FOCUSING ON DYSCALCULIA: CONTRIBUTIONS FROM A HISTORICAL-CULTURAL LENS

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ABSTRACT

This article considers issues related to developmental dyscalculia, a condition that has been associated with specific difficulties in the learning of mathematics. It begins with an attempt to locate a sample of research undertaken within Brazil, in order to identify the perspectives on dyscalculia which characterise these works. In the small number of dissertations and theses that were encountered, definitions of dyscalculia and the manner in which it is diagnosed tended to emphasise biogenetic and neurological factors in isolation from social and cultural ones. To augment this sample, we went on to search for articles published in Brazilian research journals also related to this theme, finding that they were also characterised by the same tendencies. We argue that implicit in the perspectives emphasised is a view of the developmental potential in mathematical ability as something that is largely dependent on individual brain-based factors. As we focus on the Brazilian research in the light of other research into mathematical difficulties, we highlight some limitations associated with using current neuropsychological studies and question whether dyscalculia is purely associated with a specific congenital brain-based disorder. Our explorations of this question are informed by research in the tradition of Historical-cultural psychology and we argue that, as an alternative to the current deficit model, dyscalculia might be better understood by approaches which see the development of mathematical abilities as mediated by cultural, historical and social resources, alongside biogenetic and neurological ones.

Keywords: Dyscalculia, Matematics Education and Neuroscience, Historical-cultural psychology

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RESUMO

Este artigo considera questões relacionadas ao desenvolvimento da discalculia, uma condição que tem sido associada a dificuldades específicas na aprendizagem matemática. Ele inicia com a tentativa de localizar uma amostra da pesquisa realizada no Brasil, a fim de identificar as perspectivas sobre a discalculia que caracterizam esses trabalhos. No pequeno número de dissertações e teses encontradas, as definições de discalculia e a forma como é diagnosticada tendiam a enfatizar fatores biogenéticos e neurológicos, em detrimento de fatores sociais e culturais. Argumentamos que está implícita nessas perspectivas uma visão do potencial de desenvolvimento da capacidade matemática como algo que é altamente dependente de fatores cerebrais individuais. Como focamos a pesquisa brasileira à luz de outras pesquisas acerca de dificuldades matemáticas, destacamos algumas limitações associadas aos atuais estudos neuropsicológicos para questionar se a discalculia é puramente associada a um distúrbio cerebral basicamente congênito. Nossas reflexões acerca dessa questão são ancoradas pela perspectiva da Psicologia histórico-cultural e argumentamos que, como alternativa ao modelo de déficit atual, a discalculia pode ser melhor compreendida por abordagens que vêem o desenvolvimento de habilidades matemáticas mediado pelos recursos culturais, históricos e sociais, juntamente com aqueles de origem biogenética e neurológica.

Palavras-chave: Discalculia, Educação Matemática e Neurociência, Psicologia histórico-cultural

INTRODUCTION

> *To understand the brain foundations for psychological activity, one must be prepared to study both the brain and the system of activity. (Luria, 1979, p. 173).*

This article aims to contribute to the on-going debates about specific learning difficulties in mathematics and especially to attempts to associate these difficulties with a brain-based “condition”, dyscalculia. These reflections are informed by aspects from Historical-Cultural Psychology, which has its origins in the work of Vygotsky and his colleagues in the former Soviet Union in the first half of the last century. We view this framework as a particularly relevant one from which to view learning difficulties in mathematics given that its central ideas grew from the area, called, at that time, *Defectology*[2] and more specifically from experimental work with learners with different physical or cognitive disabilities. Indeed, we concur with the sentiments expressed by Luria in the above quote and have been influenced by his attempts to link brain structure and function to culturally organized practices and environments.

One motivation in offering this reflection is that, while research in mathematics education in general has moved toward seeking social and cultural interpretations of the phenomena associated with mathematics learning[3], in relation to mathematics learners with special educational needs most studies concentrate on the search for neurological explanations (Magne, 2003). Indeed, it might even be argued that the migration of the term dyscalculia from neuropsychology to education underlines the prevalence of the search for neurologically based explanations for the (low) performances of learners identified as experiencing particular difficulties in participating in the practices of school mathematics (Munn and Reason, 2007). However, it is still far from clear that all those who make use of the term dyscalculia use it in the same way, making it difficult to ascertain whether it really is a condition that can be considered to be associated with a specific cognitive deficit – especially

[2] Defectology is (a translation of) the term used by Vygotsky to denominate the scientific study of the processes of development of differently-abled individuals.

[3] Lerman (2000) cited evidence of the social turn, while Gutiérrez (2010) talks of a socio-political turn.

since, as Gifford (2005) argues, there is not even a robust consensus as to what precisely are its defining characteristics, aside from poor recall of number facts.

To examine more closely the inter-relationships between individual, social and political factors, we begin by considering how dyscalculia has been construed in the Brazilian context and what has been published in relation to the theme in this country.

RESEARCH ON DYSCALCULIA IN THE BRAZILIAN CONTEXT

Using the Brazilian homepage for the search tool Google (www.google.com.br, access 15th November 2011), the Portuguese spelling of the word (*discalculia*) obtained 53.000 hits (the search was limited to pages in Portuguese). The first hit was to the Portuguese Wikipedia page and the second to the site www.brasilescola.com/doencas/discalculia.htm on which the following definition of dyscalculia is presented:

> *Dyscalculia is a neurological disorder which affects abilities with numbers. It is an independent learning problem, but it can also be associated with dyslexia. People with this disorder have difficulties with mathematical operations, mathematical concepts, formulas, numerical sequences, performing calculations, using numerical signs and even in using mathematics in everyday activities.*[4]
>
> *www.brasilescola.com/doencas/discalculia.htm*

This definition suggests a medical condition which might be expected to be associated with all aspects of mathematics and offers a rather dismaying picture to students, teachers and parents. According to this description having dyscalculia would appear to be synonymous with being bad at *all* mathematics. But does such a picture have a robust basis in research?

