



# The link between executive functions and literacy: introduction

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## Abstract

This special issue was born within the M2S Project (*Mindfulness to students' success: Relating executive functions and writing through a mindfulness app to promote children's cognitive, social, and health-related outcomes*) to call researchers and practitioners' attention to the role that executive functions play on the acquisition and development of literacy skills, a neglected topic in the field. The selected papers include various methods and techniques to examine the relationships between literacy and executive functions across languages/cultures and different age groups, with and without disabilities.

**Keywords** Executive functions · Literacy

Executive Function (EF) serves as an umbrella term to encompass the goal-oriented control of thoughts, behaviors, and emotions (Best & Miller, 2010). Although there is little consensus on a definition, currently EFs are conceptualized as being composed of three related capacities (working memory, inhibition, and shifting; Miyake et al., 2000), which work together to support higher-order cognitive processing (e.g., planning and problem solving; Collins & Koechlin, 2012; Lunt et al., 2012; Mueller & Kerns, 2015). EF skills are crucial for learning, and research has shown evidence for the role of these skills in academic outcomes (Best, Miller, & Naglieri, 2011; Fuhs, Nesbitt, Farran, & Dong, 2014; St Clair-Thompson & Gathercole, 2006). Most notably, EFs have been shown to support the development of literacy abilities (Schmitt, McClelland, Tominey, & Acock, 2015; Tominey & McClelland, 2011).

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Literacy is “the ability to identify, understand, interpret, create, communicate and compute using printed and written materials associated with varying contexts” (United Nations Educational, Scientific, and Cultural Organization, UNESCO, 2004, p. 13). This is a vital skill of the child’s overall growth, and those who have difficulties to develop literacy skills are at educational and occupational disadvantage. Indeed, the acquisition of a broad range of literacy-related skills such as reading, writing, and numeracy was recognized as a fundamental aspect of human rights and personal fulfillment (UNESCO, 2004).

Literacy has attracted increasing interest among researchers. Still, little is known about the relationship between literacy and specific domains of cognitive function such as EFs. Thus, this special issue is intended for gathering high-quality empirical research examining the relationship between literacy and EFs skills. Also, this collection is aimed at calling researchers and practitioners’ attention to the role that EFs play on the acquisition and development of literacy skills, which is still a neglected topic in the field. This issue was born within the M2S Project—*Mindfulness to students’ success: Relating executive functions and writing through a mindfulness app to promote children’s cognitive, social, and health-related outcomes*. The M2S Project investigates the poorly understood relationship between EF and writing.

Overall, the 11 papers cover the main areas of interest for our topic: EFs (e.g., inhibitory control, working memory, cognitive flexibility, attention, emotion regulation, and planning) and literacy skills (e.g., writing, reading, spelling, phonological awareness, and naming speed). Studies include correlational, experimental, and longitudinal designs, examining this link across languages/cultures and different age groups, with and without disabilities. Next, we introduce the articles of this issue.

Cordeiro, Limpo, Olive, and Castro’s paper evaluates the longitudinal contribution of inhibitory control, working memory, cognitive flexibility, and planning to text quality. In this study, 116 second-graders were evaluated twice within a 6-month interval. The authors concluded that working memory and planning had a significant contribution to text quality assessed 6 months later, above and beyond the effects of gender, reasoning, and transcription skills. Thus, findings provided evidence for the central role of working memory and planning in second-graders’ writing skills.

Davis, Bourke, and Harrison’s study investigates the influence of visual and phonological EFs on the developmental progression of writing skills. The focus is on the development of binding ability (i.e., the encoding and retrieval of the correct phoneme–grapheme pairings, an integrative function of working memory) and its comparative influence on writing. Five- and 6-year-olds’ ( $N=49$ ) were assessed for accuracy in retaining and retrieving bound audio-visual information alongside measures of verbal and visual complex working memory span and transcription skills (alphabet and spelling). Findings showed that the ability to bind increased across age, and binding had significant associations with working memory and early writing ability. Importantly, after controlling for binding and age, it was verbal working memory that made a unique contribution to individual differences in writing performance. This widens our understanding of working memory concept and may be important for high-quality instruction to enhance writing at the level of transcription and text generation.

