

IMPLICATIONS OF EXECUTIVE FUNCTIONS IN ACADEMIC LEARNING

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Abstract

Research has confirmed the relationship between executive functions and academic learning; the former being a greater burden for children, as it is the result of an interchange of experiences and knowledge between teachers and students. Researchers have focused on presenting a one directional causal relation. However, if we consider learning as a construal, it can impact and be impacted by brain development and academic learning, supposing a bidirectional relationship, which few studies have examined. This article reviews the state of the art of research on the relationship between executive functions and academic learning. The main contribution was to conceptualize and systematize the existing research on the relationship between executive functions and academic learning, as well as its implications. This yields a partial answer to the question Do executive functions impact academic learning? Undoubtedly, executive functions are essential to school-age children because of their role in academic learning and achievement. Nonetheless, whether their influence is only unidirectional or the potential of a bidirectional relationship exists remains unanswered. This is an effort to find other ways to consider the relationship between executive functions and academic learning. Few studies have examined this bidirectional relation, which requires further discussion among specialists.

Keywords: executive functions; academic learning; school-age children; academic achievement; academic abilities

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Introduction

For the last 150.000 years, human beings have been required to exercise the following functions: obtain power, exercise a dominant role, store goods and provisions, and relate to others and constitute a community. All of these functions are controlled by the prefrontal cortex with the direct involvement of the executive functions (Ardila, 2008).

Clearly, executive functions are not a recent ability; they have been a requirement, in the several steps of human evolution, to cope with daily life.

However, as stated by Baggetta and Alexander (2016), there currently is a growing interest in the study of this topic, which is observable by the number of investigations that have been developed in the area. This emergent interest can be associated with the pursuit of a complete understanding of complex and changing abilities such as the executive functions or a need to delve deeper into their study and provide explanations to many aspects of human behavior.

The empirical results of recent studies on this topic have been widespread regarding the age of the sample population starting from childhood (e.g. Decker et al., 2016) up to elderhood (e.g. Fjell et al., 2017), with the presence or absence of pathologies (e.g. Hutchison et al., 2016; Roberts et al., 2017; Salomone et al., 2016; Stern et al., 2017). Research measurement characteristics have included questionnaires (e.g. Castellanos et al., 2016; Skogan et al., 2016), cognitive test batteries (e.g. Longaud-Valès et al., 2015), and naturalistic observation (e.g. McAlister et al., 2013), among others. Empirical studies have been conducted in different fields, for example, cognition (e.g. D'Esposito & Postle, 2015), education (e.g. Blair & Raver, 2015; Vandembroucke et al., 2017), sports (e.g. Vestberg et al., 2017), chronic pain (e.g. Baker et al., 2016; Bjekic et al., 2017), gerontology (e.g. Fogarty et al., 2016), substance abuse (e.g. Farhadian et al., 2017; Lavigne et al., 2017), sexual abuse (e.g. Burton et al., 2016), and eating disorders (e.g. Degortes et al., 2015).

Research has shown that, as with other topics, the study of executive functions should begin from the initial stages of human development, as this will contribute to the development of programs to promote and intervene in the executive dysfunctions, which can affect an individual's future success in their different activities.

With this in mind, this review will examine studies involving children and school, which is their most demanding activity. School prepares children for

their future life in a constantly changing world. Academic learning occurs as the result of an exchange of experiences and knowledge between the teacher and the students (Stoll & Kools, 2017). Fittingly, the studies considered were those conducted with school-aged children.

As noted by Moll et al. (2014), academic learning is determined by many variables, among them, cognitive abilities, more specifically executive functions. The purpose of this paper is to review the state of the art of the research and theoretical development on the relationship between executive functions and academic learning.

To attain our goal, we limited the concept and underscored the most important definitions, namely the components with the highest consensus, and the main theoretical models. Likewise, we examined the theoretical evidence that supports the relationship between executive functions and academic learning, exploring the internal consistency and validity of this relationship and generating theoretical indicators that will help in its clarification.

