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Progress in reading and spelling of dyslexic children is not affected by executive functioning

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ABSTRACT

Although poor reading and spelling skills have been associated with weak skills of executive functioning (EF), its role in literacy is not undisputed. Because EF has different theoretical underpinnings, methods of analysis and of assessing, it has led to varying and often contrasting results in its effects in children with dyslexia. The present study has two goals. The first goal is to establish the relationship between a large number of EF tasks and reading and spelling skills in a large number of Dutch dyslexic children ($n = 229$). More interesting, however, is the second aim. To what extent do EF skills predict progress in reading and spelling in dyslexic children who attended a remediation programme? The results revealed small, but significant relationships between EF and reading and spelling skills, but no relationships between EF and progress in reading and spelling. It is concluded that training EF skills is unlikely to enhance reading and spelling skills.

1. Introduction

Most authors view dyslexia as a developmental disorder that should be studied based on a cognitive causal model. Deficiencies in phonological skills (e.g., letter-sound knowledge, phonological awareness, verbal short term memory, and rapid naming) are considered the main cause of reading problems (Vellutino, Fletcher, Snowling, & Scanlon, 2004). However, several authors have suggested that other deficits need to be considered as well, such as, deficiencies in sensory information processing (Ramus, 2003), motor and coordination skills (Ramus, 2003; Rochelle & Talcott, 2006), working memory (Gathercole, Alloway, Willis, & Adams, 2006), processing speed (Christopher et al., 2012), and attention (Franscheschini, Gori, Ruffino, Pedrolli & Facoetti, 2012).

Furthermore, other authors report that problems with so-called executive functions or executive functioning (EF) often accompany dyslexia (Altemeier, Abbot, & Berninger, 2008; Berninger et al., 2009; De Weerdt, Desoete, & Roeyers, 2013; Jeffries & Everatt, 2004; Kegel & Bus, 2013; Menghini et al., 2010; Reiter, Oliver, & Lange, 2004). Although a uniform definition is lacking, EF is generally described as a set of cognitive processes that regulate non-automatic human behaviour in a goal-directed and

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adaptive way (Banich, 2009; Best, Miller, & Jones, 2009; Hughes, 2011; Packwood, Hodgetts, & Tremblay, 2011; Miyake & Friedman, 2012), and is in many cases believed to be linked to the prefrontal cortex of the brain (Best et al., 2009; Miyake & Friedman, 2012). Although a phonological deficit is the most agreed upon cause of dyslexia, dyslexia is also often associated with a plethora of other cognitive deficits of which impairments in EF is one of the more recent suggestions.

1.1. Theoretical background of executive functions

The first recorded example of problems with EF in neuropsychological history is the case of Phineas Gage. In 1848, he happened to have his brain pierced by an iron rod. After the rod was removed, he miraculously survived his injury, but his intimates reported important changes in his personality. Twenty years later, John Harlow learned about the case of Phineas Gage and hypothesized the existence of prefrontal brain structures that allow for planning and executing socially suitable behaviour (Damasio, Grabowski, Frank, Galaburda, & Damasio, 1994). As more patients with frontal-brain damage became known, caused by accidents, medical conditions, war wounds, or frontal lobe surgery in mentally ill patients, more cases of injured rational decision-making and goal-directed behaviour were reported (Gershberg & Shimanura, 1995; Goldstein, Bernhard, Fenwick, Burgess, & McNeill, 1993; Feldman & Goodrich, 2001; Levine & Prueitt, 1989; Nauta, 1971; Stuss, Gow, & Hetherington, 1992). Based on the behaviour of these patients, it was hypothesized that goal-directed behaviour or EF is primarily located in the prefrontal cortex. Presently, EF is not just studied in brain-damaged patients, it has also become a strong focus of research in people with different types of dysfunctions, such as, autism, ADHD, dyslexia, and dyscalculia.

