



Research Article

Cognitive neuroscience, developmental psychology, and education: Interdisciplinary development of an intervention for low socioeconomic status kindergarten children



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ABSTRACT

The current study presents a 32-week intervention for kindergarten children from low socio-economic backgrounds. The main contribution of this study resides in the interdisciplinary development of the intervention, made in close collaboration between educational researchers, and researchers in cognitive neuroscience and developmental psychology. The intervention was implemented by teachers through class activities, to promote executive functions and academic achievement. These activities were articulated into the current kindergarten curriculum and, at the same time, built upon concepts and methodologies of developmental psychology and cognitive neuroscience for executive functions training. Results showed: (1) non-significant differences between groups in cognitive performance from pre- to post-training assessment, and (2) significant differences in academic achievement for *Language*, *Mathematics*, *Autonomy*, and *Contact with peers* in first grade. Our study sets a precedent for future interdisciplinary work bridging the gap between developmental psychology and education, which we believe will prove key to improving academic success.

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1. Introduction

1.1. Developmental psychology, cognitive neuroscience, and education

In the past two decades the interest of neuroscientists in building bridges between neuroscience and education has increased significantly [1–5]. Inspired by the idea that knowledge about neural development of cognitive and emotional processes could be incorporated and applied to learning and teaching, neuroscientists began working towards a model for integration. However, there are still relatively few proposals for building such bridges [3]. An increasing body of the literature, which analyses the theoretical factors linking these disciplines, stands in contrast to the considerably low number of existing applications of neuroscientific knowledge in the classroom [6]. This paucity of data derives, in part, from practical difficulties for conducting experimental research in schools [7,8]. For example, when classes, and not children, are the units of analysis it is important to increase as much as possible the number of classes used, but this will add additional sources of variation that might confound the results. On the other hand, comparisons of few classes from the same school

make it necessary to consider the potential differences between teachers [9]. Specifically, when comparing academic achievement in a few classes it is necessary to control for the “teacher effect”, that is, the possible tendency of one teacher to assign higher grades than other teachers at the same school [10–12]. Those difficulties should be addressed in order to develop scientific approaches for educational problems. In this complex, but promising, context, this paper presents an intervention aimed at unifying the theory and practice of three disciplines (i.e., developmental psychology, cognitive neuroscience, and education) to advance in the direction of an evidence-based research practice.

1.2. Executive functions

Executive functions (EF) can be defined as the abilities to inhibit and manipulate thoughts and actions, leading to goal-directed behaviours [13,14]. The involved skills in this control-processing are critical for success in school and life, since they allow us to inhibit impulses, anticipate situations, start novel actions, set goals and plans, and to design strategies and modify them if they do not work. Core EF include: attention (alerting, orienting, and executive attention) inhibitory control (resisting habits, temptations, or distractions), working memory (mentally holding in mind and manipulating information), and planning (creating and maintaining an appropriate sequence of steps for solving a task) [15–19].

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EF are considered critical in achieving success at school as they have been associated with reading ability [20], mathematics and standardized measures of academic achievement [21], mathematics and processing speed [22], mathematics and reading/writing skills [23], teacher report of learning behaviours and social competence in the classroom [24], and reasoning skills [25]. Several studies document the concurrent relationships between school-based functioning and EF, and the predictive relationships between both [26–32]. The flip side of this argument is also true: deficits in EF have been associated with difficulties in school readiness, for example, in mathematics, writing, and reading [32–34].

In addition, EF are considered critical factors in emotion regulation and play a significant role in all complex behaviours in a social context (e.g., school). For example, Neuenschwander and colleagues [23] found effortful control and EF to be independently important in improving early learning success and good classroom adjustment in children making the transition to school life. Successful adaptation to school does not seem depend only on achievement in mathematics, reading, and writing, but also on classroom behaviours such as engagement, motivation and persistence in learning situations, learning-related behaviours, classroom participation, and relationships with teachers and peers [23,35].

With the aid of neuroimaging technology [36–38] and the structural and functional analysis of lesions [39,40] different studies have associated the development and function of EF with the prefrontal cortex. In the same way that neural circuits involving the prefrontal areas develop slowly and become mature in early adulthood [41–43], EF develop slowly throughout childhood and adolescence. Behaviourally, although EF follow different developmental pathways, there is a common aspect across them: the rapid advances in performance between three and five years of age with respect to planning, inhibitory control, and working memory processing tasks, as has been shown in several longitudinal studies [11,44,45]. According to these studies, the period from three to five years of age seems to be an optimal time to implement EF training interventions.