The review methodology was to analyze publications in peer-reviewed academic journals that meet the high-quality standards to be indexed in the Institute for Scientific Information (ISI) index. We also included books written by well-known and respected authors in the field to ensure a solid and valid body of knowledge. We examined a vast selection of empirical and theoretical references.

In the first section, to conceptualize the executive functions construct, we considered recent studies conducted by the most influential authors as well as the approaches of classical authors in the field. In the second section, we analyzed the studies that were published concerning the relationship between executive functions and academic learning in school-aged children.

Executive functions

The term executive function is relatively recent in the field of neurosciences and neuropsychology. Alexander Luria (1980), is considered the precursor of the term; he proposes that the brain has three functional units. Luria's theory identified these functional units as: (1) related to arousal and the motivational state, which corresponds to the limbic and reticular systems; (2) in charge of receiving, processing and storing information, which corresponds to the cortical and pos-rolandic areas; (3) involved in programming, regulating, and verifying the activity, which corresponds to the structures of the prefrontal

cortex. Based on this approach, executive functions are related to the third functional unit.

Later, Muriel Lezak (1982), her legacy provided a framework to conceptualize executive functions regarding capacities to organize and characterize human behavior. According to this study, executive functions can be defined as complex behavior-related abilities, which enable an adaptive response to novel situations and are part of the cognitive, emotional, and social abilities. Lezak et al. (2012), stated that executive functions are divided into the following four major classes or functional categories of executive capacities: (a) volition (goal formulation); (b) planning and decision making; (c) purposive actions (carried out activities towards a goal); (d) effective performance (monitoring). Each one of these aspects involves a distinct set of activities related to behavior.

Another classic author that contributed to the understanding of the executive functions was Baddeley (1986; 2007) who proposed that human behavior can be grouped based upon the difficulties, concerning planning, inhibition, perseveration, and reduced fluency. This author coined the term *dysexecutive syndrome*.

Classic authors such as Luria, Lezak, and Baddeley have contributed to the conceptualization of the term executive functions. In the current literature, there are several models that have been used to characterize and explain executive functions. Many definitions have been given, documenting several attributes and identifying several spheres of influence.

Baggetta and Alexander (2016), documented the 25 attributes to describe the executive functions. Here, we highlight the ones most frequently used: (1) cognitive process, (2) higher-order cognitive process, (3) self-regulatory abilities, (4) psychological process, and (5) behavioral skills. The authors also present 24 spheres of influence to operationalize the concept; the most predominant ones are goal-directed behaviors, action and thoughts, cognition, self-regulation of behaviors, and cognition and emotion.

There are explicit and implicit definitions of the concept. An explicit definition can be the one suggested by authors like Banich (2009), and Ahmed and Miller (2011) that define the concept of executive functions as higher-order cognitive processes involved in a goal-oriented behavior, guiding efforts towards a goal to be achieved, especially in non-routine situations. These include prioritizing and sequencing behaviors, inhibiting inappropriate responses,

generating and retaining the notion of the task or information which is most relevant for the goal to be achieved, alternating between different tasks, receiving feedback from the environment to make decisions and cope with unknown situations successfully.

Moreover, Baggetta and Alexander (2016), found that there is an important percentage of explicit definitions that have no theoretical support and are definitions given by the authors of the various studies, that is, their own opinions.

Ardila and Surloff (2007) also propose that executive functions include the ability to reduce interference, as well as mental flexibility, self-directed behavior and the ability to anticipate other people's behavior, while Bull et al. (2008), based their definition on components, such as inhibition, cognitive flexibility, and working memory.

Before describing the internal components of the executive functions construct and considering the analyzed population in this review, school-age children, it is important to emphasize some aspects.

A uniform perspective on the approach for executive functions in children has not been established. There are compelling theoretical positions for both the unidimensional and the multidimensional approach that maintain the debate alive. However, in the adult, there is a consensus in the neuropsychology area that executive functions should be considered a multidimensional construct. Given the current scientific advancement in the research of executive functions in children, such a consensus is imminent.

Concerning the components of executive functions, several domains have been ascribed, depending on the type of study. These variations can be explained by the age of the sample population, the measurement characteristics, and the statistical techniques employed (Lee et al., 2011; Lee et al., 2013).

