficit models.

Executive function deficits are a recurring theme in comorbidity, appearing to be involved in at least some of the associations between autism and ADHD and mathematical difficulties. Although studies of Williams syndrome and other genetic disorders affecting mathematics tend to focus on the co-occurrence of mathematical and spatial difficulties, such disorders also frequently involve deficits in executive function. There are a large number of studies that indicate that executive functions are significant predictors of arithmetical performance in typically developing children (e.g. Blair & Razza, 2007;Bull & Scerif, 2001; Clark et al., 2013; Cragg & Gilmore, 2014; Cragg, Keeble, Richardson et al, 2017; Ellefson, Zachariou, Ng et al, 2020; Fuhs, Nesbitt, Farran & Dong, 2014; Welsh, Nix, Blair et al, 2010).

There is even evidence that seemingly domain-specific numerical tasks involving both symbolic and nonsymbolic magnitude comparison are in fact strongly influenced by executive functions, especially inhibition (Clayton & Gilmore, 2015; Merkley, Thompson & Scerif, 2015).

It may be that even trying to make a sharp distinction between domain-specific and domain-general abilities is oversimplified. Wilkey, Pollack & Price (2020) obtained results suggesting that that executive function in a numerical context, is more strongly related to individual differences in typical arithmetical development and to mathematical disabilities than either magnitude perception alone or executive function in a non-numerical context. Perhaps certain early numerical abilities should be seen not just as dependent on executive functions, but as a particular type of executive function.

Obviously, considerably more research needs to be carried out on this subject before firm conclusions can be drawn. In particular, only some disorders seem to be associated with difficulties in magnitude estimation and comparison: notably developmental dyscalculia as such, and genetic disorders associated with spatial difficulties, such as Williams syndrome. ADHD, autism, dyslexia and developmental language disorder seem to be far less clearly associated with magnitude comparison difficulties, though Aagten-Murphy et al (2015) did find weaknesses in magnitude comparison in an autistic group.. However, since most of these disorders are not yet diagnosed in infancy, and sometimes not until school age, we do not know whether they might be associated with very early difficulties with magnitude that may later resolve, but still contribute to later mathematical difficulties.

It is crucial to carry out more longitudinal studies and, if possible intervention studies of mathematics in developmental disorders, in order to gain a greater understanding of the directions of prediction and causation between mathematical difficulties and other cognitive difficulties. It is also important to bear in mind that, although arithmetical difficulties are commoner in children with than without other specific cognitive or learning difficulties, many children with most of the disorders described here do *not* have problems with arithmetic. If we are to understand arithmetical difficulties, and their associations with other cognitive abilities and disabilities, it is important to gain a greater understanding of why some children with specific cognitive or learning difficulties also have difficulties with arithmetic, while others, with apparently similar difficulties do not. As McGrath, Peterson & Pennington (2020) point out, it is important for models of comorbidity to take into account protective and promotive factors., as well as risk factors. They indeed propose (p. 10) that the 'Multiple Deficit Model' be 'renamed to the "Multiple Factors Model" to encourage research with a specific focus on resilience mechanisms'. More integration between studies of mathematics in different disorders, especially longitudinal studies, may help in achieving this aim.

References:

Aagten-Murphy, D., Attucci, C., Daniel, N., Klaric, E., Burr, D. & Pellicano, e. (2015). Numerical estimation in children with autism. *Autism Research, 8*, 668-651. doi.10.1002/aur.1482.

Ansari, D., Donlan, C., Thomas, M. S., Ewing, S. A., Peen, T., & Karmiloff-Smith, A. (2003). What makes counting count? Verbal and visuo-spatial contributions to typical and atypical number development. *Journal of Experimental Child Psychology, 85(1)*, 50–62. doi:10.1016/S0022-0965(03)00026-2

Arvedson, P. (2002). • Young children with specific language impairment and their numerical cognition. *Journal of Speech, Language, and Hearing Research , 45*, 970–982. doi.10.1092-4388/02/4505-0970.