While the google search resulted in over 50,000 returns, the results of the same query using the search instrument for the database of dissertations and theses of CAPES,[5] the governmental organ of the Brazilian Ministry of Education responsible for the post-graduate sector, indicated only eight works

[4] All the translations from Portuguese in English that appear in this article were made by the authors.
[5] CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior)

(www.capes.gov.br, access 3rd November, 2011): two doctoral theses and six masters dissertations. One of the theses was associated with the area of Psychology and the other Health Sciences, while two of the dissertations were from the area entitled Development Disturbances, one from Health Sciences, one from Genetics, one from Education and one from Tropical Medicine.

Neither of the two theses was available for consultation in the online database. This was also the case for one of the dissertations. Of the remaining five dissertations, one had been removed by the institution in which it was elaborated and a second, in fact, included no reference to the object of study, dyscalculia, in the body of the text. To further this search, we also consulted the databases of a number of Brazilian universities, including the State University of Campinas (UNICAMP), the Federal Universities of Minas Gerais, Rio de Janeiro, Rio Grande do Sul and São Carlos (UFMG, UFRJ, UFRGS, UFSCar) and the Catholic Universities of Campinas, São Paulo and Rio Grande do Sul (PUC Campinas, PUCSP, PUCRS), again using as our search term the Portuguese word "*discalculia*" (accesses, 27th December 2011). These searches resulted in the localization of one more work, another Masters dissertation, which had not been published in the CAPES database.

Our intention in carrying out this search was to locate a source of research resources from which we might build a picture of how dyscalculia is considered by the research community in Brazil. As it turned out, the sample of works we accumulated was very small, with the complete works available for analysis limited to only four dissertations, one from each of the areas Developmental Disturbances, Education, Genetics and Child and Adolescent Health. Before examining the perspectives on dyscalculia adopted by the authors, we briefly present the aims of each study.

The dissertation from the area of Developmental Disturbances was titled *a preliminary study about the impact of transcranium stimulation by a continuous current on multiplication tasks*, and was authored by Rita dos Santos de Carvalho Picinini. Picinini (2009) chose to focus on the impact of this kind of neurological stimulus on tasks involving multiplication because of her view that this operation would incorporate operations of addition and "also since multiplication is the inverse of the division operation" (Picinini, 2009, p. 69). The second work consulted, the dissertation of Jussara Bernardi (2006), *Students with dyscalculia: Rescuing self-esteem and self-image through play,* investigated how five children, diagnosed as dyscalculic and who were receiving psycho-pedagogic attendance, responded to activities of play. The third dissertation, produced by Gutemberg Eloi de Sousa (2010), "*MLPA-Dyscalc-Turner: development of a systems based on MLPA*[6] *for the detection of a candidate for dyscalculia in Turner Syndrome"*, aimed to develop a tool for the detection of a causal candidate for dyscalculia in the X chromosome associated with Turner Syndrome (SOUSA, 2010, p. 32). The fourth dissertation, *A contribution of the symptoms of attention deficit hyperactivity disorder (ADHD) to difficulties in learning arithmetic* by Riviane Borghesi Bravo (2011), from the area of Child and Adolescent Health, investigated the occurrence of comorbid diagnoses of ADHD in children with difficulties in learning mathematics, using as an indicator of difficulties performance inferior to the 25th percentile according to the norms associated with a test of school performance (TDE). The study also examined the association between the presence and/or degree of the symptoms of ADHD and low achievement in mathematics, analysed differences in general or specific cognitive deficits in children with only difficulties in learning mathematics as compared to those who are also diagnosed with ADHD and examined the relative contributions of behavioural and cognitive factors to achievement in arithmetic.

In addition to these four dissertations, we also consulted other possible sources for relevant Brazilian works, searching the databases of research articles of CAPES and SCIELO. However, these searches only resulted in the location of two more works deemed pertinent to augment our sample. The first of these was an article entitled *Numeric dyscalculia: assessment of numeric representation using ZAREKI-R*[7]. In this paper, Silva and Santos (2011) report on a study which aimed to investigate which aspects of number processing and calculation and working memory are related to arithmetic deficits. The second article, *Management of learning disorders and attention deficit in children* (Araújo, 2002), in which a review of research, with a medical bent, related to learning difficulties, is presented. Although

[6] Multiplex ligation-dependent probe amplification (MLPA) is a technique used for DNA analysis (Schouten et al, 2002), it enables the detection of a number of genetic issues such as number of chromosomes, gene deletions, gene duplications, and gene expansions.

[7] A Neuropsychological Test Battery for Number Processing and Calculation

both dyslexia and dyscalculia are mentioned amongst the learning difficulties considered in the paper, they receive very little attention, with the main focus on attention deficits.

Having determined our admittedly rather small sample of works (an indication, perhaps, of the need for more research in the area in the Brazilian context), our next step was to examine how the notion of dyscalculia was constructed within them.