Given that EFs and impairments in pragmatic language can have a negative impact on literacy and educational achievements, Filipe, Veloso, Frota, and Vicente aimed to further our understanding of the role played by EFs in the atypical development of pragmatic skills. As problems in EFs and pragmatic impairments are characteristics of Autism Spectrum Disorders, this study examines the associations between these skills in children with high-functioning autism (HFA). Results showed that the poor pragmatics skills of HFA children were associated with their EFs difficulties. These findings may be of clinical relevance for children with pragmatic impairments, such as Autism Spectrum Disorders.

As some studies suggest that EFs impact writing development indirectly through transcription skills, Salas and Silvente's study examined transcription (i.e., spelling and handwriting) and EF abilities in a sample of 1337 children from beginner to upper-intermediate levels of writing expertise. Each child produced a narrative and an opinion essay, and measures of inhibition, updating of working memory, handwriting fluency, and spelling accuracy were collected. Findings indicated that EFs had an impact on text generation directly and indirectly via transcription skills, particularly via handwriting. Furthermore, a comparison of the influence of transcription across schooling revealed that the impact of transcription on text generation was the same in Grades 2, 4, and 8. These results have relevant educational implications as they support that EFs are important for low-level writing skills.

Van Reybroeck and De Rom's paper discusses whether children with dyslexia have a specific reading inhibition deficit or a general inhibition deficit. Children with dyslexia ( $n=18$ ; age range: 106–131 months) were matched to typically developing children on age and reading level. All participants were asked to perform a cognitive inhibition-based task and reading inhibition task. Results showed that children with dyslexia have a specific deficit in the reading inhibition task, whereas they did not present impairments in the cognitive inhibition task. This study highlights the role of the inhibition processes under reading conditions.

Bourke et al. examine the impact of the executive (dys) functioning associated with autism spectrum disorders on the development of imagination in writing. Twenty-six children with autism characteristics and 35 typically developing peers (matched on age; mean age=9 years 7 months) participated in this study. Inhibition, sustained attention, and cognitive flexibility were measured by performance-based tasks, cognitive emotion regulation was evaluated through a questionnaire, and writing was assessed by a spontaneous narrative. The authors suggested that differences in the ability to elaborate imaginatively on a story are accounted for the attentional shifting performance. These findings are important as they extend the role of EFs in writing to children with autism.

Hooper et al. investigate the concurrent relationships between EFs and emergent literacy skills. Participants were 114 preschoolers with 3 years of age. Inhibitory self-control, flexibility, and emergent metacognition were assessed through teacher ratings of EFs. Emergent literacy skills were evaluated through measures of phonological awareness, the mastery of reading conventions, print knowledge, language, and vocabulary. Findings revealed that, after controlling for sociodemographic covariates and at-risk status for emergent literacy difficulties, when the three EF indices were included in the model the amount of variance significantly increased

for all of the emergent literacy outcomes. This paper suggested that EFs ratings may be useful for predictions of both pre-reading and pre-writing skills.

Georgiou et al. examine the predictive value of inhibition, shifting, and working memory on reading and mathematics achievements, and if the effects are the same across Western and East Asian cultures. Two groups participated in this study: an English-speaking Canadian group ( $n = 120$ ; mean age = 82.12 months) and a Mandarin-speaking Chinese group ( $n = 181$ ; mean age = 85.85 months). Participants were assessed on nonverbal IQ, speed of processing, rapid naming, inhibition, shifting, working memory, reading, and mathematics. Overall, the findings suggested that not all EF components are equally important for reading and mathematics achievements and that culture may influence this link between EF and achievements. Specifically, only working memory predicted achievements in the Canadian group, while inhibition and working memory predicted achievements in the Chinese group. The findings also suggested that in the Chinese sample inhibition was a stronger predictor of achievements than in the Canadian group. Thus, this paper brings to light that culture may influence the relations between EFs and academic achievements.