Assouline, S. G., Nicpon, M. F., & Dockery, L. (2012). Predicting the academic achievement of gifted students with autism spectrum disorder. Journal of Autism and Developmental Disorders,42(9), 1781–1789. doi/.10.1007/s10803-011-1403-x.

Best J.R, Miller P.H. & Jones. L.L.(2009). Executive functions after age 5: Changes and correlates. *Developmental Review, 29*, 180–200.

Bishop, DVM (2017) Why is it so hard to reach agreement on terminology? The case of developmental language disorder (DLD). *International Journal of Language and Communication Disorders, 52*, 671-682

Bjork, I.M. & Bowyer-Crane, C. (2013). Cognitive skills used to solve mathematical word problems and numerical operations: a study of 6-to 7-year-old children. *Europaean Journal of Psychology of Education*, *28*, 1345-1360.

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78(2)*, 647–663. https://doi.org/10.1111/j.1467-8624.2007.01019.x

Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: inhibition, switching, and working memory. *Developmental Neuropsychology, 19(3)*, 273–293. https://doi.org/10.1207/S15326942DN1903

Bullen, J.C., Swain Lerro, L., Zajic, M., McIntyre, N. & Mundy, P. (2020). A developmental study of mathematics in children with autism spectrum disorder, symptoms of attention deficit hyperactivity disorder, or typical development. *Journal of Autism and Developmental Disorders.* doi.10.1007/s10803-020-04500-9

Burgoyne, K., Witteveen, K., Tolan, A., Malone, S. & Hulme, C. (2017). Pattern understanding: Relationships with arithmetic and reading development. *Child Development Perspectives. 11*, 239-244

Burr, S.M.D. & LeFevre, J.A. (2020). Confidence is key: Unlocking the relations between ADHD symptoms and math performance. *Learning and Individual Differences, 77*: 101808.

DOI**:** 10.1016/j.lindif.2019.101808

Canu, W.H., Elizondo, M. & Broman-Fulks, J. (2017). History of ADHD traits related to general test and specific math anxiety in college students. *Learning and Individual Differences, 58*, 56-63.

Capano, L., Minden, D., Chen, S.X., Schachar, R.J., & Ickowicz, A. (2008). Mathematical learning disorder in school-age children with attention-deficit hyperactivity disorder**.** *Canadian Journal of Psychiatry/ Revue Canadienne de Psychiatrie, 53***,** 392-399**.**

Casey, B.M., Pezaris, E. & Nuttall, R. L. (1992). Spatial ability as a predictor of mathematical achievement: the importance of sex and handedness patterns. *Neuropsychologia, 30*, 35-45.

Chiang, H.M. & Lin, Y.H. (2007). Mathematical ability of students with Asperger syndrome/ high-functioning autism: A review of literature. *Autism*, *11*, 547-556. doi: 083259 1362-3613(200711)11.6

Chow, J.C. & Ekholm. E. (2018). Language domains differentially predict mathematics performance in young children. *Early Childhood Research Quarterly, 46*, 179-186 doi.10.1016/j.ecresq.2018.02.011.

Cipora, K., Hohol, M., Nuerk, H.C., Willmes, K., Brozek, B., Kucharzyk, B. & Necka, E. (2016). Professional mathematicians differ from controls in their spatial-numerical associations. *Psychological Research*, 80, 710-726.

Claessen, M ., Leitao, S., Kane, R. & Williams, C. (2013). Phonological processing skills in specific language impairment. *International Journal of Speech-Language Pathology, 15*, 471-483. doi: 10.3109/17549507.2012.753110

Clark, C. A. C., Sheffield, T. D., Wiebe, S. A., & Espy, K. A. (2013). Longitudinal associations between executive control and developing mathematical competence in preschool boys and girls. *Child Development, 84(2*), 662–677. https://doi.org/10.1111/j.1467-8624.2012.01854.x

Clayton S., Gilmore C. (2015). Inhibition in dot comparison tasks. *ZDM, 47*, 759–770. doi.10.1007/s11858-014-0655-2

Cowan, R. Donlan, C., Newton, E.J. & Lloyd. B. (2005). Number skills and knowledge in children with specific language impairment. *Journal of Educational Psychology*, *97*, 732-744. doi.10.1037/0022-0663.97.4.732

Cragg, L. & Gilmore, C.(2014). Skills underlying mathematics: The role of executive function in the development of mathematics proficiency. *Trends in Neuroscience and Education, 3* (2014), pp. 63-68.