THE CONSTRUCTION OF DYSCALCULIA

So, what is dyscalculia, what are its causes and with what learning difficulties is it associated? According to 10th International Classification of Diseases (ICD 10), amongst the entries associated with *Specific developmental disorders of scholastic skills*, is the category *Specific disorder of arithmetical skills* (F81.2). This disorder is described as

> *[A] specific impairment in arithmetical skills that is not solely explicable on the basis of general mental retardation or of inadequate schooling. The deficit concerns mastery of basic computational skills of addition, subtraction, multiplication, and division rather than of the more abstract mathematical skills involved in algebra, trigonometry, geometry, or calculus. (ICD 10).*

Similarly, the Diagnostic and Statistical Manual of Mental Disorders published by the American Psychiatry Association (APA) also mentions what is called a *mathematics disorder* (DSM-IV 315.1) and offers the following three criteria to be used in its diagnosis:

> *A. Mathematical ability, as measured by individually administered standardized tests, is substantially below that expected given the person's chronological age, measured intelligence, and age-appropriate education.*
>
> *B. The disturbance in Criterion A significantly interferes with academic achievement or activities of daily living that require mathematical ability.*
>
> *C. If a sensory deficit is present, the difficulties in mathematical ability are in excess of those usually associated with it.*
>
> *(American Psychiatry Association, 1994)*

In relation to these two definitions, a number of comments are worth stressing. First, the ICD entry makes clear that the condition relates to basic computation and not to mathematics in general. However, the mathematics disorder defined by the APA does not specifically limit difficulties to arithmetic. So are the two "disorders" the same? The ICD definition appears to be more specific, but even the terms it uses are rather general, and the implied meanings associated with "arithmetic skills" and "mastery of basic computational skills" can be seen as rather ambiguous. Gifford (2005), in her review of the dyscalculia literature, sees this ambiguity as problematic. She points to research such as that of Dowker (1998, 2004, 2005) which suggests that arithmetical ability is not unitary, but composed of a variety of components and that students who have difficulty with one component will not necessarily experience difficulty in others. Should the diagnosis of dyscalculia apply to those individuals who have difficulties with ALL components related to arithmetic or to only particular components? And if the latter option is to be chosen, which components are the crucial ones? Different researchers seem to privilege different components, with possible suggested candidates being complete reliance on count-all procedures, problems with written procedures and consistent lack of progress in remembering of number facts (see Gifford, 2006, for more details), already rather different cognitive factors.

Another issue concerns how it is decided that an individual has a deficit uniquely associated with the mastery of computational skill. One method of attempting to identify dyscalculia has involved seeking for discrepancies between children's general intelligence and their performance in relation to arithmetic – or, if the criteria offered by the APA are used, determining whether their mathematical ability is lower than would be expected according to their age or performance on other intelligence tests. Gifford (2006) points to the danger and inadequacy of such approaches. There are no agreed criterion for "average performance in arithmetic" and no universally accepted tests for assessment. There are a number of specific instruments for measuring abilities and difficulties associated with understanding number, such as Butterworth's Dyscalculia Screener (Butterworth, 2003), mainly used in the United Kingdom and the neuropsychological test battery *ZAREKI-R* used by Santos and Silva (2011), which was initially validated in Switzerland and France (Shalev, 2004). But these different instruments emphasise different aspects of number and no one instrument is universally used. It is also extremely difficult to ensure that instruments are completely unbiased culturally. Indeed, the idea that performance on any test instrument is a reflection only of purely individual factors is unsustainable, with ample research to show that performance is mediated by a variety of social and economic factors – a position we shall return to later in the paper.

In her research, Picinini (2009) accepts that the causes for difficulties in mathematics learning are diverse, but nonetheless chooses to refer to the APA definition and to argue that dyscalculia is related to the neurological system. More precisely, she considers dyscalculia to be a "difficulty in learning mathematics and weakness in acquiring abilities adequate for this cognitive domain" (Picinini, 2009, p. 27). She affirms that dyscalculia "consists in specific deficits in calculation which could be of a congenital order or could be acquired during lifetime, such as in the case of cerebral vascular accidents" (Picinini, 2009, p. 38). The author also claims that "the alterations observed in developmental dyscalculia have been related structures such as the parietal cortex" (Picinini, 2009, p. 27). Araújo (2002) also uses the APA definition of dyscalculia, in her article, describing it as a medical disturbance that leads to difficulties in operating with mathematical concepts. She groups dyscalculia alongside a rather diverse collection of "conditions", which she considers to be the "principle medical disturbances associated with low school performances" (p.106), these include visual and hearing impairments, mental retardation, dyslexia and dyscalculia, hyperactivity and attention deficit disorders[8]. Bernardi (2006) makes a distinction in her work between acalculia and dyscalculia. Acalculia is defined as "a disorder related to arithmetic, acquired following a cerebral lesion" (p.17), while dyscalculia "is not caused by lesions in the cerebral region and is associated principally with students who present difficulties during the learning of mathematical abilities" (Bernardi, 2006, p. 18) and is related to a "structural maturation disorder in mathematical capabilities" (Bernardi, 2006, p. 18) which cause children to commit "a variety of errors during mathematical activities, with difficulties polarised around the areas of number comprehension and the solution of verbal problems" (Bernandi, 2006, p. 19). In this sense, dyscalculia is posited as a developmental disorder. In

[8] Although not the focus of this paper, we feel we must register our concern about this association of a lack of access to one or other sensory field with learning disorders. On the basis of results from our own research with blind mathematics learners and deaf mathematics learners (Healy and Fernandes, 2011; Healy, 2012), we strongly question the implication that of lack of sight or lack of hearing – per se – can be considered as responsible for learning difficulties in mathematics.

fact, many authors use the term “developmental dyscalculia” to distinguish between “congenital” arithmetic difficulties and acalculia which manifests itself following damage to particular areas of the brain (Shalev & Gross-Tsur, 2001; Butterworth, 1999; Landerl, Bevan & Butterworth, 2004).

