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Remote delivery of executive function training to children. Feasibility and preliminary efficacy of two interventions in clinical and educational settings.

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INTRODUCTION

In the last decades there has been a noticeable growing interest in individuating processes of promotion, improvement and rehabilitation of Executive Functions (EF) in children. This comes from a growing awareness of these skills' role in fostering a positive development trajectory. In fact, better EF has been found to be related to a wide range of cognitive and social abilities, such as school readiness (Welsh et al., 2010), early literacy, and numeracy achievement (Blair & Razza, 2007), school success and job satisfaction (Moffitt et al., 2011) and social abilities (Riggs et al., 2006). EF impairment has been linked to behavioral problems and evidenced in individuals with neurodevelopmental disorders including reading disorders, attention deficit hyperactivity disorder (ADHD), autism and several genetic syndromes. In addition, EF seems to be particularly vulnerable to early brain damage, probably due to the prolonged development of EF, which continues until adolescence. EF deficit has been found in children who suffered a brain injury, such as traumatic brain injury or stroke. For these reasons, several interventions to promote EF in the school setting have been developed in the last years, as well as rehabilitation programs for children with brain damages, although to a much lesser extent.

Given these premises, the present work aims to deepen both research lines: i) executive functioning and rehabilitation in children with a history of stroke, and ii) executive functioning improvement in typically developing children and its relationship with school achievement. For this reason, after a first introductory chapter, the present work was divided into two sections. Section 1 is called "Executive function and telerehabilitation in pediatric stroke" and section 2 is called "Executive function improvement and school achievement in typically developing children". In detail, the first chapter will address the issue of the definition of EF, its developmental trajectories, the EF impact on the child's development and finally the issue of the difficulty of measuring EF. Then, in section 1, the second and third chapters will address the theme of the rehabilitation of EF in children with a history of stroke. In particular, the second chapter will present a study investigating the EF functioning of children with stroke and its correlates, while the third chapter will present a pilot study investigating the efficacy and feasibility of an EF telerehabilitation program in children with stroke. After, in section 2, the fourth and fifth chapters will address the theme of improvement of EF in primary school children. In the fourth chapter will be presented a study investigating the role of school adjustment as a mediator of the relationship between EF and school achievement, while in the fifth chapter will illustrate the development of an integrated App-based training and a pilot study of its efficacy and feasibility. Finally, in the last chapter, final consideration will be given to all the presented studies and potential future directions will be considered.

1. EXECUTIVE FUNCTION

1 Introduction

The term Executive Function (EF) has been used to indicate a variety of different and partially overlapping sets of neurocognitive skills involved in complex and goal-directed behavior. EFs are crucial in complex and novel situations in which familiar and automatized behavior are not efficient, that require planning, decision making and problem solving (Norman & Shallice, 1986; Shallice & Burgess, 1991). EF is also defined as attentional-regulation skills, which allow us to sustain attention, keep goals and information in mind, not to be impulsive, manage interference and distraction, tolerate frustration and plan for the future (Zelazo et al., 2016). More generally EF refers to a set of skills that allow the voluntary control of cognitive processes and behavior (Lehto, 1996; Pennington & Ozonoff, 1996). Historically, the concept of EF derives from the study of prefrontal cortex (PFC) damages and their consequences. It has been known that patients with damage to the frontal lobes, including the well-known patient Phineas Gage, demonstrate severe problems in the control and regulation of their behavior with important consequences in their everyday lives. Although some of these patients demonstrate intact performance on various cognitive tasks and IQ tests (e.g., Damasio, 1994; Shallice & Burgess, 1991), they tend to show, as a group, some impairments on a series of executive tasks. These include a series of different but correlated neuropsychological deficit that can be described as follow:

"Lesions of prefrontal cortex in humans yield a constellation of neuropsychological deficits that have been described variously as difficulties with planning, concept formation, abstract thinking, decision-making, cognitive flexibility, use of feedback, temporal ordering of events, fluid or general intelligence, and monitoring one's own actions…" (Wise et al., 1996, p. 325).

Based on these studies, EF was used to indicate the psychological abilities whose impairment is presumed to underlie these manifest deficits, but without a clear definition of the concept. Researchers were only focused on defining a list of abilities instead of defining EF. For example, after reviewing several lists proposed to define EF, Tranel, Anderson and Benton (1994) suggest that EF corresponds to planning, decision-making, judgment, and self-perception. Subsequently, different approach was used to characterize EF. First, researchers started to focus only on one aspect of EF and attempt to explain various behavioral deficits in terms of this aspect (e.g., Carlson et al., 1998; Dempster, 1992). In this vein, the most diffuse approach was to reconceptualize EF as inhibitory control. This can appear useful because failures of EF are often manifested as perseverative errors. Perseveration implies the emission of a behavior that should have been inhibited, so, according to this hypothesis, individuals with EF deficits try to suppress interfering responses but cannot do so because of an immature or inefficient inhibition mechanism. Generally, however, this approach is inadequate to describe the complexity of the processes involved in EF. For example, it does not allow to predict that 3 years old children perseverate in certain card-sorting tasks, such as the Dimensional Change Card Sort (Frye et al., 1995), but not in the A-not- B task (Zelazo & Muller, 2002).

2 Unitary model of EF

The first models that try to reflect the complexity of these processes considered EF as a unitary higher-order cognitive mechanism or ability that coordinates, manages and controls lower order cognitive processes, according to a hierarchical organization of cognitive system (Goldberg & Bilder, 1987). In this vein, Norman and Shallice (1986) proposed a Supervisory Attentional System (SAS) deputy to the control of cognitive processes through the strategic allocation of attention, while Baddeley (1996) proposed a Central Executive, as a component of the working memory that coordinates underlying cognitive processes.

Norman and Shallice's (1986) model of attentional control assumes that two complementary processes operate in the selection and control of action, the "Contention scheduling" and the "Supervisory Attentional System". The *contention scheduling* is a lower-level mechanism that is thought to be able to control routine activities automatically, without conscious control or attentional resources. Contention scheduling ensures the proper schema is activated and, through inhibition, prevents multiple competing actions from executing simultaneously. The *SAS* is a higher-level mechanism that controls the contention scheduling in nonroutine situations requiring novel or difficult actions (Norman & Shallice, 1986; Shallice et al., 1989). The SAS monitors conscious and deliberate planning of actions, novel situations that cannot be solved by previously learned schemata and/or when preventing error or habitual responses is critical (i.e. in dangerous situations). It allows to activate the appropriate schema in case of conflict and adjusts to solve problems that existing schemata failed to resolve. In other words, it modifies general strategies to solve non-routine problems. If there are no existing schemata related to the issue then under attentional control a new schema may be created, assessed and implemented (Badgaiyan, 2000). In summary, the operation of the SAS is thought to be necessary for appropriate behavior in situations that involve planning and decision making, error correction, contain novel sequences of actions or technically difficult actions, and when the overcoming of a strong habitual response is required (Norman & Shallice, 1986). While the contention scheduled is fast and automatic, SAS is slow, voluntary, and uses flexible strategies to solve a variety of difficult problems. Similarly to Norman and Shallice (1986), Baddeley (1996) proposed the Central Executive (CE) model. CE is defined as a component of the working memory together with the phonological loop (that temporarily stores verbal information) and the visuospatial sketchpad (that temporarily stores visuospatial information). According to this model, CE is a control system responsible for the coordination of the latter and for the inhibition of inappropriate behavior, suppressing dominant or automatic responses when necessary. Despite the importance of these models, the unitary approach has been the focus of a debate, as it results not fully adequate to describe the complex nature of the EF processes. In particular, one important research question that has been a source of controversy was raised by Teuber (1972): to what extent can different functions often attributed to the frontal lobes or to the central executive (or SAS) be considered unitary in the sense that they are reflections of the same underlying mechanism or ability?

Important progress in the conceptualization of EF as a multidimensional mechanism derived from the studies of adult patients with frontal lesions, as results showed a dissociation between different functions of the Central Executive (Bechara et al., 1998; McCarthy & Warrington, 1992). For example, some patients may fail on the Wisconsin Card Sorting Test, but not on the Tower of Hanoi, whereas others may show the opposite pattern, suggesting that executive functions may not be completely unitary (e.g., Godefroy et al., 1999; Shallice, 1988). Additional evidence of the non-unitary nature of EF derives from individual differences studies. These studies examined a wide range of populations, including normal young adults (Lehto, 1996), normal elderly adults (Lowe & Rabbitt, 1997; Robbins, 1996), brain-damaged adults (Burgess, 1997; Duncan et al., 1997), and children with neurocognitive pathologies (Levin et al., 1996; Schachar et al.,1993; Welsh et al., 1991) using a battery of EF tasks. Then they examined how well these tasks correlated with one another. Regardless of the study populations, results show that the intercorrelations among different executive tasks are low and often not statistically significant. In addition, also developmental studies confirm the multicomponential hypothesis, showing that different EF abilities develop in different stages of development (Welsh & Pennington, 1988). More recently, also neuroimaging supported this hypothesis, showing that different EF abilities activate different areas in the prefrontal cortex (Roberts & Wallis, 2000; Rushworth et al., 2004).

3 Origins and development of multicomponential models

In contrast to the unitary models, different authors suggested multicomponential models of EF. Even if the multicomponential theories have emerged later than the unitary ones, based on the evidence of neurocognitive and neuropsychological studies, their origins can be founded in the ‘70s. In fact, the first to provide an approach to capture the diversity of the processes attributed to EF without simply listing them and without hypostasizing homuncular abilities was Luria (e.g., 1973). Luria characterized the hierarchical nature of brain function. In his model, the PFC was at the highest level in the hierarchy, controlling other lower-level brain regions, but also was influenced by these other regions in a reciprocal, bidirectional way. According to this model, PFC and other neurological systems consist of *interactive functional systems* that involve the integration of subsystems. Subsystems have specific roles to play but cannot be considered outside of the larger systems of which they are a part (Zelazo & Muller, 2002). Zelazo and coll. (1997) applied the Luria’s idea of functional systems to EF, assuming that EF is a function, and not a mechanism or cognitive structure. Functions are essentially behavioral constructs defined in terms of their outcome. In the case of EF, the outcome is deliberate problem solving. The task of characterizing a complex function such as EF involves describing its hierarchical structure, characterizing its subfunctions, and organizing these subfunctions around their constant common outcome. In the case of EF, functionally distinct phases of problem solving can be organized around the constant outcome of solving a problem, and we can attempt to show how these phases contribute to that outcome (Zelazo et al., 1997). To better understand these assumptions, can be helpful to consider the case of the “prototypical EF task in neuropsychology” (Pennington & Ozonoff, 1996, p. 55), the Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948). To perform correctly on the WCST, one must first construct a representation of the problem space, which includes identifying the relevant dimensions. Then, one must choose a promising plan (for example, sorting according to shape). After selecting a plan, one must keep the plan in mind long enough for it to guide one's thoughts or actions, and actually carry out the prescribed behavior. Finally, after acting, one must evaluate one's behavior, which includes both error detection and error correction. As can be seen, numerous aspects of EF are involved and is difficult to determine the cause of errors. For example, perseveration could occur after a rule change in the WCST either because a new plan was not formed (one type of *representational inflexibility*; Zelazo et al., 1995) or because the plan was formed but not carried out (an example of *lack of response control*; Zelazo et al., 1995). Even if also the delineation of PS phases does not *explain* EF, this framework proposed by Zelazo and colleagues (1997) results more adequate than those described above to reflect the complexity of EF, overcoming the idea of EF as an unitary construct (e.g., Central Executive: Baddeley, 1996). In fact, it clarifies how diverse aspects of EF work together to fulfill the higher-order function of PS and suggests relatively well-defined measures of EF. In addition, it captures key aspects of EF, including goal selection, conceptual fluency, and planning in novel situations (e.g., Tranel et al., 1994) and permits the formulation of specific hypotheses regarding the role of basic cognitive processes (e.g., attention-switching, procedural memory, response inhibition) in different aspects of EF.

Given the growing evidence derived from literature, the idea of EF as a single mechanism has now been abandoned, in favor of a multi-dimensional conceptualization of EF. According to this idea, EF is considered as a set of different but interconnected abilities implicated in complex and goal-directed behaviors. Despite this, a variety of different multi-componential models has been proposed and a clear and shared definition of EF is still missing.

Within developmental psychology, the most recognized model is those of Miyake and colleagues (2000). According to this model, based on the adult population, EF includes three interrelated core skills: shifting, inhibition and working memory. Shifting (or cognitive flexibility) refers to the ability to change mental operation flexibly to respond to changed demands or priorities.

It also allows one to look at the same thing in different ways or from different perspectives and is involved in problem-solving. Inhibition (or inhibitory control) involves resisting an impulse to do something inappropriate or an automatized and prepotent response and is crucial when this automatic impulse is inadequate for the situation and a more reasoned and adaptive response is required. More recently, inhibition has been described as comprising not only these abilities, also called self-control, bat also interference control that is the ability to select attention and inhibit distractors (cognitive inhibition; Diamond, 2013). Working memory (WM) involves keep information in mind while performing mental operations on it. Subsequently, the model was applied also to the children population (Letho et al., 2003), confirming its validity. In particular, Letho et al. (2003) conducted a study to analyze FE between 8 and 13 years, as many of the FE abilities seem to be already developed by the age of 8 (Welsh et al., 1991). The aim of the study was to investigate whether EF is organized in children as in adults. Results confirm the same tripartite organization and show that EF seems to mature with age.

4 FE and prefrontal cortex

As mentioned above, EF is strictly related to the prefrontal cortex (PFC). Several studies showed an association between PFC damage and EF dysfunction, in particular decision making and planning (Bechara et al., 1994). For example, adults with PFC damage show more perseverative errors in the WSCST (Goldberg et al., 1998; Anderson et al., 1991), while in the TOL they took more moves to solve the problems and solved fewer problems without error than the control participants (Owen et al., 1990). In the same vein, studies show that PFC damage in children leads to a range of impairments in insight, foresight, social judgment, empathy, and complex reasoning (Price et al., 1990; Tranel & Eslinger, 2000; Eslinger et al., 1992). Over the years, several authors focused on the wide range of EF dysfunction after PFC damage, founding some differentiation in the PFC damage symptoms depending on the lesions area. Damage to dorsolateral PFC leads to the

EF deficit in the so called “cool” EFs, that are activated in emotionally neutral situations, while damage in the Orbitofrontal cortex leads to deficits in the “hot” EF, involved in problems that are characterized by high affective involvement, producing inappropriate social and emotional behavior. Regarding the development of PFC, is now recognized that it follows an extremely protracted developmental course, as synaptic density reaches the adult level at age 16 (Huttenlocher, 1990) and myelinization continues into adulthood (Yakovlev & Lecours, 1967). This evidence is in line with the evidence of the development of EF starting from infancy to adolescence (Garon et al., 2008). Despite PCF is still considered the core brain area involved in EF functioning, is now recognized that although various PFC regions play key roles in EF skills, EF also involves regions outside the PFC. Neuroimaging studies on adults demonstrate the activation of other brain areas during the execution of an EF task, such as parietal cortex and cerebellum (Owen et al., 2005), the striatum, the amygdala and other parts of the limbic system and the motor area (e.g., Niendam et al. 2012). More recently the same results are be replicated in children and adolescents aged below 18 years (McKenna et al., 2017). These results are in line with the hypothesis of an EF network that coordinates lower-level cognitive function and is related to multiple brain areas and numerous structures of the central nervous system, both cortical and subcortical (Alvarez & Emory, 2006)

5 Development of EF

Is now well recognized that the term executive function indicates a multicomponent construct comprising inhibition, working memory (WM) and cognitive flexibility, a set of cognitive abilities that reflect partially dissociable constructs that rely on overlapping but distinct neural circuitry and that collectively contribute to goal-directed behaviors (Miyake et al., 2000). From these core components, higher order EFs such as reasoning, problem solving, and planning are built (Collins & Koechlin, 2012; Lunt et al. 2012).

Evidence on the development of these abilities shows that it starts from early infancy until late adolescence, in line with the low and prolonged development of the PFC (Diamond, 2002). In addition, results show that each executive component has a different developmental trajectory. Based on the tripartite model proposed by Miyake et al. (2000), Lehto and colleagues (2003) administered eight different EF tasks to 108 children ages 8 to 13 years. A three-factor structure like that found in adults (Miyake et al., 2000) emerged, showing that in middle childhood the adult EF structure is reached. Subsequently, Wiebe and colleagues (2008) administered 10 EF tasks to 243 preschool children who were on average 3.9 years old. In this case, a one-factor model emerged, showing that in early childhood EF is an undifferentiated set of cognitive skills, which subsequently differentiate during the transition to middle childhood. Several studies try to understand when EF structure shifts from undifferentiated to multicomponential. Results show that a first differentiation appears starting from five years of age when two separate dimensions consisting of WM and inhibition are identified (Lee et al., 2013; Miller et al., 2012; Usai et al., 2014). Cognitive flexibility emerges later in development (Gandolfi et al. 2014; Lehto et al., 2003; Lee et al., 2013) after inhibition and WM abilities have been established. Collectively, these studies suggested that the cognitive processes implicated in the completion of performance-based EF tasks might undergo developmental reorganization during the transition from early childhood into middle childhood and adolescence, with the first 5 years of life having a crucial role, as the greatest changes are observed in this phase (Garon et al., 2008).

Despite the general agreement on the developmental trajectory of EF and its protraction until adolescence, number of studies reported contradictory results. For example, some studies that involved elementary school-aged children concluded that EF was best characterized by a single undifferentiated factor (Brydges et al. 2012; Xu et al., 2013). Finally, a longitudinal study by Lee and colleagues (2013) reported that while a two-factor model, which distinguished working memory from inhibitory control and cognitive flexibility for children 5- to 13-years old, a three-factor model, which distinguished working memory, inhibitory control, and cognitive flexibility, provided the best fit to the data among 15-year-olds (Lee et al., 2013). Nevertheless, the preponderance of studies has lent support to the idea that cognitive flexibility, working memory, and inhibitory control represent separable (but correlated) dimensions of cognitive function in school aged children, adolescents, and adults. What is less clear is whether EF has an undifferentiated structure in early childhood and when it begins to differentiate (Zelazo et al., 2016).

6 EF in atypical development

EF deficits have been found in several psychopathological conditions such as Attention-Deficit Hyperactivity Disorder (ADHD; Castellanos et al., 2006), conduct disorders (Pennington & Ozonoff, 1996), learning disabilities (Andersson & Lyxell, 2007), autism spectrum disorder (ASD; Hughes et al., 1994) and depression (Tavares et al., 2007). The presence of EF difficulties across disorders suggests that the disruption of EF development may be a common consequence of many different kinds of developmental perturbation (e.g., genetic/environmental/ epigenetic, cognitive/emotional/social), although different types of perturbation may lead to different ranges of symptoms, and different EF deficits may be present in different disorders or within a single disorder (Zelazo, 2020). For this reason, the presence of EF difficulties can usefully be considered a transdiagnostic indicator of atypical development in general (e.g., Beauchaine & Cicchetti 2019, Sonuga-Barke et al. 2016). Some recent neuroimaging and behavioral research with adult patients provides some explanation of EF dysfunction in psychopathology. For example, a meta-analysis conducted by McTeague et al. (2017) indicate a transdiagnostic pattern of atypical brain activation in regions (left lateral PFC, right insula, right intraparietal sulcus, and anterior midcingulate/ presupplementary motor cortex) (Duncan, 2013) which is activated across different EF tasks and likely reflects relatively general processes (e.g., reflection, task analysis and decomposition, sequencing, monitoring) common to all EF skills (Zelazo, 2020). In addition, also developmental research helps explain why EF difficulties are such a pervasive feature in developmental psychopathology. In particular, Zelazo (2020) gives the following explanation: 1) EFs are implicated in complex and intentional behaviors, which are crucial for flexible adaptation to everyday-life events. Disruption of these skills therefore has widespread behavioral and developmental consequences (e.g., Moffitt et al. 2011), cutting across academic and social domains and across diagnostic categories; 2) higher-order abilities are particularly vulnerable to disruption because of their position in a hierarchy: deficits in any one of the many subnetworks involved may lead to EF difficulties. The atypical development of lower-order networks has the potential to disrupt the later-developing PFC networks supporting EF skills; 3) PFC and EF skills are among the last cerebral areas and abilities to mature, and therefore they are relatively malleable. A long window of plasticity is useful for the acquisition of EF skills because these skills depend importantly on environmental influences including social and cultural support (e.g., language, autonomy support, play). At the same time, however, the extended malleability of EF skills leaves them vulnerable for longer to disruption from a wide range of influences, such as poverty, abuse, chaos, and stress. (Zelazo, 2020).

7 Implications of EF in development and school

In the past two decades interest for EF skills has been grown considerably, given their implication for correct development. As seen in the previous paragraph, EF is compromised in a wide range of psychopathological conditions, first of all ADHD (Castellanos et al., 2006). In addition, studies on typically development children highlight the protective role of EF in development. EFs are predictive of learning achievement, health and quality of life throughout life even more than IQ or socioeconomic status (Moffitt et al., 2011), and are a protective factor against the academic risks associated with extreme poverty (Masten et al., 2012; Obradović et al., 2010). In addition, they are predictive, more than IQ, of school readiness (Alloway et al., 2005; Blair, 2002; Blair & Razza, 2007; Hughes & Ensor, 2008) and more in general of academic success from preschool through university (Alloway and Alloway, 2010; Borella et al., 2010; Gathercole et al., 2004). Good EF is crucial also in adolescence and adulthood, as several studies demonstrated that EFs are predictive of job success and career advancement (Bailey, 2007), and social relationships (Hughes & Dunn, 1998). They also reduce the risk of criminal behaviors and substance abuse (Miller et al., 2011). Adults with better EFs also report they are happier and have a better quality of life (Moffitt, 2012). Taken together, these results highlight the broad role of EF in ensuring effective development and adaptation through life. Developmental and educational psychology focused on the role of EF in learning and school adjustment. In this vein, numerous studies have found EF to be a unique predictor of academic learning and achievement in kindergarten and during the school-age years (Fuchs et al. 2003, 2006; Siegler & Pyke, 2013; Vukovic et al., 2014). This is clearly established for mathematics (e.g., Bull & Lee, 2014; Monette et al., 2011), but also for reading (e.g., St. Clair-Thompson & Gathercole, 2006) and science (Nayfield et al., 2013). EF is also central to ensure a successful transition to kindergarten (Blair & Razza, 2007) and more in general to support school readiness and early school achievement (Blair, 2002; Blair & Raver, 2015) as self-regulation and attentional control are crucial to face the demands of primary school and new educational and didactic experiences.

