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Issues Related to the Diagnosis of Developmental Dyscalculia

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ABSTRACT *With the increase in the growing number of children diagnosed with developmental dyscalculia (DD), its understanding is essential for pedagogues to ascertain workable instructional strategies. One of the most promising ways to ensure the well- being of DD individuals is to document relatively reliable identification of such cases so that well timed remediation can be provided. This paper underlines the issues for diagnosis of DD in context of the psychometric properties (reliability and validity) of the tools, appropriateness of using standardized tests, necessity of item-timed tests, dependability on single measure, adopting dissimilar parameters in different tools, cost and technology, level of education and need of longitudinal studies. Suitability of using response to intervention for the identification of DD students is also discussed. We conclude by recommending for further research to document relatively reliable investigation of DD.*

Developmental Dyscalculia (DD) is a specific learning disability (SLD) in mathematics. Sharma (2013) is of the opinion that "DD is manifested as poor number concept, difficulty in estimating the size and magnitude of numbers, lack of understanding and fluency in number relationships, and inefficiency of numerical operations". A number of nebulous terminologies are associated with DD namely 'Mathematics Disorder' - Diagnostic and Statistical Manual of Mental Disorders [DSM-IV](American Psychiatric Association, 1994), 'Specific Learning Disabilities' (McLean & Hitch, 1999), 'Mathematics Learning Disabilities' (Geary, 2004), 'Developmental Dyscalculia' (Price, 2008; Szucs et al., 2013) and 'Dyscalculia' (Gilga & Gilga, 2011; Wang, Tasi & Yang, 2012). Butterworth, Varma and Laurillard (2011) proffered that all of the above refer to a severe difficulty in arithmetic. For this paper, the term Developmental Dyscalculia (DD) will be used. Moreover, there is no consensus on the working definition of DD (Szucs & Goswami, 2013); the one given by Department of Education and Skills (DfES) befits the purpose of the present review.

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, p. 2).

Thus, DD is not concerned with impairment in any other subject than mathematics. It is a domain specific disorder (Askenazi & Henik, 2010) and manifests itself in an impaired processing of numbers and arithmetic (Moller, Fischer, Cress & Nurek, 2012). Furthermore, DD is sometimes considered synonymous with mathematical difficulties stemming from environmental factors such as lack of motivation, inappropriate teaching etc. However, children who exhibit the same difficulties as DD because of such factors are described to have acquired dyscalculia (Sharma, 2013).

The majority of research provides a modest evidence that the prevalence rate of DD lies approximately between 3% to 6 % (Shalev, 2004; Price, Holloway, Rasanen, Vesterinen, & Ansari, 2007; Reigosa-Crespo et al., 2012; Jovanvic, Jovanvic, Bankovic- Gajic, Nikolic, Svetozarevic, & Ignjatovic-Ristic, 2013). However, the most recent estimates place the occurrence of DD at 18.8% (Orraca- Castillo, Estevez-Perez, Reigosa-Crespo, 2014). Although DD has same prevalence as its counterpart dyslexia (Sharma, 2013), still more research on DD is required. When a PubMed search for refereed articles with keywords developmental dyscalculia and dyslexia was conducted for the year 2010-2014, it unveiled 1460 hits for dyslexia and only 153 hits for DD. This example clearly exhibits that knowledge about DD is much less established (Moller et al., 2012).

Mathematical impairments can cause a deleterious effect on many facets of life (Rubinsten & Tannock, 2010). The risks can be limited jobs, stigma and financial deception. Moreover, DD may lead to low self esteem and lack of confidence (Rubinsten & Tannock, 2010) and anxiety and depression can also set in (NCLD, 2006). Therefore, the problem of DD is acute and if not treated, it persists into adulthood (Kaufmann, Pixner & Goebel, 2011).

One major challenge is developing best strategies for identification, assessment and diagnosis, before interventions could be planned (Shattuck & Grosse, 2007). It is imperative for the practitioners to be conscious of the accurate diagnosing and identification of DD. But it is still a matter of controversy on how to obtain and validate the measures necessary to diagnose DD (Shalev, 2004). Hence, the issues related to the diagnosis of DD in context of the psychometric properties (reliability and validity) of the tools, appropriateness of using standardized tests, necessity of item-timed tests, dependability on single measure, adopting dissimilar parameters in different tools, cost and technology, level of education and need of longitudinal studies are discussed.

