



Behavioral inhibition in children with learning disabilities



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ABSTRACT

Children with reading disabilities (RD, $n = 17$), mathematical disabilities (MD, $n = 22$), combined reading and mathematical disabilities (RD + MD, $n = 28$) and control peers ($n = 45$) were tested on behavioral inhibition with a Go/no-go task in a picture, letter and digit-modality. In contrast to children without RD, children with RD made significantly more commission errors on alphanumeric (letter and digit) modalities compared to the non-alphanumeric picture modality. As compared to children without MD, children with MD made as much commission errors on the picture modality as on the letter modality. No significant interaction-effect was found between RD and MD. These results can be considered as evidence for behavioral inhibition deficits related to alphanumeric stimuli in children with RD but not in children with MD.

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1. Introduction

1.1. Behavioral inhibition

Executive functions can be described as the general purpose control mechanisms that coordinate, regulate and control cognitive processes during the operation of cognitive tasks (Miyake et al., 2000) and are localized in the central executive control system of working memory (Baddeley, 1986). Among them, behavioral inhibition is seen as one of the most crucial processes (Miyake et al., 2000). According to Nigg's (2000) taxonomy, behavioral inhibition is a type of effortful inhibition, besides interference control, oculomotor and cognitive inhibition. It is considered as the capacity to suppress a prepotent or dominant response and entails the deliberate control of a primary motor response in compliance with changing context cues (Nigg, 2000). Both the Go/no-go (Luce, 1986) and the Stop-signal task (Logan, Cowan, & Davis, 1984) are frequently conducted measures of behavioral inhibition (e.g., Friedman & Miyake, 2004; Purvis & Tannock, 2000).

1.2. Behavioral inhibition in children with reading disabilities

Reading disabilities (RD) are defined as persisting impairments in reading and/or spelling abilities, at a level that remains significantly below expected given the age, and despite good instruction, and that are not explained by extraneous factors, such as sensory deficits (Schatschneider & Torgesen, 2004; Vellutino, Fletcher, Snowling, & Scanlon, 2004). Prevalence of RD is estimated between 5% and 12% (Schumacher, Hoffmann, Schmal, Schulte-Korne, & Nothen, 2007).

Deficits in phonologically related processes are often considered as the core problem of RD (e.g., Vellutino et al., 2004), but impairments in inhibition are reported as well (e.g., de Jong et al., 2009). Theoretical accounts of reading emphasize the

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important role of behavioral inhibition in the reading process (Schmid, Labuhn, & Hasselhorn, 2011). Poor behavioral inhibition may contribute to poor letter and word recognition. For instance, children with RD have to inhibit inadequate grapheme-phoneme correspondences (for instance reading 'p' as 'b' or 'm' as 'n' or 'nam' as 'man'). Failures to inhibit improper (though more dominant) pronunciations might impair word recognition performance in a more profound manner (Chiappe, Hasher, & Siegel, 2000).

In addition, several studies reported behavioral inhibition deficits in children with RD (e.g., de Jong et al., 2009; Purvis & Tannock, 2000; Schoot, Licht, Horsley, & Sergeant, 2000). Research of de Jong et al. (2009) and Purvis and Tannock (2000) revealed that children with RD had an impaired stop signal reaction time in comparison to control children. However, other studies found no differences between both groups (e.g., Reiter, Tucha, & Lange, 2005; Schmid et al., 2011). For instance, Voorde, Roeyers, Verte, and Wiersema (2010) found no behavioral inhibition problems, as measured by a Go/no-go task, in RD when a baseline measure of functioning was taken into account.

To conclude, mixed results largely depending on the paradigm used, were found concerning behavioral inhibition deficits in children with isolated RD. Paradigms used to assess behavioral inhibition sometimes also depend on working memory, making results difficult to interpret.