More recent evidence of the association between EF and academic learning derives from the study on *self-regulated learning* (Zimmerman, 2008), that is an active form of learning, in which the learner is metacognitively, motivationally, and behaviorally engaged in the learning process. Although the specific relation of EF to self-regulated learning remains to be explored, EF is surely a key contributor to self-regulated learning, as it is based on goal setting, self-monitoring, and strategy use (Zelazo et al.,2016). For example, Fuchs et al. (2003) found that children who received activities designed to promote goal-setting and self-assessment in math learning, as well as assistance with the transfer of problem solutions, have better performance than those assigned to control or transfer-training-only conditions. Similarly, also research on school adjustment and learning-related behavior provides important evidence of the importance of self-regulation (EF) at school. Historically, school adjustment has been characterized in terms of students' academic performance, with children showing the best academic results considered more adjusted. However, some researchers started to define school adjustment more broadly, including in its conceptualization indicators that are not solely academic in nature. For example, Ladd and colleagues (Birch & Ladd, 1996; Ladd, 1989) defined school adjustment not only in terms of children's school performance, but also in terms of their school affect and attitude, and their involvement or engagement with the school environment. Similarly, learning-related behaviors have been defined as working independently, seeking challenges, accepting responsibility, sitting still and listening to the teacher (McClelland et al., 2000). The two constructs of school adjustment and learning-related behaviors are partially overlapping and both connected to EF skills (Stipek et al., 2010), but only a few studies investigated this association. This topic will be thoroughly examined in chapter 4.

8 Critical issues in the assessment of EF

In the study and evaluation of EF, researchers and clinicians had to face with different problems. One of the most important problems is the so called “impurity problem” (Miyake et al., 2000) that includes different aspects. First, EF refers to a set of different but interrelated abilities, so they are not completely independent of each other. For this reason, EF tasks generally require multiple executive processes to be completed. For example, tasks measuring cognitive flexibility generally involve complex instructions that need to be kept in mind and activated according to some kinds of rules, thus requiring working memory skills. So, even if different tasks have been proposed to measure specific EF components, there are no “pure” measures of any EF skills. Second, because executive functions by definition operate on other cognitive processes, any executive task will involve both EFs and other cognitive processes not relevant to the target EF, producing difficulties in accurately measuring executive processes (Burgess, 1997). In addition, due to the nature of the construct and its complexity, EFs partially overlap with several abilities that required EF. For instance, EF is strictly implicated in metacognitive control, that is the ability to monitor one's own ongoing cognitive activities and to control their efficacy (Roebers, 2017). Evidence also confirms the overlapping of EF and fluid intelligence, especially when complex behaviors requiring reasoning and problem solving are considered (Diamond, 2013; van Aken et al., 2016). Moreover, EFs are implicated in creativity, that is a clear expression of cognitive flexibility, as it is defined as the ability to generate new ideas, combine in different ways unrelated concepts and avoid common paths (Benedek et al., 2014). Given these problems, EF assessment should be based on more than one task for each domain in order to partially control the influence of non-target EF or non-executive abilities on the task's performance. However, the impurity problem remains a problem and an active area of research (see Willoughby et al. 2014).

The impurity problem, which concerns the performance-based tasks, is not the only one when considering EF assessment. Another important issue concerns the use of questionnaires. Over the last two decades, there has been a growing interest in developing questionnaires assessing EF in children, adolescents, and adults (e.g. Gioia et al., 2000). While performance-based tasks are a direct measure of the child's cognitive skills, questionnaires are assumed to represent behavioral manifestations of children's underlying EF skills (Gioia et al., 2000). When they are used to assess EF in children, they are typically completed by parents and teachers, and, in case of older children and adolescents, self-report scales are also available. One of the advantages of using questionnaires is the opportunity to obtain a more ecological measure of EF, as parents and teachers can observe children's behaviors in multiple contexts of everyday life, while performance-based tasks measure EF under controlled conditions and may not be indicative of a child's typical use of those skills in everyday life. In addition, questionnaires are easier to administer compared to performance-based measures. Despite these advantages, questionnaires and performance-based measures are poorly correlated. A meta-analysis of 20 studies showed that in only 24% of the studies correlations between performance-based and questionnaire-based assessments of EF were statistically significant and also in these cases the average correlation was low (r= .19) (Toplak et al., 2013). Different interpretations of this dissociation emerged from literature. While some authors highlight the low validity of the indirect measures (Conklin et al., 2008; McAuley et al., 2010; Sølsnes et al., 2014), others suggest that these results may reflect the existence of two partially dissociable domains of EF. According to this hypothesis, the direct measure of EF taps the cognitive dimension, while the indirect measures reflect the behavioural one (Anderson et al., 2002). Even if the debate is still open, it is reasonable to consider direct and indirect measures as complementary instruments to obtain a more complete description of the individual's functioning, that includes both the child's cognitive functioning and parent and teacher impressions of the child's behaviors in everyday contexts.

9. The importance of improving EF

As we have seen, EF is crucial in everyday life. Without inhibitory control, our behavior would be guided by impulses, habits and automatized responses. WM is a key aspect of reasoning and problem-solving because those require holding items in mind and manipulate them. Cognitive flexibility is crucial for creative problem- solving. Taken together, EFs are essential to resist impulse, stay focused despite distraction, wait before speaking or acting, carry out tasks through to completion despite not wanting to do it, look at a situation from multiple perspectives or flexibly change behavior if necessary (Diamond & Ling, 2020). In addition, research confirms that EFs are crucial in a wide range of life domains such as school readiness and school success through university, career success and quality of life in general (Bailey, 2007; Blair & Razza, 2007;). They are also crucial for the development of adequate social and emotional abilities (Riggs et al.,2006). Considering these results, it’s clear that support EF development in children is essential, as it can influence the developmental trajectory from infancy to adulthood (Moffit et al., 2011). Research suggests that early EF improvement can reduce the later incidence of school failure, substance abuse, addiction, aggression, crime, and other antisocial or inappropriate behaviors (Hall et al., 2010; Nagin & Tremblay, 1999; Olson et al., 2005; Vitaro et al., 2012). Indeed, Moffitt et al. (2011) predicted “that interventions that achieve even small improvements in [the inhibitory control component of EFs] for individuals could shift the entire distribution of outcomes in a salutary direction and yield large improvements in health, wealth, and crime rate for a nation” (p. 2694).

In the last decades there has been a growing interest in how to improve EF. Generally, literature confirms that EF can be improved at different stages of development and in different ways, such as through cognitive training, computer-based training, physical activities or school curricula (Diamond & Ling., 2016; Karbach & Unger, 2014). However, results on transfer effect and generalization in non-trained abilities and in real-life situations are limited and contrasting (Diamond & Ling, 2020). For example, a meta-analysis conducted by Karbach and Verhaeghen (2014) found that process-based EF training have a small but significant effect on fluid intelligence. In contrast, another meta-analysis (Melby-Lervåg & Hulme, 2013) found no convincing evidence of the generalization of WM training to other cognitive skills. Different explanations for these contrasting results have been hypothesized and observing differences between effective and ineffective training some different principles to follow for an effective training have been conceptualized. They concern motivation, level of difficulties, amount of time and session, together with the relevant importance of the trainer’s abilities. A more detailed discussion of these principles will be done in chapter 3.

SECTION 1

Executive function and telerehabilitation in pediatric stroke

2. EXECUTIVE FUNCTION AFTER PEDIATRIC STROKE

1 Introduction

The World Health Organization defines stroke as “rapidly developed clinical signs of focal (or global) disturbance of cerebral function, lasting more than 24 hours or leading to death, with no apparent cause other than of vascular origin”. Stroke can be classified into two major subtypes:

- Arterial Ischemic Stroke (AIS), a brain damage resulting from the blockage of a blood vessel, typically by a blood clot;
- Hemorrhagic Stroke (HS), a bleeding into the brain from the rupture of a blood vessel.

Another important classification depends on the time of presentation (Ferriero et al., 2019; Golomb et al., 2001):

- a stroke occurring between 28 weeks of gestation and 28 days of life is broadly classified as *perinatal stroke*. Perinatal stroke includes neonatal stroke (acute stroke presentation from 0 to 28 days of life) and presumed perinatal stroke, diagnosed in children with normal perinatal neurological histories who developed neurological deficits or seizures after 28 days of age;
- a stroke occurring between 29 days and 18 years of age is classified as *childhood stroke*.

The term pediatric stroke refers globally to stroke occurring in one of these developmental phases.

Despite its relatively low incidence and mortality compared to adult stroke, pediatric stroke is a serious condition, with more than half of survivors suffering permanent neurological morbidity. Due to rapid brain development, stroke in children has the potential to cause impairment in already developed skills and to disrupt the development of emerging skills and the neural networks underpinning them. Cognitive deficits may be immediate and then remit following injury, they can persist or they may not be immediately apparent following injury but a child may ‘grow into the deficit’ and fail to keep up with developmental trajectories of non-injured peers (Ross et al., 2011).

Consequences of stroke in childhood include psychosocial and relational problems (for a review see Gomes et al., 2014) and poorer quality of life in general (O'Keeffe et al., 2012). Outcomes also include impairment in a range of neuropsychological functions such as cognitive functioning, verbal and nonverbal reasoning, memory, visuospatial abilities and processing speed (Fuentes et al., 2016; Gomes et al., 2014; Murias et al., 2014). In addition, many studies that focused on cognitive outcomes after pediatric stroke reported a significant vulnerability in attention and executive functioning (Max et al., 2003; Westmacott et al., 2009; Westmacott, McDonald, Roberts et al., 2018; Williams et al., 2018), as well as a higher risk to receive a diagnosis of Attention Deficit/Hyperactivity Disorder (ADHD) (Everts et al., 2008; Max et al., 2002; Williams et al., 2018). A growing number of studies showed that children with a history of stroke have a deficit in EF including difficulties with working memory, inhibition and cognitive flexibility (Everts et al., 2008; Lansing et al., 2004; Max et al., 2003; Pavlovic et al., 2006). They also receive higher rates in parent-report questionnaires investigating EF impairment in everyday life (Long, Anderson et al., 2011). Moreover, EF is a unique predictor, aside from the severity of neurological deficits, of quality of life following pediatric stroke as reported by both parents and children (O'Keeffe et al., 2012). Despite these interesting findings, studies are still limited and results are conflicting, in particular regarding the impact of age at stroke (Westmacott et al., 2010; O'Keeffe et al., 2014; Kolk et al., 2011) and the role of lesion characteristics such as size or location (Kornfeld et al., 2018; Hajek et al., 2014; Bosenbark et al., 2017).

In order to guide future research and to provide coherent information to clinicians and families, we conducted a systematic review of the literature on this topic. Then, we studied EF functioning in a sample of 30 children who suffered a pediatric AIS. Finally, we investigated the efficacy and feasibility of an EF telerehabilitation program on a sample of 8 children.

2 EF in children with a history of stroke: a systematic review

Methodological framework for the search strategy

To guide the search and selection of articles, we based on the executive function model suggested by Miyake and colleagues (2000) described in chapter 1. This framework excludes functions commonly considered “executive” such as conceptual reasoning, planning, or attentional skills, that, in contrast, are included in other EF models (e.g., Anderson, 2002). It also does not consider the emotional aspects of EF such as emotion regulation and “hot” EF (Zelazo & Cunningham, 2007).

We also chose to focus our revision only on studies that included performance-based measures of EF, excluding articles in which only questionnaire-based assessment of EF was used. This choice was based on the evidence that questionnaire-based and performance-based assessment of EF are poorly correlated (Conklin et al., 2008; McAuley et al., 2010; Sølsnes et al., 2014). Finally, because of the impurity problem, we chose to include only articles in which at least two performance-based measures of EF were administered.

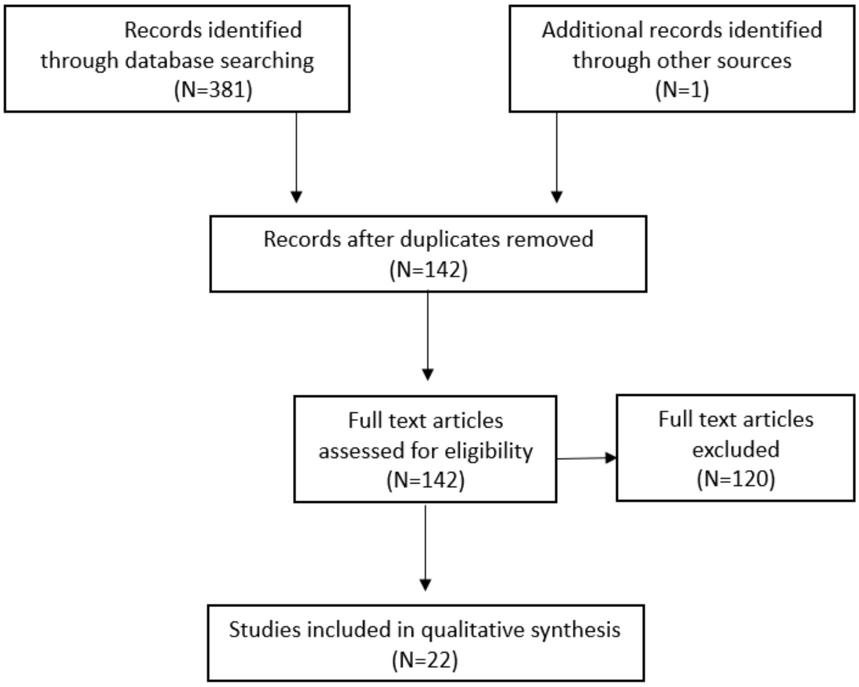
Search strategy

Literature searches were conducted in PsychInfo, PsychArticles and PubMed databases using the following keywords: “stroke” or “cerebrovascular accident” or “cerebral infarction” or “arterial ischemic stroke” or “cerebral thrombosis” AND “executive function” or “cognitive outcome” or “working memory” or “inhibition” or “task switching” or “set shifting” or “cognitive control”. Keywords were selected based on the definition of stroke and executive function mentioned above. The search was limited to articles published between 1990 and 2018 and including children and adolescents (0-18 years). The inclusion criteria were as follows: (1) English language; (2) sample consisted of children who experienced perinatal or childhood strokes; (3) studies comparing stroke with other pediatric populations were included; (4) if other brain injuries or pediatric populations were included, the data for the stroke subgroup were available; (5) participants were aged 0-18 years or the majority of participants were ≤18 years old if adults were also included or separate data for those ≤ 18 were available; (6) at least two performance-based EF tasks were administered to children. Articles in which both EF performance-based and questionnaire-based measures were used, were included and results of both direct and indirect measures of EF are reported in this review. The exclusion criteria were as follows: (1) single case studies and reviews; (2) age of the study sample not clearly defined; (3) presence of stroke in the sample not clearly defined. Articles with overlapping samples were considered separately if they focused on different aspects and reported different results. The literature searches produced 381 papers, and one article was identified by reviewing the reference lists of the included articles.

Study selection process

The overall process for selecting studies is shown in Figure 1. After removing duplicates, 142 articles were reviewed independently by me and my tutor. Title and abstract were reviewed to identify the relevant articles. The full text of all the relevant articles was reviewed to identify those that met the inclusion criteria. When discrepancy arose, articles were discussed and re-reviewed to determine inclusion or exclusion. The process led to the selection of 22 papers that met the inclusion criteria.

Figure 1. Studies selection.



Summary of the selected studies

A brief summary of the studies included in the review is presented in Table 1. Characteristics of the study populations, types of stroke considered, and main findings are reported. Among the 22 studies, six had overlapping samples (Long, Anderson et al., 2011; Long, Spencer-Smith et al., 2011; Max et al., 2010; 2003; O'Keeffe, 2012; 2014). They were considered separately as they focused on different aspects of EF impairment after stroke. All but one of the studies (Murphy et al., 2017) were cross-sectional and retrospective. Five studies included healthy controls (Fuentes et al., 2017; Kolk et al., 2011; Kornfeld et al., 2018; Schatz & Buzan, 2006; Schatz et al., 1999), and four studies included chronic illness control groups (asthma or orthopedic injuries; Araujo et al., 2017; Hajek et al., 2014; Max et al., 2010; Max et al., 2003). Many differences can be found across the studies' samples in terms of stroke types, age ranges at both stroke onset (0 – 17 years) and assessment (3-23 years) and lesion characteristics. Specifically, all except six studies included only AIS; among these six studies, one study included only hemorrhagic stroke (Murphy et al., 2017) and five studies included mixed samples with hemorrhagic and ischemic stroke (Kolk et al., 2011; Long, Anderson et al., 2011; Long, Spencer-Smith et al., 2001; Max et al., 2003; 2010). Regarding age onset, only one study focused on perinatal stroke alone (Bosenbark et al., 2018) while nine studies included only childhood stroke. Finally, three studies included only unilateral lesions (Fuentes et al., 2017; Kolk et al., 2017; Westmacott et al., 2018). Additionally, the inclusion criteria varied for each study in terms of the comorbid conditions included (e.g. sickle cell disease). The sample size ranged from 7 to 145 children. Finally, in terms of EF measures, most studies used the Delis–Kaplan Executive Function System (Delis et al., 2001) or the Test of Everyday Attention: Children's Version (Manly et al., 1999) but a wide range of other EF measures were used in the studies, such as fluency or planning tasks, and the WM index of the Wechsler Intelligence Scale for Children **(**WISC; Wechsler et al., 2003). The Behavior Rating Inventory of Executive Functions (Gioia et al., 2000) is used in all the studies that included a questionnaire-based EF measurement.

Executive function outcome

The first aim of this paper was to investigate whether children with stroke have lower EF performance than typically developing children. Of all the studies reviewed, only one study found no difference in EF between children with stroke and typically developing children (Kolk et al., 2011). All the other studies showed that as a group, children with stroke had lower performance in EF tasks than did typically developing children and they had higher EF difficulties in everyday life, as reported by parents. The severity of EF impairment reported by the studies ranged from a clear clinically impaired performance (with scores in standardized measures of EF below 2 sd with respect to normative data) to a mild impairment, with EF scores in the lower end of the average range. The effect size ranged from medium (d=.68; Hajek et al., 2014) to large (d=.9; O'Keeffe et al., 2012).

Table 1. Synthesis of selected studies

Study	Participants	Age at stroke	Age at assessment and time since stroke	Measure FE	Main findings
Allman and Scott, 2013	N= 44 unilateral cortical AIS No controls	AgeS = 5.9 y Range: 1 mo-16 y n= 12 infancy (1 mo-1 y) n= 11 early (1–6 y) n= 21 late (6–16 y)	AgeA= 9.2 y TimeSS= 3.3 y	WISC-III/IV, WPPSI-III, D-KEFS, CVLT-C,	Stroke in infancy or late childhood is associated with worse outcomes in a wide range of abilities, including working memory and inhibition. Left hemisphere lesions are associated with worse outcomes in a wide range of abilities including working memory.
Araujo et al., 2017	N= 82 TBI N= 36 AIS N= 74 BT N= 144 controls (n= 15 asthma, n= 61 orthopedic injury, n= 68 no medical illness)	AgeS= 4.17 y Range: 0 mo- 14 y	AgeA= 9.15 y Range: 6-16 y Time SS=4.97 y Range: 1-16 y	TEA-Ch (Creature Counting, Walk/ Don't Walk, Code Transmission).	Childhood brain disorders are associated with poorer EF performance overall when compared with controls. The AIS group had worse performance than controls in inhibition (partial η^2=.81), while there was no difference in WM and shifting (partial η^2=.02 and .37 respectively). The AIS group had better performance in shifting (partial η^2=.44) and lower performance in inhibition (partial η^2=.76) than the TBI group. Different childhood brain disorders result in distinct patterns of EF deficits that differ from those in children without brain disorders.
Bosenbark et al., 2016	N= 40 PAIS No controls	AgeA=7.2 y Range: 3-16 y	AgeA=7.2 y Range: 3-16 y n=16 3-5 y n= 24 6-16 y	WPPSI-IV, WMTB-C, NEPSY, TOL, TMT, TEA-Ch, ADHD rating scale IV, BRIEF	PAIS group had lower performance than the normative group in attention and EF, except for WM. Increased rate of ADHD symptoms in the PAIS group compared to the normal population (57.5% vs 5%). Older age at assessment is related with increased difficulties in WM and ADHD symptoms.
Fuentes et al., 2017	N=32 unilateral AIS N=32 healthy controls	AgeS=1.37 y TimeSS 8.20 y n= 22 perinatal n= 10 Childhood	AgeA =9.16 y Range: 6-14 y	WMTB-C, BRIEF	AIS < controls in WM test (partial η^2=.21) and in WM subscale of BRIEF (partial η^2=.24). Early age at stroke is associated with greater impairment (not statistically significant; partial η^2=.18).
Hajek et al., 2014	N= 36 AIS N= 15 asthma controls	AgeS= 4.17 y Range: 0 mo- 14 y	AgeA= 9.15 y Range: 6-16 y Time SS=4.97 y Range: 1-16 y	TEA-Ch (Walk/Don't Walk, Creature Counting, Code Transmission), WISC IV (PS index)	AIS < controls in inhibition (*d*= .68). Non-significant trends of poorer performance in processing speed, working memory, and cognitive flexibility (*d*= .09, .30 and .57 respectively) Combined cortical + subcortical lesions lead to poorer inhibitory performance.
Kolk et al., 2011	N= 31 stroke (IS or HE) n= 21 neonatal n= 10 childhood N=31 healthy controls	AgeS= 5.49 y	AgeA neonatal=6.86 y AgeA childhood= 8.21 AgeA controls= 7.34	NEPSY	No difference between stroke group and controls in EF domain. No difference between neonatal and childhood subgroups. (effect sizes ranged from medium to large)

Kornfeld et al., 2018	N= 20 AIS N= 22 healthy controls	AgeS= 7.26 Range= 1 mo-15.7 y	AgeA= 16 y Range: 9.5-23.1 TimeSS=8.65	TAP, D-KEFS (category fluency, Color Word Interference) WISC IV (PS index, letter-number sequencing), BRIEF	The stroke group had a higher rate of impairment in WM than did the controls (25% vs 4.5%). Non-significant trend of lower EF in everyday life in children with stroke (*d*= -.54). Association between interhemispheric connections after stroke and EF performance. Larger lesions lead to worse EF in everyday life.
Long, Anderson et al., 2011	N= 28 stroke n= 21 IS n= 7 HE No controls	AgeS= 0-14 y Time SS= 7 y Range: 1-13 y	AgeA= 12.5 y Range:10-15 y	TEA-Ch (Score!, Sky Search, Sky Search dual task, Creature Counting), D-KEFS (Verbal Fluency, Color Word Interference, TMT, Tower Test), RAN, BRIEF	AIS < normative group in all EF domains and in everyday EF. Larger lesions are associated with poorer EF outcomes (all the effect size are large).
Long, Spencer-Smith et al., 2011	N= 28 stroke n= 21 IS n= 7 HE n= 12 frontal lesion n= 9 extrafrontal lesion No controls (same Long, Anderson et al., 2011)	AgeS= 0-14 y Time SS= 7 y Range: 1-13	AgeA= 12.5 y Range:10-15 y	TEA-Ch (Score!, Sky Search, Sky Search Dual Task, Creature Counting), D-KEFS (Verbal Fluency, Color word interference, TMT, Tower Test), RAN, BRIEF	Stroke < normative group in EF, independent of the lesion location (frontal or extrafrontal). Frontal subgroup < extrafrontal subgroup in everyday EF functioning (all the effect size are large). Early stroke (<5) associated with poorer EF performance.
Max et al., 2010	N= 29 stroke (IS or HE) N= 29 orthopedic controls	n= 17 early (perinatal-12 mo) n=12 late (1-14 y)	Early AgeA= 11.8 y Late AgeA= 13.2 y	Design Fluency, COWA, WCST	Late < early in EF (small to large effect size). Early < late in all other domain investigated.
Max et al., 2003	N= 29 stroke (IS or HE) n= 15 stroke+ADHD n=13 stroke-ADHD N= 29 orthopedic controls (same max et al., 2010)	n= 17 early (perinatal-12 mo) n=12 late (1-14 y)	Early AgeA= 11.8 Late AgeA= 13.2	K-SADS-PS, CBCL, COWA, WCST	Stoke+ADHD < stroke-ADHD in some aspects of EF (perseverative errors of WCST).
Murphy et al., 2017	N= 7 HE stroke No controls	AgeS Range: 6-16 y	AgeA Range: 6-16 y	WASI II, WISC IV, WAIS III	WM and PS remained at a lower level than those of the peers at the 12 and 24 follow-ups. Verbal comprehension and perceptual reasoning improved over 24 months.
O'Keeffe et al., 2012	N= 49 AIS No controls	AgeS=5.08 y Range: 4 mo–15.66 y	AgeA=11.08 y Range: 6-18 y TimeSS= 6 y Range : 7 mo-15 y	PedsQL, CFSEI III, TEA-Ch (Sky Search, Sky Search Dual Task, Score!, Score Dual Task, Walk/ Don't Walk), TMT, BRIEF	Children in the low HRQoL group had lower abilities in processing speed, EF (in particular inhibition. *d*= .9) and attention and higher levels of executive dysfunction in everyday life (all the effect sizes are medium to large). EF is a predictor of parent proxy-rated HRQoL.