Sousa (2010) defines dyscalculia as “a specific disorder in the learning of arithmetic” (Sousa, 2010, p. 4), “a cognitive disorder that affects children impeding the normal acquisition of arithmetic” (Sousa, 2010, p. 18) and “a genetic disease that is characterised by a disproportionate deficiency in arithmetic calculations that affects 3 to 6 % of school aged children” (Sousa, 2010, p. 18). For Bravo (2011), children with dyscalculia are those who “fulfil the criteria for problems with the understanding of basic arithmetic, in the absence of sensory or motor deficiencies, mental retardation, emotional disturbances and without having deprivation of mathematics education or environmental factors” (p.20).

Dyscalculia, then, in all these definition is associated with mathematics abilities (or rather lack of them) inherent in the subject and dependent on her or his development. The association of dyscalculia with development leads Bernardi (2006) to cite Mosquera (1984 apud Bernandi, 2006, p. 21) who argued that learning can only happens effectively when the individual is “sufficiently mature” affirming also that “this neuropsychological readiness or physiological maturation, added to the rhythm and level of interest of each student, constitutes the basic elements for learning” (Bernardi, 2006, p. 21).

Silva and Santos (2011) hold a similar view and claim that “there exists an innate capacity for quantitative abilities which include an implicit understanding of numerosity, ordinality, counting and simple arithmetic” (p. 169). They go on to describe how learning diseases, amongst which they include dyscalculia,

> *have as a characteristic low performance on standardised tests for writing, reading and arithmetic in comparison to children of the same age, level of intelligence and scholarisation (APA, 2000) that cannot be justified by the lack of opportunity for learning, pedagogic failure, sensory deficiencies or acquired lesions (OMS, 1993). (Silva and Santos, 2011, p. 170)*

In sum, dyscalculia, in these Brazilian works, is constructed as an individual process that involves neurobiological and neuropsychological components of the individual, which are innate, congenital. They also ascribe to a point of view that individual development, enabled by these neurological factors, is the driving force for learning. On the whole, the descriptions of dyscalculia are consistent with the specific learning disorders for arithmetic/mathematics as defined by ICD 10 and by the APA.

Yet, despite this consistency, it is still not clear which of the various difficulties in learning mathematics that different people manifest during their lifetime can be associated with this so-called disorder. Above, we pointed to the concerns of some researchers that, despite this sense of overall consensus, there is no agreement as to the specific characteristics of dyscalculia or in the instruments by which it might be diagnosed. It is also important to stress here that there is also still much controversy as to the existence of conclusive neurological evidence that developmental dyscalculia is caused by a specific brain abnormality. Evidence from studies of the brain mechanisms involved in numerical processing have clarified which regions of the brain appear to be associated with certain numeric skills (Grabner and Ansari, 2010), however, although recent developments continue to advance the nature of the information that can be obtained from techniques such as brain imaging (Obersteiner, Dresler , Reiss, Vogel, Pekrun and Fallgatter, 2010; Menon, 2010), a precise attribution of what each area actually does is still not available (Gifford, 2006), Moreover, most evidence concerning the relationships between brain structure and mathematics learning is cross-sectional rather than longitudinal. This leads De Smedt and Verschaffel (2010) to suggest:

> *On the basis of these data, it is not possible to determine whether individual differences in brain structure and function are the origin or the consequence of individual differences in mathematical performance. (De Smedt and Verschaffel, 2010, p. 650)*

They believe that longitudinal studies in which the structure and function of different aspects of the same individual's brain are measured at different points in time are necessary to further our understanding of the neurological underpinnings of mathematical performance. It is also the case that most evidence from cognitive neuroscience studies comes from investigations involving adults rather than children. This worries Grabner and Ansari (2010) since they argue that those studies that do focus on young people indicate that dramatic changes in the neural correlates of the cognitive functions related to arithmetic problem-solving occur over the course of development. They also point to another possible limitation related to the population samples involved in experimental studies of brain activity.

> *Most frequently, adult samples consist of undergraduate students from middle-class socio-economic (SES) backgrounds and are thus hardly representative of the general adult population, especially given the recent research revealing that brain mechanisms underlying cognitive processes are modulated by factors such as SES. (Grabner and Ansari, 2010, p.656.)*

Although they were not referring directly to brain-based evidence related to dyscalculia, this comment is relevant, since it will have been such studies that have contributed to the construction of so called "normal" brain-functioning, used as a basis from which to infer abnormalities. It also suggests that the functioning of the adult brain is not something of a purely individual nature, environmental factors appear to interact in the development of cognitive processes. Finally, we mention one further complication of importing results from the area of cognitive neuroscience into education: studies in the former area tend to be carried out in conditions that differ substantially from educational contexts, leading De Smedt and Verschaffel to caution:

> *Few efforts have been made to examine how performance on specific experimental tasks used in neuroscientific studies, and by extension their correlated brain activity, is related to (or can even predict) performance on broad and authentic measures of classroom learning. This is clearly a priority on the agenda of research that tries to connect cognitive neuroscience to education. (De Smedt and Verschaffel, 2010, p. 652).*

It is not our intention here to imply that evidence from neuroscience has little relevance to those interested in learning or that particular difficulties (or indeed particular abilities) in mathematics do not have some correlation with the brain-based mechanisms of particular individuals. Far from it. Investigations which lead to more precise evaluations of what brain-based mechanisms have a role in which arithmetical and mathematical activities and how these mechanisms change over time – in concert, not only with biological maturation, but also with participation in particular social and cultural activities – could bring enormous benefits to our knowledge about supporting learners to appropriate all aspects of mathematical knowledge. What does concern us though is that the association of learning difficulties with a disorder, or disease, tends to privilege a deficit-model of the learner: the individual can come to be constructed as lacking in something – or as having something missing from, or wrong with, his or her brain – which impedes their development.

