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Preschool predictors of mathematics in first grade children with autism spectrum disorder

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ABSTRACT

Up till now, research evidence on the mathematical abilities of children with autism spectrum disorder (ASD) has been scarce and provided mixed results. The current study examined the predictive value of five early numerical competencies for four domains of mathematics in first grade. Thirty-three high-functioning children with ASD were followed up from preschool to first grade and compared with 54 typically developing children, as well as with normed samples in first grade. Five early numerical competencies were tested in preschool (5–6 years): verbal subitizing, counting, magnitude comparison, estimation, and arithmetic operations. Four domains of mathematics were used as outcome variables in first grade (6–7 years): procedural calculation, number fact retrieval, word/language problems, and time-related competences. Children with ASD showed similar early numerical competencies at preschool age as typically developing children. Moreover, they scored average on number fact retrieval and time-related competences and higher on procedural calculation and word/language problems compared to the normed population in first grade. When predicting first grade mathematics performance in children with ASD, both verbal subitizing and counting seemed to be important to evaluate at preschool age. Verbal subitizing had a higher predictive value in children with ASD than in typically developing children. Whereas verbal subitizing was predictive for procedural calculation, number fact retrieval, and word/language problems, counting was predictive for procedural calculation and, to a lesser extent, number fact retrieval. Implications and directions for future research are discussed.

1. Introduction

Autism spectrum disorders (ASD) are characterized by persistent deficits in social communication and social interaction, together with restrictive, repetitive patterns of behaviour, interests or activities (American Psychiatric Association [APA], 2013). Despite the predominant clinical focus on the social-communicative impairments in children with ASD, interest in the academic functioning of these children has grown more recently (Tincani, 2007; Whitby & Mancil,

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2009). Indeed, when tackling the issue of educational inclusion of children with ASD, it is important to gain insight into their academic strengths or needs. Even though a large part of children with ASD are defined as "high-functioning" (i.e., displaying an IQ score of at least 70), appropriate support or accommodation might still be needed to reach their full potential (Whitby & Mancil, 2009). Regarding the field of mathematics, teachers and therapists often consider mathematics as one of the difficult subject matters for children with ASD (Department for Education and Skills, 2001; van Luit, Caspers, & Karelse, 2006). However, the amount of research on this topic does not match their concern. Not only are studies on mathematics in children with ASD scarce, the few existing studies focus on different aspects of the topic: mathematical processes (e.g., Gagnon, Mottron, Bherer, & Joanette, 2004) versus mathematical outcomes (e.g., Chiang & Lin, 2007) or within-group (mathematical abilities relative to own cognitive abilities; e.g., Mayes & Calhoun, 2003) versus between-group (mathematical abilities of children with ASD compared with typically developing children; e.g., Iuculano et al., 2014) analyses or comorbidity studies (e.g., Mayes & Calhoun, 2006). When consulting existing literature, two opposite views emerge. First of all, anecdotal and descriptive research (Baron-Cohen, Wheelwright, Burtenshaw, & Hobson, 2007; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001; Sacks, 1986) as well as some empirical studies (Iuculano et al., 2014; Jones et al., 2009) have put forward that children with ASD show enhanced mathematics compared to their typically developing (TD) peers. In contrast, other empirical studies such as comorbidity studies (Mayes & Calhoun, 2006; Reitzel & Szatmari, 2003) and some within-group studies (Chiang & Lin, 2007; Mayes & Calhoun, 2003) suggest mathematical problems in children with ASD.

A limitation of the aforementioned research is the cross-sectional nature of these studies (e.g., Iuculano et al., 2014; Jones et al., 2009; Mayes & Calhoun, 2003). Recently, a longitudinal study examined the reading and mathematics profiles and their growth trajectories in children with ASD (Wei, Christiano, Yu, Wagner, & Spiker, 2014). However, despite the identification of several early numerical competencies of preschoolers as strong predictors of later mathematical abilities (e.g., DiPema, Lei, & Reid, 2007; Duncan et al., 2007; Kroesbergen, Van Luit, & Aunio, 2012; Locuniak & Jordan, 2008), the predictive value of these early numerical competencies for later mathematical abilities in children with ASD remains unexplored as yet.