O'Keeffe et al., 2014	N= 49 AIS No controls (same O'Keeffe et al., 2012)	AgeS=5 .08 y Range: 4 mo–15.66 y	AgeA=11.08 y Range: 6-18 y TimeSS= 6 y Range : 7 mo-15 y	TEA-Ch (Sky Search, Score, Sky Search Dual Task, Score Dual Task, and Walk/Don't Walk), TMT, BRIEF	AIS < normative sample in all domains (effect sizes are medium to large). Earlier age at stroke associated with better EF outcomes.
Schatz and Buzan, 2006	N= 16 stroke+SCD n= 8 overt n= 8 silent N= 12 SCD controls N= 16 healthy controls		Overt AgeA= 13.9 Silent Age A= 12.2	WISC-III (Freedom from Distractibility factor), D-KEFS (Verbal Fluency Test), SOPT	Stroke group performed worse than the SCD with no lesion group and non-SCD controls for all cognitive variables and worse than the silent infarct group for all variables except for a measure of attention/WM (SOPT). The silent infarct group performed worse than the SCD with no lesion group or non-SCD on attention and WM. Association between corpus callosum size and EF performance.
Schatz et al., 1999	N=28 stroke+SCD n= 7 anterior n= 18 diffuse N= 17 healthy sibling controls	AgeS range:1.5-17 y AgeS anterior= 5.5 y AgeS diffuse= 6.5 y	AgeA= 12.8 y Range: 7 – 21 y AgeA anterior= 11.8 AgeA diffuse= 13.6	TOVA, Tower of Hanoi, WCST, CVLT-C	Stroke< controls in attention and EF. Anterior group had more selective impairment than diffuse group. Lesion size is not associated with EF domain.
Studer et al., 2014	N= 99 AIS n= 24 early (1 mo–2.11y) n= 22 preschool (3y–5.11y) n= 22 middle (6y–9.11y) n= 31 (≥10 y). No controls	AgeS= 7.27 Range: 1 mo-16 y n= 24 early (1 mo–2.11 y) n= 22 preschool (3y–5.11 y) n= 22 middle (6y–9.11 y) n= 31 (≥10 y).	AgeA= 9.45 TimeSS: 24.46	BSID-II, KABC, WISC-III\IV\R,	Combined lesions (cortical+ subcortical) lead to worse performance in WM and PS indexes of the WISC. Younger age at stroke leads to a poorer cognitive outcome.
Williams et al., 2018	N= 75 stroke (IS or HE) n= 36 stroke+ADHD n= 39 stroke only N= 45 developmental ADHD controls	Stroke+ADHD AgeS= 1.4 y Stroke only AgeS= 3.1 y	Stroke+ADHD AgeA= 9.4 y (3.4) Stroke only AgeA= 10.5 y (3.67)	WISC-IV\V, WPPSI-III\IV, WAIS-III	Children with secondary ADHD had the lowest WM scores compared to both the children with stroke-only and developmental ADHD group and had lower PS than the children with developmental ADHD.
Westmacott et al., 2010	N= 145 unilateral AIS No controls	AgeS= 4.5 y n= 46 perinatal n= 57 early (1 mo-5 y) n= 42 late (6-16 y)	AgeA= 9.1 y	WISC-II\-IV, WPPSI-R\III	The perinatal group had worse performance than the early and late group with respect to the normative group. Combined cortical subcortical damage is associated with worse performance. There is an interaction effect between the lesion location and age at stroke.
Westmacott, McDonald, deVeber et al., 2018	N= 98 unilateral basal ganglia AIS n= 26 dystonia n= 27 no dystonia No controls	AgeS= 3.91 (4.19) Range: 0 mo- 16 y	AgeA= 11.49 y Range: 6-20 y Time SS= 8.31	D-KEFS (Color-Word Interference), BRIEF.	AIS < controls in all measures. Dystonia < no dystonia in all subtests (large effect sizes). No difference between dystonia and no dystonia in BRIEF (small effect sizes).

Westmacott, McDonald, Robert et al., 2018	N= 44 subcortical AIS n= 32 basal ganglia n= 12 thalamus No controls	AgeS= 5.7 y	AgeA= 11.9 y Range: 6-20 y TimeSS= 6.1 (3.1)	WISC-IV\V, WAIS-III, TEA-Ch (Sky Search, Score!), D-KEFS (Color-Word Interference Test), BRIEF	AIS group had lower WM and attention performance than the normative group, and there is a non-significant trend of worse performance in inhibition. The AIS group had also greater difficulties in everyday EF functioning. The basal ganglia group had lower WM performance than the thalamus group. A larger lesion size was significantly correlated with poorer performance on measures of working memory and visual attention.

Note: AgeA= age at assessment; AgeS=age at stroke; TimeSS= time since stroke; AIS= arterial ischemic stroke; BRIEF= Behavior Rating Inventory of Executive Function; BSID= Bayley Scales; BT= brain tumor; CBCL = Child Behavior Checklist; CFSEI III= Culture-Free Self-Esteem Inventory 3rd Edition; COWA= Multilingual Aphasia Examination Controlled Oral Word Association; CVLT-C= California Verbal Learning Test for Children; D-KEFS= Delis–Kaplan Executive Function System; HE= hemorrhagic stroke; IS= ischemic stroke; KABC= Kaufman Assessment Battery for Children; K-SADS-PL= Schedule for affective disorders and schizophrenia for school-aged children, present and lifetime version; NEPSY= Developmental Neuropsychological Assessment battery; PAIS= perinatal arterial ischemic stroke; PedsQL= Pediatric Quality-of-Life Inventory 4.0; PS= processing speed; RAN = rapid automated naming; SCD = sickle cell disease; SOPT= Self-Ordered Pointing Test; TAP= test of attentional performance; TBI= traumatic brain injury; TEA-Ch= Test of Everyday Attention for Children; TMT= Trial Making Test; TOL= Tower of London; TOVA= Test of Variables of Attention; WAIS= Wechsler Adult Intelligence Scale; WASI= Wechsler abbreviated scale of intelligence; WCST= Wisconsin Card Sorting Test; WISC= Wechsler Intelligence Scale for Children; WM= Working Memory; WMTB-C= working memory test battery for children; WPPSI= Wechsler Preschool and Primary Scale of Intelligence.

The impact of stroke on the different components of EF is not clear, given the wide range of EF tasks that were used. However, the most vulnerable component of EF appears to be inhibition. It was specifically assessed in eight studies. Five studies reported lower scores in inhibitory processes than in working memory processes or cognitive flexibility, regardless of age at stroke onset or lesion characteristics (Araujo et al., 2017; Bosenbarket al., 2018, 2017; O'Keeffe et al., 2012; Westmacott, McDonald, deVeber et al., 2018). In contrast, one study found a higher rate of impairment in dual tasks than in inhibitory tasks (O'Keeffe et al., 2014).

Only two studies investigated EF outcomes longitudinally (Murphy et al., 2017; O'Keeffe et al., 2014), and they showed different results. Murphy et al.'s study found a decline in processing speed and WM abilities over 24 months, supporting the "growing into deficit" hypothesis, which suggest that difficulties may emerge over time when cognitive demands increase (Westmacott et al., 2009). Differently, in another study no changes were found at follow-up, compared with baseline assessment, in measures of inhibition and cognitive flexibility (O'Keeffe et al., 2014); these results support the hypothesis that cognitive deficits remain stable over time (Ballantyneet al., 2008). However, it should be noted that both studies had small sample sizes (7 and 9 respectively), limiting the strength of their findings.

Three studies investigated EF outcomes and ADHD incidence after stroke, finding a higher risk to receive a diagnosis of ADHD and lower EF performance in children with a history of stroke (Bosenbark et al., 2018; Max et al., 2003; Williams et al., 2018). A study found that the incidence of ADHD diagnosis or ADHD traits was significantly higher after stroke than after an orthopedic diagnosis (46% vs 17%). Moreover, children with a diagnosis or traits of ADHD after stroke had lower performance in EF than those with stroke only, specifically on a cognitive flexibility task (Max et al., 2003). Interestingly, no impact of lesion pattern, size or laterality has been found on the development of secondary ADHD (Williams et al., 2018). In addition, children with secondary ADHD after stroke have been found to have the lowest scores across WM and Processing Speed indexes of the WISC compared with children with stroke (but without ADHD) or ADHD (without stroke). Only in the Processing Speed index there was no significant difference between the children with secondary ADHD and the children with stroke only (Williams et al., 2018). Taken together, these results highlight an elevated risk of ADHD in children after stroke and suggest the importance of evaluating EF and ADHD symptoms after pediatric strokes.

Determinants of EF outcomes

The second aim of this review was to identify which factors are related to EF outcomes. In particular, the studies reviewed took into account the age at stroke onset, time since stroke, age at assessment and lesion characteristics.

<u>Age at stroke onset</u>

Nine studies investigated the impact of age at stroke onset on EF outcomes. However, the presence of methodological differences across the studies made it difficult to compare and generalize the results. A synthesis is shown in Table 2. Two studies found that an earlier age at stroke onset was associated with better performance on most EF tasks (Max et al., 2010; O'Keeffe et al., 2014) and with fewer everyday executive function behavioral difficulties as reported by parents (O'Keeffe et al., 2014). However, earlier age at stroke was not associated with better functioning in all EF measures or in other cognitive domains, such as intellectual functioning or academic achievement, suggesting that the impact of age at stroke onset is domain dependent and varies within different EF domains, which likely possess various developmental trajectories and periods of peak vulnerability to stroke.

In contrast to these findings, most studies showed that an older age at stroke onset was related to better performance in the EF domain (Bosenbark et al., 2017; Fuentes et al., 2017; Long, Spencer-Smith et al., 2011; Westmacott et al., 2010). A recent cross-sectional study showed that children with presumed perinatal AIS performed worse than children with neonatal AIS on attention and inhibition tasks and had more clinically significant symptoms of hyperactivity, as reported by the parents; according to the authors, this is probably because children with neonatal AIS are identified sooner and receive earlier and more aggressive intervention (Bosenbark et al., 2017). A study showed that the WM index of the WISC was significantly lower in the perinatal group than in the 6-16 age group (Westmacott et al., 2010), while another study found a trend suggesting that strokes occurring during childhood are related to better performance on working memory tasks and higher WM ratings on the Behavior Rating Inventory of Executive Functions compared with perinatal strokes (Fuentes et al., 2017). Some results also suggested a domain-dependent impact of the age at stroke onset, as younger age at stroke onset (<5 years) was associated with poorer performance on selected EF tasks and with greater everyday difficulties in shifting and planning, as reported by the parents, but with better performance on a goal setting task (Long, Spencer-Smith et al., 2011). One study demonstrated a nonlinear relationship between the age at stroke onset and executive function abilities. In particular, the children who had a stroke between 1 and 6 years had higher working memory and inhibitory abilities than did the children who experienced a stroke between 1 and 12 months of age or between 6 and 16 years of age (Allman & Scott, 2013). Finally, in some studies, no effects of age at stroke onset on EF were detected (Hajek et al., 2014; Kolk et al., 2011; Kornfeld et al., 2018; Westmacott, McDonald, Roberts et al., 2018).

An interesting result was reported by Westmacott et al. (2010), who found an interaction between the age at stroke onset and lesion location. In fact, they found that in a group with subcortical lesions, the perinatal group had significantly poorer results in the WM index of the WISC than both the 1-month-old to 5-year-old group and the 6- to 16-year-old group. In contrast, in the cortical group, lower scores were found for children aged from 1 month to 5 years. In the combined cortical-subcortical group, there were no differences related to the age of onset. These results suggest that there are different periods of vulnerability depending on the lesion location.

Table 2. Age at stroke onset impact on EF outcomes. Synthesis of the results.

Hypothesis supported	Authors	Findings
Early plasticity hypothesis	Max et al., 2010	Early stroke is associated with better outcomes than late stroke in the EF domain (fluency tasks). Early stroke is associated with worse performance in an EF switching task (WCST).
	O'Keeffe et al., 2014	Early stroke is associated with better outcomes than late stroke in EF tasks involving sequencing and switching and with better everyday executive function. No differences were found between early and late stroke in the intelligence, reading, inhibition and attention scores.
Early vulnerability hypothesis	Bosenbark et al., 2017	Late stroke is associated with better performance than early stroke in attention and inhibition tasks. Late stroke is associated with fewer clinical symptoms of hyperactivity, as reported by parents.
	Westmacott et al., 2010	Late stroke is associated with a higher WM index than early stroke. There is an interaction between age at onset and lesion location.
	Fuentes et al., 2017	Late stroke is related to better performance on working memory tasks and higher WM ratings than early stroke.
	Long, Spencer-Smith et al., 2011	Late stroke is related to better performance than early stroke in inhibition, information processing and shifting and planning in everyday life. Early stroke is associated with better outcomes than late stroke in goal setting.
Interaction between age at stroke onset and EF	Max et al., 2010	Early stroke is associated with better outcomes than late stroke in two fluency tasks and worse performance in a switching task. The impact of age at stroke onset varies within different FEs.
	O'Keeffe et al., 2014	The impact of age at stroke onset on EF was found in sequencing and switching tasks and in everyday executive function but not in inhibition. The impact of age at stroke onset is domain dependent and varies within different FEs.
	Long, Spencer-Smith et al., 2011	Late stroke is related to better performance than early stroke in inhibition, information processing and shifting and planning in everyday life and with worse performance in goal setting.

		The impact of age at stroke onset varies within different EFs.
Nonlinear impact of age at stroke onset	Allman & Scott, 2013	1- to 6-year-old group had better working memory and inhibitory abilities than earlier and later group.
No impact of age at stroke onset	Kolk et al., 2011	Neonatal= childhood.
	Hajek et al., 2014	Neonatal= childhood.
	Westmacott, McDonald, Roberts et al., 2018	No age impact within a childhood stroke group.
	Kornfeld et al., 2018	No age impact within a perinatal and childhood stroke group.

Note: WCST= Wisconsin Card Sorting Test; MCD= malformation of cortical development.

Time since stroke and age at assessment

Time since stroke was not considered in the analyses in all studies. Of the 24 studies reviewed, only three studies considered this aspect. Two of them did not find time since stroke to be significantly associated with the outcome (Allman & Scott, 2013; Kornfeld et al., 2018). One study showed a nonsignificant trend of correlation between the time since stroke and measures of WM and Processing Speed, but the trend was only present when the stroke group was considered as a whole rather than by age at onset (Westmacott et al., 2010). Similarly, the age at assessment was seldom considered. Two studies found no association with the outcome (O'Keeffe et al., 2014; Westmacott et al., 2010), whereas one study found that older age at assessment was related to greater difficulties in WM and a higher incidence of clinically elevated ADHD symptoms (Bosenbark et al., 2018). In general, the age at stroke onset, age at assessment and time since stroke are all highly intercorrelated, and it is not easy to evaluate their roles separately.

Lesion location and lesion size

The role of the lesion size and/or location was analyzed in 10 studies (see Table 3 for a synthesis of the results). Regarding lesion location, most studies focused on cortical/subcortical location comparison. Three studies found that combined cortical-subcortical lesions led to worse EF outcomes compared to cortical or subcortical lesions alone (Hajek et al., 2014; Studer et al., 2014; Westmacott et al., 2010). In particular, one study found that combined lesions lead to lower inhibition abilities, whereas no associations were found between the lesion location and working memory and shifting abilities (Hajek et al., 2014). In contrast, two studies (Studer et al., 2014;

Table 3. Lesion location and lesion size impact on EF outcome. Synthesis of the results.

Hypotheses supported	Authors	Findings
Combined (cortical-subcortical) vulnerability	Hajek et al., 2014;	Combined lesions are associated with worse outcomes than cortical or subcortical lesions in inhibition. No association with WM or shifting.
	Studer et al., 2014;	Combined lesions are associated with worse outcomes than cortical or subcortical lesions in the WM and PS indexes of the WISC.
	Westmacott et al., 2010	Combined lesions are associated with worse outcomes than cortical or subcortical lesions in the WM and PS indexes of the WISC. (Lesion size partialled out).
Domain dependent	Long, Spencer-Smith et al., 2011	Subcortical lesions are associated with greater behavioral and emotional difficulties as reported by parents. Cortical lesions are associated with worse performance in an information processing task. (Lesion size partialled out).
No effect of lesion location	Bosenbark et al., 2017	No differences between cortical and combined lesions in EF task performance.
	Schatz et al., 1999	No differences between focal anterior to the central sulcus lesions and combined anterior and posterior to the central sulcus lesions in EF.
	Kornfeld et al., 2018	No impact of lesion location within a perinatal and childhood AIS group.
No central role of frontal regions in childhood	Long, Spencer-Smith et al., 2011	No differences between frontal and extrafrontal lesions in EF task performance. Frontal lesions are associated with greater difficulties in emotional control and planning/organization as reported by parents.
Role of basal ganglia	Westmacott, McDonald, Roberts et al., 2018	Basal ganglia lesions are associated with poorer performance in WM tasks and a higher risk of ADHD than thalamus lesions.
No effect on lesion size	Schatz et al., 1999	Lesion size is not associated with EF impairment. Lesion size is associated with spatial and language impairment.

	Hajek et al., 2014	Lesion size is not associated with EF impairment.
Larger lesion	Long, Anderson et al., 2011	Larger lesions are associated with worse performance in EF tasks and greater difficulties in everyday executive function.
	Schatz and Buzan, 2006	Larger lesions and smaller CC volumes are associated with deficits in attention and EF but not with general cognitive ability.
	Westmacott, McDonald, Roberts et al. 2018	Larger lesions are correlated with poorer performance on WM and visual attention tasks and with a higher risk of a learning disability.
	Bosenbark et al., 2017	Larger lesions are associated with poorer performance on standardized attention and EF measures, as well as more severe real-world functional problems in many areas, as reported by the parents.
	Kornfeld et al., 2018	No impact of lesion size on EF task performance but greater EF difficulties in everyday life.

Note: CC= corpus callosum

Westmacott et al., 2010) found an association between combined lesions and lower WM and Processing Speed scores. One study found that subcortical stroke is associated with greater behavioral difficulties than in cortical stroke, even though the cortical group had significantly larger lesions (Long, Spencer-Smith et al., 2011). Two studies did not find any effects of the lesion location on EF performance (Bosenbark et al., 2017; Kornfeld et al., 2018). It should be noted that only Westmacott et al. (2010) and Long, Spencer-Smith et al. (2011) controlled for lesion size in the analysis. In other studies, the effects of the lesion location may be confounded by those of lesion size because combined lesions are often larger than subcortical or cortical lesions only (Hajek et al., 2014; Studer et al., 2014). In addition to these results, children with basal ganglia stroke tend to score lower on working memory tasks and have higher rates of ADHD than children with thalamic stroke (Westmacott et al., 2018). It is well known that both the basal ganglia and thalamus are highly interconnected with the prefrontal regions (Herrero et al., 2002; Ide et al., 2015) and have a strong relation with attention and EF (Liebermann et al., 2013; Moreno-Alcazar et al., 2016; Nadeau, 2008; Van Der Werf et al., 2003; Ward, 2013). In addition, the results reported by

Westmacott et al. (2018) suggest that the basal ganglia are more specifically implicated in WM than in inhibition and cognitive flexibility. Finally, two studies focused on the impact of anterior and posterior lesions. One study indicated no association between anterior or posterior lesions and EF performance (Long, Spencer-Smith et al., 2011). The second study found that children with significant smaller lesions limited to frontal regions had similar attentional and EF deficits as did children with larger, diffuse lesions (Schatz et al., 1999). This study, according to the authors, supports the central role of the frontal regions in EF performance in children, just like in adults. Regarding the lesion size, several studies found that larger lesions are associated with more severe EF deficits (Kornfeld et al., 2018; Long, Anderson et al., 2011; Schatz & Buzan, 2006; Westmacott, McDonald, Roberts et al., 2018). In particular, inhibitory control, verbal retrieval, and processing speed were more likely to be influenced by the clinical variables than other aspects of attention and executive functioning, such as sustained attention, working memory, flexibility, and planning (Bosenbark et al., 2017). Research also suggests that the volume of the anterior corpus callosum area is a predictor of attentional and EF abilities (Schatz & Buzan, 2006). One study did not find any effects of the lesion size on EF performance but found a relation with the Behavior Rating Inventory of Executive Functions self-rating scores, indicating that children with larger lesions reported worse EF in everyday life (Kornfeld et al., 2018). One study did not find any correlation between lesion size and EF outcome (Hajek et al., 2014).