To paraphrase Luria (2006b), the Soviet psychologist and one of the forefathers of neuropsychology, such a view raises a series of questions: Is development really a primary state, without quality, given directly to each one of us? Is it a simple and undividable state, destitute of all of history, through which the individual can be gradually formed? Should development, in fact, be understood as a primary "inner state" and should its roots be sought in the interior of the organism, in the deepest caverns of the mind or the neuronal structures brain? In the light of these questions, we refocus once again on mathematics learning and associated difficulties, this time from a historical-cultural perspective.

REFOCUSING ON DYSCALCULIA THROUGH A HISTORICAL-CULTURAL LENS

According to Vygotsky (2005), learning refers to the appropriation of knowledge, capacities or specific habits, while development involves "the reasoning capacity and intelligence of the child, his or her ideas about what surrounds him or her, his or her interpretations of physical causes, his or her mastery of logical forms of thinking and abstract logic" (Vygotsky, 2005, p. 25). In the conceptions of development dyscalculia presented above, the position adopted appears to be one in which learning is presumed to depend on individual development in isolation from social factors. Vygotsky was sceptical of such a view, describing how it implies that "development must reach a determined stage, with the consequent maturation of determined functions, before the child can be schooled to acquire determined knowledge and habits. The course of development precedes that of learning" (Vygotsky, 2005, p. 26). In this conception, the presence of certain psychological and neurobiological functions would appear to be pre-requisites for, rather than the results of, learning. Moreover, a consequence of accepting this conception is that any individual's learning necessarily follows his or her level of development and that "the educational process can only limit itself to following mental formation" (Vygotsky, 2005, p. 27).

Historical-cultural psychology posits an alternative to this perspective, with its claim that

> *[...] learning is not development; however adequately organised learning results in mental development and puts into movement various developmental processes which, in any other form, would not be able to occur. In this way, learning is a necessary and universal aspect of development. (Vygotsky, 1994, p. 118).*

There, development is viewed as an eminently social process, in which the subject is situated both historically and culturally and in which "learning and development are inter-related from the first day of the child's life". (Vygotsky, 1994, p. 110).

For Pino (2005), Vygotsky doesn't just include culture in the analysis of the human condition, he assigns to it analytic primacy and treats it as the "raw material" of all human development. In this way, the human being is seen as, above all, a cultural being, and culture is, at the same time, both "a condition and a result of the emergence of man as human being" (Pino, 2005, p. 54). In this perspective, development cannot be a purely individual biological process, it is also a cultural phenomenon which presupposes two factors: biogenetic and neurological equipment, on the one hand, and social contact, on the other. Development, then, is mediated by the interactions between these factors. In considering them, Pino writes that

> *The first corresponds to elementary functions that are products of genetic inheritance; the second aspect is responsible for higher-level functions, that are not works of nature, but of mankind, they are constructions and "propagate themselves through social practices". (Pino, 2005, p. 53).*

Both are inseparable, the higher-level functions cannot be considered to be simple manifestations of the biogenetic and neurological equipment of the individual, rather "[t]he higher-level functions, in contrast to the elementary functions, are subordinated in their development to historical regularities" (Kranz, 2011, p. 41). That is, "these functions have a social origin, both in phylogenesis and in ontogenesis" (Vygotsky, 1997, p. 213):

> *[...] each psychic function appears twice in the process of conduct development first, as a function of collective conduct, as a form of collaboration or interactions with the means of social adaptation, that is as a inter-psychological category and, in second place, as a mode of individual conduct of the child, as a means of personal adaption, as an inner process of conduct, that is to say an intra-psychological category. (Vygotsky, 1997, p. 214)*

In relation to collaboration and interaction, Vygotsky (2000, p. 24) claims that we constitute ourselves on the basis of our relationships with others in a process of development influenced by an objective reality, resulting from social history, and "also under the constant influence of communication between the child and the adult" (Luria, 2006b, p. 19). In this view, it is language and interaction which is responsible for the radical reorganisation of the psychological process, transforming it, little by little, into a "form of the organisation of psychological human activity" (Luria, 2006b, p. 197). Luria goes further in his analysis of the development of psychological processes, pointing to how

> *The psychological processes emerge not from the interior of the living cell, but in its relations with the surrounding environment, on the frontier between the organism and the exterior world, and it assumes the forms of active reflection of the exterior world that characterise all vital activity of the organism. (Luria, 2006b, p. 194).*

In this perspective, to define dyscalculia as a consequence only of the biogenetic equipment of the individual effectively extinguishes any influence of the historical-cultural context in the constitution of the individual and in his or her learning of arithmetic (or mathematical) concepts. Furthermore, there is a risk that in relating dyscalculia only to the neurological system, to the parietal cortex, and in attributing to it the character of a disorder of maturation, a cognitive disorder or genetic disease, it will be implied that so called carriers of this disease are incapable of learning arithmetic. That is, there is a danger that, once diagnosed as having dyscalculia, little can be done in the sense of mathematics learning, since it is compromised by factors inherent to the individual. Indeed, this view seems to be present in at least some of the Brazilian works, with Bernardi (2006) arguing "functions indispensable in the process of realizing calculations are not sufficiently developed" (Bernardi, 2006, p. 19) and Silva and Santos describing dyscalculia as "a persistent disorder, extending even beyond adolescence" (Silva and Santos, 2011).