Cragg, L. Keeble, S., Richardson, S. Roome, H.E. & Gilmore, C. (2017). Direct and indirect influences of executive functions on mathematics achievement**.** *Cognition, 162*, 12-26.

Cueli, M., Areces, D., Garcia, T., Alves. R.A. & Gonzalez-Castro, P. (2020), Attention, inhibitory control and early mathematical skills in preschool students. *Psicothema, 32*, 237-244. DOI: 10.7334/psicothema2019.225

De Smedt, B. & Boets, B. (2010). Phonological processing and arithmetic fact retrieval: Evidence from developmental dyslexia. *Neuropsychologia, 48*, 3973-3981 doi.10.1016/j.neuropsychologia.2010.10.018

De Smedt, B., Swillen, A., Verschaffel, L. & Ghesquere, P. (2009). Mathematical learning disabilities in children with 22Q11.2 deletion syndrome: a review. *Developmental Disabilities Research Reviews, 15*, 4-10. doi.10.1002/ddrr.44

De Smedt, B., Taylor, J., Archibald, L. & Ansari, D. (2010). How is phonological processing related to individual differences in children's arithmetic skills? *Developmental Science, 13*, 508-520. doi.10.1111/j.1467-7687.2009.00897.x

Donlan, C., Cowan, R., Newton E.J. & Lloyd, D. (2007). The role of language in mathematical development: evidence from children with specific language impairments.
Cognition, *103*, 23-33

Donlan, C., & Gourlay, S. (1999). The importance of non-verbal skills in the acquisition of place-value knowledge: Evidence from normally-developing and language-impaired children. *British Journal of Developmental Psychology, 17*, 1-19.

Donlan, C., Bishop, D. V. M., & Hitch, G. J. (1998). Magnitude comparisons by children with specific language impairments: evidence of unimpaired symbolic processing. *International Journal of Language and Communication Disorders, 33*, 149-160.

Dowker, A.D. (2008). Individual differences in numerical abilities in preschoolers. *Developmental Science*, *11*, 650-654.

Dowker, A. (2015). Individual differences in arithmetical abilities: the componential nature of arithmetic. In R. Cohen Kadosh. & A. Dowker. (2015, eds.). *Oxford Handbook of Mathematical Cognition*. Oxford: Oxford University Press (pp. 878-894).

Dowker, A. (2019). *Individual Differences in Arithmetic: Implications for Psychology, Neuroscience and Education, 2nd edition.* Hove: Psychology Press.

Ellefson, M., Zachariou, A., Ng, F.F.Y., Wang, Q. & Hughes, C, (2020, in press). Do executive functions mediate the link between socioeconomic status and numeracy skills? A cross-site comparison of Hong Kong and the United Kingdom. *Journal of Experimental Child Psychology, 194*. doi.org/10.1016/j.jecp.2019.104734 .

Fazio, B. B. (1994). The counting abilities of children with specific language impairment: A comparison of oral and gestural tasks. *Journal of Speech and Hearing Research, 37,* 358368.

Fazio, B. B. (1996). Mathematical abilities of children with specific language impairment: A two-year follow-up. *Journal of Speech and Hearing Research, 39*, 839-849.

Fazio, B. B. (1999). Arithmetic calculation, short-term memory, and language performance in children with specific language impairment: A 5-year follow-up. *Journal of Speech, Language, and Hearing Research, 42*, 420-431.

Friedman, L.M., (Rapport, M.D., Orban, S.A., Eckrich, S.J. & Calub, C.A. (2018). Applied problem solving in children with ADHD: The mediating roles of working memory and mathematical calculation *Journal of Abnormal Child Psychology, 46*, 491-504. doi. 10.1007/s10802-017-0312- .