A classic research work that considers executive functions as a multidimensional ability was conducted by the team of Akira Miyake (Miyake et al., 2000) and involved young college students. With this work, the authors contributed one of the strongest theoretical positions on the components of executive functions and one of the most cited studies (7042 using Google scholar citation).

Considering the executive functions as a multidimensional construct, Baggetta and Alexander (2016) reported 39 different components. The most frequently mentioned component was inhibitory control or response inhibition,

usually defined as the ability to deliberately control or inhibit dominant or automatic responses (behavior and thoughts). The second most documented ability was working memory, which refers to the ability to retain a task or idea in the mind while adding relevant information or eliminating non-relevant material. There are some studies focusing on cognitive flexibility (Diamond, 2013), which is described as the ability to alternate flexibly between tasks and different goals. Finally, there are also studies that mention planning (e.g. Hughes et al., 2010) and attention (e.g. Barkley, 1997; 2014) as secondary components.

Although there are different views regarding the unidimensional or multidimensionality of the executive functions construct in children, there seems to be an inclination towards multidimensionality. The construct could be composed of different components that are independent between them but have a certain level of dependency.

Relation between executive functions and academic learning

After describing the executive functions construct, it is important to circumscribe its importance in the study of school-age children. The field of neurosciences and neuropsychology continues to expand towards other areas of human development, due to the strong interest in understanding the biological bases of human behavior. This interest has resulted in an upsurge in studies focused on brain development and the factors that can affect it.

Childhood and adolescence are characterized by changes in cognitive and behavioral processes, which are inherent to normal brain maturation. Barrasso-Catanzaro and Eslinger (2016) documented that the first 12 years are key in terms of the neuronal changes which can be produced. During this period, children acquire most of their social, cognitive and emotional knowledge.

Barrasso-Catanzaro and Eslinger (2016), state that each aspect of human experiences is organized in the brain with a temporal and situational reference. Thus, the family and caregiver contexts influence the development of executive functions, directly impacting the development of self-regulation and behavioral flexibility; as shown in several studies (e.g. Bernier et al., 2010), the family environment is central to brain development.

Prefrontal cortex and executive function-related brain maturational events are complex and depend on neurobiological, anatomical, and physiological factors as well as experiences. These developmental changes will impact the emerging neural networks and brain plasticity processes related to the

prefrontal cortex functions and related areas (Barrasso-Catanzaro & Eslinger, 2016). Conditions of chronic stress and environmental deprivation affect brain development exacerbating physiological stress, which is related with the increment of the production of cortisol, among other aspects. The previous adversely impacts the development of the prefrontal cortex and related processes, which are particularly sensitive to these types of changes.

Some authors (e.g. Blair & Raver, 2012) have attempted to describe how a supporting environment modulates the neurobiological response to stress and prevent emerging neurodevelopmental changes. Therefore, protective and supporting caregivers foster the adaptive development of executive functions.

Similarly, Duncan et al. (2017), argued that inhibitory control could be the component of the executive functions least influenced by environmental changes. Contrarily, cognitive flexibility and working memory are the most vulnerable to environmental conditions.

Duncan et al. (2017) state that the transition from preschool to formal educational is a critical period in a child's development. For that reason, executive functions have a key role in school adaptation, providing the abilities for behavioral regulation and focus on the learning administered in the classroom. Thus resulting in an emerging interest to delve deeper into the relationship between executive functions and academic learning, to understand how it is characterized and their possible implications in the field of education.

Academic achievement is determined, in part, by the ability to be successful in a specific academic area (Passolunghi & Lanfranchi, 2012). Nevertheless, current studies are still searching for the predictors or keys to academic success. In this context, executive functions have become popular in the last years with many studies documenting the role of executive functions in academic learning and academic achievement.

Baggetta and Alexander (2016), found 15.900 publications with titles such as "Executive functions skills predict children's success in life and school"; "Are the executive functions the new IQ?"; "Five reasons why every parent should be familiar with executive functions"; "Executive function abilities are essential for the present and future".