Lesion laterality

The majority (4) of the studies investigating the impact of lesion laterality on EF measures did not show any effects (Bosenbark et al., 2017; O'Keeffe et al., 2014; Schatz et al., 1999; Studer et al., 2014). Two studies found that right hemisphere lesions are associated with better performances in EF tasks (Allman & Scott, 2013; Kolk et al., 2011). In addition, Allman and Scott's study found that when the study population was stratified by age, in the infancy group, the children with left hemisphere lesions were significantly more impaired in the cognitive measures associated with right hemisphere functioning, such as processing speed, compared to older children, suggesting an interaction between age at onset and laterality.

Results

Summarizing the results, the current review indicates that executive functions are highly vulnerable following pediatric stroke. All but one of the studies reviewed (Murphy et al., 2017) show that as a group, children with stroke have worse performance in EF tasks than typically developing children. Moreover, in the studies that concurrently used parent-report questionnaires, EF impairment was also associated with behavioral difficulties in everyday life. Inhibition was found to be particularly vulnerable; nevertheless, it is not possible to draw conclusions concerning the selective impact of pediatric stroke on EF components since the studies used different definitions of EF and different tasks; in some studies, selected EF components (for example, either working memory or inhibition) were assessed, whereas in some other studies, comprehensive measures that did not differentiate dimensions of EF were used. Although variables such as the age at stroke onset, time since stroke and lesion characteristics are considered to have an impact on cognitive outcomes following pediatric stroke (e.g., Westmacott et al., 2010; Westmacott, McDonald, Roberts et al., 2018), the influences of these variables on executive function are not yet clear. The results regarding the impact of stroke onset are inconsistent, with some findings supporting the early vulnerability hypothesis and others supporting the early plasticity hypothesis. A third approach suggests that the outcomes of age at stroke onset might depend on the specific EF component. This hypothesis is consistent with the developmental models of EF that indicate that EF components show different developmental trajectories (Lee et al., 2013) and possibly show different periods of vulnerability. Nevertheless, the studies supporting this hypothesis (Long, Spencer-Smith et al., 2011; Max et al., 2010; O'Keeffe et al., 2014) assessed different EF components in different ways, preventing us from drawing any definitive conclusions. It should be also noted that the effects of age at stroke onset on EF are possibly influenced by a variety of potentially important variables, such as lesion characteristics, rehabilitation interventions and the home environment, whose influences were generally neglected in the studies reviewed.

As expected, larger lesions as well as combined cortical and subcortical lesions are generally associated with greater impairment in EF. The involvement of frontal regions is less clear. In the adult brain, EF functioning is closely related to the frontal regions (Stuss, 2011), while results of studies that focused on EF functioning after pediatric stroke showed mixed results. Long, Spencer-Smith et al. (2011), regardless of whether the lesion was located in the frontal or extrafrontal regions, found significant impairment in measures of EF. Similarly, Araujo et al. (2017) found that in a sample of children with different kinds of brain injuries, including AIS, EF was impaired in the children with non-frontal lesions. In contrast, Schatz et al. (1999) suggested a specific relationship between frontal injury and EF performance. However, in this study children had focal anterior or combined anterior and posterior lesions whereas no children with posterior lesions only were included.

Limitations

Limitations exist across the studies that limit our understanding of cognitive outcomes following pediatric stroke. First, the characteristics of the study populations did not allow us to reach clear and consistent conclusions about the determinants of EF impairment. The sample sizes were limited in the majority of the studies reviewed (eight studies included fewer than 30 children; nine studies included 30 to 50 children), and results reported often did not reach significance. The little effect size reported in part of the studies highlight the necessity of bigger sample to have more consistent results. The three studies that had larger sample sizes (98 to 145 children; Studer et al., 2014; Westmacott et al., 2010; Westmacott et al., 2018) based their assessment of EF on general measures, such as the WISC WM Index. In addition, many studies had heterogeneous study populations in terms of the types of stroke (hemorrhagic or ischemic), comorbid conditions (such as sickle cell disease or heart disease), age at stroke (perinatal or childhood), and age at assessment (range 0-16 in the majority of studies). These aspects led to inconsistent results across studies regarding the impact of stroke characteristics on EF.

Second, most studies were not based on clear developmental models of EF. For example, according to recent studies (Lee et al., 2013), shifting appears to be a clear and well-defined process in late childhood and adolescence, suggesting that shifting can be validly assessed at an older age than inhibition and working memory. Despite this, most studies did not consider the different times of emergence and development of each EF process.

Another important limitation concerns the impact of psychosocial variables, such as socioeconomic status (SES) and parenting characteristics, on cognitive outcomes. This aspect has been largely neglected in pediatric stroke research. However, given that the home environment and SES are associated with EF development in typical children (Hackman & Farah, 2009) and have been shown to correlate with behavioral outcomes in other populations with brain lesions (e.g., Li & Liu, 2013), it is plausible that these aspects may in part explain EF outcomes in the pediatric stroke population as well.

Some limitations have to be mentioned regarding the methodological aspects of our revision. First, we chose to focus only on the three EF components mentioned by Miyake and colleagues (2000). Other keywords could have been used to reach a larger number of articles. Second, we excluded articles that used only one performance-based measure of EF or only questionnaire-based measures. The rationale for this choice was to select those articles with a more solid assessment of EF. It is in fact recognized that the use of a single measure is not enough to assess EF impairment and there is an increasing emphasis on using more complex tasks that tap several executive domains (Chan et al., 2008). As regards questionnaires, the literature indicates that the association between performance-based and rating measures of EF is low and that possibly performance-based and rating measures assess different underlying mental constructs (Toplak et al., 2013). Nevertheless, we recognize that our methodological approach limited the number of included articles.

Future directions

Although the number of studies concerning pediatric stroke and its impact on EF has increased considerably, many aspects of the impact of pediatric stroke on EF are not yet clear. A critical factor limiting the knowledge about pediatric stroke is the lack of understanding concerning the interactive effects of specific demographic, lesion, etiological, and psychosocial factors on cognitive and behavioral outcomes. As a consequence, any conclusions about the cognitive outcomes of pediatric stroke are rather inaccurate, as the outcomes may be dependent on many of these factors. Multicenter studies with larger and more homogeneous samples are necessary to reach more definite conclusions. Furthermore, future research studies should also include measures of the different components of EF since some components seem to be more compromised than others. In addition, the results in adults after stroke suggest a correlation between functional resting state network connections and relative cognitive functions (Carter et al., 2010; He et al., 2007; Stevens & Spreng, 2014). In other words, not only the lesion location but also specific network disconnections may influence cognitive outcomes after stroke. This aspect should be investigated further in the pediatric population. In this sense, the results of Kornfeld and colleagues (2018) seem to confirm this relation in children. In their study, a correlation between frontoparietal network connections at rest and EF was found, suggesting that EF impairment in children after stroke may be due to a reduction in the interhemispheric connection strength of the frontoparietal network. Another understudied aspect is the association between EF and motor functioning. Despite in healthy children some evidence exists (Van der Fels et al., 2015; Wassenberg et al., 2005), the association between these two processes is rarely described in patients after pediatric stroke and no one of the studies selected investigated this aspect. However, an association between motor abilities and cognitive functions would have and important impact on rehabilitation. Motor and cognitive impairments are usually addressed as separate domain, while a training program in one domain could improve performance in the other domain and a multimodal intervention could be most effective (Abgottspon et al., 2021). Finally, our revision focused on cognitive aspects of executive functioning and only partially on behavioral aspects. A similar revision concerning specifically emotional and behavioral aspects of EF is needed.

Clinical implications

It is important for clinicians and families to understand the cognitive and behavioral outcomes after perinatal and childhood stroke. In particular, EF impairment is associated with a wide range of difficulties, including learning disabilities, impaired social functioning, behavioral problems and poor emotional control, which are in fact, frequently associated with pediatric stroke (Champigny et al., 2020; Greenham et al., 2018; O'Keeffe et al., 2017) and adversely impact the quality of life and psychological well-being (Everts et al., 2008; Härtel et al., 2004). Consequently, the assessment of EF appears to be important for informing families of the potential challenges that EF deficits are associated with and to provide adequate support and training for children. Even though interventions supporting EF in children with neurological damage are reported infrequently and the evidence of their efficacy is therefore limited (Greenham et al., 2017), different types of interventions have been shown to be useful in promoting EF development in typically developing children (Diamond & Lee, 2011). In addition, a meta-analysis (Robinson, et al., 2014) provided evidence that cognitive interventions are beneficial for children with neurological disorders and acquired brain injuries, especially in the domains of attention and working memory. These findings, though they are preliminary due to the limited number of studies involved and the limited quality of the evidence, suggest that cognitive interventions are feasible and possibly effective and that rigorous research in this field is necessary.

3 Executive functions profiles in children aged 7-12 whit a history of stroke

Few studies have investigated neuropsychological development and cognitive outcomes of stroke in children. According to these preliminary studies and as indicated by the review of the literature previously presented, EF seems to be particularly vulnerable to early brain lesions. The present study has multiple aims. The first aim is to describe EF functioning following childhood and perinatal stroke in a sample of children without cognitive impairment aged 7-12 years, which is the developmental phase in which the tripartite adult EF's structure is achieved (Letho et al., 2003). In order to study the selective impact of pediatric stroke on EF components, specific measures of inhibitory control, working memory, cognitive flexibility and attention were used. The second aim was to examine the relationship between EF impairment and clinical and neuroradiological features. In particular, age at stroke onset, functional outcome (including language impairment, motor impairment and comprehensive neurological deficit severity), lesion location and lesion size were considered. The third aim was to analyze the relationship between EF impairment and emotional and behavioural functioning, as assessed by parents.

We expect to find an impairment of different components of EF. Considering predictors of EF impairment, we hypothesize to find a relationship with lesion size. In addition, given the existing literature concerning the relationship between EF, motor and linguistic development, we hypothesize that the presence of linguistic or motor impairment following stroke is associated with a higher risk of EF impairment. Finally, we expect that EF impairment following stroke is associated with social and behavioural difficulties.

3.1 Materials and methods

Participants

Participants of this study were children with childhood or perinatal stroke referred to the Stroke Centre of the Giannina Gaslini Children Hospital in Genoa, Italy, from June 2018 to June

2020. The study was conducted according to ethical standards laid down in the 1964 Declaration of Helsinki. The study was also approved by the Gaslini Ethical Committee. Written informed consent was obtained from all parents.

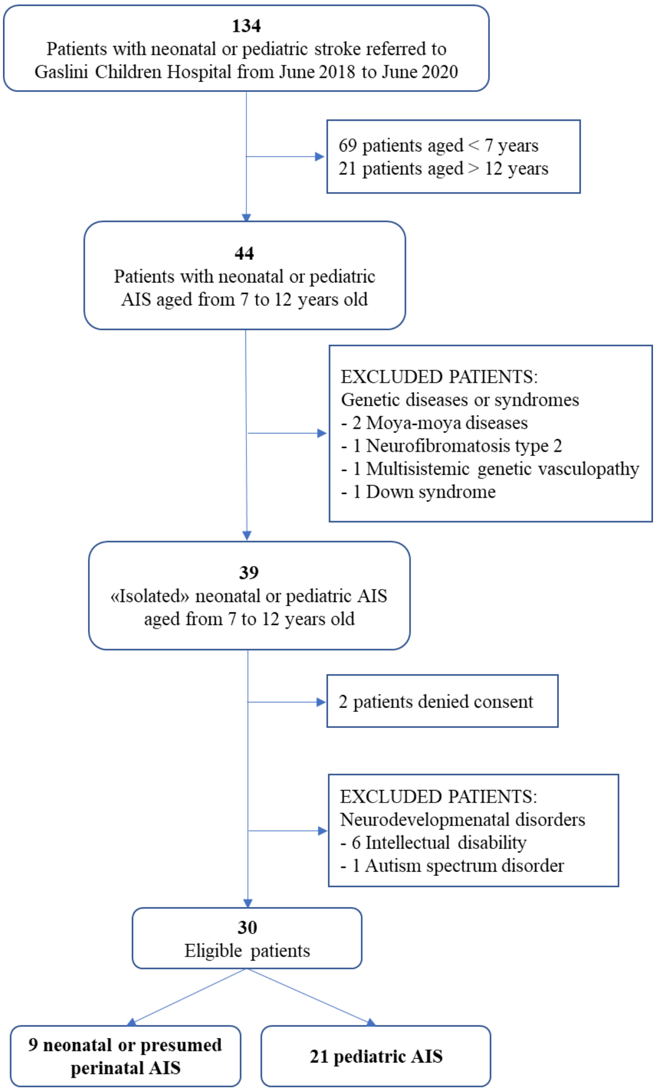
The inclusion criteria for this study were as follows: (1) aged between 7 and 12 years at the time of testing; (2) stroke sustained at least 3 months before testing; and (3) documented history of perinatal or childhood arterial ischemic stroke (AIS), as detected by brain magnetic resonance imaging (MRI). The exclusion criteria were as follows: (1) non-Italian speaking; (2) severe cognitive or motor impairment that would prevent valid administration and/or interpretation of the neuropsychological measures, or cognitive functioning below the 15th percentile, as measured by the Coloured Progressive Matrices (CPM; Raven et al., 1998); (3) birth before the 36th week of gestation and/or hypoxic-ischaemic encephalopathy; (4) significant comorbidities, with possible neuropsychological implications (i.e. down syndrome). In total, 30 children were identified. The sample selection process is presented in Figure 1.

Clinical and neuroradiologic features

Clinical and radiological data were extracted from medical records, specifically age at stroke onset and age at the time of evaluation. A comprehensive neurological exam was performed on all patients. Linguistic and motor impairment was recorded as present or absent at the assessment time based on clinical evaluation, or based on notations by any specialized healthcare professional, as done in other studies (i.e., Sherman et al., 2021). In particular, motor impairment refers to the presence of hemiplegia or hemiparesis, while language impairment refers to the presence of aphasia or dysarthria.

Neurological functioning was assessed using the Pediatric Stroke Outcome Measure (PSOM), which consists of 5 subscales (right/left sensorimotor, language production/ comprehension, and cognitive or behavioural) rated from 0 to 2 (0 = no deficit; 0.5 = mild deficit

Figure 1. Flowchart of the sample selection process.



but no impact on function; 1 = moderate deficit with some functional limitations; 2 = severe deficit with missing function). For statistical analysis, the PSOM outcome was classified as ‘good’ if the child had no impairments or if the child had a mild deficit (final score <= 0.5). In all other cases, the outcome was categorized as ‘poor’ (Bulder et al., 2011). The total PSOM in our sample ranged from 0 to 2.5, indicating no severe neurological impairment.

Brain MRI studies were acquired using 3T or 1.5T MRI systems. Imaging protocols varied but always included axial T1, T2 and FLAIR images; diffusion-weighted imaging (DWI);

susceptibility-weighted imaging (SWI); and intracranial MR arterial angiography (MRA). Neuroradiological images were reviewed by a pediatric neuroradiologist with more than 10 years of experience, focusing on the presence and localization of AIS, cerebral arteriopathy, porencephaly, calcifications, as well as additional brain anomalies.

Neuropsychological testing

Age-appropriate neuropsychological measures were used to assess general intellectual ability, EF and attention in a 1-hour session conducted by a neuropsychologist as part of the routine multidisciplinary evaluation. Short breaks were provided if needed. Emotional and behavioural aspects were assessed using parent-rated questionnaires.

General intellectual ability. The Coloured Progressive Matrices test (CPM; Raven et al., 1998) was administered. The CPM is a non-verbal measure of general intellectual functioning that consists of 36 figures with a missing piece. For each figure, the children had to choose among six alternatives to identify the piece that completed it. The total number of correct responses was recorded (range 0-36).

Executive function Measures were selected to tap processes associated with the four cognitive components of executive function (Anderson, 2002).

Inhibition: i) *Numerical Stroop* subtest of the Italian ADHD Battery (Marzocchi et al., 2010): children are required to count numbers (instead of naming them). The test consists of a baseline session that requires counting groups of stars and a stroop session that requires counting groups of identical numbers. The number of naming errors in the stroop session (when the child names numbers instead of counting them) and the interference time (difference in time to count stars and count numbers) were calculated. Then, corresponding percentiles were coded based on standardized norms. ii) *Inhibition subtest-part B* (Inhibition-B) of the Developmental Neuropsychological Assessment – Second Edition (NEPSY-II; Korkman et al., 2007): children look at a series of black and white shapes (squares and circles) or arrows (up or down) and name either the shape or direction in the opposite way, regardless of the colour (e.g., naming the circles square and the squares circle). The number of errors (including self-corrections) and the time were recorded. The combined scaled score (M=10, SD=3) was calculated. Internal reliability and test-retest reliability are .80 and .75 respectively.

Working memory: i) *Listening span test* (LST; Belacchi et al., 2010): in this dual task, children listen to lists of 2 to 5 words and have to remember the last word of the list and tap on the table when an animal noun is presented. Words were presented at the rate of one per second. The task ended when the child failed on both lists of the same length; the remaining items were considered incorrect. The number of correctly recalled words (range 0-28) was used for the analysis. ii) *Backward digit span* subtest of the Italian Neuropsychological Battery for evaluation of developmental age (BVN 5-11, Bisiacchi et al., 2005): children are required to recall digits in reverse order, starting from the last heard until the first. The task starts with two digits and increases until the child makes three consecutive errors. The longest list correctly recalled was recorded. Z scores were calculated based on the normative data for both tests. Test-retest reliability and validity are not provided by the manual.

Cognitive flexibility: i) *Trail making test* (TMT; Scarpa et al., 2016): this consists of three parts, each with 25 circles distributed over a white sheet of paper. In Part A, the circles are numbered from 1 to 25, and the children had to connect the circles in numerical sequence as quickly as possible. Part A/B consists of letters from A to Z (only Italian letters are included) to connect in alphabetical order. Part B includes numbers from 1 to 13 and letters from A to L. Children have to alternate between numbers and letters following numerical and alphabetical orders (1-A-2-B, etc). The number of seconds needed to finish part B was used for the analysis. Test-retest reliability for section B is reported as r=.61 (Scarpa et al., 2016). ii) *Inhibition subtest- part C* (Inhibition-C) of the NEPSY-II (Korkman et al., 2007): children look at a series of black and white shapes or arrows and name either the shape or direction correctly or oppositely, depending on the colour of the figures (e.g., naming the circles square when the circle is white and naming it the correct way when it is black). The number of errors (including self-corrections) and the time of execution were recorded. The combined scaled score (M=10, SD=3) was calculated. Internal reliability and test-retest reliability are .83 and .78 respectively.

Visual Attention: the Cancellation subtest of the Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV; Wechsler, 2003) was used. In this task, a child is asked to scan both a random and a structured set of pictures on two different sheets, and they mark target pictures within a specified time limit. The sum of identified targets in both conditions was registered, and the standard scalar score was calculated (M=10, SD= 3). Test-retest reliability ranges from .73 to .86 depending on the considered age.

Emotional and behavioural functioning. Emotional and behavioural aspects were assessed using two parent-reported questionnaires: i) the Scale for identifying Attention Deficit Hperactivity Disorder (SDAG; Marzocchi et al., 2010) and ii) the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997). The first questionnaire provides information about attention and hyperactivity difficulties in everyday life. Good reliability has been reported (r=.95; Marzocchi et al., 2010). The second investigates behavioural and emotional functioning. In particular, the SDQ comprises five scales: Emotional Symptoms, Behavior Problems, Hyperactivity/Inattention problems, Peer Relationship Problems, and Prosocial Behavior. It also provides a Total difficulties scale, an Internalizing Problems scale and an Externalizing Problems. For all the scales except for Prosocial Behavior, higher scores indicate higher difficulties. Reliability for the Total difficulties scale is reported as α .70 for the Italian sample, and it ranges from .27 (peer problems) to .67 (prosocial behavior) (Di Riso et al., 2010).

3.2 Statistical Analysis

Statistical analysis was conducted using SPSS (version 25). Z-scores, percentiles, or scaled scores were calculated for all the neuropsychological tasks with respect to the age-matched normative sample values. As a large part of the literature classify EF as compromised when it falls in the lower end of the normal range (i.e. Long et al., 2011; Max et al., 2003; O'Keeffe et al., 2014), task performance was considered as impaired if z-scores were -0.9 or below, percentiles were 10° or below or if the scaled score was 7 or below, depending on the task. This is because the purpose of the study was not to investigate the prevalence of a clinically significant impairment, but that of detecting the presence of fragility in EF following stroke. To assess the impact of stroke on EF functioning, the percentage of impaired children in each task was calculated.

Due to the small sample size and the extreme variability of EF profiles within the sample, to investigate the relationship between the level of EF impairment and clinical characteristics, the sample was divided into two groups, based on the number of impaired EF tasks: the no or mild dysfunction group (at most three impaired tasks), and the moderate-severe dysfunction group (four or more impaired tasks, that is most than half of the tasks). Clinical characteristics of the two groups were compared using contingency tables and chi-square test in order to find statistically significant relationships.

As regards emotional and behavioural functioning, the percentage of children under the clinical cut-off was calculated for each subscale of the SDAG and the SDQ. Second, mean differences between the dysfunction and no dysfunction group were computed for all the subscales using univariate ANOVA, in order to investigate the associations between the level of EF impairment and emotional and behavioural functioning.