Despite the fact that EF is being studied in a wide variety of cognitive domains, an accepted theory, and means of assessing EF are still lacking. Different definitions highlight different attributes, such as changing strategies according to task demands (Borkowski & Burke, 1996), control mechanisms regulating cognitive behaviour (Miyake et al., 2000), cognitive functions that adapt human behaviour to unfamiliar situations (Packwood et al., 2011), cognitive functions of the prefrontal cortex used for goal-directed behaviour (Best et al., 2009), and the interplay of various cognitive functions needed for goal-directed behaviour (i.e., attention and inhibition, task management, planning, updating working memory, and coding into working memory; Smith & Jonides, 1999). Most authors, however, agree that EF appears to be associated with cognitive functions necessary for performing goal-directed actions (Borkowski & Burke, 1996). These functions tend to develop into mature mental functions during childhood and adolescence (Jurado & Rosselini, 2007; Steinberg, 2004) and appear to deteriorate with age (Jurado & Rosselini, 2007; Treitz, Heyder, & Daum, 2007; but see Ramscar, Hendrix, Shaoul, Milin, & Baayen, 2013 for a different view).

Another debate concerns the structure of EF. Some authors argue that EF is best represented by assuming one overarching mechanism responsible for regulating all goal-directed behaviour (referred to as "the unity viewpoint"), whereas others state that EF should be understood as a coherent set of mental functions (referred to as "the non-unity viewpoint"). It is still not clear which functions have or can be distinguished in the latter case (Best et al., 2009).

Next, it is unclear whether EF should be viewed as a separate construct or whether it is part of the concepts of (fluid) intelligence, attention, and working memory (Borkowski & Burke, 1996). After all, performance on EF tasks reveals high correlations with tasks measuring fluid intelligence (skills that concern logical reasoning and problem solving in new situations, that are independent of previously learnt knowledge; Duncan, Emslie, Williams, Johnson, & Freer, 1996; Pennington & Ozonoff, 1996; Salthouse & Davis, 2006). This leads Salthouse and Davis (2006) to question the discriminant validity of EF. One particular difficulty arises from the incongruent relationships among intelligence, performance on EF-tasks, and frontal lobe damage. According to Sternberg (1985) executive processes form the basis of the general factor (g-factor) in tasks demanding intelligent behaviour. Frontal lesions appear not to influence general measures of intelligence (WAIS IQ), but do affect measures of fluid intelligence (Duncan, Burgess, & Emslie, 1995). Nevertheless, general intelligence of healthy individuals is associated with performance on EF-tasks (Obonsawin, Crawford, Page, Chalmers, & Cochrane, 2002).

Not only intelligence, attention as well as working memory have also been associated with EF at the conceptual, neuropsychological, neuroanatomical, and theoretical level (Barkley, 1996; Lyon, 1996; Pennington, Bennetto, McAleer, & Roberts, 1996). In particular, inhibition appears to play a role in the relationship between working memory and EF.

In short, it appears difficult to strictly separate EF from other cognitive functions. Fluid intelligence, attention, and working memory resemble EF, albeit none of these cognitive functions seem to completely cover the concept of EF.

1.2. Research concerning EF in general

The large number of empirical studies on EF forced us to concentrate the discussion on recent review articles. The Royall et al. (2002) survey pertaining to 46 studies on EF using confirmatory factor analysis did not reveal one single overarching construct on which all EF tasks loaded. On the contrary, most studies found four distinct factors of EF: "rule-discovery factor" (Wisconsin card sorting test), "working-memory factor" (California verbal learning test, Digit span, Tower of London), "attentional-control factor" (Continuous performance task, Digit cancellation), and "response-inhibition factor" (Digit span backward, Trial B, Stroop Task).

Packwood et al. (2011) adopted a different approach in their review of 60 studies on EF. Their investigation yielded 68 different terms describing EF. Using latent semantic analysis and hierarchical cluster analysis, the authors tried to extract a limited number of factors corresponding to the 68 terms. Their analysis did not lead to a parsimonious solution, because the minimum number of factors was 18. A more veracious approach would be to consider EF as a system responsible for guiding goal-directed behaviour, independent of the specific behaviours necessary to perform EF tasks.