1.1. The importance of early numerical competencies for later mathematics

Jordan and Levine (2009) identified five early numerical competencies, namely verbal subitizing, counting abilities, magnitude comparison, estimation, and arithmetic operations. *Verbal subitizing* can be described as the rapid (40–100 ms/item), automatic and accurate enumeration of small quantities of up to three (or four) items (Kaufman, Lord, Reese, & Volkmann, 1949). Several studies demonstrated that subitizing is an important factor in mathematical development (Landerl, Bevan, & Butterworth, 2004; Penner-Wilger et al., 2007; Traff, 2013), and longitudinal research demonstrated that subitizing is a domain-specific predictor for later mathematical performance over and above domain-general abilities (Krajewski & Schneider, 2009; Kroesbergen, Van Luit, Van Lieshout, Van Loosbroek, & Van de Rijt, 2009; LeFevre et al., 2010; Reigosa-Crespo et al., 2012). *Counting* has also proven to be of central influence for the development of adequate mathematical abilities (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Fuson, 1988; Le Corre, Van de Walle, Brannon, & Carey, 2006; Passolunghi, Vercelloni, & Schadee, 2007; Wynn, 1990). Whereas procedural counting knowledge (the ability to perform a counting task) has proven to be predictive for numerical facility, conceptual counting knowledge (the understanding of why a procedure works or is legitimate) is predictive for untimed mathematical achievement (Desoete, Stock, Schepens, Baeyens, & Roeyers, 2009; LeFevre et al., 2006). *Magnitude comparison* is the ability to discriminate two quantities in order to point out the largest of both (Gersten et al., 2012). Although number comparison has proven to play an important role in the development of mathematical abilities (De Smedt, Verschaffel, & Ghesquiere, 2009; Holloway & Ansari, 2009; Jordan, Glutting, & Ramineni, 2010), there is still debate on whether non-symbolic number comparison as well as symbolic number comparison performance relates to later mathematics. Whereas some researchers state it does (Halberda, Mazzocco, & Feigenson, 2008; Libertus, Feigenson, & Halberda, 2013; Mazzocco, Feigenson, & Halberda, 2011), others endorse only the contribution of symbolic number comparison (Bartelet, Vaessen, Blomert, & Ansari, 2014; Holloway & Ansari, 2009; Sasanguie, De Smedt, Defever, & Reynvoet, 2012; Sasanguie, Gobel, Moll, Smets, & Reynvoet, 2013). *Estimation* is often assessed using a number line task (Booth & Siegler, 2006; Siegler & Booth, 2004; Siegler & Opfer, 2003). Several studies indicated that the linearity of number line judgments is positively correlated with math achievement scores (Ashcraft & Moore, 2012; Siegler & Booth, 2004). Moreover, estimation accuracy (measured with mean percentages of error on the number line estimation task) has proven to be a unique predictor of mathematical achievement later on, next to the predictive role of linearity (Sasanguie et al., 2012, 2013). Finally, *arithmetic operations* involve the ability to perform basic addition and subtraction transformation exercises (Purpura & Lonigan, 2013). Arithmetic operations, as part of a larger early numerical competencies battery, have proven to be predictive for later mathematical abilities, especially for applied problem solving (Jordan et al., 2010).

This short overview demonstrates that early numerical competencies are the first mathematical building blocks on which later mathematics is built (Berch, 2005; Geary, 2000; Jordan et al., 2010). However, two remarks should be made. On the one hand, a lot of studies incorporate only one of the early numerical competencies, relating it to one outcome score for mathematics (e.g., De Smedt et al., 2009; LeFevre et al., 2006; Siegler & Booth, 2004). On the other hand, many studies combine domain-specific and domain-general factors in one study, investigating the relative contribution of these categories without making a distinction between numerical competencies (Jordan, Kaplan, Locuniak, & Ramineni, 2007;