Fyfe, E. R., Matz, L. E., Hunt, K. M., & Alibali, M. W. (2019). Mathematical thinking in children with developmental language disorder: The roles of pattern skills and verbal working memory. *Journal of Communication Disorders, 77*, 17–30. doi.10.1016/j.jcomdis.2018.11.001.

Gagnon, L., Mottron, L., Bherer, L. & Joanette, Y. (2004). Quantification judgement in high functioning autism: Superior or different? *Journal of Autism and Developmental Disorders*, *34*, 679-689.

Ganor-Stern, D. & Steinhorn, O. (2018). ADHD and math - The differential effect on calculation and estimation. *Acta Psychologica, 188*, 55-64. DOI: 10.1016/j.actpsy.2018.05.013

Gross-Tsur, V., Manor, O. & Shalev, R.S. (1996). Developmental dyscalculia: Prevalence and demographic features. *Developmental Medicine and Child Neurology, 38*, 25–33.

Hart, S.A., Petrill, S.A. Willcutt, E., Thompson, L.A., Schatschneider, C., Deater-Deckard, K. & Cutting, L.E. (2010). Exploring how symptoms of attention-deficit/hyperactivity disorder are related to reading and mathematics performance: General genes, general environments. *Psychological Science, 21*, 1708-1715.

Heavey, L. (2003). Arithmetical savants. In A.J. Baroody & A. Dowker (eds). *The Development of Arithmetic Concepts and Skills: Constructing Adaptive Expertise* (pp. 409– 33). Mahwah, NJ: Erlbaum.

Hermelin, B. & O'Connor, N. (1986). Spatial representations in mathematically and in artistically gifted children. *British Journal of Educational Psychology*. *56*, 150-157.

Hermelin, B. & O'Connor, N. (1991). Factors and primes: a specific numerical ability. *Psychological Medicine, 20*, 163-169.

Jones, C.R., Happé, F., Golden, H., Marsden, A.J., Tregay, J., Simonoff, E., Pickles, A., Baird, G. & Charman,T. (2009). Reading and arithmetic in adolescents with autism spectrum disorders: peaks and dips in attainment. *Neuropsychology, 23*, 718-728. doi. 10.1037/a0016360.

Jordan, J.A., Wylie, J. & Mulhern, G. (2010). Phonological awareness and mathematical difficulty: A longitudinal perspective. *British Journal of Developmental Psychology, 28*, 89– 107.

Kim, H. & Cameron, C.E. (2016). Implications of visuospatial skills and executive functions for learning mathematics: Evidence from children with autism and Williams syndrome. *AERA Open, 2*, 1-16. doi: 10.1177/2332858416675124

Kleemans, T., Segers, E. & Verhoeven, L. (2012). Naming speed as a clinical marker in predicting basic calculation skills in children with specific language impairment. *Research in Developmental Disabilities, 33*, 882-889. doi: 10.1016/j.ridd.2011.12.007

Koponen,, T.; Eklund,, K. & Salmi,, P. (2018). Cognitive predictors of counting skill. *Journal of Numerical Cognition, 4,* 410-428. doi.10.5964/jnc.v4i2.116

Koponen, T., Eklund, K., Heikkila, R., Salminen, J., Fuchs, L., Fuchs, D. & Aro, M, (2020), Cognitive correlates of the covariance in reading and arithmetic fluency: Importance of serial retrieval fluency. *Child Development, 91*, 1063-1080. doi 10.1111/cdev.13287

Koponen, T., Mononen, R,, Rasanen, P.. & Ahonen, T. (2006). Basic numeracy in children with specific language impairment: heterogeneity and connections to language. J*ournal of Speech, Language and Hearing Research 49*, 58-73.

