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Alphanumeric and non-alphanumeric Rapid Automatized Naming in children with reading and/or spelling difficulties and mathematical difficulties

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ABSTRACT

Although poor Rapid Automatized Naming (RAN) is a risk factor for reading and/or spelling difficulties (RSD) as well as for mathematical difficulties (MD), many questions surround this relationship. The main objective of the present study was to obtain insight in the relationship between alphanumeric vs. non-alphanumeric RAN and reading/spelling and mathematics in groups of 7-to-10-year-old children with RSD, MD, both RSD + MD, and in typically developing (TD) children. Analyses of variance between the groups showed that the RSD and comorbid (RSD + MD) groups were impaired on both alphanumeric and non-alphanumeric RAN, whereas the MD group was impaired only on non-alphanumeric RAN. Furthermore, non-alphanumeric RAN correlated with all measures except spelling, whereas alphanumeric RAN correlated with the reading and spelling measures only. These findings point towards different/additional cognitive processes needed in non-alphanumeric RAN compared to alphanumeric RAN, which affects the relationship with literacy and math.

1. Introduction

The high comorbidity between reading and/or spelling difficulty (RSD) and mathematical learning difficulty (MD; e.g., Badian, 1999; Kovas et al., 2007; Landerl & Moll, 2010) makes research on the cognitive underpinnings of both an important subject of research. RSD (or dyslexia) is characterized by severe and persistent reading and/or spelling difficulties at word level (Snowling, 2000). MD (or dyscalculia) is defined as a severe and persistent problem in learning and quickly and/or accurately retrieving or applying mathematical knowledge (Ruijssenaars, Van Luit, & Van Lieshout, 2006). Studies describing the relationship between RSD and MD report two different conclusions regarding the shared underlying causes. One finding is that the cognitive profiles of children with RSD and children with MD seem to be largely different (e.g. Landerl, Fussenegger, Moll, & Willburger, 2009; Rubinsten & Henik, 2006; Tressoldi, Rosati, & Lucangeli, 2007; Willburger, Fussenegger, Moll, Wood, & Landerl, 2008). Another is that RSD and MD are linked and share some common underlying etiology (e.g. Simmons & Singleton, 2009; Vukovic, Lesaux, & Siegel, 2010; Willcutt et al., 2013). The present exploratory study contributes to this discussion by examining the role of one of the most promising candidates for explaining the overlap between RSD and MD: Rapid Automatized Naming (RAN). RAN is the ability to quickly retrieve and provide the names of highly familiar symbols (colors, pictures, digits, and letters; as designed by Denckla & Rudel, 1974).

Multiple issues surround the relationship between RSD, MD, and RAN. They are broadly divided into two clusters. The first issue pertains to the question which cognitive processes underlie RAN. In the field of literacy, some researchers have proposed that RAN is related to phonological processing. Within this view, one interpretation is that RAN mainly reflects the ability to access and rapidly retrieve phonological representations of orthographic codes from long-term memory (e.g. Bowey, McGuigan, & Ruschena, 2005; Lervåg & Hulme, 2009; Snowling, 2001; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997). Others have purported that RAN predominantly taps skills related to rapid integration of phonological and visual processes (Manis, Seidenberg, & Doi, 1999; Wolf & Bowers, 1999; Wolf & Denckla, 2005), relevant for both orthographic and numeric representations (Georgiou, Tziraki, Manolitsis, & Fella, 2013). Related, RAN has been interpreted as measuring phonological processing speed combined with fast cross-modal matching of visual symbols and phonological codes (Vaessen, Gerretsen, & Blomert, 2009). In contrast to these phonology-related interpretations, it has also been proposed that poor RAN reflects a general access deficit in dyslexia (Jones, Branigan, Hatzidaki, & Obregón, 2010). This debate has not been settled yet, as research outcomes do not refute or fully endorse one single interpretation of RAN. Yet, it seems that many different cognitive skills are involved in

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RAN, including general processing speed (e.g. Georgiou et al., 2013; Kail & Hall, 1994; Van Daal, Van der Leij, & Adèr, 2013), attentional, visual, lexical, temporal, and recognition sub-processes (Wolf & Bowers, 1999; Wolf & Denckla, 2005).