Such conceptions of learning disabilities certainly appear to influence the processes of teaching and learning of school mathematics, since, as several different authors have pointed out, pedagogic practices are guided by the conceptions that educational professionals possess about the potential for learning and development of the individuals with whom they work (Hargreaves, 1975; Mitjáns Martínez, 2007; Marques, 2009; Beyer, 2010; Kranz, 2011). Hence, the diagnosis of a learning difficulty can become interpreted as the diagnosis of a learning "impossibility", which in turn will influence the actions undertaken in educational establishments.

> *With respect to the expectations of teachers about the learning potential of their students, the effect of the self-fulfilling prophecy is well known. The projection that teachers make about the school lives of their students usually influences that failure or success in school. (Beyer, 2010, p. 76).*

In a similar vein, a recent review of European research into teacher education and inclusion concluded that teaching students with special educational needs is likely to be ineffective where the dominant belief system is one that "regards some students as being 'in need of fixing' or worse, as 'deficient and therefore beyond fixing' (European Agency for Development in Special Needs Education, 2010, p. 30).

This brings us back to the question of how a student is classified as dyscalculic. We touched upon the complexity of this process earlier in the paper; we now look more closely at the Brazilian studies and the parameters used in this diagnosis.

"DIAGNOSING" DYSCALCULIA

To a certain extent, the very notion of diagnosing something can have the effect of objectifying it as a disorder or even as a disease. In relation to dyscalculia, the diagnosis processes is permeated, not surprisingly, by conceptions of what dyscalculia is. The research studies we consulted, in general, made use of some kind of standardised tests, considered appropriate by the authors since they were using definitions for dyscalculia such as "a specific disorder which affects the **normal acquisition** of arithmetic abilities in children of **normal intelligence** and with adequate schooling opportunities" (Silva and Santos, 2011, p. 170, our emphases) or beliefs such as "when early years students in the process of constructing mathematical notions present a **performance in arithmetic lower than expected performance** for their age, they can be characterized as dyscalculic students" (Bernardi, 2006, p. 27, our emphasis).

It would thus seem that it is some supposed standard of normality which essentially guides the process of diagnosing dyscalculia, and that, it is on the basis of this stance that tests are elaborated, aiming to "identify and specify the profile of mathematical ability in the domain of calculation and number processing" (Silva and

Santos, 2011, p. 170). One example is the battery of tests ZAREKI-R used in their study (Silva and Santos, 2011, p. 170), which they describe as “specialised in the diagnosis of developmental dyscalculia” (Silva and Santos, 2011, p, 174). These two researchers applied the tests with children aged between 9 and 10 years, in order to pinpoint aspects of number representation and operational memory that explain the arithmetic difficulties of children with learning disorders. Their conclusion was, amongst other considerations, that the group of children classified as with CDA (*Com Dificuldade em Aritmética* or With Arithmetic Difficulties) “presented a profile compatible with DD [developmental dyscalculia], characterised by problems in numeric representation both in relation to calculation and to symbolic numeric processing (Silva and Santos, 2011, p. 175). They also concluded that, in function of the characterisation and careful selection of the sample, as well as the statistical treatments undertaken, “the results obtained in the study were reliable” and indicate that “ZAREKI-R was efficient for the detection of the weak points associated with mathematical abilities and should be integral to the assessment of DD” (Silva and Santos, 2011, p. 175).

Bernandi (2006), in her research, used the Luria Neuropsychological Diagnostic Battery tests, standardised by Manga e Ramos (1991), in order that she might identify and characterise the children selected to participate in the study (Bernardi, 2006, p. 110). These test instruments were applied in two distinct moments – one before the pedagogic interventions and another following them. The subjects of her study were 8 year-old students in their second year of study at a school in Porto Alegre, Rio Grande do Sul. One of the conclusions stressed by the researcher was that the data obtained from these tests,

> *evidenced that all the subjects presented difficulties or lack of ability to realise basic arithmetic abilities, such as quantification, numeration or calculation, indicating a mathematical performance much lower than expected for their age level or level of schooling. (Bernardi, 2006, p. 180).*

She went on to argue that

> *In relation to the learning disorder in mathematics, in particular dyscalculia, the subjects registered a series of incapacities mathematics associated with the concept of number. [] In the same way, the maturation disorder of mathematical abilities associated with calculation mechanisms was also presented by all the subjects investigated. (Bernardi, 2006, p. 180).*

What is interesting to note is that, while it is true that the children obtained low scores on tests of both understanding of number structure and arithmetic operations on the first occasion of testing, all five of them improved by the second. The student with the lowest number of correct responses on the first test (3 out of 24 or 12.5%) improved by 5 points after the intervention (obtaining 8 correct responses or 33.3%), while the student with the highest initial score (9 out of 24 or 37.5%) made an even bigger gain, with 17 out of 24 correct responses on the second test (71%). It is also rather strange that the author did not mention these learning gains more emphatically in her final conclusions. In fact, she almost seems to minimise the gain in mathematics learning in relation to gains in self-image and esteem.