3.3 Results

We enrolled 30 children (21 males, 70%) aged 7-12 years at assessment (M (SD) = 9.44 (1.65)), with a history of perinatal or childhood stroke and intellectual abilities within the normal range, as measured by the CPM subtest. The average age at stroke onset was 4.93 years (SD=3.84), while the average time between stroke and assessment was 4.59 (SD=3.38) years. None of the participants was diagnosed with ADHD prior to stroke neither before nor after the stroke. The demographic features of the sample are reported in Table 1. Lesion size was not available for one participant.

Table 1. Demographic and clinical features of the sample

N	30
Male, n (%)	21 (70%)
Age at assessment, M (SD)	9.44 (1.65) y
Age at stroke, M (SD)	4.93 (3.84) y
Time since stroke, M (SD)	55.17 (40.5) mths
Stroke age, n (%)	
Perinatal	3 (10)
Presumed perinatal	6 (20)
Childhood	21 (70)
Stroke type, n (%)	
AIS	27 (90)
Porencephaly	3 (10)
Lesion location, n (%)	
Cortical	4 (13.3)
Subcortical	13 (43.3)
Combined	13 (43.3)
Lesion lateralization, n (%)	
Right	14 (46.7)
Left	14 (46.7)
Bilateral	2 (6.7)
Lesion size, n (%)	
Small	10 (34.5)
Medium	17 (58.6)
Large	2 (6.9)
PSOM, n (%)	
Good	17 (56.67)
Poor	13 (43.33)
Epilepsy, n (%)	3 (10)

EF performance

Descriptive statistics for each EF measure and the CPM are reported in Table 2. Six children do not complete the TMT part B because of marked difficulties due to motor impairment or lack of automatization of number or letter order. Two children do not complete the Stroop task. Concerning WM, approximately half of the sample (51.9%) showed an impaired performance in the Listening Span Test; only one child (3.3%) obtained a score under the cut-off in the backward digit span. Regarding inhibition, 32.2% and 36.7% of children had an impaired performance in the Stroop task and inhibition task of the NEPSY-II, respectively. Finally, 41.7% and 36.7% obtained scores under the clinical cut-off in the Trail making test and the switch task of the NEPSY-II, respectively, tapping cognitive flexibility (see Table 2). Visual Attention was under the cut-off in 11 children (36.7%). Overall, 50% of the children were impaired in at least one of the two tasks of inhibition, WM and cognitive flexibility. The results show that 22 children (73.3%) had no or mild dysfunction, and 8 children (26.7%) had moderate or severe EF dysfunction. EF profiles of the eight children in the impaired group are presented in Table 3.

Table 2. Descriptive statistics for each neuropsychological test

	N	Min	Max	M (ds)	N (%) under 1 cut off	N (%) under 2 cut off
General intellectual ability						
CPM	30	15	45	29.03 (6.14)		
Inhibition						
Numerical stroop_errors	28	0	6	0.96 (1.45)	0	1 (3.6)
Numerical stroop_time	28	**	**	**	8 (28.6)	**
Inhibition-B (SP)	30	5	14	8.23 (2.55)	10 (33.3)	1 (3.3)
Working memory						
LST (sd)	27	-2	4	-.31 (1.48)	10 (37.04)	4 (14.8)
Backward digit span (sd)	30	-1	4	1.09 (1.28)	1 (3.3)	
Cognitive flexibility						
TMT (sec)	24	46	267	128.67 (50.79)	3 (12.5)	7 (29.2)
Inhibition-C (SP)	30	4	14	8.9 (2.73)	9 (30)	2 (6.66)
Visual Attention						
Cancellation (SP)	30	2	18	9.53 (4.21)	8 (26.7)	3 (10)

Note:**Only an index of impaired/not impaired performance was recorded. CPM= coloured progressive matrices; Inhibition-B = inhibition task part B of the Nepsy-II; LST= listening span test; SP= standard point; TMT= trail making test.

EF functioning and clinical characteristics

The associations between EF impairment and clinical characteristics are reported in Table 4. No association was found with lesion location, either including or excluding the cortical group (χ^2= 1.777, *p*= .411 and χ^2= 1.759, *p*= .185, respectively), or with lesion laterality, either including or excluding the bilateral group (χ^2= .779, *p*= .677 and χ^2= .190, *p*= .663, respectively). Also, the association between EF functioning and age at stroke was not statistically significant (χ^2= 2.078, *p*= .149). As expected, lesion size was significantly associated with EF impairment, with a medium effect size (χ^2= 4.856 *p*= .028, φ=.409).

Then, the relationship between the level of EF impairment and children's functional characteristics was investigated: a significant relationship was found with language impairment (χ^2=4.176, *p*=.041, φ=.373). No statistically significant association was found with motor impairment (χ^2=3.438, *p*= .064), although all children except one in the impaired group had motor impairment. Similarly, no statistically significant association was found between EF impairment and neurological functioning (χ^2= 1.632, *p*= .201).

Table 3. EF profiles of the impaired group.

	Inhibition		**Working memory**		**Cognitive flexibility**		**Visual Attention**
	Stroop	Inhibition-B	LST	Span	TMT	Inhibition-C	Cancellation
1		**			*	*	*
2		*	*		*	**	**
3	*	*	*			*	
4		**	*			*	*
5			*		**	*	**
6	*	**	**		**	**	*
7	*		**		**	**	**
8	*	**	**		*		**

Note: *= -1 sd from the normative sample; **= -2sd from the normative sample.

Table 4. Associations between EF impairment and clinical characteristics

	No EF impairment N (%)	EF impairment N (%)	χ^2	*p*	φ
Clinical characteristics					
Stroke onset					
Perinatal/presumed	5 (55.6)	4 (44.4)			
Childhood	17 (81)	4 (19)	2.078	.149	
Laterality*					
Dx	11 (78.6)	3 (21.4)			
Sx	10 (71.4)	4 (28.6)	.190	.663	
Localization					
Cortical	3 (75)	1 (25)			
Subcortical	11 (84.6)	2 (15.4)			
Combined	8 (61.5)	5 (38.5)	1.477	.411	
Lesion size					
Small	10 (100)	0 (0)			
Medium/large	12 (63.2)	7 (36.8)	4.856	.028	.409
Functional Characteristics					
Motor impairment					
No	11 (91.7)	1 (8.3)			
Yes	11 (61.1)	7 (38.9)	3.438	.064	
Language impairment					
No	17 (85)	3 (15)			
Yes	5 (50)	5 (50)	4.176	.041	.373
PSOM					
Good	14 (52.9)	3(47.1)			
Poor	8 (27.3)	5 (72.7)	1.632	.201	

Note: *2 bilateral cases were excluded from the analysis.

EF and emotional and behavioural functioning

In Table 5, emotional and behavioural functioning scores are reported. According to mothers' evaluation, 20% of children obtained a score above the clinical cut-off for inattention in the SDAG scale, and almost 27% of parents reported significant emotional difficulties and problems with peers in the SDQ. Conversely, prosocial behavior was preserved. Comparing the no or mild impairment group with the moderate or severe impairment group, significant differences were found in most subscales, except for behavior problems and prosocial behavior, with the severely impaired group showing higher mean scores. The results suggest that children with moderate or severe EF impairment show more symptoms of inattention and hyperactivity and more emotional and peer relationship problems. In addition, they obtain higher scores as concerns both externalizing and internalizing problems and the total score of the SDQ, indicating a higher risk of psycho-social maladjustment.

3.4 Discussion

The present study aimed to investigate EF impairment and its relationship with clinical characteristics and with emotional and behavioural functioning in a sample of children with AIS aged 7 to 12 at the time of assessment without severe cognitive dysfunction and intelligence in the normal range. Compared to most previous studies, this one investigated EF functioning after stroke in a well-defined and age-homogeneous sample of children. Most previous studies included a wide age range, from pre-school to young adulthood (Bosenbark et al., 2017; O'Keeffe et al., 2012), making it difficult to understand the impact of stroke in specific developmental phases. Since EF processes emerge at different times and develop until late adolescence, the impact of stroke on EF processes could be different according to age.

Table 5. Descriptive statistics and groups comparison for emotional and behavioural functioning

	All sample				No EF impairment	EF impairment			
	Min	**Max**	**M(ds)**	**N (%) above cut-off**	**M(ds)**	**M(ds)**	**F**	***p***	***Partial η2***
SDAG									
Inattention	1	22	7.9 (5.57)	6 (20)	6.45 (4.55)	11.88 (6.45)	6.645	.015	.19
Hyperactivity	0	23	6.2 (5.03)	4 (13.3)	4.86 (2.98)	9.88 (7.55)	7.046	.013	.20
SDQ									
Emotional symptoms	0	8	2.53 (1.99)	8 (26.7)	1.91 (1.44)	4.25 (2.38)	10.804	.003	.28
Behaviour problems	0	4	1.3 (1.24)	3 (10)	1.14 (1.25)	1.75 (1.16)	1.47	.236	
Hyperactivity/ Disattention	0	9	2.43 (2.19)	3 (10)	1.73 (1.52)	4.38 (2.67)	11.722	.002	.3
Peer relationship problems	0	7	2 (2.26)	8 (26.7)	1.5 (2.26)	3.38 (1.69)	4.534	.042	.14
Prosocial behaviour	4	10	8.2 (1.83)	1 (3.3)	7.91 (1.97)	9 (1.07)	.2177	.151	
Total difficulties	0	25	8.27 (5.98)	5 (16.7)	6.27 (4.3)	13.75 (6.78)	12.938	.001	.32
Externalizing problems	0	13	3.73 (3.09)	- *	2.86 (2.42)	6.13 (3.64)	8.109	.008	.22
Internalizing problems	0	13	4.53 (3.56)	- *	3.41 (2.82)	7.63 (3.7)	11.093	.002	.28

Note: * no normative data are available for internalizing or externalizing subscales.

The first aim of the study was to investigate the prevalence of EF deficits in a sample of children without severe cognitive outcomes following stroke. As the sample included only children with a general good neurological and cognitive recovery after stroke, as it didn't include children with intellectual dysfunction, nor children with PSOM scores indicating a severe neurological impairment, the presence of children with EF fragilities and dysfunctions was not a foregone conclusion. Results indicate that almost 30% of children had a moderate or severe EF dysfunction, falling in the lower end of the average range or below. This percentage is lower compared to previous results that found an EF deficit following pediatric stroke using both performance-based tasks (e.g., Araujo et al., 2017; Bosenbark et al., 2018; Bosenbark et al., 2017; O'Keeffe et al., 2012; Westmacott, McDonald, deVeber et al., 2018) and parent or teacher reports (Fuentes et al., 2017; Westmacott, McDonald, Roberts et al., 2018). However, considering that our sample comprised only children with a good recovery after stroke, this prevalence is relatively high, indicating that EF is particularly vulnerable to stroke and could be compromised also when cognitive and neurological functioning seem to be preserved. In addition, results show that more than 60% of the children did not show any significant EF impairment, suggesting that there is heterogeneity in EF abilities within this population of children. Concerning the selective impact of stroke on different EF skills, working memory, inhibition and cognitive flexibility were equally impaired, in contrast to most studies that found the pediatric stroke population to be particularly impaired in inhibition (Araujo et al., 2017; Bosenbarket al., 2018). Nevertheless, previous studies did not systematically analyze or compare the selective impact of pediatric stroke on different EF components (Rivella & Viterbori, 2020) but generally focused on specific EF dimensions (in particular inhibition) or used comprehensive measures of EF.

The second aim was to examine the relationship between EF dysfunction and clinical and neuroradiological features. Results show that lesion size was the only clinical variable associated with EF impairment, while lesion side and location were not associated with EF impairment. These results are in line with previous studies that generally did not find any associations between EF impairment and lesion location and laterality (Bosenbark et al., 2017; O'Keeffe et al., 2014; Studer et al., 2014). However, they found that children with larger lesions had weaker EF abilities (Kornfeld et al., 2018; Long, Anderson et al., 2011; Westmacott, McDonald, Roberts et al., 2018). These results are in line with the hypothesis of a diffuse functional representation of executive function in the young brain. According to this hypothesis, EF relates to multiple brain areas and numerous structures of the central nervous system, both cortical and subcortical (Alvarez et al., 2006). Thus, a diffuse lesion led to higher impairment due to a greater network impairment. As regards age at stroke onset, no statistically significant differences were found in EF performance between perinatal and childhood stroke, even though perinatal strokes were more frequently associated with EF impairment, in agreement with previous studies showing that older age at stroke onset was related to better performance in the EF (Bosenbark et al., 2017; Fuentes et al., 2017; Long, Spencer-Smith et al., 2011; Westmacott et al., 2010). Interestingly, results show an association between EF impairment and functional outcomes in the domain of language. To our knowledge, no study had previously investigated this relationship within the pediatric stroke population. The results suggest a statistically significant association between language deficit and EF impairment. This association may be explained in different ways. First, several brain structures and regions that control language are also involved in executive function, thus, a lesion in those areas may result in multiple impairments to different functions (Diamond, 2000). In particular, basal ganglia were found to be implicated in a wide range of complex processes including speech, motor control and executive functions (Zenon & Olivier, 2014; see Leisman et al., 2014 for a review). In addition, early impairment in a given function might impact the development of other skills. For example, in typical development, early language skills were found to have both direct and indirect effects on children's later executive functions (Kuhn et al., 2014). Moreover, children with specific language deficits were found to score poorly on EF tasks (Pauls & Archibald, 2016). One interpretation of these findings is that language allows children to think in more complex ways that ultimately support the emergence of EF. From a clinical point of view, this association indicates that children with a persistent functional impairment, in particular in the domain of language, are at higher risk of showing EF difficulties and need to be adequately assessed and supported in order to prevent subsequent learning disabilities and psychological maladjustment.

The third aim was to analyze emotional and behavioural functioning and its relationship with EF impairment. Inattention, emotional difficulties and problems with peer relationships were identified as the main problems by parents, whereas prosocial behavior was positively assessed by parents, as only one child obtained a score within the clinical range. These results indicate that, although children who suffer from stroke tend to be isolated, they search for peer relationships and show prosocial behaviors, such as sharing and feeling empathy for others. Children with EF dysfunction showed more symptoms of inattention and hyperactivity and more behavioural and social problems compared to children without EF dysfunction. This result is not unexpected, since EF is involved in self-regulation (Hofmann et al., 2012) and predictive of behavioural and affective difficulties (Hughes & Ensor, 2011; Lantrip et al., 2016). In addition, a training of EF was found to reduce externalizing behaviour, suggesting a direct causality between EF and behaviour problems, at least in preschoolers (Volckaert, & Noël, 2015).

3.5 Limitations

This study showed significant results; however, several limitations need to be considered. First, the sample size was relatively small, limiting the statistical power of the analysis. In particular, the lack of significant relationship between EF and clinical and functional characteristics could be due to the distribution of the considered variables, and in particular the large prevalence of not impaired EF children (22), childhood stroke (21) and not impaired language (20). In addition, given the small sample size, no deeper comparison between different EF components and EF profiles could be done. Nevertheless, the sample included a very limited age range (7-12 years) approximately corresponding to primary school years, which is different from previous studies in which the age of the samples ranged from preschoolers to young adults (Rivella & Viterbori, 2020). Second, given the limited sample size, the interactive effects of lesion, etiological, emotional and behavioural factors on cognitive and behavioural outcomes could not be analyzed. Third, some limitations emerge with regard to the EF measures used. In particular, the error indices of the Stroop test and the backward digit span, seem to be not sensitive, as only one subject falls within the clinical range in contrast to the other inhibition and WM measure, in which 36.7% and 51.9% falls respectively. In addition, we used two measures for each EF domain, except for visual attention which was measured only with one task. Fourth, some limitations concern results on motor and linguistic functioning, as they are broadly categorized as impaired or not impaired, without a distinction between different impairment causes (i.e articulatory or linguistic). A deeper differentiation among disfunction could help in understanding their relationship with EFs. Finally, the literature has shown that the home environment and socio-economic status are associated with EF development in typical children (Hackman & Farah, 2009) and correlate with behavioural outcomes in other populations with brain lesions (e.g., Li & Liu, 2013). Nevertheless, in our study, we did not include such measures that could explain EF outcomes in the pediatric stroke population, just like in typical children.

3.6 Future directions

EF is crucial for success throughout the lifespan and is related to a wide range of daily-life functions that could improve with training such as behavioural and social abilities. The possibility to improve them with adequate treatment is well documented in different clinical populations (e.g. Diamond & Lee., 2011), but not in that of children with stroke. The high prevalence of EF impairment in our sample of children with childhood or perinatal stroke suggests the need to develop and implement adequate interventions to support EF development and to prevent the associated behavioural and emotional problems. It is also crucial to provide parents with counseling concerning the difficulties that their children may encounter due to their EF impairment, both in the area of behavioural regulation and emotional problems. In addition, the results suggest some clinical manifestations that could help clinicians to identify children at higher risk of showing EF impairment, in particular language impairment.

3.7 Conclusion

Overall, children with a history of stroke show reduced EF functioning compared to normative data. Our results demonstrate that also when recovery after stroke seems to be good, and children show adequate intellectual and neuropsychological functioning, there may equally be fragility in specific cognitive domains, such as EF. In addition, such fragilities have a negative impact on the quality of life of the children, as they are related to behavioural problems in terms of inattention and hyperactivity and emotional problems in particular regarding peer relationships. These results are of clinical relevance, as they highlight the importance of not underestimating the cognitive outcomes of stroke, regardless of the degree of functional and neurological recovery, and the importance to evaluate EF in order to provide training interventions even in the presence of non-clinical difficulties, as also less severe impairment could have important repercussions on behavioural and emotional functioning.

3. TELE-REHABILITATION OF EF AFTER PEDIATRIC STROKE: A PILOT STUDY

1. Introduction

Despite the growing evidence of cognitive dysfunction after pediatric stroke, there are currently no evidence-based cognitive interventions for this population (Catroppa et al., 2012). Literature on cognitive rehabilitation of pediatric stroke is very limited and most intervention studies focused on the broader and heterogeneous childhood populations with Acquired Brain Injury (ABI). This population mainly includes children with traumatic brain injury (TBI) or brain tumors, which are the most frequent types of ABI (Slomine & Locascio, 2009), and only in very few cases children with stroke are included (i.e., Madsen Sjö, et al., 2010). Literature on ABI rehabilitation shows that the use of remote interventions has consistently increased in recent years (Corti et al., 2019) as it allows to reduce the limits of traditional interventions, such as high time demand, elevated costs and related accessibility issues. It makes the interventions more easily accessible to families and promotes consistency of rehabilitation for patients. In addition, it makes the activities more enjoyable and engaging, favoring adherence to the training.

To our knowledge, only a study specifically focused on EF rehabilitation of children who suffered an AIS (Eve et al., 2016). In their pilot study, Eve and colleagues (2016) investigated the efficacy and feasibility of a computerized WM training (Cogmed) with a sample of seven children with AIS. To measure changes in WM capacity, different WM domains were measured: i) phonological loop (Digit Recall, Word List Matching, Word List Recall and Non-word list Recall); (ii) visuospatial sketchpad (Block Recall) and (iii) the central executive (Listening Recall and Backward Digit Recall). Results indicate a significant improvement only in phonological loop measures; however, this improvement was not maintained over 12 months. No additional significant improvements on standardized psychometric outcome measures were seen either immediately or at 12-month follow-up. Except for this study, literature on EF rehabilitation refers to the broader ABI population. A review conducted by Lindsay and colleagues (2015) reported that online home-based intervention addressing cognitive and behavioral aspects could a provide significant improvement in children with TBI (Wade et al., 2008; Wade et al., 2010), highlighting the potential of computer-based treatments performed out of the clinical setting and with limited participation of a therapist. Similarly, again Linden and colleagues (2016) in a meta-analysis focusing on neuropsychological outcomes of ABI found positive effects of web-based interventions on self- and/or parent-report measures on everyday behavioral problems associated with executive dysfunction. However, such meta-analysis was based on three studies from the same research group, and potential sources of methodological biases were reported. More recently, Resch and colleagues (2018) provided a review of the studies that described cognitive rehabilitation interventions for ABI in children, classifying them according to their characteristics as (1) metacognition and/or strategy use; (2) computerized drill-based exercises; (3) interventions combining metacognition and/or strategy use and drill-based exercises; and (4) external aids. Results indicated that metacognition and/or strategy-use interventions improve adaptive behavior but have only limited effects on cognitive functions, while computerized drill-based exercises generate only near-transfer effects on the trained abilities with no far transfer effects on other cognitive abilities or adaptive behavior. Therefore, authors suggested that the best practice to improve both cognitive and behavioural impairment is to integrate these two types of training. In addition, the provision of the interventions in family settings was indicated to be a positive factor in promoting effectiveness of the training.

Taken together, the reviews described above indicated the use of technology as a promising method to implement rehabilitation interventions for children with ABI, even though they recognize that it is not possible to draw conclusions because of methodological issues, such as the heterogeneity of samples and outcomes, and lack of control groups. However, they did not distinguish between treatments delivered in a clinical setting and those delivered remotely. Conversely, a recent review and meta-analysis (Corti et al.,2019) investigated the effects of computerized training programs for children with ABI that were delivered at home, without the intervention of a therapist at all or that required it only to a limited extent (at most, once a week). This review described 32 technology-based training, of which 18 were cognitive and 14 behavioral. Results indicate that the majority of cognitive training and all the behavioral training were found to be effective. In particular, cognitive training showed both near and far transfer effects on cognitive abilities and also positive effects on functioning in daily life, confirming that computer-based training delivered in an ecological setting are effective at improving cognitive abilities and adjustment in children with ABI. Also in these cases a high level of heterogeneity between studies was detected in terms of characteristics of the samples (e.g., age range, diagnosis subcategory, and time from injury) or of the training (e.g., focus, duration, adaptation of exercise difficulty, and trained cognitive domains). To note, only two studies included also stroke children, one is that of Eve and colleagues (2016) described above, and the other one focused on occupational therapy and not on EF. In light of this, caution must be taken in applying findings from ABI cohorts to the stroke population due to the differences in etiology and sequelae following the different kinds of injuries (e.g. discrete lesions of ischemia compared to diffuse damage caused by traumatic brain injuries). Further research is needed to identify whether specific training characteristics and population subgroups are more likely to be associated with greater training efficacy, but the results are promising.