Koponen, T., Salmi, P. Eklund, K. & Aro, T. (2013). Counting and RAN: Predictors of arithmetic calculation and reading fluency. *Journal of Educational Psychology, 105*, 162-175. doi.10.1037/a0029285

Landerl, K. & Moll, K. (2010). Comorbidity of learning disorders: prevalence and familial transmission. *Journal of Child Psychology and Psychiatry, 51*, 287-294. doi.10:1111/j.1469-7610.2009.02164.x

Mayes, S.D. & Calhoun, S.L. (2006). Frequency of reading, math, and writing disabilities in children with clinical disorders. *Learning and Individual Differences*, *16*, 145–157.

Mazzocco, M.M.M. (2001). Math learning disability and math LD subtypes: Evidence from studies of Turner syndrome, fragile X syndrome, and neurofibromatosis Type 1. *Journal of Learning Disabilities, 34,* 520-533.

McArthur, G. & Castles, A. (2013). Phonological processing deficits in specific reading disability and specific language impairment: same or different? *Journal of Research in Reading, 36*, 280-302. doi: 10.1111/j.1467-9817.2011.01503.x

McGrath, L.M., Peterson, R.L & Pennington, B.F. (2020). The multiple deficit model: progress, problems, and prospects. *Scientific Studies of Reading, 24*, 7-13.

doi**.** 10.1016/B978-0-12-811529-9.00006-6

Merkley, R., Thompson, J. & Scerif, G. (2015). Of huge mice and tiny elephants: Exploring the relationship between inhibitory processes and preschool math skills. *Frontiers in Psychology, 6*:685. DOI: 10.3389/fpsyg.2015.01903

Miles, T.R. (1993). *Dyslexia: The Pattern of Difficulties, 2nd edition*. London: Whurr.

Molko, N., Cachia, A., Riviere, D., Mangin, J., Bruandet, M., LeBihan, D,, Cohen, L. & Dehaene, S. (2004). Brain anatomy in Turner syndrome: Evidence for impaired social and spatial-numerical networks. *Cerebral Cortex, 14*, 840-850. doi.10.1093/cercor/bhh042

Moll, K., Landerl, K., Snowling, M.J. & Schulte-Korner, G. (2019). Understanding comorbidity of learning disorders: task-dependent estimates of prevalence. *Journal of Child Psychology and Psychiatry, 60,* 286–294 doi:10.1111/jcpp.12965

Moll. K., Snowling, M.J., Gobel, S.M. & Hulme, C. (2015). Early language and executive skills predict variations in number and arithmetic skills in children at family-risk of dyslexia and typically developing controls. *Learning and Instruction, 38,* 53-62. doi.10.1016/j.learninstruc.2015.03.004

Moss, E., Batshaw, N., Solot, C., Gerdes, M., McDonald-McGinn, D., Driscoll, D., Emanuel, B., Zackai, E. & Wang, P.P. (1999). Psychoeducational profile of the 22q11.2 microdeletion: A complex pattern. *Journal of Pediatrics, 134*, 193-198. doi. 10.1016/S0022-3476(99)70415-4

Murphy, M.M. & Mazzocco, M.M.M. (2010). Mathematics learning disabilities in girls with fragile X or Turner syndrome during late elementary school. *Journal of Learning Disabilities, 41*, 29-46.

Oner, O., Vatanartiran, S. & Karadeniz, S. (2019). Relationships between teacher-reported ADHD symptom profiles and academic achievement domains in a nonreferred convenience sample of first- to fourth-grade students. *Psychiatry and Clinical Psychopharmacology, 29,* 502-508. doi.10.1080/24750573.2018.1457488.

Pimperton, H. & Nation, K. (2010). Understanding words, understanding numbers: An exploration of the mathematical profiles of poor comprehenders. *British Journal of Educational Psychology, 80,* 255-268.

Pritchard, R.A., Miles, T.R., Chinn, S.J. & Taggart, A.T. (1989). Dyslexia and knowledge of number facts. *Links, 14*, 17–20.