Diagnosis

Learners should be helped to attain a level of numeracy at which they can survive in the modern workplace (Butterworth et al., 2011). The consequences of low numeracy

Volume : 5 | Issue : 1 | Jan 2015 | ISSN - 2249-555X

(Butterworth et al., 2011) can be detrimental and hence the diagnosis of DD should be done with intense care. There is much focus in both the psychological and educational fields to ameliorate sound testing measures (Sparrow & Davis, 2000) so that they are relevant enough to sieve intended individuals. Each of the studies reported above focuses on the diverse ways of determining DD students. Thus, we begin by disclosing several issues that have been a stumbling block in the accurate and timely diagnosis of DD with probable suggestions.

PSYCHOMETRIC PROPERTIES (RELIABILITY AND VALIDITY)

Measures such as Dyscalculia Screener (Butterworth, 2003), DysCalculiUM (Beachman & Trott, 2006), Romanian screening instrument (Gilga & Gilga, 2011) and the on-line Dyscalculia Test (Dyscalculia Center, n.d) are seen as a resurgence of interest among the educationists to identify DD students. However, authors' raises concern about the psychometric properties of these tools. The efficacy of any assessment tool can be questioned if its reliability and validity has not been established (Hobden & LeRoy, 2008). For instance, a dyscalculic child will perform poorly in the dot enumeration and number comparison tests of the Dyscalculia Screener while a non-dyscalculic child will attain a high level on these tests (Michaelson, 2007). Moreover, in many ways this screener has adopted the procedures of standardization which is quite evident from its manual but there is a need to address its reliability and validity too, perhaps of all the tools constructed to diagnose DD. Moreover, if some standardized tools are used to identify DD students then also the complete details are missing. For example, Szucs et al. (2013) in their work used several standardized test namely Mathematics Assessment for Learning and Teaching Test, Hodder Group Reading Test II, levels 1 and levels 2, Numerical Operations subtests of Wechsler Individual Achievement Test (WIAT-II) to locate DD students. But only the reliability and validity of WIAT-II was accessible. Thus, it must be reiterated that investigators should seek psychometrically appropriate research instruments for the identification of DD students. It is also advised to provide open access to the manual of the tools including descriptions regarding the tool standardization, tasks included, scoring, ways of interpreting the scores and psychometric properties or to make it available at nominal price. This will further assist the researchers to compare the tools available.

STANDARDIZED TESTS

For the identification of DD students, investigators such as Kaufmann et al. (2009), Cappelletti and Price (2013), Price (2008), Reigosa-Crespo et al. (2012) and more used different standardized tests viz TEDI-MATH, Graded Difficulty Arithmetic Test, a mathematical achievement test and Basic Numerical Battery respectively. But these measures are not specifically designed for diagnosing DD. Learning difficulties can stem from a number of factors like improper teaching methods, lack of motivation or poor learning environment (Butterworth, 2003; Wilson, 2007). DD students will perform poorly on these standardized tests but other pupils will also demonstrate poor attainment (Butterworth, 2003) leading to non-discrimination of dyscalculics from their peers. Moreover, these standardized tests differ widely in content (Wilson, 2012), do not measure the same kind of mathematics (Szucs & Goswami, 2013) and include kinds of arithmetical problems taught and practiced in schools (Butterworth, 2003). Another crucial angle is that these tests do not differentiate children who solved the problem confidently in two seconds from those who took whole 45 seconds to solve it using age inappropriate strategies (Butterworth, 2003). Also, Peard (2010) from his findings concluded that more research is required to determine the occurrence of true dyscalculia. Hence, it can be concluded that explorers should primarily aim at employing tools that are specifically meant for identifying DD students.

ITEM TIMED TESTS

Another possible impediment to accurately diagnose DD is the lack of executing item-timed tests. According to Cappelletti and Price (2013), DD people often retain some residual abilities to perform numerical and quantity tasks which act as compensatory means for them in the absence of timed responses. Moreover, when there is no time limit, DD individuals use strategies which increase their accuracy of response (Montani, 2007). Furthermore, Reigosa-Crespo et al. (2012) argued that workability of arithmetic tests without time control may not be able to discriminate between children who process numerical information efficiently and those who take long time to process it. Thus in the light of these limitations, it is recommended to use item time bound tests.