1.3. Behavioral inhibition in children with mathematical disabilities

Mathematical disabilities (MD) are defined in exactly the same way as RD, but concerning mathematical abilities (Desoete et al., 2013; Geary, Hoard, Nugent, & Bailey, 2011; Landerl, Bevan, & Butterworth, 2004; Passolunghi, Vercelloni, & Schadee, 2007). Most researchers currently report a prevalence of MD between 3% and 14% of children (Barbarelli, Katusic, Colligan, Weaver, & Jacobsen, 2005; Rubinsten & Henik, 2009; Shalev, Manor, & Gross-Tsur, 2005). Recently, Geary (2011) estimated a prevalence of approximately 7% of children.

Besides the important emphasis on number representation (Butterworth, 1999, 2005; Noël & Rouselle, 2011), studies focus on executive functioning as well (Bull & Scerif, 2001; D'Amico & Passolunghi, 2009; De Weerd et al., 2012). Research has shown that inhibition is predictive for mathematical abilities and necessary in math performance for the active suppression of immature or incorrect strategies (Bull & Scerif, 2001). Children with MD and -to a lesser extent- control children might for instance have the tendency to make table-related or counting-string errors (Geary, 2011). Table-related errors are those mistakes that are in fact correct answers to similar problems in the multiplication table (e.g., $3 \times 4 = 15$). A counting-string error can be defined as a wrong answer that follows one of the addends (typically the last one) in the counting string (e.g., $3 + 5 = 6$; Geary, 2011). In contrast to research studying behavioral inhibition in children with RD, to our knowledge, no MD study was conducted with a Stop-signal task and only one study, concerning both ADHD and MD, used a Go/no-go task (Passolunghi, Marzocchi, & Fiorillo, 2005). This study revealed difficulties in inhibiting irrelevant numerical information in solving arithmetic word problems, but did not report any differences between the control children and the children with MD with regard to behavioral inhibition (Passolunghi et al., 2005).

However, some studies investigated prepotent response inhibition in children with MD (Bull & Scerif, 2001; Censabella & Noel, 2005, 2008; van der Sluis, de Jong, & van der Leij, 2004). The prepotent response inhibition of Friedman and Miyake (2004) encloses Nigg's behavioral and oculomotor inhibition. Whereas Nigg (2000) considers the Stroop task (Stroop, 1935) as a measure of interference control, Friedman and Miyake (2004) use this task as a measure of prepotent response inhibition. Results of MD studies using the Stroop task are mixed. Zhang and Wu (2011) reported impairments in children with MD on both a color-word and a numerical Stroop. A study of Bull and Scerif (2001) emphasized a significant correlation between mathematical performance and the level of interference control on a numerical Stroop task (the lower the mathematics ability, the higher the interference). However, no impairments on the numerical Stroop were found by Censabella and Noel (2005), nor by van der Sluis et al. (2004). Moreover, the latter found no impairments on an object version of the Stroop (van der Sluis et al., 2004).

To conclude, studies on behavioral inhibition in children with isolated MD are rare and inconclusive. Paradigms used to assess behavioral inhibition sometimes also depend on other executive functions such as working memory, making results difficult to interpret.

1.4. Comorbidity and shared cognitive risk

Comorbidity can be defined as two or more disorders that co-occur together (Neale & Kendler, 1995). In accordance with Angold, Costello, and Erkanli (1999), we can distinguish homotypic from heterotypic comorbidity. The first form refers to the co-occurrence of two disorders from the same diagnostic grouping (e.g., RD and MD), whereas the latter refers to two or more disorders from different diagnostic groupings (e.g., MD and ADHD; Angold et al., 1999). It is estimated that between 3.4% (Badian, 1999) and 7.6% (Dirks, Spyer, van Lieshout, & de Sonneville, 2008) of the elementary school children suffers from both RD and MD.

Research on comorbidity in developmental disorders seems to evolve from single to multiple deficit models (Pennington, 2006). As a consequence, the focus of studies is changing from searching for one correct comorbidity model (e.g., the phenocopy model, see Neale & Kendler, 1995 and Rhee, Hewitt, Corley, Willcutt, & Pennington, 2005 for an overview of these models) to looking for possible shared cognitive risk factors (e.g., McGrath et al., 2011). The multiple deficit model assumes that developmental disorders are multifactorial and that correlations between developmental disorders at the cognitive

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