Salla, J., Michel, G., Pingault, J.B., Lacourse, E., Paquin, S., Galera, C., Falissard, B., Boivin, M., Tremblay, R.E. & Cote, S.M. (2016). Childhood trajectories of inattention hyperactivity and academic achievement at 12 years. *European Child and Adolescent Psychiatry, 25*, 1195-1206.DOI: 10.1007/s00787-016-0843-4

Sella, F., Sader E., Lolliot S., & Cohen Kadosh R. (2016).Basic and advanced numerical performances relate to mathematical expertise but are fully mediated by visuospatial skills. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 42*, 1458-1472.

Shalev, R.S., Weirtman, R. & Amir, N. (1988). Developmental dyscalculia. *Cortex, 24*, 555-561.

Simmons, F., Willis, C, & Adams, A.M. (2012). Different components of working memory have different relationships with different mathematical skills. *Journal of Experimental Child Psychology, 111*, 139-155.

Simms, V., Gilmore, C., Cragg, L., Clayton, S., Marlow, N., & Johnson, S. (2015). The nature and origins of mathematics difficulties in very preterm children: A different aetiol*ogy* than Developmental Dyscalculia. *Pediatric Research*, *77*, 389-395.

Simms, V., Karmiloff-Smith, A., Ranzato, E. & Van Herwegen, J. (2020). Understanding number line estimation in Williams syndrome and Down syndrome. *Journal of Autism and Developmental Disorders, 50,* 583-591. dOI: 10.1007/s10803-019-04268-7

Singer, V., Strasser, K. & Cuadro, A. (2019). Direct and indirect paths from linguistic skills to arithmetic school performance. *Journal of Educational Psychology, 111*, 434-445. doi. 10.1037/edu0000290

Spanoudis, G., Papadopoulos, T. & Spyrou, S. (2019). Specific language impairment and reading disability: Categorical distinction or continuum? *Journal of Learning Disabilities, 52*, 3-14. doi:10.1177/0022219418775111

Steeves, K. (1983). Memory as a factor in computational efficiency of children with dyslexic children with high reasoning ability. *Annals of Dyslexia, 33*, 141–151

Titeca, D, Roeyers, H. & Desoete, A. (2017). Early numerical competencies in 4- and 5year-old children with autism spectrum disorder. *Focus on Autism and Other Developmental Disabilities, 32*, 279-292.

Traff, U., Olsson, L., Skagerlund, K. & Ostergren, R. (2020). Kindergarten domain-specific and domain-general cognitive precursors of hierarchical mathematical development: a longitudinal study. *Journal of Educational Psychology, 112,* 93-109. doi.10..1037/edu0000369

Tymms, P. & Merrell, C. (2011). ADHD and academic attainment: Is there an advantage in impulsivity? *Learning and Individual Differences, 21,* 753-758. DOI:10.1016/j.lindif.2011.07.014.

Van Garderen, D. (2016). Spatial visualization, visual imagery and mathematical problem solving of students with varying abilities. *Journal of Learning Disabilities, 39*, 496-506.

Wiebe, S. A., Sheffield, T., Nelson, J. M., Clark, C. A. C., Chevalier, N., & Espy, K. A. (2011). The structure of executive function in 3-year-olds. *Journal of Experimental Child Psychology, 108*, 436-452.

Wilkey, E.D., Pollack, C. & Price, G.R. (2020). Dyscalculia and typical math achievement are associated with individual differences in number-specific executive. *Child Development, 91*, 596-619.

Willcutt, E., Pennington, B.F, Duncan, L, Smith, S.D. Keenan, J.M, Wadsworth, S., DeFries, J.C., & Olson. R.K. (2010). Understanding the complex etiologies of developmental disorders: Behavioral and molecular genetic approaches. *Journal of Developmental and Behavioral Pediatrics, 31*, 533-544. doi.10.1097/DBP.0b013e3181ef42a1

Wong, A., Ho. C., Au, T.K.F, Kidd, J. Ng, A.K.H., Yip, L.P.W &(; Lam, C. (20 _ (Dis)connections between specific language impairment and dyslexia in Chinese. *Reading and Writing, 28*, 699-719. doi:10.1007/s11145-015-9546-3