In line with this ongoing discussion, the interpretation of the cognitive processes underlying RAN is also influenced by the design of the measure and therefore partly dependent on task format (e.g., De Jong, 2011). An important and influential task characteristic concerns the type of symbols that have to be named: naming of colors, pictures, digits, and letters. A distinction has been made between alphanumeric symbols (digits and letters) and non-alphanumeric symbols (colors and pictures; e.g., Närhi et al., 2005; Savage, Pillay, & Melidona, 2008; Van den Bos, Zijlstra, & Van den Broeck, 2003). The naming of digits and letters might require mainly phonological processing: the corresponding verbal codes of these stimuli are readily accessible at surface level. Naming of colors and pictures seems to demand additional steps. These stimuli might also require conceptual processing to establish *meaning* and subsequently the selection of the *appropriate* name code, before phonological processing results in articulating a response (Poulsen & Elbro, 2013; Theios & Amrhein, 1989).

This distinction relates to the second major issue, concerning the relations between RAN, RSD, and MD, specifically, whether the relationship with RAN is the same for both disorders. Studies show that children with either RSD or MD on average show lower scores on RAN outcomes than children without such difficulties (e.g. Cardoso-Martins & Pennington, 2004; Frijters et al., 2011; Mazzocco & Grimm, 2013; Van den Bos, Zijlstra, & Lutje Spelberg, 2002). Furthermore, research has compellingly shown that RAN is associated with and predictive of RSD (for a review of this research, see Kirby, Georgiou, Martinussen, & Parrila, 2010; Norton & Wolf, 2012). Although results regarding MD are more limited, several studies have found significant relations between RAN and MD (see Bull & Johnston, 1997; Chard et al., 2005; Landerl, Bevan, & Butterworth, 2004; Van der Sluis, De Jong, & Van der Leij, 2004). Further research is needed, as the relationship between RAN and mathematics might be partly different than between RAN and literacy, although this might be dependent on the type of RAN, which we turn to below.

With respect to reading, multiple studies have shown that alphanumeric RAN is a better predictor of reading outcomes than non-alphanumeric RAN, both in the general population and in differentiating between normal and poor readers (Bowey et al., 2005; Cardoso-Martins & Pennington, 2004; Heikkilä, Närhi, Aro, & Ahonen, 2009; Schatschneider, Carlson, Francis, Foorman, & Fletcher, 2002; Van den Bos et al., 2002, 2003; Wolf & Bowers, 1999). Non-alphanumeric RAN is an important predictor of (variation in) later reading in young children (prereaders), but at later ages this influence shifts to alphanumeric RAN (e.g. De Jong & Van der Leij, 1999; Kirby, Parrila, & Pfeiffer, 2003; Lervåg & Hulme, 2009). The increased automaticity of the print-to-sound translation typically targeted in alphanumeric RAN might relate to increased reading fluency. In other words, alphanumeric RAN becomes more strongly related to reading ability when children are increasingly exposed to digits and letters during formal instruction (Norton & Wolf, 2012). Because children are less intensively exposed to the non-alphanumeric stimuli, it is plausible that these do not become automatized in the same pace. The faster naming of stimuli that are more practiced than less-practiced stimuli is also shown by Pan, Yan, Laubrock, Shu, and Kliegl (2013), who studied digit naming versus dice pattern naming. On the basis of these findings, alphanumeric RAN has been proposed to serve as a 'microcosm' for reading (for an overview, see Norton & Wolf, 2012). In this view, the degree of automaticity is important; for typically developing readers it is easier to construct efficient pathways connecting more frequent visual symbols and their sounds, such as letters and digits, than those that are less frequent, such as colors and pictures. Children with RSD have more difficulties with this automaticity and therefore show slower performance on RAN digits and letters (Norton & Wolf, 2012).