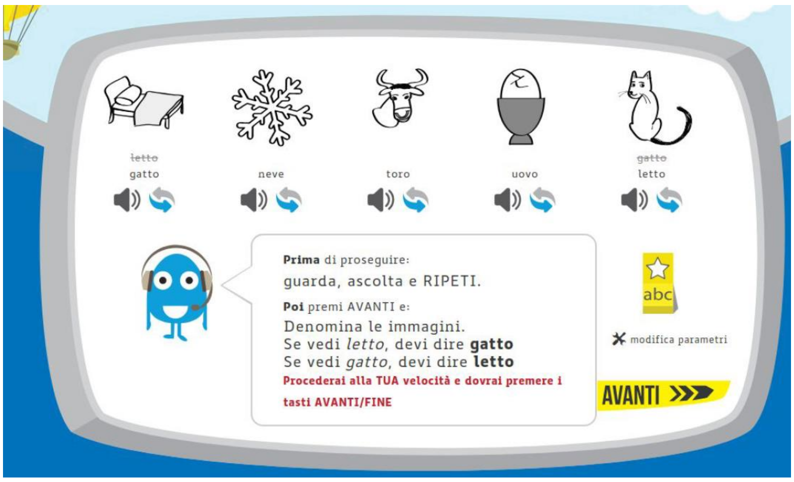
The present study aimed to investigate the feasibility and efficacy of a home-based computerized EF training with a sample of children with a history of stroke. In the following paragraph the computerized training will be presented and then the study and its results will be shown.

2. MemoRAN computerized EF training

MemoRAN is a telerehabilitation app included in the Ridinet platform developed by Anastasis. It was developed to train executive functions and to increase response inhibition, interference control and cognitive flexibility of information maintained in working memory (Memo), in tasks requiring visual-verbal integration of multiple stimuli (RAN, Rapid Automatized Naming). All the exercises included in MemoRAN consist in naming as quickly as possible timed visual nonalphanumeric stimuli (colors or pictures), presented in matrices. The number of items per matrices is determined by the clinician, from a minimum of 20 to a maximum of 100. Each matrices is composed of 5 items that alternate randomly. The exercises are organized for increasing complexity and, thanks to the self-adaptive algorithm, the training is continuously adapted to the individual child's performance. Alternatively, the parameters of the tasks can be changed manually by the clinician to respond to the needs of the child. The stimuli, drawn in black and white, are organized in libraries that contain 400 pictures, corresponding to different lexical items varying in lexical frequency, word length, and syllable structure.

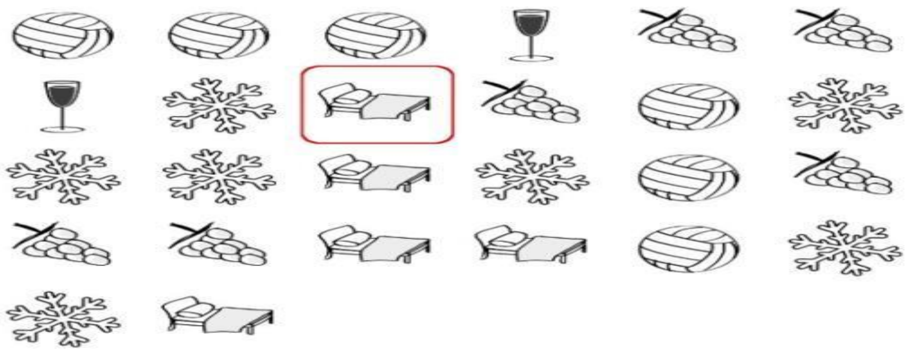
MemoRAN includes 8 different exercises:

1. **Inversion:** in this inhibition task, two of the five stimuli that compose the matrices are selected to be named inversely (i.e., bed must be named cat and vice versa). The other three stimuli had to be named correctly.

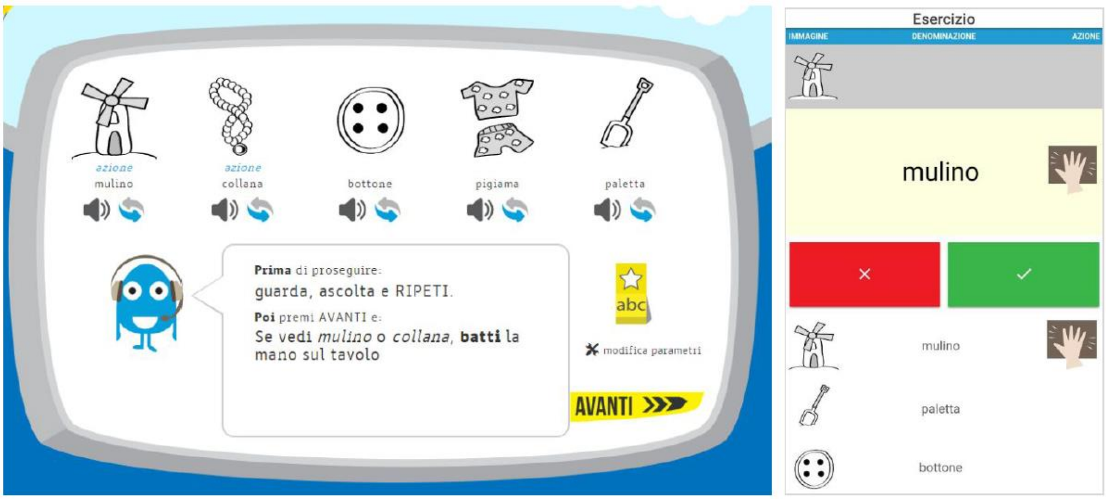


2. **Cluster:** the child must only name the stimulus inside the red rectangle that is inserted in a larger yellow rectangle.

3. **Ran with variable time:** the child must name all the stimuli on the screen, keeping the naming speed provided by the algorithm. A cursor indicates the picture to be named with variable and unpredictable times so that the child must adjust to the rhythm imposed by the application and inhibit the impulse to follow his own naming rhythm.

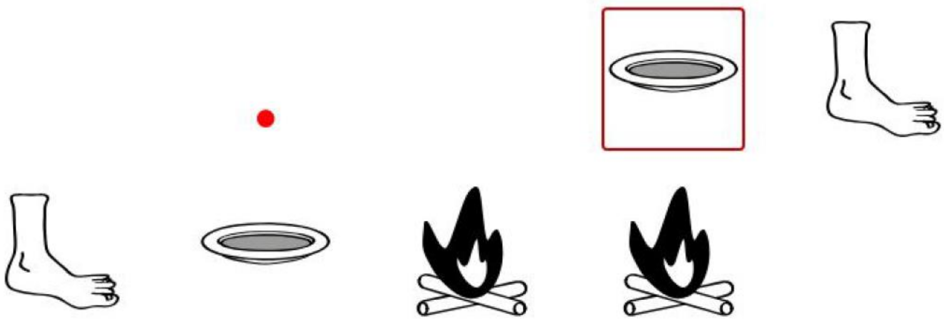


4. **Action**: this is a double task; the child must name the stimuli, but for two of them must also make a gesture (clap his hand on the table) at the same time as naming them.



5. **1-Back:** in this task the denomination starts from the second stimulus and the child must name the stimulus just disappeared and replaced by a red dot.
6. **Inversion and action:** this is a double task; among the five stimuli of the matrices, two have an indication of inverted denomination and other two of association with an action (clap the hand on the table).

7. **Silence and action:** this is a double task that also includes an inhibition component. The child must name the stimuli presented except for two items that require silence and silence plus beating on the table, respectively.
8. **2-Back:** in this task the denomination starts from the third stimulus and the child must name the stimulus that disappeared two stimuli before and replaced by a red dot.



Task difficulty increases on three levels simultaneously:

- *system processing capability* expressed by the timing of the stimuli and the complexity of the instructions;
- *visual-verbal processing mode* by modifying the visual or verbal parameters of the exercise (e.g., types of lexical items, size and distance of the pictures, presentation mode of the pictures) it is possible to simplify or increase the visual or verbal load of the task.
- *EF involved*: exercise progression ranges from the simplest EF components (e.g., inhibition) to the most complex ones (e.g., double task, 2-back).

The application requires a daily exercise on the PC/tablet of 15/20 minutes for a period of two/three months, carried out by the child with the support of an adult. The adult follows the child's performance with the "App for parent" on a smartphone and records errors. At the end of the session, the "App" automatically provides a report (number of errors, presentation time of stimuli, type of exercises performed, and parameters used in the exercise) which is available online to the clinician. The report allows the clinician to monitor the progress of the training and thus to decide whether parameters must be changed (e.g., time of presentation or lexical complexity of the stimuli).

3. Feasibility and training outcome of MemoRAN for children with stroke

The aim of the present study was to investigate the feasibility of MemoRAN on a sample of children who suffered a stroke. In addition, preliminary data on training outcomes were collected by assessing the change in cognitive performance after the training program.

3.1 Materials and methods

Participants

Participants of this study were children with childhood or perinatal stroke referred to the Stroke Centre of the Giannina Gaslini Children Hospital in Genoa, Italy. The study started in February 2019 and is still ongoing. It was interrupted from February to October 2020 during the

COVID-19 pandemic, as only children in the acute phase or with severe disease (that were not eligible for the training) access the Hospital in those months. The recruitment started again in October 2020, but families of eligible patients were not willing to return to the hospital for the final assessment, because of travel restrictions and the complexity of the procedures for the hospital admission. Only one family living in Genoa was recruited between October 2020 and October 2021. The study was conducted according to ethical standards laid down in the 1964 Declaration of Helsinki and also approved by the Ethical Committees of both Gaslini Hospital and the Department of Educational Science, University of Genoa. Written informed consent was obtained from all parents.

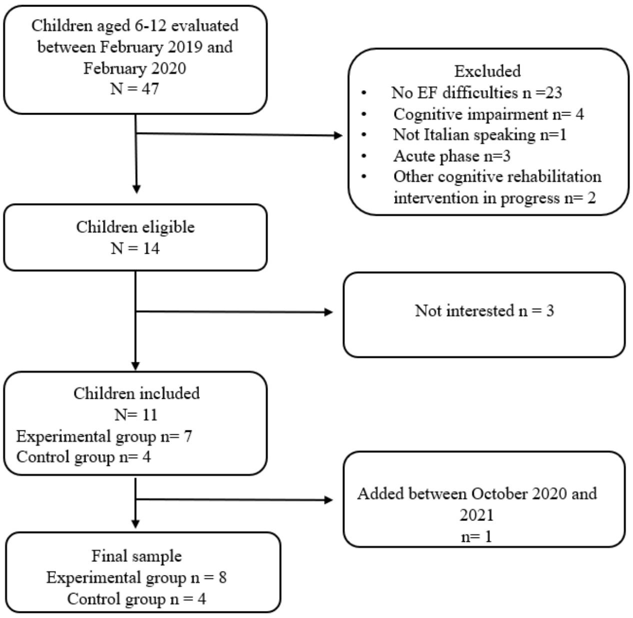
Inclusion criteria were as follows: (1) aged between 6-12 years at the time of testing; (2) documented history of perinatal or childhood stroke, as detected by brain magnetic resonance imaging (MRI); (3) EF deficit (<1ds) in at least 2 EF tasks; (4) both parents and children fluent in Italian; (5) availability of a PC with an internet connection at home; (6) availability for the post-training evaluation. Children with a severe cognitive impairment (<15° percentile) as measured by the Coloured Progressive Matrices (CPM) were excluded. In total, 11 children were identified. Participants were assigned to the control or experimental group in agreement with their parents.

The sample selection process is presented in Figure 1.

Feasibility outcome

To assess the feasibility of the training, we used 9 indicators taken from previous studies on computer-based cognitive training for adolescents with brain damage (Corti et al., 2018; Verhelst et al., 2017; Table 1). Among these 9 indicators, 4 were related to the training intervention (accessibility, training compliance, technical smoothness, and training motivation) and 5 to procedures and participation (participation willingness, participation rates, loss to follow-up, assessment timescale, and assessment procedures). In addition, training motivation was investigated

Figure 1. Sample selection.



for both children and parents, due to the active role of the parents in carrying out the training. Thus, feasibility indicators were 10. In accordance with previous studies (Corti et al., 2018; Verhelst et al., 2017), the global criterion for intervention success requires that all the 10 indicators are positively evaluated by end-users (parents and children).

To assess training compliance, two different custom-made questionnaires have been administered to children and their parents respectively. The questionnaires were adapted from the Intrinsic Motivation Inventory (IMI; Ryan, 1982; Mcauley et al., 1989) and other feasibility custom-made questionnaires used in feasibility studies involving ABI (Corti et al., 2018; Verhelst et al., 2017). Participants were asked to rate to what extent they agreed with 8 (for the self-report) or 12 (for the parent-report) statements using a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5) (a score of three representing a neutral score and higher scores reflecting increased levels of motivation/satisfaction). Statements focus on interest/enjoyment (e.g., ‘‘This training was fun to do’’, “I would recommend this training to friends”), perceived competence (e.g., ‘‘I think I am pretty good at this training’’), effort/importance (e.g., ‘‘It was important to me to do well at this training''), and value/usefulness (e.g., ''I believe doing this training could be beneficial to me''). In the parent-report, the presence of technical problems was also investigated. An average score of training compliance was calculated for both parents and children.

Training outcomes

For children aged 7-12 years, EF and attention battery used for pre- and post- test evaluation are the same described in the previous study. Inhibition was measured using *Numerical Stroop* (BIA, Marzocchi et al., 2010) and *Inhibition- Inhibition* (NEPSY-II; Korkman et al., 2007) tasks. Working memory was measured using the *Listening span test* (LST; Belacchi et al., 2010) and the *Backward digit span* (BVN 5-11, Bisiacchi et al., 2005) task. Cognitive flexibility was measured using the *Trail making test* (TMT; Scarpa et al., 2016) and the *Inhibition- Switching* (NEPSY-II; Korkman et al., 2007) tasks. Finally, visual attention was measured using the *Cancellation* subtest of the WISC-IV (Wechsler, 2003).

For children aged 6, inhibition was measured using the *Day-night Stroop* (FE-PS 2-6; Usai et al., 2017) and *Inhibition- Inhibition* (NEPSY-II; Korkman et al., 2007) tasks. Working memory was measured using the *Listening span test* (PAC-SI; Scalisi et al., 2009) and the *Backward digit span* (BVN 5-11, Bisiacchi et al., 2005) tasks. Cognitive flexibility was measured using the *Dimensional Change Card Sort* (DCCS; FE-PS-2-6; Usai et al., 2017) and the *Dots task* (FE-PS 2-6, Usai et al., 2017). Finally, visual attention was measured using the *Cancellation* subtest of the WISC-IV (Wechsler, 2003).

The Day-night Stroop consists of two different conditions, one neutral and one incongruent. In the neutral condition children are instructed to say the word "day" when they see cards with a checkerboard and to say "night" when they see cards with a cross. In the incongruent condition children are asked to say "day" when they see cards with stars and moon and to say "night" when they see cards with a sun. Each condition includes 16 trials. Accuracy and time were recorded.

Accuracy is calculated by subtracting the number of correct responses in the incongruent condition from the number of correct responses in the neutral condition (range 16/-16). Time is calculated as the difference in time between the neutral and the incongruent condition.

In the Listening span test, children listen to sets of two to five sentences. After each sentence, they have to say if the sentence is true or false. After the last sentence of each set, they have to recall the final word of each sentence. Three trials for each set length are presented. The total number of correctly remembered words was recorded (range 0-42).

In the Dimensional Change Card Sort children are required to sort a series of cards, according first to the colour, then to the shape and finally according to the colour or the shape depending on the presence or not of a border on the card. The test is stopped if the child does not pass five of six trials in the first two sessions. The score is the proportion of total correct trials (of 24 trials).

In the Dots task a flower or a star appear on the right or left of the computer screen. Children had to press the “A” or “L” key on the keyboard. For the flower, children are instructed to press the button on the same side of the screen (congruent trial), while for the star children are instructed to press the button on the opposite side of the screen (incongruent trial). Accuracy (number of correct responses) and reaction time (average response time for the correct responses) were recorded.

Intervention

All the participants performed the MemoRAN training for two months, five times a week. After the evaluation session, a demonstration session was held to show how to perform the training to the child and parents. The starting time of presentation and complexity of the stimuli varied for each participant according to age and EF abilities.

3.2 Results

We proposed participation in the study to 15 eligible families and 12 (80%) agreed to participate. Reasons for declining were inability to respect the study timelines due to distance from the hospital (67%) or no interest in participating (33.3%). Among the 12 participants, eight were included in the experimental group, and four in the control group. Descriptive characteristics of the sample are reported in Table 1.

Table 1. Demographic and clinical features of the sample.

	Experimental Group	Control Group
N	8	4
Male, n (%)	7 (87.5)	4 (100)
Age at assessment, M (SD)	8.3 (1.3) y Range: 6-10 y	9.1 (2.32) y Range: 6-12.5 y
Age at stroke, M (SD)	2.47 (2.58) y Range: 0-6 y	5.1 (4.35) Range: 0-10.5 y
Time since stroke, M (SD)	5.82 (3.49) y	4.00 (3.51)
Stroke age, n (%)		
Perinatal	1 (12.5)	1 (25)
Presumed perinatal	3 (37.5)	0
Childhood	4 (50)	3 (75)
Stroke type, n (%)		
AIS	8 (100)	4 (100)
Lesion location, n (%)		
Cortical	1 (12.5)	1 (25)
Subcortical	2 (25)	0 (0)
Combined	5 (62.5)	3 (75)
Lesion lateralization, n (%)		
Right	5 (62.5)	2 (50)
Left	2 (25)	2 (50)
Bilateral	1 (12.5)	0 (0)

Feasibility outcomes

Feasibility outcomes are presented in Table 2. Four out of five criteria regarding training intervention were met: (1) all participants (100.00%) understood game goals and rules without requiring further explanations; (2) overall, 97.20% (SD = 6.04; range: 82.50-100.00%) of training sessions were completed after 8 weeks. No participants dropped out the training; (3) 1 family (12.5%) encountered a technical issue with the App for parents due to problems with a mobile phone, but the problem was resolved by changing the device and participants could continue the training program without any significant interruption. Thus, no noteworthy technical issue was registered; (4) regarding training compliance, 6 out of 8 of the children who completed the training program (75.00%) and all the parents (100.00%) showed neutral to positive mean scores in the acceptability questionnaire. Means and standard deviations of scores in this questionnaire are shown in Table 3. Four out of 5 criteria concerning the feasibility of study design and procedures were met: (1) 80% of eligible participants (12 of 15) agreed to take part in the study; (2) 100% of them actually performed and completed the training program. (3) 85.7% of the efficacy outcome measures were collected at baseline and follow-up assessment. For 3 participants we could not collect all defined outcome measures, as they haven't automated alphabetical ordering required by the TMT task; (4) for all participants who finished the training program (100.00%) post-training data were collected within two weeks.

Training outcomes

Descriptive statistics were calculated for each subtest in order to investigate improvement after training. Pre and post test evaluation are reported for both the experimental (Table 4) and control (Table 5) groups. Results for the 6-year-old battery are not reported in Table 4 as only one child performed those tests. In addition, the child tested in 2021 was administered a different backward digit span (WISC-IV) due to a change in the neuropsychological battery used by the Stroke Group. Given the limited number of participants, no statistical analysis could be performed to investigate the efficacy of the training. The data indicate a general improvement in accuracy and time after training and a decrease in the number of children with test scores under the cut-off. In addition, results of the control group show equal or lower performance at post test for most of the tasks.

In addition, the performance graph of each child was observed for qualitative considerations. The performance graph shows the child performance through the training sessions, allowing to monitor errors number, time of presentation of the stimuli, numbers and types of exercise performed. It also allows to know in which session the child complete a level and move to the next word category. Even if the starting level and the goals (words category and presentation time) were different for each subject, some trend emerges. In particular, most of the children spend more time to pass from the first level to the second (about two weeks), while they are faster in performing the following steps. Two children completed the training, reaching the higher level, before the end of the four weeks and was invited to continue to train for four weeks

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Table 2. Feasibility outcomes.

