Research in Developmental Disabilities 35 (2014) 27–35

Contents lists available at ScienceDirect

Research in Developmental Disabilities

Enumeration of small and large numerosities in adolescents with mathematical learning disorders☆

Annelies Ceulemans [a,*], Daisy Titeca [a], Tom Loeys [b], Karel Hoppenbrouwers [c], Sofie Rousseau [d], Annemie Desoete [a,e]

[a] Department of Experimental Clinical and Health Psychology, Ghent University, Ghent, Belgium
[b] Department of Data Analysis, Ghent University, Ghent, Belgium
[c] Centre for Youth Health Care, Catholic University of Louvain, Louvain, Belgium
[d] Parenting and Special Education Research Unit, Catholic University of Louvain, Louvain, Belgium
[e] Department of Speech Therapists, Artevelde University College, Ghent, Belgium

ARTICLE INFO

Article history:
Received 10 June 2013
Received in revised form 13 October 2013
Accepted 14 October 2013
Available online 9 November 2013

Keywords:
Enumeration
Subitizing
Speed
Accuracy
Mathematical learning disorders

ABSTRACT

The accuracy and speed in an enumeration task were investigated in adolescents with typical and atypically poor development of arithmetic skills. The number naming performances on small and large non-symbolic numerosities of 18 adolescents with mathematical learning disorders (MLD) and 28 typically achieving age-matched (TA) adolescents were compared. A mixed logistic regression model showed that adolescents with MLD were not significantly less accurate on numbers within the subitizing range than control peers. Moreover, no significant differences in reaction times were found between both groups. Nevertheless, we found that within the control group adolescents with higher ability tended to respond faster when taking into account the whole range (1–9) of numerosities. This correlation was much weaker in the MLD group. When looking more closely at the data, however, it became clear that the correlation between accuracy and speed within the control group differed in direction dependent on the range (subitizing or counting) of the numerosities. As such, our findings did not support a limited capacity of subitizing in MLD. However, the data stressed a different correlation between speed and accuracy for both groups of adolescents and a different behavioral pattern depending on the numerosity range as well. Implications for the understanding and approach of MLD are considered.

1. Introduction

Mathematical literacy is important in our society (e.g., Vanmeirhaeghe, 2012). Numbers and mathematics are inherently present in everyday life; each day we are confronted with it while paying in the shop, baking a cake, traveling by train . . .. However, it is a fact that in some children determining numerosity ‘gives stress’ (e.g., Vanmeirhaeghe, 2012). Although specific mathematical learning disorders (MLD) have serious educational consequences, this area has received less attention than it deserves contrary to specific reading disorders (Dowker, 2005; Tymms, 1999). The estimated prevalence of MLD lies

* Corresponding author at: Department of Experimental Clinical and Health Psychology, Henri Dunantlaan 2, 9000 Ghent, Belgium. Tel.: +32 9 264 94 14; fax: +32 9 264 64 89.
E-mail addresses: Annelies.Ceulemans@UGent.be (A. Ceulemans), Daisy.Titeca@UGent.be (D. Titeca), Tom.Loeys@UGent.be (T. Loeys), karel.hoppenbrouwers@med.kuleuven.be (K. Hoppenbrouwers), sofie.rousseau@ppw.kuleuven.be (S. Rousseau), Annemie.Desoete@UGent.be (A. Desoete).

0891-4222/$ – see front matter © 2013 The Authors. Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ridd.2013.10.018

between 3% and 14% of the population depending on the country of study and the used criteria (American Psychiatric Association (APA), 2013; Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2005; Dowker, 2005; Shalev, Manor, & Gross-Tsur, 2005).

In the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM-5; APA, 2013), the term MLD refers to the specific learning disorder with a significant degree of impairment in mathematics, manifesting itself in difficulties with mastering number facts, mathematical reasoning or calculation skills. In accordance with the definition in the DSM-5 (APA, 2013) as described below, three criteria are used to determine whether a child has a clinical diagnosis of MLD, namely the severeness criterion, the resistance criterion and the exclusion criterion (Fuchs et al., 2007). The mathematics abilities of individuals with MLD situate themselves substantially and quantifiably below those expected for the individual's chronological age, causing interference with academic performance (APA, 2013). This is known as the severeness criterion (Fuchs et al., 2007). In addition, the symptoms persist for at least 6 months despite the provision of interventions that target the specific difficulties (APA, 2013). This is referred to as the resistance criterion or a lack of responsiveness to intervention (RTI; Fuchs et al., 2007). Finally, the MLD related problems cannot be better accounted for by intellectual disabilities or external factors (such as inadequate educational instruction) that could provide sufficient evidence for scholastic failure (APA, 2013), also known as the exclusion criterion (Fuchs et al., 2007).