> *Verification of the modifications presented by the subjects in relation to mathematics learning indicated that the use of activities involving play in the learning laboratories positively influenced not only the intellectual aspects, but, above all, the social and the emotional. The subjects presented advances, although small in relation to the specific mathematical knowledge, but sufficient to feel able and valorised by their contemporaries (Bernardi, 2006, p. 181).*

The author does not make clear why she considered the learning gains to be small, but surely any learning gains would be worth attention for students who are supposed to have some kind of cognitive learning disorder! If the students gained from the relatively short pedagogic intervention involved in the study, it becomes somewhat questionable to attribute their initial lack of success to some kind of neurological pathology, rather than, say, exposure to inadequate learning situations prior to the first test.

In the study by Sousa (2010), assessment of arithmetic skills was realised through an assessment of mathematical cognition of the laboratory of Developmental Neuropsychology of the Federal University of Minas Gerais. The participants were 15 subjects with Turner Syndrome. In the research developed by Picinni (2009), subjects between the ages of 18 and 30 years completed 14 neurological subtests of the Wechsler Intelligence Scale for adults, which included multiplication tests composed of “multiplication operations of one digit by one digit and of two digits by two digits, with two response alternatives, one correct and one incorrect” (Picinni, 2009, p. 66). Bravo (2011) used yet another different instrument, TDE, a psychometric test of school performance chosen to “investigate the performance of children in tasks of calculation and problem solving” (Bravo, 2011, p. 41).

Viewing these diagnoses through the Historical-cultural lens

A constant in all these studies, independent of their particular aims, was the application of some form of standardised tests. So what do these tests actually indicate? According to the researchers, they point to some innate problems in arithmetic and in carrying out numerical calculations, which they associate with the condition of dyscalculia.

For Vygotsky, however, this interpretation has a number of limitations. He suggests that “when we establish the mental state of the child with the aid of tests, we refer always to the level of effective development” (Vygotsky, 2006, p. 111), that is, to “the level of psycho-intellectual functions of what the child can achieve as a result of a specific process of development already realised” (Vygotsky, 2006, p. 111). In these quotes, he is referring to what he also called the level of actual or real development, a construct he contrasts with the level of potential development. According to Vygotsky (1994), the level of real development is characterised by what the child can do by his or herself and is indicative of the cycles of development already completed. One of his concerns was that focusing only on this level of development can lead to an understanding that development has, for each child, an impassable limit (Vygotsky, 2006). He, on the other hand, believed that “this level of effective development does not completely indicate the state of development of the child (Vygotsky, 2006, p. 111) and rather that it is also necessary to take into account what the child may not be able to manage with complete autonomy, but is able to achieve with help from others (the level of potential development). It is the distance between these two levels, the real and potential, that Vygotsky called the Zone of Proximal Development (Vygotsky, 1994).

> *The area of potential development enables us, then, to determine the future steps of the child and the dynamic of his or her development, and to examine not only what development has already produced, but also what it will produce in the maturation process..[...]. Therefore the state of mental development of the child can also be determined by reference to at least the two levels: the level of effective development and the area of potential development. (Vygotsky, 2006, p. 113).*

Referring to a conversation of Leontiev with respect to this perspective, Wertsch (1988), highlights a central difference between researchers in the United States and those in the former Soviet Union: “the American investigators constantly dedicate themselves to assessing how the child comes to be what he or she is, in the

Soviet Union the aim is to discover not how the child comes to be how he or she is, but how the child can come to be what he or she is not yet" (Bronfenbrenner, 1997 apud Wertsch, 1988, p. 84). Leontiev (2005), himself, was explicit in questioning the value of diagnoses of children classified as mentally delayed:

> *What value do the investigations of medics and psychologists about the problems of mental delay have? To what final result do their prognoses, diagnoses and their selection methods lead? Can they lead to a decrease in the number of children classified as mentally under-developed, or determine perhaps the opposite result? (Leontiev, 2005, p. 87-88).*

For him, these children are simply those "who show themselves unable of learning adequately according to a "normal" rhythm, in conditions defined as "normal" (Leontiev, 2005, p. 87). He believed that, even in the best of cases, standardised measures give only a superficial idea of the level of development, "the tests never discover the nature of the delay, nor permit an absolute interpretation. They only give an illusion of an explanation of the causes of the delay" (Leontiev, 2005, p. 89).

Leontiev's worries about defining children according to supposed "norms" do not seem to be echoed in the Brazilian literature that we encountered through our searches. Even the dissertation from the area of Education (Bernardi, 2006), which included references to the historical-cultural approach of Soviet psychology, had a strong emphasis on classifying students as "having" a learning disorder, in spite of evidence that indicated that the children who took part in the study were capable of moving beyond the levels of the original "diagnoses". Before Leontiev, Vygotsky too, in his work in the 1920s with students with disabilities, had been expressing his own concerns about the usefulness of methods which rely basically on the identification of quantitative differences in achievements between those with and without certain abilities. Instead, he proposed that a qualitative perspective should be adopted to understand how access to different mediating resources impacts upon development (Vygotsky, 1997).

Rather than using a model that posits students with disabilities as deficient in relation to those without, Vygostsky's stance involves considering how and when the substitution of one tool by another may empower different mediational forms and hence engender different practices (Healy and Fernandes, 2011, Healy and Powell, in press). Although he did not discuss mathematical practices in particular, we believe that his view can be applied in the case of learners with difficulties in mathematics learning – rather than concentrating on the development of batteries of tests for diagnosing a particular disorder, what his work suggests might be more useful is investigating differences in responses to different ways of presenting and working with mathematical ideas.