	Feasibility measures	Feasibility questions	Data collected	Feasibility criterion for success	Outcome	Success
Feasibility of intervention	Accessibility	Did participants understand all game objectives and rules?	Number of participants who asked for further instruction during the training period	100% of participants understand all games	No participant required further instructions on games.	Yes
	Training compliance	Did participants play all training sessions during the 8 weeks training period?	Mean percentage of sessions completed during the 8-week training period	80% of training is completed after 8 weeks	All participants completed at least 80% of the training in 8 weeks. Average completion was 97.2% (range 82%-100%).	Yes
	Technical smoothness	Were there any technical issues with the training material?	Number of participants who encountered technical issues that could generate a training interruption of more than 3 days consecutively, possibly influencing the total training duration.	100% of participants were able to perform their training without technical issues	1 participant encountered a technical issue with the Parent-App. This issue was resolved by installing the app in another phone, without consequences on the training.	Yes
	Training motivation-children	Were the children motivated to perform the training?	Scores at an acceptability questionnaire on the training program.	80% of participants have a neutral or positive score on the global score of the questionnaire	6 out of 8 participants (75.00) who completed the 8-week training period showed neutral to positive global mean scores	No
	Training motivation-parents	Were the parents motivated to perform the training?	Scores at an acceptability questionnaire on the training program.	80% of participants have a neutral or positive score on the	All the parents showed neutral to positive global mean scores.	Yes

				global score of the questionnaire		
<u>Feasibility of study design and procedures</u>	Participation willingness	What was the participation rate?	Number of participants who agreed to take part in the training among those who were contacted.	75% of eligible participants agree to take part in the study	12 out of 15 eligible participants (80%) agreed to take part in the study. 3 participants were not interested.	Yes
	Participation rates	Did all the eligible participants who agree to take part actually perform the training?	A number of participants who agreed to take part and who performed the training and number of children who abandoned the training.	80% of participants who agree to take part actually participate in the study	All the participants participate in the study.	Yes
	Loss to follow-up	Could all data be collected without any problems?	Number of participants for whom all pre-treatment and post-treatment measures were collected.	90% of the outcome measures are collected	85.7% of the outcome measures were collected. For 3 participant we could not administer TMT task at the pre-test due to the lack of knowledge of the alphabet.	No
	Assessment time scale	Could post-training data be collected within two weeks after the training period?	Number of patients whose follow-up data were collected within two weeks after the training period.	Time from the end of training to post-training data collection <14 days for all participants	Post-training measurements of all participants were collected within 1 week after training	Yes
	Assessment procedures	Was the loss to post-training acceptable?	Number of patients who failed to complete post-training assessment.	Less than 20% of participants fail to complete outcome measures on post-training assessment	100% of participants who finished the intervention completed post-training assessment.	Yes

Table 3. Items and scores of the self-report and parent compliance questionnaire

	SELF-REPORT	M	% 4-5
1	I enjoyed the training.	3.75 (1.04)	37.5
2	I would recommend these activities to friends.	3.5 (1.51)	50
3	The activities were difficult.	3.75 (.89)	50
4	Mom or Dad had to force me to do the exercises.	3.63 (.92)	37.5
5	It was challenging to do the activities 5 times a week.	3.38 (1.41)	50
6	I think I have improved.	4.13 (1.46)	75
7	I was committed to doing well in this activity.	4.5 (.76)	87.5
8	I felt agitated/concerned while doing this activity.	3.0 (1.41)	37.5
Total		3.27 (0.61)	
	PARENT-REPORT	**M**	**%4-5**
1	I am satisfied that I took part in this online training program	5.0 (0)	100
2	I would recommend this training to others.	5.0 (0)	100
3	I found useful the possibility to do the training from home.	5.0 (0)	100
4	The trial session with the clinician and the information in the manual was sufficient to understand how to access the App and create the profile.	4.75 (0.71)	87.5
5	The trial session with the clinician and the information in the manual was sufficient to understand how to conduct the sessions and exercises.	4.63 (0.74)	87.5
6	The trial session with the clinician and the information in the manual was sufficient to understand how to use the Parent App and support my child.	4.63 (0.74)	87.5
7	I needed to contact the researcher for further clarification on the use of the App.	2.0 (1.31)	25
8	It was difficult to be able to do all 5 of the scheduled weekly sessions.	2.38 (1.51)	25
9	The activities were not difficult for my son/daughter.	3.38 (1.06)	50
10	My son/daughter enjoyed doing the activity.	3.5 (1.31)	50
11	I felt that the training was helpful and I noticed improvements in my son/daughter.	4.88 (0.35)	100
12	I found it very challenging to mentor and monitor the training sessions.	2.0 (1.60)	50
Total		52.75 (5.23)	

Table 4. Performance in EF tasks pre- and post-training for the training group

		N	Pre-test M(sd)	Post-test M (sd)	Under cut-off Pre-test N (%)	Under cut-off Post-test N (%)
Working Memory						
Backward digit span		7	3.29 (0.95)	3.50 (0.93)	0	0
LST		7	1.57 (.98)	3.86 (2.73)	6	3
Inhibition						
Inhibition-B	Time	8	109.63 (28.17)	90.88 (24.72)		
	Errors		9.5 (8.9)	5.13 (5.17)		
	SP		6.63 (1.41)	9.25 (2.82)	6	2
Numerical stroop:	Errors	7	1 (1,15)	0.43 (0.55)	0	0
	Interference		0.45 (0.32)	0.80 (.49)	2	3
Cognitive flexibility						
TMT	Time	3	186. 33 (82.56)	115 (23.14)	2	0
Inhibition-C	Time	7	138.14 (35.91)	134 (28.37)		
	Errors		13.71 (8.36)	8.14 (5.05)		
	SP		7.43 (1.51)	10.29 (2.69)	5	1
Visual Attention						
Cancellation	target	8	46.88 (15.43)	58.38 (19.35)		
	SP		6.75 (3.81)	9.13 (3.94)	5	3

Note: Inhibition-B = inhibition task part B of the Nepsy-II.; Inhibition-C = inhibition task part C of the Nepsy-II: LST= listening span test; SP= standard point; TMT= trail making test.

Table 5. Performance in EF tasks pre- and post-training for the training group

		N	Pre-test M(sd)	Post-test M (sd)
Working Memory				
Backward digit span		4	2.5 (1.91)	3 (2)
LST		4	19.5 (24.74)	13 (19.16)
Inhibition				
Inhibition-B	Time	4	114 (80.46)	115.75 (78.98)
	Errors		15.25 (13.67)	7.25 (9.22)
	SP		4.5 (2.52)	7 (3.56)
Numerical stroop:	Errors		*	
	Interference			
Cognitive flexibility				
TMT	Time		*	
Inhibition-C	Time	4	125.5 (31.82)	127.5 (43.13)
	Errors		9.5 (6.36)	9.5 (3.54)
	SP		5 (1)	5 (1)
Visual Attention				
Cancellation	target	4	63.33 (18.5)	57.25 (33.17)
	SP		7.33 (3.22)	7.5 (3.7)

3.3 Discussion

The present pilot study aimed to investigate the feasibility of a home-based cognitive training for children with a history of stroke, together with the feasibility of the study design. Results show that almost all the feasibility outcomes are reached. Regarding the feasibility of the intervention, outcomes considered were accessibility, compliance, technical smoothness and motivation. Given the mode of use of MemoRAN, which includes an active role of parents in recording the child's responses through the parent app, differently from previous studies we include a motivation measure both for children and parents. Globally, the elevated compliance demonstrates that despite the length and the intensity of the training, both children and parents are able to carry out it adequately. In addition, results show neither problems with the comprehension of the tasks nor relevant technical issues, proving the feasibility of the training at home. Regarding motivation, while parents reported a global positive satisfaction with the training, two out of eight children reported low acceptability of MemoRAN. This is a relevant result, as the motivation of the children is crucial in determining training compliance and training efficacy (Burke et al., 2007). However, our results show that adherence is preserved also in the case of low motivation. This is probably due to the fact that, given the young age of the children, parents ensured adherence, more than children themselves.

Regarding the feasibility of the study design, we considered participation willingness, participation rates, loss to follow-up, assessment time scale and assessment procedures. Four out of five criteria were met. A total of 80% of the eligible participants agreed to take part in the study and all the participants actually perform the training. Moreover, all the participants carried out a post-training evaluation within the scheduled timing. The only problem regarding study design concerned the measures used, as 3 children were not able to complete all of them. In particular, TMT task proved to be inadequate as it requires automation of the alphabet and good hand-motor functioning. In our sample, some children had learning difficulties or motor disabilities that interfered with the execution of the test, making it impossible to perform. In addition, considering the three participants (20%) who did not take part in the study, and the almost total lack of participation during the pandemic periods, some important considerations can be drawn. The most frequent reason given to decline in participation was the need to reach the Institute to perform neuropsychological assessments. A similar result was found in a previous study conducted by Corti et al. (2018). In their study, they included also a follow-up evaluation and assumed that by eliminating this assessment phase, the number of declining families would be reduced. However, our result shows that the reason for non-accession is post-test evaluation per se, indicating the need to provide also the assessment phases remotely.

Efficacy of the training was not the focus of this study, and the small sample size did not allow to make statistical analysis to compare experimental and control groups. However, the preliminary descriptive results show that almost all the measures increase or remain stable in the experimental group, while remain stable or decrease in the control group. These results are particularly relevant as part of the literature shows that cognitive disfunction may emerge and increase over time after brain damage in children (Felling et al., 2020; Westmacott et al., 2009). In this particular population, the training allowed not only to rehabilitate cognitive dysfunctions, but also to prevent possible cognitive decline. The maintenance of the ability over time is a positive result that can reduce the gap between children with stroke and their peers, with implications on the general well-being of children and their families.

Taken together the results shed light on the potential of telerehabilitation for children with a history of brain damage, and in particular stroke. Traditional cognitive rehabilitation is based on face-to-face or group interventions delivered in Hospitals or in medical specialized centers (Kueider et al., 2012). However, this type of intervention has some limits related to time, cost and accessibility (Kesler et al., 2011; How et al., 2016; Zampolini et al., 2008). To overcome these limits, telerehabilitation, that is rehabilitation provided remotely through technological devices, is increasingly used. It allows to increase opportunities and the consistency of rehabilitation. In addition, the use of technology for rehabilitation allows for the provision of services in a non-medical setting, and it is not a secondary aspect, especially for children with severe damage that require frequent hospitalizations (Schmeler et al., 2008; Zampolini et al., 2008). Tele-rehabilitation can be particularly useful in the Hospital context as it allows to take in charge the families not only in the evaluation phase, as it often happens in public health care, but also in the intervention phase, allowing care continuity (Zampolini et al., 2008). In fact, given to limited resources, not all patients can be treated in a hospital, especially when their clinical situation is not severe. However, also patients without severe cognitive impairments may benefit from cognitive stimulation, as they can improve their performance level as a result (Klingberg et al., 2002; 2005). Telerehabilitation can reduce the costs of both health care providers and patients compared with standard inpatient or person-to-person rehabilitation. Furthermore, patients who live in remote places, where rehabilitation services may not be available, can benefit from this technology. In addition, even though providing patients with a proper amount of training can be a key factor in driving favorable outcomes, it is not always possible to ensure intense and continuous person-to-person training.

Despite the important clinical implication of the present work, several limitations had to be considered. First of all, the small sample size limited the power of our results. For this reason, the study is still ongoing in order to provide more adequate numerosity and draw strongest results. In addition, could be interesting to compare the MemoRAN group with an active control group in order to compare the enjoyment of different training. In addition, regarding efficacy, it could be verified as efficacy change modifying the training length. Finally, even if it reduces the feasibility of the study design, future studies should include also follow-up evaluations in order to test the long-term outcomes of the training.

In conclusion, this pilot study demonstrated the feasibility of a home-based cognitive training in children aged 7 to 12 years. In addition, some preliminary evidence of efficacy is provided. This finding provided important clinical indication on the utility of telerehabilitation provided by Hospitals, in order to facilitate the taking charge of patients, regardless of the severity of the cognitive damage or the distance of the family from the hospital.

SECTION 2

Executive function improvement and school achievement in typically developing children

4. EF AND SCHOOL ACHIEVEMENT: DIRECT AND INDIRECT EFFECTS

1. Introduction

As mentioned in Chapter 1 (paragraph 7), EF has a foundational role in school learning, both directly and indirectly. Regarding the direct effects, individual differences in EF development were found to be associated with or predictive of school readiness and school achievement and this relationship emerged over and above IQ (Alloway et al. 2005; McClelland et al. 2007; Morrison, Ponitz, and McClelland 2010; St. Clair-Thompson and Gathercole 2006; Mazzocco and Kover 2007; Fuchs et al. 2003, 2006; Vukovic et al. 2014). A well-documented link between EF and math performance is reported in the literature (Cragg et al., 2017; Ribner et al., 2017; Viterbori et al., 2015). Many math tasks rely on the ability to update information in WM, inhibit irrelevant information, or flexibly shift among operations, solution strategies, and notations. For example, mental calculation requires children to manipulate and concurrently hold information in mind or update partial and intermediate results (Caviola, Mammarella, Cornoldi, & Lucangeli, 2012); in other math tasks, such as problem solving, inhibitory abilities are necessary, when the text of the problem contains irrelevant information that must be suppressed (Pasolunghi et al., 1999, Passolunghi and Siegel, 2001) or when an overlearned procedure or strategy must be inhibited in favor of a new one (Khng and Lee, 2009, Viterbori et al., 2017). This relationship was also well established for reading abilities, especially because of the role of working memory in letters and words acquisition prior to school (Fuhs et al., 2014) and in reading comprehension in older students (Daneman & Carpenter, 1980; see Carretti et al., 2009 for a review and meta-analysis). In addition, preliminary results suggest that interference suppression is a key process in the acquisition and construction of both phonological awareness and early orthographic knowledge in preschool children (Gandolfi et al., 2021; Shaul & Schwartz, 2014).

Regarding the indirect effects of EF on school achievement, several aspects could be mentioned. For example, given that children who start school with higher EF skills learn more easily (direct effect), this will result in a series of positive cascade indirect effects, such as being more motivated to learn and more positive towards school activities (Dweck, 2006). In addition, theoretical links have been proposed between EF and self-regulated learning (SRL) (Rutherford et al., 2018; Zelazo et al., 2016) which is in turn associated with school achievement. SRL refers to children's management of the cognitive and motivational aspects of their own learning (Zimmerman, 2008) and encompasses personal initiative, perseverance, metacognition and self-monitoring. Even though traditionally researchers have investigated either EF or SRL in isolation, and experimental evidence of their relationship are limited, some studies found positive associations between EF and selected components of SRL when measured concurrently, and some evidence suggests that EF may predict SRL longitudinally, at least in some age groups. Pintrich and Zusho (2002) found, for example, that working memory directly influences SRL and argue that other executive control processes might also influence the effective use of SRL. Roebers et al. (2012) reported concurrent and predictive associations between EF and metacognitive control, but not metacognitive monitoring, in a sample of 7-year-old children. Bryce et al. (2015) reported strong concurrent correlations of teacher-rated SRL with inhibition and working memory tasks in 5-year-olds and only weak associations among 7-year-olds. In young children SRL manifests as learning-related behaviors, such as showing enthusiasm for new activities, attending to and persisting with learning tasks in the face of difficulty (McDermott et al., 2014), being compliant with classroom rules (Sung & Wickrama, 2018), participating in class activities (Brock et al., 2009), showing independence and cooperation. These behaviors are tipically measured by teacher reports or classroom observations and refer to the way a child approaches the learning process rather than the academic outcomes (McDermott et al., 2014).

The mediational role of learning-related behavior

Literature on LRBs is relatively recent. Historically, school success was primarily evaluated in terms of school performance and achievement. However, from the end of the last century, preschooler educators and primary school teachers realized that also other skills had to be considered, because of their contribution to academic success (Stipek, 2006). Thus, researchers started to consider school success more broadly. Ladd and colleagues (Birch & Ladd, 1997; Ladd, 1996) introduced the term “school adjustment” and defined it as the children’s school affect and attitude, and their involvement or engagement with the school environment. According to the authors, school adjustment was operationalized as the level of children’s school liking and school avoidance, self-directedness, autonomy and cooperation (Birck & Ladd, 1997). Subsequently, behavioral aspects related to school achievement have been investigated and defined in different but partially overlapping terms, such as “approach to learning” (Anthony et al., 2014) or “learning-related behaviors” (Anthony & Ogg, 2019). Independently from the specific terms used, LRBs have demonstrated a strong association with concurrent and later reading and mathematics achievement (DiPerna et al., 2007; Duncan et al., 2007).

Despite there is no doubt that learning-related behaviors are at least in part related to cognitive skills and EF, only few studies investigated this association. For example, Ponitz et al. (2008) showed an association between preschoolers’ performance on the “Touch your Toes!”, which measures attention and working memory, and teachers’ ratings of classroom behavior (e.g., complying with adult directions, observing rules, and completing tasks). Even less are the studies that investigated the mediational hypothesis in which LRBs act as mediators between EF and achievement. This hypothesis posits that EF positively affects learning-related behaviors in school activities, which in turn predict academic achievement. In this vein, Brock et al. (2009) conducted a study with a sample of 173 kindergarteners and found that EF was predictive of both school achievement and learning-related behaviors, but they did not find any mediational role of LRBs between EF and achievement. Similarly, Neuenschwander and colleagues (2012) conducted a longitudinal study to test the mediational hypothesis of learning-related behaviors in a sample of 459 kindergarten and young elementary students. In particular, they tested the predictive role of EF on school achievement tests, grades and learning-related behaviors and found that EF was predictive of all the three aspects investigated. In addition, EF association with grades was partially mediated through learning-related behaviors, whereas no mediational role of LRBs was found between EF and achievement test scores. A more recent study (Rutherford et al., 2018) used a measure of inhibition-cognitive flexibility (Hearts and Flowers task; Davidson et al., 2006) and a working memory task (backward digit span) and found that the inhibition-cognitive flexibility measure was predictive of achievement and LRBs. In addition, in contrast with previous studies, they demonstrated the mediational role of LRBs. No correlations emerged between WM and school achievement measures or LRBs. Another study investigating the possible mediational role of LRBs in the relationship between EF and school achievement was conducted by Sasser et al. (2015). The authors carried out a longitudinal study with a sample of children from low-income families to examine the predictive links between EF skills measured in the fall of the pre-kindergarten year and the trajectories of elementary school outcomes through third grade. Results show a mediational role of LRBs between EF and literacy skills, but not between EF and mathematics, highlighting the indirect impact of EF on school achievement.

2. Executive functions, learning-related behaviors and school achievement. A study on first graders.

The direct relationship and the predictive role of EF on academic achievement is widely recognized. However, only a few studies tried to explain how EF impact on achievement. In fact, in addition to direct impact, multiple indirect effects could explain this relationship, as EF impact on multiple processes implicated in learning and achievement, such as staying focused on the task, comply with the teacher's instructions and working independently. These behaviors, in turn, promote achievement. Although the relationship between FE and learning-related behaviors is easily understood, as well as the relationship between LRB and school achievement, few studies have studied these aspects together.

The present study aimed to shed light on the relationship between EF and academic achievement, testing the possible mediational role of LRBs. In particular, we examined the separate contributions of two EF components that are clearly distinguishable in early elementary school: inhibition and working memory (see Lee et al., 2013). We focused on children in first grade, as the transition from kindergarten to primary school determines a meaningful change in terms of environmental demands and thus, in terms of self-regulation. Compared to the activities proposed in kindergarten, those offered at school are much more demanding in terms of attentive resources, as the duration of learning activities increases and the time spent on recreational activities reduces. In addition, while in kindergarten teachers act as co-regulators of the child's behavior, in primary school children are required to self-regulate their behavior in order to meet teachers' requests. For this reason, we hypothesize that the mediational role of LRB could be particularly relevant in this phase of development.

We hypothesized that EF positively impacts school achievement as children with higher EF abilities are more able to adjust to the school context and its demands, by implementing appropriate behaviors such as paying attention, participating, being more engaged in school activities and working independently. No a-priory hypothesis was formulated in terms of the different mediational roles of LRB when considering different EF components.

2.1 Materials and methods

Participants

The study involved 95 first graders evaluated in 2020 and 2021. Parental consent was obtained for each participant. The study was carried out according to the ethical standards and requirements of the Italian psychological association and was approved by the local ethical committee of the University of Genoa. Participants with a score below 5°percentile at the Coloured Progressive Matrices (Raven, 1954) or without a complete assessment were excluded from the analysis. For this reason, the final sample was composed of 91 participants [Male= 44 (48.4%); $M_{Age=}$ 6.62(0.3)]. Of these, 54 were evaluated in 2020 and 37 in 2021.

Procedure

Children were assessed throughout four assessment sessions lasting ~30 min. In particular school achievement (Math, Reading and Writing) was assessed during 2 collective sessions in class, while executive functions were assessed in 2 individual sessions. EF evaluations that took place in 2020 were carried out in a quiet room at school. In 2021, due to the pandemic situation, researchers were not allowed to assess children at school and the evaluations were carried out remotely via computer while the children were at home and connected with the experimenters through a Skype video call. To conduct the remote evaluation, a PDF file of the tasks' stimuli was created and shown to the children by the experimenter by sharing the screen. In both cases, assessment was conducted by trained psychology students. Teachers were asked to fill in two questionnaires to assess learning-related behaviors at school.

Measures

Fluid intelligence. The Coloured Progressive Matrices Test (CPM; Raven, 1954) was administered to measure fluid intelligence and was used as a control measure. It is a multiple-choice task in which the child is required to complete a geometrical figure by choosing the missing piece among six possible alternatives; the patterns progressively increase in difficulty. For each child, the percentile corresponding to the number of corrected answers was coded (range 0-36).

Academic achievement. To assess academic achievement, the following measures were administered:

Math*:* we administered the AC-MT 6-11 (Cornoldi et al., 2012), an Italian battery for the evaluation of math skills. In particular, we administered the collective task section, including calculation (two additions and two subtractions), magnitude comparison (six comparisons) and reordering of numbers from the largest to the smallest and vice versa (eight comparisons in total). The number of correct responses was used for the analysis (range 0-18).

Reading*:* we administered a silent reading task that requires children to identify with a slash at the end of a series of 58 words written with no spacing between them (Bellocchi et al., 2014). The task had a time limit of 4 minutes. The number of correct responses was used for the analysis (range 0-58).

Writing**:** we administered a 40-word dictation (Bellocchi et al., 2014). The task increases in difficulty, starting from two-syllable words to three-syllable words. The number of errors (incorrect or omitted words) was used for the analysis (range 0-40).

Executive function. To assess EF, two tasks for each EF domain were administered.

To assess WM, the following tasks were administered:

Backward digit span: the task requires the child to recall a sequence of spoken numbers in reverse order (Bisiacchi et al., 2005). Numbers were presented approximately once per second. The task increases in difficulty over trials, starting from three trials of two digits until trials of seven digits. The task ends when three lists of the same length are recalled incorrectly. The maximum list length at which two sequences were correctly recalled was scored and used for the analysis (range 1–7).

Dual WM task: the test consists of 12 blocks of sentences. The number of sentences per block increases every three blocks from 2 to 5. The child's task is to listen to the sentences and, at the end of each sentence, say whether they are true or false. In addition, at the end of each block, the child had the recall the last word of each sentence. For each block, 1 point is assigned for each remembered word, regardless of the order (Desimoni et al., 2010). The task was interrupted when the child gets a score of 0 in all 3 blocks of the same length. The sum of the correctly recalled words was scored and used for the analysis (range 0-42).

To assess inhibition, the following tasks were administered:

Matching familiar figures task (MFFT): this task required to select, from six alternatives figures, the one which is identical to the target picture at the top of the page (Marzocchi et al., 2010). The task comprises 20 items. The number of errors was recorded (range 0–100). In addition, the average time of first response was calculated. Both accuracy and time scores were used for the analysis.

Inhibition: we administered the inhibition subtest of the Developmental Neuropsychological Assessment – Second Edition (NEPSY-II; Korkman et al., 2007). Children look at a series of black and white shapes (squares and circles) or arrows (up or down) and name either the shape or direction in the opposite way, regardless of the colour (e.g., naming the circles square and the squares circle). The number of errors (including self-corrections) and the time were recorded. The combined scaled score (M=10, SD=3) was also calculated according to the normative data.