The present study has assessed the relationship between spelling and RAN in addition to reading and RAN. In The Netherlands, the official guidelines prescribe that dyslexia must be diagnosed based on reading and/or spelling performance (see Blomert, 2013; Kleijnen et al., 2008; and Method). Although the literature has shown a relationship with reading difficulties, the relationship between spelling and RAN is not as clear-cut. Some studies have shown that alphanumeric RAN predicted later spelling skills after controlling for other relevant variables, such as initial reading skills, age, and IQ (e.g. Cardoso-Martins & Pennington, 2004; Furnes & Samuelsson, 2011; Savage et al., 2008). Other studies found that non-alphanumeric RAN predicted early spelling skills (e.g. Caravolas et al., 2012; Lervåg & Hulme, 2010). However, studies focusing on more consistent orthographies failed to find a longitudinal predictive relation between RAN and spelling acquisition (e.g., Landerl & Wimmer, 2008).

With respect to math, we are not aware of any studies specifically investigating the distinction between non-alphanumeric and alphanumeric RAN in relation to mathematical ability in general. Although some studies reported domain-specific deficits in alphanumeric RAN for children with MD, and in the rapid naming of digits in specific (Landerl et al., 2004; Van der Sluis et al., 2004), other studies did not find such a weakness (Landerl et al., 2009; Moll, Göbel, & Snowling, 2015). These differences may be explained by the types of mathematical difficulties exhibited by the MD groups, since the nature of mathematical difficulties might have an effect on how RAN is influenced. Moll et al. (2015) argued that mathematical problems can arise from either phonological weaknesses or number processing weaknesses. Children with phonological weaknesses especially show difficulties in mathematical tasks that involve reading, hence phonological processing, such as word problem solving. The performance of these children on RAN tasks might be more comparable to children with RSD. However, children with MD with a specific weakness in number processing seem to have difficulty with accessing quantities represented by digits, rather than quick access to digit words (Landerl et al., 2009). This relates to a domain-specific deficit in naming quantities, but not in the naming of digit words and pictures (Willburger et al., 2008).

A different interpretation for the findings on RAN and mathematics has been made by Georgiou et al. (2013), who suggest that the quality of visual–verbal associations may not be as important for mathematics as for reading, and that it might mainly be the processing speed element that is defective, as children with MD are thought to suffer from a deficit in the speed of activating information from long-term memory (D'Amico & Passolunghi, 2009). Such an interpretation would relate to either general RAN difficulties, or to non-alphanumeric RAN difficulties because these stimuli seem to require conceptual processing to establish meaning and the appropriate name code in addition to phonological processing (Poulsen & Elbro, 2013; Theios & Amrhein, 1989). The relationship between mathematics and (non-)alphanumeric RAN might thus be dependent on the specific mathematical problems of the participants. Furthermore, RAN performance might reflect different underlying abilities in MD than in RSD.

On the basis of the literature on RSD and MD, RAN difficulties can be expected for both children with RSD and MD. Yet, for children with RSD alphanumeric difficulties might be more prominent, whereas for those with MD either general RAN difficulties or specific non-alphanumeric difficulties might be found. Several studies have shown that children with both RSD and MD have more severe and broader RAN deficits than those with only one disability (D'Amico & Passolunghi, 2009; Moll et al., 2014; Van der Sluis et al., 2004; Willburger et al., 2008). However, only a few studies have looked at the individual types of stimuli and assessed the type of RAN-deficits in RSD and MD as well as RSD + MD groups separately. Pauly et al. (2011) and Willburger et al. (2008) reported a domain-general naming deficit, including both alphanumeric (digits and letters) and non-alphanumeric RAN (pictures), in children with comorbid RSD and MD as well as in children with RSD.