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Reading and math abilities of Finnish school beginners born very preterm or with very low birth weight

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ABSTRACT

Reading and math skills of preterm born (birth weight ≤ 1500 g or gestational age ≤ 32 weeks) children and full-term (FT) children were compared during the first weeks of grade 1. The participants were 194 preterm born and 175 FT children born between 2001 and 2006.
There were more precocious readers among FT than among preterm students, but even the latter performed close to the national norm. FT and preterm group differences among non-readers were minor with only rapid naming showing a robust difference. Math performance showed a stable difference in favor of FT students and the difference was sustained in the full-scale IQ control. Major brain pathology increased the likelihood of poor scholastic skills, but lower birth weight relative to gestational age did not. Somewhat surprisingly, maternal education was not associated with school readiness skills.

1. Introduction

It is well established that children born very preterm meet difficulties in their general cognitive development (Aylward, 2002; Hornby & Woodward, 2009; Johnson, Wolke, Hennessy, & Marlow, 2011). By definition, a birth before 37 weeks' gestation is labelled as 'preterm'. However, the lower the gestational age is, the higher is the risk for a wide range of developmental problems (for a review, see Anderson, 2014; for a succinct presentation of relevant terms, see Tucker & McGuire, 2004). Many studies and clinical follow-up programs have chosen the cut-off of 32 gestational weeks, usually referred to as 'very low gestational age' or 'very preterm' as opposed to 'extremely preterm' referring to infants born before 28 weeks' gestation, even if more mature preterm infants also have an increased risk for developmental problems compared to full term infants. Moreover, poor intrauterine growth is also a risk for development (Guellec et al., 2016), which justifies using a birth weight limit regardless of gestational age for choosing a high-risk group. Birth weight below 1500 g, usually referred to as 'very low birth weight', or that under 1000 g ('extremely low birth weight') put an infant to a risk for developmental problems even during modern neonatology with much improved prospects with preterm infants compared to earlier decades (Gardella et al., 2015). Many preterm born children start school with special educational needs (Hornby & Woodward, 2009; Litt, Taylor, Klein, & Hack, 2005; Sucksdorff et al., 2015), with these needs tending to increase along with a shorter gestational age or a more severe growth restriction (Larroque et al., 2011).

Among the prime consequences of preterm birth, a compromised cognitive development has been identified. Children born very preterm have a lower IQ than their full term peers (Saigal, Hoult, Streiner, Stoskopf, & Rosenbaum, 2000; Schneider, Wolke, Schlagmüller, & Meyer, 2004), the difference being roughly one standard deviation (Breeman, Jaekel, Baumann, Bartmann, & Wolke, 2015; Schneider et al., 2004; Stjernqvist & Svenningsen, 1999). While the association between global IQ and school achievement is well known, the usefulness of IQ as a predictor of learning difficulties has recently been called into question. First, the risk factors for prematurity may differ in different societies. In societies with a strong link between social risk and preterm birth, the growth environment is also likely to affect the occurrence of learning difficulties in addition to the biological, prematurity related

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origins affecting brain development (Gray, Edwards, Schultz, & Miranda, 2014). Second, preterm birth was associated with adolescents' cognitive profile only in cases of severe antenatal growth restriction or the lowest gestational age (Lundequist, Böhm, Lagercrantz, Forssberg, & Smedler, 2015). Third, a recent meta-analysis suggests that a lower birth weight is not predictive of global cognitive impairment in children older than five years (Linsell, Malouf, Morris, Kurinczuk, & Marlow, 2015). Fourth, a prediction based on a global measure does not inform teachers of useful interventions (Decker, Hale, & Flanagan, 2013).

Consequently, there is a need for predictive measures that are more focused on cognitive skills important to learning in the first grades in school, in other words, those relevant to learning literacy and math. In this vein, the school readiness of very preterm children can be seen as a useful framework tying together influences of biological risks, possibly impaired cognitive skills and unfavorable environmental factors (Pritchard, Bora, Austin, Levin, & Woodward, 2014). Support has come from recent studies suggesting that extremely preterm children need increased teacher support to compensate for their poor ability to focus on classroom activities (Wong et al., 2014). Moreover, persistent neurological abnormalities during the first year of life predict poorer kindergarten performance in letter–word identification, spelling, and math among extremely preterm children at six years of age (Harmon, Taylor, Minich, Wilson-Costello, & Hack, 2015). However, contrary to research in school-age achievement, studies on the school readiness skills of preterm born children are still scarce.

In the following, we present findings on reading and math difficulties among very preterm children. We also provide a comparative summary in Appendix 1.

1.1. Pre-reading skills and reading development

Consensus prevails that three cognitive skills are paramount to literacy acquisition. Phonological awareness is a bridge between spoken and written language. Letter knowledge reflects a perceived presence of written words in the child's developmental environment. Rapid automatized naming is an indicator of the effectiveness of verbal information processing. Obviously, the prognostic testing should be conducted before formal teaching of reading, preferably no later than during the fall term of Grade 1. All three factors strongly differentiate, for example, pre-schoolers with a familial risk for dyslexia from children not at risk, starting from the age of 3.5 years (Puolakanaho et al., 2008). Analogously, preterm born children may be supposed to run a similar risk.