There are several models trying to describe or explain the mechanisms underlying quantity processing deficits in children with MLD. Some models focus on immature counting and calculation strategies, deficits in working memory or retrieving from semantic long term memory, problems with visual spatial elaboration, and executive deficits (e.g., Geary, 2011; Passolunghi & Siegel, 2004). However, other researchers consider the above mentioned deficits as 'higher' order problems of children with MLD resulting from a 'low-level' deficient or imprecise number representation (e.g., Butterworth, 2005a,b; Butterworth, Varma, & Laurillard, 2011). From this perspective, MLD is the result of a specific disability in basic numerical processing rather than the consequence of a deficit in other cognitive abilities such as outlined above (e.g., Landerl, Bevan, & Butterworth, 2004; Noël & Rousselle, 2011).

Within the field of MLD, subitizing or the rapid (40–100 ms/item), automatic and accurate assessment of small quantities of up to three (or four) items (Kaufman, Lord, Reese, & Volkmann, 1949; Koontz & Berch, 1996; Trick & Pylyshyn, 1993) is investigated as a core deficit in this basic numerical processing (e.g., Fischer, Gebhardt, & Hartnegg, 2008; Schleifer & Landerl, 2011). According to some studies, children with MLD serially count items within the subitizing range, while typically achieving (TA) children subitize the same amount of items (e.g., Bruandet, Molko, Cohen, & Dehaene, 2004; Butterworth, 1999; Moeller, Neuburger, Kaufmann, Landerl, & Nuerk, 2009). Although it is demonstrated that children with MLD are slower in subitizing tasks compared to TA children (e.g., Koontz & Berch, 1996; Landerl et al., 2004; Schleifer & Landerl, 2011), there is no consensus on this 'subitizing problem' since some studies do not support children with MLD being slower on small numbers (De Smedt & Gilmore, 2011; Rousselle & Noël, 2007). In addition, some studies revealed that, indeed, some of the children with MLD (but not all of them) have subitizing problems. Desoete and Grégoire (2006), for example, found a subitizing deficit in 33% of the children of 8.5 years old with a clinical diagnosis of MLD. Fischer et al. (2008) found that between 43% and 79% of the subjects in the age range of 7–17 years with MLD performed below the 16th percentile of the peer control groups on subitizing tasks.

In the above mentioned studies different tasks were used, making studies difficult to compare. In some studies, stimuli were presented during a short time span, disabling counting and urging subjects to use subitizing (e.g., Fischer et al., 2008). In other studies, subjects were allowed to count as stimuli were shown until a response was given (e.g., Moeller et al., 2009). Although the former method is the best way to assess rapid enumeration of a small set of items without counting, the latter is used more often.

This study aims to enlarge the knowledge about subitizing in MLD using an enumeration task presenting numerosities (up till nine) only for a short time to MLD and TA adolescents. The main question is whether these groups differ in accuracy and reaction time for either small (up till four) or larger numbers (from five to nine). In line with Fischer et al. (2008), who used a similar task to investigate enumeration in subjects with and without MLD (age 7–17 years), it is expected that the MLD group will perform both slower and less accurate than the TA group, especially regarding the small numbers within the subitizing range.

2. Method

2.1. Participants and procedure

Participants were 18 adolescents with MLD and 28 TA adolescents between 13 and 16 years old. Age, IQ and gender of the subjects are described in Table 1. As shown in this table, no significant differences in age ($p = .482$) or gender ($p = .953$) were found between the groups. However, there was a significant difference in intelligence between the groups ($p = .002$).

All subjects were living in Flanders, the Dutch speaking part of Belgium. About half of the 46 participants were a subsample of a larger cohort study of JOnG!, from which this study is only one part. The cohort study was carried out by the universities of Ghent and Louvain at the request of the Belgian government (http://www.steunpuntwvg.be/jong). For information about the larger study design see Grietens, Hoppenbrouwers, Desoete, Wiersema, and Van Leeuwen (2010). Additional adolescents ($n = 22$) for the current study were recruited from mainstream and special education schools and an informed consent was obtained for each participant. The present study – as part of the larger study – was approved by the