DEPENDABILITY ON SINGLE MEASURE

A major hindrance to accurately diagnose DD is the use of single instrument as the sole determinant for ascertaining any child with a disability (IDEA, 2004). For instance, Peard (2010) in his work, besides structured clinical interview used no other measuring instrument to determine DD students. Likewise, Skagerlund and Traff (2014) merely used mathematics screening test battery to identify students with DD. But according to Cappelletti & Price (2013), DD students use developmentally immature and time-consuming problem solving strategies like verbal or finger counting which acts as compensatory mechanisms for them. This is a major drawback of these approaches as DD students may score well in these tests by using such strategies and are often left undiagnosed. Another limitation of using single measure approach is the risk of including students who are poor in mathematics because of exogenous factors like lack of motivation, improper teaching methods, non-conducive environment to learning, etc. Wilson (2012) is of the view that the diagnostic tests should not only identify difficulty in mathematics but also eliminate these factors. To address these shortcomings, it is proposed to use convergent measures for identifying DD students. This will avoid the risk of selecting those children who are weak in mathematics because of the other reasons than a genuine disability in mathematics. To some extent Szucs et al. (2013) and Regeso-Crespo et al. (2012) did imbed convergent measures to identify DD students but still do not seem to be promising. Szucs et al., (2013) did not consider item-timed test to identify DD children and Regeso-Crespo et al., (2012) did not administer IQ test in particular. Since DD is not the case of low intelligence (American Psychiatric Association, 1994), and dyslexia has no contribution in causing DD (Askenazi & Henik, 2010), the administration of reading test and IQ test is mandatory. Thus, one such strategy that can be used to investigate DD is recommended below: 1. The marks of all the students in the subject mathematics should be collected from their previous school records. Consider students who have achieved for example standard score below 70 for further assessment. Conduct teacher's interview for students scoring above 70 to ascertain if any of these students faced some difficulty in solving mathematical problems like taking longer time to solve simpler problems or making use of finger counting strategy. These identified students should also be considered for further inspection. 2. On this selected

Volume : 5 | Issue : 1 | Jan 2015 | ISSN - 2249-555X

sample, administer a mathematics test to filter out children who are poor in mathematics because of exogenous factors. 3. Next apply an IQ and a reading test to select student with normal intelligence and reading ability. 4. Lastly, an item-timed diagnostic test (specifically meant for diagnosing DD) should be administered on the resulting sample which will yield DD students. Incase of doubtful cases, Lorusso et al (2014) recommends quality analysis of errors during diagnosing of DD.

DISSIMILAR PARAMETERS

Another critical issue in identifying DD students is that there is no consensus regarding what parameters should be considered while investigating DD. For instance, Moeller et al., (2009) considered addition, subtraction, multiplication, division, magnitude comparison and fill-in equation of Heidelberger Rechentest (Haffner, Baro, Parzer & Resch, 2005), while Price (2008) included items single and multi-digit addition, subtraction, division, multiplication, decimal conversions, fractions calculations and simple algebra of mathematical achievement test (RMAT; Rasanen, 2004) for the diagnosis of DD. But Salvador-Carulla et al. (2013) suggests that an international consensus should be achieved pertaining to any such issue. In response to this reality, Nominal Group Technique (NGT) can be incorporated by the practitioners as one of the proven practices to get unanimity over the parameters on which the diagnostic test should be based. The purpose of NGT is to generate myriad of ideas pertaining to an issue, prioritizing them and hence selecting the most important ideas (Abdullah & Islam, 2011) with consensus of all domain experts involved. Duggan and Thachenkary (2003) described NGT as a five step process: In the first step, the participating members independently and silently produce a list of ideas. In the second step, the facilitator records the ideas from each member in a round robin format. One idea is recorded from each member every time in subsequent rounds till the list is exhausted. Next, each idea is discussed only for clarification without critical evaluation. Now members are asked to rate and rank each idea independently. Lastly, based on mathematical pooling and voting, the group decides the priority ordering of the alternatives. Thus ideas which are highly rated by the group as a whole are selected for dealing with the concerned issue (Abdullah & Islam, 2011). An important element to be taken care of while employing NGT is inclusion of all prominent domain experts in this area.