Available evidence suggests that five to six-year-old, very preterm children perform less well than full-term children in letter knowledge and phonological skills (Lundequist et al., 2015; Munck et al., 2012; Stjernqvist & Svenningsen, 1999; Taylor et al., 2011; Wolke, Samara, Bracewell, & Marlow, 2008; Wolke & Meyer, 1999). However, a recent Dutch study alludes to a somewhat different pattern with pre-schoolers showing only a tendency toward an inferiority of the phonological skills among very preterm children (Aarnoudse-Moens, Oosterlaan, Duivenvoorden, van Goudoever, & Weisglas-Kuperus, 2011). Interestingly, when reading has been stabilized by eight years of age and onward, the association between preterm birth and reading deficiency appears to become more diffuse. Some studies report a difference between preterm born and full-term students (Larroque et al., 2011; Lee, Yeatman, Luna, & Feldman, 2011; Pritchard et al., 2014; Samuelsson et al., 2006; Schneider et al., 2004; Wocadlo & Rieger, 2007), while in others no difference has been found (Anderson & Doyle, 2003; Feldman, Lee, Yeatman, & Yeom, 2012; Hagen, Palta, Albanese, & Sadek-Bawawi, 2006; McGrath & Sullivan, 2002; Pritchard et al., 2009; Rickards, Kelly, Doyle, & Callanan, 2001). There are also mixed findings (Aarnoudse-Moens et al., 2011; Guarini et al., 2010). Only in the subgroup of students with extremely low birth weight does the difference occur consistently as shown by recent studies (Hutchinson, De Luca, Doyle, Roberts,, & Anderson, 2013; Johnson et al., 2011; Litt et al., 2012). All things considered, it is reasonable to state that evidence concerning reading development of preterm born children is equivocal.

1.2. Math skills

Symbolic number identification is a foundational skill for basic math in the same way as letter knowledge is that for beginning reading. Its level in kindergarten strongly predicts math achievement in first grade (e.g. Martin, Cirino, Sharp, & Barnes, 2014; Östergren & Träff, 2013). Another set of strong predictors are various counting skills. An example of basic counting is rote verbal counting from number 1 forward. More advanced counting requires knowledge of the number continuum and is needed in basic arithmetic (e.g. Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Nguyen et al., 2016). Counting forward from a given number is involved in basic addition and counting backward from a given number is needed in basic subtraction (e.g. Zhang et al., 2014). Good counting skills are a prerequisite for the development of an arithmetic fact retrieval strategy, which is faster than the mere counting-based strategy (Koponen, Aunola, Ahonen, & Nurmi, 2007). Measurements of number knowledge, counting ability, and arithmetic fact retrieval were available for the present sample. Studies with more covering sets of predictors have found a considerable overlap between them (e.g. Cirino, 2011; Koponen et al., 2007; Nguyen et al., 2016),

There are only few studies focusing on early mathematical skills of very preterm children. It has been suggested that these children cannot name as many number symbols as the control children (Wolke & Meyer, 1999) and they have difficulties in numerical reasoning skills (classifying, sorting, comparing and counting of objects) in preschool (Aarnoudse-Moens et al., 2011). The predictive power of counting skills appears particularly strong in the face of concurrent comparison at 9 years of age, and is sustained even after Bonferroni correction and controlling for nonverbal IQ (Simms et al., 2015).

In contrast to the scarcity of domain-specific predictors acquired prior to formal schooling, there are a number of studies suggesting that children born very preterm demonstrate a poorer school performance in math than their peers (Aarnoudse-Moens et al., 2011; Hagen et al., 2006; Johnson et al., 2011). Overall, math disabilities at all the measured school ages appear to be more severe than reading disabilities in very preterm children (Aarnoudse-Moens, Smidts, Oosterlaan, Duivenvoorden, & Weisglas-Kuperus, 2009; Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009; Aarnoudse-Moens et al., 2011; Anderson & Doyle, 2003; McGrath & Sullivan, 2002; Rickards et al., 2001; Saigal et al., 2000). There is also evidence that among preterm born children, lower birth weight influences math scores with ELBW children being outperformed by their birth weight 1001–1500 g peers (Espy, Fang, Charak, Minich, & Taylor, 2009; Hagen et al., 2006).

1.3. School readiness skills and neonatal brain pathology

In their recent meta-analysis, Linsell et al. (2015) concluded that the role of neonatal brain injury as a prognostic factor for language impairment is equivocal. There is some evidence that among preterm born seven-year-olds, neonatal brain injury is related with processing speed (Murray et al., 2014) as well as with spatial memory and list learning (Omizzolo et al., 2014). Setänen et al. (2013) found that the severity of neonatal brain pathologies was strongly associated with full scale IQ among preterm born five-year-olds. However, gross measures such as these are conceptually remote to foundational reading and math skills. The only study directly bearing on this issue appears to be that of Harmon et al. (2015). The authors found that at six years of age, extremely preterm born children with either transient or persistent neonatal abnormalities showed an impairment in letter and