Larigauderie, Guignouard, and Olive explore the implications of working memory in the detection of various types of errors (i.e., phonological, orthographical, and grammatical). Eighty undergraduate participants completed working memory and error detection tasks. In particular, the authors examined the contribution of nonexecutive (verbal and visuospatial storage) and executive (coordination of verbal and visuospatial storage and processing, strategic retrieval from long-term memory, effortful shifting) functions of working memory. Overall, the results showed that the executive component of working memory appeared more linked to the verbal domain than the nonexecutive component, while the nonexecutive component seems more involved in the visuospatial domain than the executive component. Importantly, this study discloses new knowledge about how executive and non-executive functions of working memory contribute to the detection of various types of errors.

Given that EFs are hypothesized to play an interactive role during oral reading fluency, Nguyen and colleagues evaluated the relationship between miscues and self-corrections while reading baseline versus experimentally-manipulated passages for text complexity and EFs. The sample included 143 participants (aged 9 to 15 years) assessed with a large battery of behavioral and cognitive assessments. Results showed that, after controlling for reading and language skills, EFs (planning/organization and working memory) contributed significantly to the variance in the production of miscues; also, a higher probability of self-corrections was predicted by better EFs (reasoning, cognitive flexibility, and working memory). These findings elucidated the contribution of EF to reading performance and strategies—that is, self-correcting oral reading miscues—especially within the framework of text complexity.

Papadopoulos, Spanoudis, and Chatzoudi presented a longitudinal study examining whether second-graders can be distinguished retrospectively from kindergarten based on their EFs (planning, attention, and working memory) and linguistic (phonological and naming speed) skills. Participants were organized in four groups on the basis of word fluency and spelling measures: (a) poor readers/poor spellers ( $n = 9$ ), (b) poor readers/good spellers ( $n = 12$ ), (c) good readers/poor

spellers ( $n=13$ ), and (d) good readers/good spellers ( $n=45$ ). Results suggested that the double dissociation between reading and spelling is associated with EFs impairments and that these impairments are visible early in development. Specifically, the poor readers/poor spellers group showed the most marked impairments in phonological, naming speed, and working memory measures in kindergarten. The poor readers/good spellers presented impairments in phonological and naming speed measures in kindergarten, and the good readers/poor spellers group experienced difficulties only in orthographic processing in Grade 1. Also, the average range of change for the poor readers/poor spellers and poor readers/good spellers' groups in word reading fluency was negative, whereas the corresponding growth of good readers/poor spellers and good readers/good spellers was positive. These results shed some light on the role of linguistic and cognitive skills in the dissociation of reading and spelling impairments.

In sum, this special issue is an important step forward in the expansion of research into the field of EFs and literacy. This relationship was examined in different age groups, in populations with and without disabilities, and in different languages and cultures. What next steps can be foreseen? First, as claimed by the authors of this collection, more research on EFs is needed to better comprehend the typical development of literacy abilities. Second, given that research studies about this link are crucial for a full understanding of atypical development, studies should include a wider range of disorder types to provide useful evidence for those with difficulties in EF and literacy skills. Finally, there is also a need for more basic and applied research about this relationship to better understand how practitioners may facilitate the acquisition and development of literacy abilities.

Furthermore, the contributions of the special issue must be considered together with the limitations of its papers. First, most of the studies measure EFs through single indicators; however, it is worthwhile to cross-validate the results using multiple indicators of each component of EF. Second, as some inconsistency of results may be due to the statistical techniques employed, researchers may consider employing more complex statistical models such as structural equation modeling to explore models with several indicators per latent construct. Third, given that EFs skills can be measured using a diversity of tasks, it is important to understand the complex link between cognitive testing using performance-based measures and questionnaires of everyday executive functioning. Finally, most of the studies restricted the assessment of EFs to cognitive/"cold" aspects activated during the resolution of abstract and decontextualized problems. As recent definitions of EF also include affective/"hot" aspects that are critical in conditions that are emotionally and motivationally relevant (Zelazo, Qu, & Müller, 2005), it would be fruitful focus on both "cold" and "hot" components of EFs.

On closing, we would like to thank all the authors and the reviewers who contributed to this special issue. We believe that their work will motivate others and contributes to a growing body of knowledge on EF and literacy, an under-represented topic of research.

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