To end this section, we consider briefly the position of another Soviet psychologist, Luria, in relation to understanding intellectual processes and their development. Luria is known for his work with brain-injured individuals, and for his attempts to understand the mechanisms of the brain in the light of the historical and cultural organisation of society. In his investigations of the socio-historical formation of mental processes in the 1930s, he worked with habitants of Uzbekistan and Kirgizia. In these studies, he explained that "the administration of isolated "tests", however, could lead to results that are not representative of the true capabilities of individuals" (Luria, 1990, p. 31). Instead he opted for sessions involving long conversations with his subjects, generally conducted with groups. In these conversations, all participants could intervene, the problems could be resolved by more than one individual and various answers could be proposed. In this context, the researcher would gradually introduce new issues, elaborated to stimulate new questions or debates, leading in turn to new answers, "without interrupting the flow of free exchange of ideas" (Luria, 1990, p. 32).

Another concern of Luria's related to the content of the tasks presented to the participants. According to him "it would be foolish to propose problems which could be considered without meaning to the individuals" (Luria, 1990, p. 32) and that using "tests developed and validated by other cultures would produce repeated failures, compromising our aims" (Luria, 1990, p. 32). Thus, he affirmed,

> *We don't use standardised psychometric tests; we work exclusively with specially developed tests, tests with meaning for the individuals and open to diverse solutions, each one of them indicating some aspect of cognitive activity. For example, the studies of generalization were elaborated so as to permit both graphical-functional, situational solutions and abstract categorical ones. The individual could solve problems involving deductive reasoning by using the available practical experiences as well as solving them by transferring them to situations beyond the limits of experience. The openness of the problems to diverse solutions permits a qualitative analysis of the results. (Luria, 1990, p. 32)*

It is perhaps a little ironic given this quote that, while Luria chose to use open-ended qualitative approaches in his attempts to develop a model for understanding brain functions, after his death an instrument was developed which attempted to combine features associated with his model with a psychometric approach (Golden, Hammeke and Purisch, 1979). Indeed it is a version of this standardised instrument that Bernardi (2006) chose to apply in her research. Perhaps, the desire to standardise and quantify the qualitative methods favoured by Luria is a continuing illustration of the differences between North American approaches and those of the Soviet researchers. Whatever the case, the resulting standardised psychometric battery has been criticised as removing much of the richness that was the essence of Luria's work (Tupper, 1999).

As we reflect on contrasting positions about the use of standardized tests, we suggest that the Brazilian works we surveyed appear to correspond more closely to the North American desire of classifying the learner essentially on the basis of static assessments of what he or she cannot do, rather than with the more dynamic approach of historical-cultural psychology, which seeks rather to understand the (multiple) routes by which the learner might achieve his or her full potential.

This leads us to a final comment on diagnosis. Currently, it is behaviour-based tests rather than evidence from neuroscientific techniques such as brain-imagining that determine whether an individual is described as having dyscalculia or not. It would be a shame if, as the nature of the evidence obtained by these techniques becomes increasingly more precise, they are employed only – or even mainly – to explore the learners actual level of development. Rather, we would hope that some of the messages from historical-cultural psychology might contribute to approaches to neuropsychology which respect Luria's desire to understand how the development of the intellect requires the interaction of developing neurological resources with stimuli of a cultural, historical and social nature.

Models of difference not deficits

In this paper, we have attempted to survey approaches to understanding specific learning difficulties in mathematics and especially those approaches which have associated these difficulties with dyscalculia. Our starting point was a sample of research works developed in Brazil which addressed this condition. We have argued that these works promote an essentially deficit model of learners, according to which some individuals have difficulties with specific aspects of mathematics because their cerebral structures deviate from the norm – or to put it rather simply and bluntly, they have something wrong with their brains.

As an alternative to this deficit model, we have also highlighted a rather different approach which began its development in the Soviet Union in the 1920s and 1930s. The approach centres on identifying qualitative differences mediated by cultural, historical and social resources, alongside biogenetic and neurological ones, rather than on measuring quantitative performance differences among and between different groups through assessment tools geared to idealised norms.

We mentioned above Leontiev's misgivings about defining children according to supposed "norms". Similar misgivings can also be identified in more contemporary writing related to low achievement and learning difficulties. Magne (2003), for example, argues that low achievement is a social construct, "not a fact but a human interpretation of relations between the individual and the environment" (p. 9). Gervasoni and Lindenstov (2011) also agree, stressing the influence of the mathematics background against which achievement is being assessed. For them, low achievers in mathematics are those "who underperform in mathematics due to their explicit or implicit exclusion from the type of mathematics learning and teaching environment required to maximize their potential and enable them to thrive mathematically" (p. 308).

In this vein, the view we have attempted to explore in this paper is that gaining the label as a low achiever in mathematics, or as dycalculic, is not simply the inevitable result of some static characteristic of a certain group of individuals. It also involves the complex set of social, political, economic and psychological practices that determine what come to be seen as the dominant norms of a particular society. Indeed, we have seen that diagnosing a learner as dyscalculic currently involves determining "normal" or "ideal" achievement, and positioning those that deviate from this norm as problematic and in need of remediation.

Who is it that gains most from this labelling? Is it the learner or is it the educational institution responsible for his or her development? For Borgioli (2008), while exclusively brain-based explanations prevail, it is the institution, rather than the learner, which benefits most from the labelling, since “locating the obstacle within the brains of the individual offers a convenient explanation for student failure” (p. 137). Perhaps worse still, the process of “othering”, that is of, framing students who differ from the socially and politically defined norms as deviant or damaged, can have the effect of perpetuating inequitable practices, and of legitimising the exclusion of those who come to be seen as lacking. It is for this reason that we believe that we should stop equating difference with deficiency and seek to better understand the interdependence between individual, social and cultural factors in the development of mathematical practices.

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