Likewise, there are more than 20 laboratories (e.g. Schuhfried, 2017; Instituto Gutman, 2017) interested in developing software to improve executive functions in academic and health contexts.

The previous is in line with promising results obtained in research in the area over the last decades. Recent advances show that the executive functions are key for success in many aspects, such as reasoning, reading and math achievement, school adjustment, reduction of Attention Deficit Hyperactivity Disorder symptoms, school readiness, and academic achievement, among others (Baggetta & Alexander, 2016; Dias & Seabra, 2016).

Between 2000 and 2013, 1,400 articles can be found on research topics related to executive functions and academic learning, (data from PsyInfo *cited in* Baggetta & Alexander, 2016). The authors of this review did not include studies in other scientific databases or in thesis, monographs, and book chapters written about executive functions and its relationship with academic learning, which would yield a much higher number.

Although recent advances contribute to understanding this research topic, this evidence is insufficient to provide a clear and comprehensive explanation in a field as important as childhood development.

Authors like Dias and Seabra (2016), and Duncan et al. (2017), argue that executive functions and behavioral regulation are strong predictors of academic achievement. As explained by the authors, children that can focus their attention and inhibit inappropriate behaviors can adapt their behavior flexibly to novel situations. These children, can use these abilities whenever needed; this will impact their learning and daily life.

Duncan et al. (2017) reported a relationship between a child's socio-economic level and the combination of executive functions, behavioral regulation in the classroom and academic achievement; they found that these variables are equally related to academic performance.

Authors such as Lyons and Zelazo (2011), and Dweck (2006), pointed out that executive functions have direct and indirect effects on academic learning. The direct effects concern the ability to remain in the workplace, pay attention to information, remember and follow the rules, and learn and adapt to environmental changes. These are linked to inhibitory control, cognitive flexibility and working memory. Whereas, indirect effects are associated with motivational achievement, the child's intrinsic motivation and focus to assume an optimistic and positive attitude concerning the student's own learning process and aptitudes.

In a longitudinal study McClelland et al. (2013), demonstrated that executive functions predict academic achievement from the early developmental stages to the completion of college.

Allan et al. (2014) conducted a meta-analysis and concluded that executive functions are associated with school readiness. The authors explained that better executive functions correlate with a better disposition for the acquisition of reading and math skills. In a similar manner, executive functions, specifically in the domain of inhibitory control, cognitive flexibility and working memory, were found to be more important in predicting academic success than intelligence (McClelland et al., 2006).

Zelazo et al. (2016), and Bull and Lee (2014), reconfirmed the well-established impact of executive functions in mathematical abilities. Learning math and solving a math problem correctly involves working memory and cognitive flexibility abilities.

Considering the relationship between executive functions and reading, authors like Loosli et al. (2012) also showed the importance of working memory in the development of these skills. Fuchs et al. (2014) found a consistent relation between executive functions (specifically in inhibitory control, cognitive flexibility, and working memory) and reading fluency and comprehension.

Zelazo et al. (2016), and Daneman and Merikle (1996) hypothesized that executive functions impact the development of language. As stated by Decker et al. (2016), the acquisition of language is key to the process of behavioral self-regulation and for the internal language development, which will be a determinant for the development of problem-solving abilities.

Household socioeconomic characteristics can impact the relationship between executive functions and academic learning. Duncan et al. (2017) maintain that the impact of social background on the relationship between executive functions and academic achievement and how they are associated remains unclear.

Morrison et al. (2010) state that children from more favored socioeconomic levels have better inhibitory control abilities and academic skills. Some studies confirm this and others contest this conclusion. These opposing views suggest the need to examine the consistency of such a relationship.

The literature review indisputably shows that executive functions are related to academic learning and achievement. However, further research is

needed to explain the influence of a child's environment and family background on this relationship.

Based on the findings of the reviewed authors, current research has focused on presenting a unidirectional relationship between executive functions and academic learning; however, if we consider academic learning as a construal, it can impact and be impacted by normal brain development, supporting the possibility of a bidirectional relationship, which few studies have examined.