COST AND TECHNOLOGY

Despite the availability of different diagnostic tests, the accessibility to these tests is called into question. According to Michaelson (2007), schools may not encourage using these tests because of their heavy costs. For example, Heidelberger Rechentest (HRT; Haffner, Baro, Parzer & Resch, 2005) which is a standardized German dyscalculia test according to Kaufmann et al. (2009) has an estimated cost of 106,00 €. Also Jones (2014) talks about a case NumericallyConfusedBatman (age 17) who is interested in getting officially tested for DD but even the most reasonable test would charge $100 to $200. In this regard, Gilga and Gilga (2011) had sought to construct a Romanian screening instrument so that it can be obtained at nominal rates but its psychometric properties still needs to be established. Thus the mantra should be to find ways to make these tests available in the reach of the common man. Another element of attention is towards the assessments like Dyscalculia Screener (Butterworth, 2003), on-line Dyscalculia Test (Dyscalculia Center, n.d) and DysCalculiUM (Beachman & Trott, 2006), technology based measures to identify DD pupils. Although technology based tools seem to be a motivating component in today's tech savvy world but in reality there are sites which are unprepared to take the advantage of this besides the affordability. Hence, it is incumbent on the investigators to provide a supplementary paper pencil test of their diagnostic tools like in case of on-line Dyscalculia Test (Dyscalculia Center, n.d) and DysCalculiUM (Beachman & Trott, 2006).

LEVEL OF EDUCATION

Most of the research instruments mentioned in this review are inclined towards determining DD children predominantly at school level. Implications of DD can be quite adverse. According to Kaufmann and von Aster (2012) it is an economic issue. It limits the choice of courses, future prospects and is a major setback for such individuals to get a job. Also Butterworth (2003) views pupils with low numeracy as a substantial cost to the nation. Consequently, there is a need for identifying DD students in higher education too. On this matter, the works of Beacham and Trott (2006) and Dyscalculia Center (n.d) are warranted. Beacham and Trott (2006) developed a first-line screening tool DysCalculiUM and on-line Dyscalculia Test by The Dyscalculia Center (n.d) for diagnosing DD in adults with the limitation as discussed in preceding section. Thus, it is suggested that more research endeavors should be planned to develop diagnostic tests that investigates DD encompassing pupils beyond school level.

LONGITUDINAL STUDY

According to Gersten, Jordan and Flojo (2005), some of the children out-grew their developmental delays or are misidentified over time. Even when using the same assessments, a given individual may not continue to meet the math disability criteria (Mazzocco & Myers, 2003). Hence it is recommended to conduct longitudinal studies incorporating more than one assessment point for determining DD students.

RESPONSE TO INTERVENTION (RTI)

With the advent of increasing limitations of the contemporary diagnostic practices, response to intervention (RTI) is seen as an emerging solution to the problem of identifying students with specific learning disability. Fuchs, Mock, Morgan, & Young (2003) described RTI as

1. Students are provided with generally effective instruction by their classroom teacher; 2. Their progress is monitored; 3. Those who do not respond get something else or something more, from their teacher or someone else; 4. Again, their progress is monitored; and 5. Those who still do not respond either qualify for special education or for special education evaluation. (p. 159).

But since every coin has two sides, RTI approach is also led to several criticisms. For instance, Ofiesh (2006) is of the opinion that it may also identify students who may not have SLD and Mastropieri and Scruggs (2005) argues that it won't be able to distinguish SLD from mental retardation, emotional or behavioral disorders, attentiondeficit/hyperactivity disorder, or generic low achievement.

With reference to the diagnosis of DD, use of RTI alone appears unsatisfactory. RTI does not take into account IQ of the students which is mandatory while dealing with DD as it is not reserved for individuals with low IQ. Moreover, RTI neglects the use of item timed test which is very important to identify finger counters, an important criterion for diagnosing DD. Also this approach is likely to identify

Volume : 5 | Issue : 1 | Jan 2015 | ISSN - 2249-555X

students who are weak in mathematics because of external factors. Last but not the least, the interventions to be planned in order to omit above conditions is another challenge. Thus, Wodrich, Spencer and Daley (2006) recommends for the concurrent use of RTI and Psychoeducational testing to adequately plan and identify for SLD students. Ofiesh (2006) also supports that use of RTI as the sole criteria to identify SLD is insufficient.

Conclusion

In composite, this paper presents encouraging and unequivocal data by uncovering a number of demerits of diagnostic procedures which is ubiquitous in DD research base. It provides contours for explorers to realize the importance of implementing psychometrically recognized and robust tools to identify DD pupils. Timely diagnosis will not only facilitate suitable treatment but families will also discover about their ward's developmental challenges (Shattuck & Grosse, 2007). As a field, we have yet to spawn further research to come up with an appropriate diagnostic process that may not locate students who were misidentified as DD because of any previous investigation. There is a pressing societal demand to help such individuals and hence contemporary practices must take initiatives, a step in this direction. Thus it is hoped that this short communication will provide a productive way forward to give meaning to lives of these individuals by fostering confidence in their ability to do mathematics.

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