1.3. Poverty impact on cognitive development

Beyond all debates about the definition of poverty and the different ways of measuring it [46,47], children with a low socio-economic status (SES) tend to have poorer EF and poorer school achievement, compared with middle or high SES children [48,49]. Psychometric and educational studies [50,51], and also studies that are part of a cognitive neuroscience paradigm [49,52–55], have largely verified the impact of poverty in EF. In general, low SES has been negatively associated with attention processes, inhibitory control, working memory, flexibility, planning, phonological awareness, self-regulation, and theory of mind in infants, kindergarten, primary, and secondary school children [56–62]. Brain activation patterns associated with tasks demanding EF are also influenced by prevailing SES factors [56,59,63,64]. Given such disparities, children living under vulnerable conditions constitute a priority target for interventions aimed at optimising EF.

1.4. Interventions aimed at optimising cognitive functioning

In recent years, several interventions targeting cognitive development have been implemented and evaluated [65]. Overall, the main goal of such early interventions has been the furtherance of cognitive development in early childhood, expecting this will then influence broader, longer-term outcomes such as academic and social adjustment. In general, these studies reached their goals [66,67]; however, there have been difficulties in replicating successful outcomes in the long term or on larger scales [68]. Since most of these interventions are based on theories of developmental psychology, the inclusion of aspects from the perspectives of cognitive neuroscience could magnify gains in cognitive and academic outcomes [69].

During recent years, several studies have shown that EF can be improved following a systematically-increasing EF-demand schedule [70–79]. However, few of those trainings have been conducted by teachers in classes. Although EF can be trained, teachers receive little instruction in how to improve them [71]. Furthermore, teachers do not usually learn about these kinds of processes, neither their development, nor how they are a fundamental part of everyday activities in school [80].

There are two areas that provide appropriate opportunities for applying developmental cognitive and neuroscientific proposals: teacher training and school curriculum. On one hand, teachers study child development during their training, although not from a neuroscientific point of view [81]. During their training teachers usually do not receive information about brain development and functioning. Stimulation of EF from a developmental cognitive neuroscience perspective is not covered during the training. Teachers' training in general neuroscience knowledge would help them to understand the developing minds and brains of students, their behaviours, the constraints on learning, and the adequate times for learning, among other things [82]. Besides that, teachers' training in general neuroscience would provide teachers with an additional level of analysis that could help them evaluate problems in education, and would contribute to an informed, research-oriented, multifaceted perspective based on empirical evidence. This kind of training will ultimately encourage teachers to appreciate their roles as key players in building bridges between disciplines. On the other hand, the content of the school curriculum is relatively flexible, in the sense that teachers can design their own specific class activities [83]. The curriculum provides teachers with a content outline and general guidelines within which they must build activities aimed at teaching key topics. However, since each teacher designs their own specific activity, they can construct them in such a way as to train EF or not. Instead of that, a sequence of activities specially designed for EF stimulation ensures that the training of EF is not left to chance.

These opportunities open a double gateway for developmental psychology and cognitive neuroscience. First, they provide a chance to train teachers in issues of developmental psychology and cognitive neuroscience that are directly bound up with their profession (by understanding these processes teachers could enrich their class methods). Second, these opportunities allow for the creation of curriculum-based activities that train EF.

1.5. Objective

The objective of the study was to design, implement and evaluate an intervention to promote EF and academic achievement in kindergarten children. Our hypotheses were that (1) kindergarten children in the intervention group will have higher cognitive performances, compared to children in the control group, and (2) these benefits will transfer to academic grades along first grade. The intervention was designed by an interdisciplinary team made up of educational researchers, and researchers in cognitive neuroscience and developmental psychology. Only part of the team (researchers in cognitive neuroscience and developmental psychology) conducted the study in the school. The teachers implemented the intervention, through class activities. The activities were in agreement with the current curriculum of the City of Buenos Aires, but articulated with concepts and methodologies of developmental psychology and cognitive neuroscience for the training of EF.

2. Materials and methods

2.1. Study design

The study consisted of a longitudinal quasi-experimental design in which kindergarten classes were randomly assigned to control and

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