According to Weiland and Yoshikawa (2013), the exercise of reading and math skills contribute to an improvement of the executive functions. Other authors (e.g. Welsh, 2010; Fuchs et al., 2014) have analyzed the development of academic skills and executive functions through longitudinal studies and proposed that academic learning may favorably contribute to the development of executive functions and that the opposite may also occur. The conclusions reached by these authors indicate the possibility of a bidirectional relation that must be explored further.

Discussion

The objective of this review was to examine the studies on the relationship between executive functions and academic learning. The empirical and theoretical works examined yield a partial answer to the question *Do executive functions impact academic learning?* Undoubtedly, executive functions are essential to school-age children because of their role in academic learning and achievement. Nonetheless, whether their influence is only unidirectional or the potential of a bidirectional relationship exists remains unanswered.

In the last 10 to 20 years, the literature reveals that research on the development of executive functions in children and its differences according to the individual, as well as its impact on the cognitive, socio-emotional and academic areas has been a focus of interest.

The previous is plausible because executive functions are related to the adaptive behavior in children and school adjustment. According to Blair (2016), adequate executive functions skills enable the child to retain and manipulate information, inhibit impulsive or inadequate responses to produce non-dominant responses, maintain or reach different viewpoints and alternate between them, manage emotional and attentional behavior to maintain the required activation and motivation levels.

These abilities are determinant to academic learning, justifying the need to expand the studies in this area that consider different developmental stages and other learning environments.

Regarding the conceptualization of the executive functions construct, several studies have documented the existence of three main components: inhibitory control, working memory, and cognitive flexibility. These should be functionally independent, but maintain a certain level of association between them. Secondary components such as planning and attention abilities are also mentioned.

Both the main and the secondary components have been found to predict school readiness (Strasser et al., 2016) and academic achievement (Fuchs et al., 2014). Beyond academic learning, executive functions are important for the individual's physical and mental health. Children with better executive function skills have better peer and teacher relations, allowing them to make positive attributions to their own learning process and abilities.

The influence of socioeconomic status on executive functions and, consequently, on academic learning has been reported in studies that aver that executive functions can be a protective factor for adverse socioeconomic conditions (e.g. Blair, 2016). There are also theoretical positions that document the negative impact of socioeconomic conditions on executive functions (e.g. Morrison et al., 2010; Hanson et al., 2013), as well as other opposing positions (e.g. Obradovic et al., 2016). However, future research can explore this association, between a child's socioeconomic background and the implied variables.

Additionally, recent developments support the notion that the mother's educational level is a key variable to consider when studying academic learning in school-age children (Baggetta & Alexander, 2016; Cladellas et al., 2017).

Then, Dias and Seabra (2016) suggest that besides the academic learning, small changes in executive functions can impact the socio-emotional development of children and consequently their lives. The authors show that the intervention on executive functions could benefit children.

This research evidenced the need to investigate the relationship between executive functions and academic learning. Researchers should be focusing on developing programs to promote and intervene executive functions in early ages; this could prevent future problems. Especially in developing countries in which

socioeconomic conditions are precarious; these programs can be a protective mechanism against future risk behavior.

This literature review contributed to conceptualize and systematize the existing research on the relationship between executive functions and academic learning. Further work is needed such as future research opportunities regarding the bidirectional relationship between the constructs of academic learning and executive functions.

Concluding remarks

To summarize, the research reported in this review emphasized the implications of executive functions in academic learning. If researchers can prove that there is a bidirectional relationship, this could open other research opportunities on this topic. Moreover, researchers can try to determine which math and reading contents are related with the main components of executive functions to promote the improvement of executive functions by teaching these math and reading subjects.

Equally important, future studies should also investigate which activities could be implemented in the classroom to improve executive functions in school-aged children.

Finally, these opportunities for improvement can help prevent future disruptive and antisocial behaviors.

In conclusion, we have provided an overview of the theoretical and empirical works on the subject and underscored some important questions that may be answered in future studies. This work also highlights the importance of finding new ways to consider the relationship between executive functions and academic learning that has already been established.

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