Learning-related behavior

The ***Teacher Rating Scale for School Adjustment*** *(TRSSA;* Birch & Ladd, 1998*)* was developed to tap several constructs that are reflective of young children's behavioral and relational adjustment to school or classroom settings. We used two subscales of the TRSSA assessing cooperative participation at school (8 items, i.e. “Follows teacher's directions”, “uses classroom materials responsibly”) and independent participation (9 items, i.e. “works independently”, “is tuned in to what's going on in the classroom”). For each item, the teacher rated if it was “applicable”, “sometimes applicable” or “not applicable” to the child, scored 2, 1 and 0 respectively. A total score of LRBs was calculated summing up the scores of the two scales (range 0-34) and used for the analysis.

2.2 Statistical Analysis

Data analysis was conducted using SPSS (version 25). First, a t-test for independent samples was carried out to test whether the EF evaluation modality (in-person vs. remotely) impacts the children’s performance. That is, we expected similar means in the tasks administered in person in 2020 vs. the same tasks administered remotely in 2021. Second, a confirmative factor analysis (CFA) with Promax rotation was conducted on EF tasks to verify whether these tasks could load on two latent factors, that is, inhibition and working memory. Third, correlations between measures were calculated to verify the possibility to test the mediational models.

Finally, the mediation hypothesis was tested using the SPSS add-on software PROCESS. Regression analyses based on 5,000 bootstrap samples were used to estimate path coefficients for the regression equations (Hayes, 2013). This procedure bases inferences regarding the presence of mediation on the indirect effect, which is an estimate of the overall mediation pathway and is defined as a product of the various individual regression coefficients that constitute the mediation pathway. Significant mediation (indirect effect) is indicated by a 95% confidence interval that excluded zero, whether or not the independent variables had a significant total effect on the dependent variable (Shrout & Bolger, 2002). In all the models, sex, parents’ education level and Raven’s scores were included as covariates.

2.3 Results

Preliminary analysis

The independent sample t-test revealed no significant differences in the performances of the children evaluated in presence and remotely (Table 1), except for the time scores of both MFFT and Inhibition, that was removed from subsequent analysis. Globally, the results show that at least for the accuracy index, the assessment modality did not influence the children's performances. Thus, we proceeded with the CFA on the EF measures, and in particular we entered the backward digit span, the dual WM task, the MFFT-errors and the inhibition combined score. Results show that the backward digit span alongside the dual WM task loaded on factor 1, so called WM, while the MFFT-Errors and the Inhibition combined score loaded on factor 2, so called Inhibition (Table 2).

Descriptive statistics and Pearson correlations for all measures are shown in Table 3.

Table 1. Descriptive statistics and comparison between 2020 and 2021 samples.

	2020 (n=54)		**2021 (n= 37)**		**Mean difference**	**t**	**p**
	M (sd)	**Min-Max**	**M (sd)**	**Min-Max**			
Span	2.87 (0.73)	2-5	2.86 (0.82)	2-5	0	.034	.973
Dual-task	19.80 (6.41)	2-33	19.30 (6.15)	8-32	0.50	.371	.712
MFFT-E	16.04 (9.45)	0-43	17.27 (9.95)	0-33	-1.23	-.599	.551
MFFT-T	15.63 (9.78)	3.57-58.85	20.50 (13.42)	7.08-73.17	-4.88	-2.006	.048
Inhibition-E	7.67 (5.36)	0-32	11.32 (11.65)	0-65	-3.66	- 1.785	.081
Inhibition-T	106.78 (22.39)	65-172	117.95 (24.57)	74-174	-11.17	- 2.229	.028
Inhibition-C	10.04 (2.53)	6-16	8.97 (2.61)	4-15	0.06	1.945	.055

Note: Inhibition-E= Inhibition subtest part B, errors; Inhibition-T= Inhibition subtest part B, time; Inhibition-C = Inhibition subtest part B, combined score; MFTT-T = Matching Familiar Figure test, time; MFTT-E = Matching Familiar Figure test, errors.

Table 2. Factor loadings for the confirmative factor analysis concerning the EF tasks.

	WM	**Hinibition**
Span	.698	
Dual-task	.894	
MFFT-E		-.794
Inhibition-C		.843

Note: Inhibition-C = Inhibition subtest part B, combined score; MFTT-E = Matching Familiar Figure test, errors;

Table 3. Descriptive statistics and correlations.

	1	2	3	4	5	6
Inhibition	1					
WM	.359**	1				
Reading	.281**	.411**	1			
Writing	-.452**	-.362**	-.675**	1		
Math	.348**	.369**	.338**	-.380**	1	
LRB	.566**	.389**	.405**	-.503**	.395**	1
M			31.47	11.98	15.80	3.09
SD			18.20	10.34	3.09	7.01

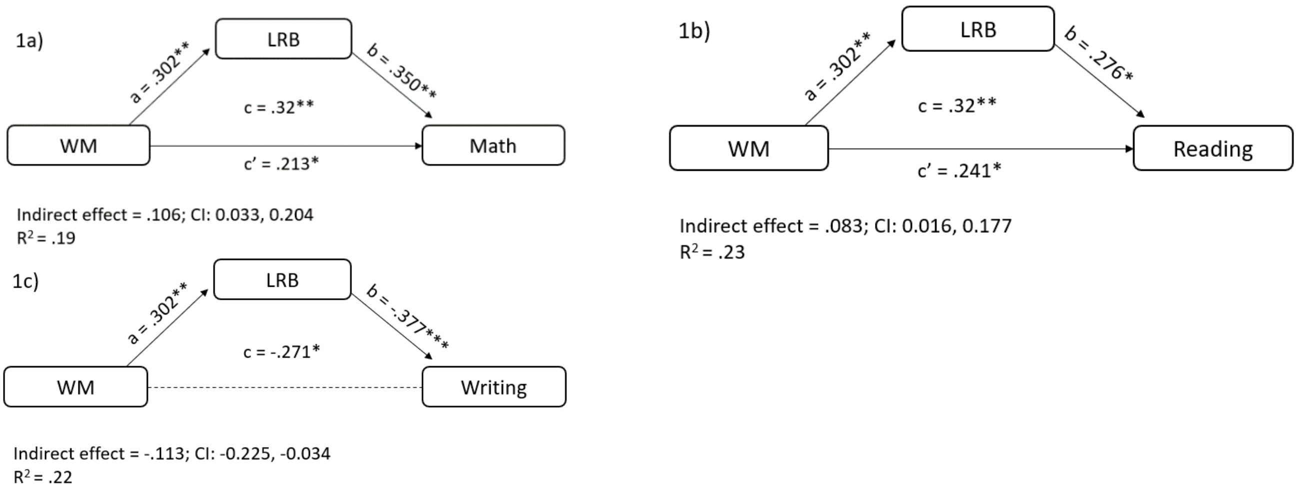
Mediation model with working memory as a predictor

We performed three mediational models entering WM factorial score as an independent variable, LRB score as a mediator and Math (Model 1a), Reading (Model 2a) or Writing (Model 3a) as a dependent variable. Results are shown in Figure 1. WM abilities predict LRB, with children with higher WM scores showing higher LRB scores (p = 0.003, CI: [0.760, 3.477], R^2= 0.30). Moreover, in Model 1a, the effect of LRB on the Math score was significant, with children with higher LRB showing higher Math scores (p = 0.002, CI: [0.057, 0.252]). The mediation hypothesis was also confirmed, as the indirect path was significant (CI: 0.033, 0.204). To note, also the direct effect of WM on Math was significant (p = 0.046, CI: [0.011, 1.306]), indicating a partial mediation.

In Model 2a we entered Reading as a dependent variable. As in Model 1, the effect of LRB on the Reading score was significant, with children with higher LRB showing higher Reading score (p = 0.014, CI: [0.149, 1.284]). The mediation hypothesis was also confirmed, as the indirect path was significant (β = 0.083, CI: [0.016, 0.177]). Also in this case, the direct effect of WM on Reading was significant (*p* = 0.023, CI: [0.613, 8.158]), indicating a partial mediation.

Finally, in Model 3a, we entered Writing as a dependent variable. In this case, results show a total mediation. In fact, the effect of LRB on the Writing score was significant, with children with higher LRB showing lower Writing errors (*p*< 0.001, CI: [-0.872, 0.240]). The mediation hypothesis was also confirmed, as the indirect path was significant (CI: -0.225, -0.034). Differently from the previous model, when LRB enter in the model, the direct effect of WM on Writing was not significant (β = -0.158, *p* =0.126, CI: [-3.732, 0.470]).

Figure 1. Mediational model with WM as a predictor.



Note: standardized effects are reported. Sex, parents' education level and Raven's scores were included as covariates.

Mediation model with Inhibition as a predictor

As for WM, we performed three mediational models entering Inhibition factorial score as an independent variable, LRB score as a mediator and Math (Model 1b), Reading (model 3b) or Writing (Model 6b) as a dependent variable. Results are shown in figure 2. Inhibition predict LRB, with children with higher Inhibition scores showing higher LRB scores (β= 0.567, *p*< .001, CI:

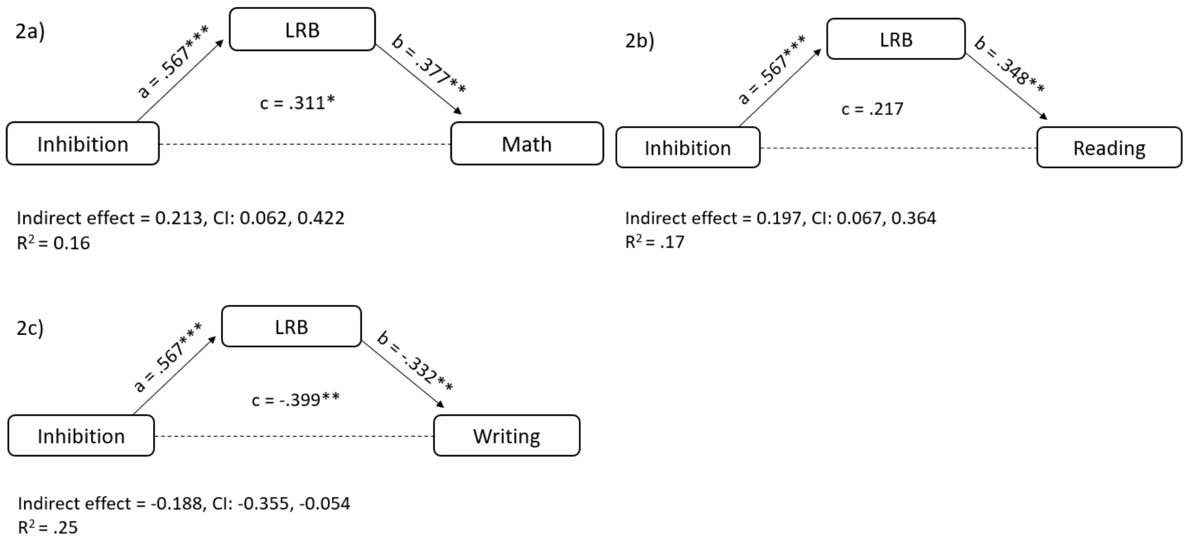
[2.539, 5.406], R^2=0.43). In Model 1b, the effect of LRB on the Math score was significant, with children with higher LRB showing Higher math scores (*p*= 0.004, CI: [0.056, 0.276]). The mediation hypothesis was also confirmed, as the indirect path was significant (β= 0.213, CI: [0.062, 0.422]). Differently from the model including WM as a predictor (Model 1a), direct effect of Inhibition on Math was not-significant (β= 0.98, p = 0.481, CI: [-0.5479, 1.1532]), indicating a total mediation.

In Model 2b, we entered Reading score as an independent variable. Results show that LRB predicts Reading scores, with children with higher LRB showing Higher Reading (*p*= 0.006, CI: [0.257, 1.550]). The mediation hypothesis was also confirmed, as the indirect path was significant (β= 0.197, CI: [0.067, 0.364]). Also in this case, the direct effect of Inhibition on Reading was not significant (β = 0.194, p = 0.889, CI: -4.651, 5.359), indicating a total mediation.

Finally, results of Model 3b show that LRB predicts Writing scores, with children with higher LRB showing lower Writing errors (*p*= 0.007, CI: [-0.839, -0.141]). The mediation hypothesis was also confirmed, as the indirect path was significant (β= -0.188, CI: [-0.355, -0.054]). Also in this case the direct effect of Inhibition on Writing was not significant (β= -0.211, p= 0.113, CI: -4.877, -0,523), indicating a total mediation.

Summarizing, the relationship between WM and school performance is partially mediated by LRBs (except for writing), indicating that WM affects learning skills both directly and indirectly through LRBs; differently, the relationship between inhibition and school performance is fully mediated by LRBs, indicating that when LRBs are entered in the models, inhibition is no longer associated to learning outcomes.

Figure 2. Mediational model with Inhibition as a predictor.



Note: standardized effects are reported. Sex, parents' education level and Raven's scores were included as covariates.

3 Discussion

Executive functions have a crucial role in supporting school achievement and promoting academic success (see Pascual et al., 2019 for a review and meta-analysis). It is recognized that among the different EF domains, the one to be more related to school performances is WM (Willoughby et al., 2012; Wu et al., 2017). In contrast, evidence regarding inhibition are less clear, with some studies founding a relation (Gilmore et al., 2015; Laski & Dulaney, 2015; St Clair-Thompson & Gathercole, 2006) and others not (Davidse et al., 2011, Lan et al., 2011, McClelland et al., 2014; Waber et al.,2006). Moreover, EF and in particular WM seems to be primarily implicated in math achievement (Allan et al., 2014; Blair & Razza, 2007; Gerst et al., 2017;), while the impact of EF on reading and writing is generally smaller (Gathercole et al., 2005; 2006; Swanson & Jerman, 2007). The aim of the present study was to test the hypothesis that part of the effects of EF - in particular WM and inhibition - on school achievement are mediated by learning-related behaviors, at least in the first years of primary school. Given that previous studies found that the impact of EF and LRBs is different across academic domains (Antony & Ogg, 2019; Neuenschwander et al., 2012), we tested our mediational hypothesis for math, reading and writing skills. Our results are in line with previous studies that have examined the mediational hypothesis (Nesbitt et al., 2015; Neuenschwander et al., 2012; Sasser et al., 2015). We found that the effect of WM on math and reading is partially mediated by LRBs, while its effect on writing abilities is totally mediated by LRBs. Differently, the impact of inhibition on school achievement is fully mediated by LRBs, regardless of the academic domain considered. Taken together, these results suggest that EFs impact on academic performance not only because of the direct implication of EF processes in school tasks but also because adequate EFs allow children to implement a series of behaviors that are appropriate to the school context that in turn promote better school performance. Moreover, our results strengthen the evidence that WM is more strongly directly related to learning processes than inhibition and help explain the reasons behind the heterogeneous results reported in the literature about the relationship between inhibition and school performance. The role of inhibition on learning skills appears to be mainly due to the impact that inhibition has on LRBs, that in turn affect school achievement, without any direct impact of inhibition when the mediational hypothesis is tested. In other words, inhibition allows children to fully benefit from the school experience, by promoting attention and control of impulsivity and favoring the display of appropriate behaviors in the school context.

With respect to WM, its role in learning outcomes is well-known, as already highlighted in the introduction. Our results are in line with those studies showing differential effects of WM across reading, writing and mathematics outcomes, with stronger effects typically being found for mathematics than literacy (Allan et al., 2014; Fuchs et al., 2005). In addition, our results indicate that also within the literacy domain there are some differences, with reading skills stronger related to WM than writing. In fact, the association between WM and writing was no longer significant when LRBs were included as a mediator in the model. The association found between WM and LRBs, though less studied in the literature, is in line with the results found by Alloway et al. (2009) that found a highly distinctive profile of behavioral problems in children with low WM characterized by poor attention span and high levels of distractibility. In addition, they were described by teachers as forgetting what they were currently doing, failing to remember instructions, and to complete tasks, and more prone to make careless mistakes, particularly in writing, and having difficulty in solving problems.

Other aspects could explain our results, in particular the age of children and the tasks we use to assess EFs. First, we involved in the study children attending the first grade. At the beginning of schooling, behavioral aspects have a higher impact on school outcomes. However, the association between EFs, LRBs and school achievement might change over the school years. For example, LRBs could be more relevant in the first grades and less relevant in the following years. Second, results regarding inhibition could also be linked to the nature of this cognitive process and the tasks we used to evaluate it. Inhibition is typically divided into response inhibition, which is the suppression of a behavioural response, and cognitive inhibition (interference control), which is responsible for suppressing attention toward non-relevant information and directing attention towards relevant information (Brydges et al., 2013). In our study, the tasks used to assess inhibition tap on the behavioral aspect of inhibition. This could explain the high association between the LRB measure, which assesses behavior in class, and why the direct impact of inhibition on school outcomes become not significant in the mediational model. It could be possible that using interference control measures of inhibition, that is a most “cognitive” inhibition measure, different patterns would emerge.

To sum up, our results are in line with existing literature on EF and school achievement and support the idea that the relationship between EF and achievement is complex and not unique, but there are different patterns of interaction depending on the specific EF component and school domain considered. In addition, these interactions may include some kinds of mediators

Limitations and future directions

Some limitations must be considered, and further investigations are needed to better understand the nature of the EF-school achievement link. The main limitation of the present study is the limited sample size, which reduced the statistical power of our analysis. Future research should confirm these results with larger samples. In addition, older children should be involved, to evaluate whether age and school experience may influence the relationships we found. Finally, both response inhibition and interference control should be examined in relation to LRBs and achievement.

Practical implications

Both EF and learning-related behavior demonstrated to be relevant for academic success in first grade. These findings support the importance to provide adequate interventions to remediate impairments in working memory and inhibition and to adequately support learning-related behaviors in children's early school career. Recent research has demonstrated the efficacy of universal classroom interventions (Diamond & Ling 2020; Raver et al., 2011) that are developed to enhance EF and self-regulation in all children. This seems particularly relevant because teachers have difficulties in both identifying and providing support to children with poor EF (Alloway et al., 2012), especially when poor EF is not associated with a clinical diagnosis. Focusing on the improvement of these skills early in children's academic career may have long-term effects, by allowing children to develop skills that in turn enable them to adjust to the school context, be engaged in the learning process and learn better. Such interventions may result in both better school climate and higher academic achievement for all children.

5. THE ELLI'S WORLD: A NEW MODEL TO IMPROVE EF

1 Introduction

Given the vast evidence of the EF implication in school achievement and school success in general (Best et al., 2011), in the last decades increasing attention has been given to the promotion of EF. Different kinds of programs to improve EF have been developed for any stage of development (preschoolers, school-aged children, adolescents and adults). These include specific cognitive training, computer-based training, games, physical activities and school curricula (Diamond et al., 2015; Karbach & Unger, 2014; Mackey et al., 2011; see Diamond & Ling, 2020 for a review) and there is convincing evidence that EF can be enhanced using these interventions at any stage of development (Diamond & Ling, 2016). A recent review (Diamond & Ling, 2020) highlighted that the most promising results were achieved by school-based programs or school curricula, such as the Chicago School Readiness Program (CSRP), Montessori, PATHS, and Tools of the Mind. Besides being the most effective, school programs have several advantages, as they reach more children, are cheaper, and thus fairer than any other approach. One of the reasons for the effectiveness of school programs is that, as EF training is embedded in activities throughout the school day, children are challenged on diverse EFs under truly diverse circumstances. This allows to improve different EFs and to generalize skills to novel situations. In contrast, cognitive training, and in particular the computerized ones, appeared to be less effective, especially in terms of generalization on different tasks or abilities. School programs can also provide a more intense, frequent and prolonged stimulation than other types of approaches, with positive effects on efficacy. In fact, the longer and more distributed is the training, the higher are the results (Diamond & Ling, 2020). In addition, compared to computerized training, school programs include greater interactions with teachers and peers, and also this aspect probably affects the training efficacy (Diamond &

Ling, 2020). Results suggest that this combination of characteristics is particularly effective. For example, evidence about the Chicago School Readiness Program shows that it was able to improve EFs of disadvantaged children by the end of that preschool year (Raver et al., 2008; 2011) and that children who experienced this program perform better in both math and literacy than their peers who had attended a regular school program for the following 3 years. In addition, those academic gains were almost entirely mediated by the improvement of EFs (Li- Grining et al., 2011). Similarly, the Tools of the Mind curriculum delivered in kindergartens in Massachusetts not only improved EFs by the end of kindergarten, but also improved reading, vocabulary, and math more than did regular kindergarten, and that difference in academic progress was still evident in first grade (Blair & Raver, 2014).

Despite the growing evidence of EF training efficacy, an important limitation is the limited evidence of far transfer effect. Generally, results show improvement on the trained tasks and only rarely on the untrained ones, so that effects remain specific rather than general. That is, despite the evidence of an association between EF and academic achievement, the improvement of EF does not always lead to achievement improvement (Diamond & Lee, 2011; Melby-Lervåg & Hulme, 2013). Several studies have been conducted to determine how to improve these skills in ways that lead to meaningful outcomes that transfer to academic skills. In trying to identify the factors able to discriminate between effective and non-effective training, Diamond (2012) identifies six fundamental factors: I) the children who have the greatest difficulty in FE are those who benefit most from the training; II) the effects of transferring the benefits of training to skills not directly trained are limited; III) the proposed activities must have increasing difficulty, to be continually challenging for the child and require continuous effort; IV) there must be repeated practice of the activities; V) activities must be proposed to be engaging and motivating; VI) the pre-and post-training evaluation tools must be adequate to capture the changes related to the training itself. More recently, after reviewing 179 studies on EF training, Diamond & Ling (2020) identified other important principles: I) EF benefits should last in time (Ball et al., 2002; Bigorra et al., 2015; Borella et al., 2010; Carretti et al., 2013); II) generally longer training produce better results than the shorter, regardless of the type of training (cognitive, computerized, etc.); III) similarly, also the length of each session seems to be important as in most cases session <30 min have little impact on EF, even if some exceptions exist (e.g. Au et al., 2015; Ben-Soussan, et al., 2015); IV) spaced, or distributed, practice produces better long-term outcomes than massed practice. That is, relatively shorter training or practice sessions spaced out over time produce better outcomes than compressing the training into a shorter period with longer sessions; V) often, the benefits of an intervention are only seen or are seen most clearly, on outcome measures that are highly demanding. Complex, multicomponent measures (such as the Tower of London or Wisconsin Card Sort Test, which require multiple EF skills) are good candidates for detecting outcome differences between the intervention and control group, as they require more than one EF skill. On the other hand, they are not adequate to isolate which particular EF skill improved.

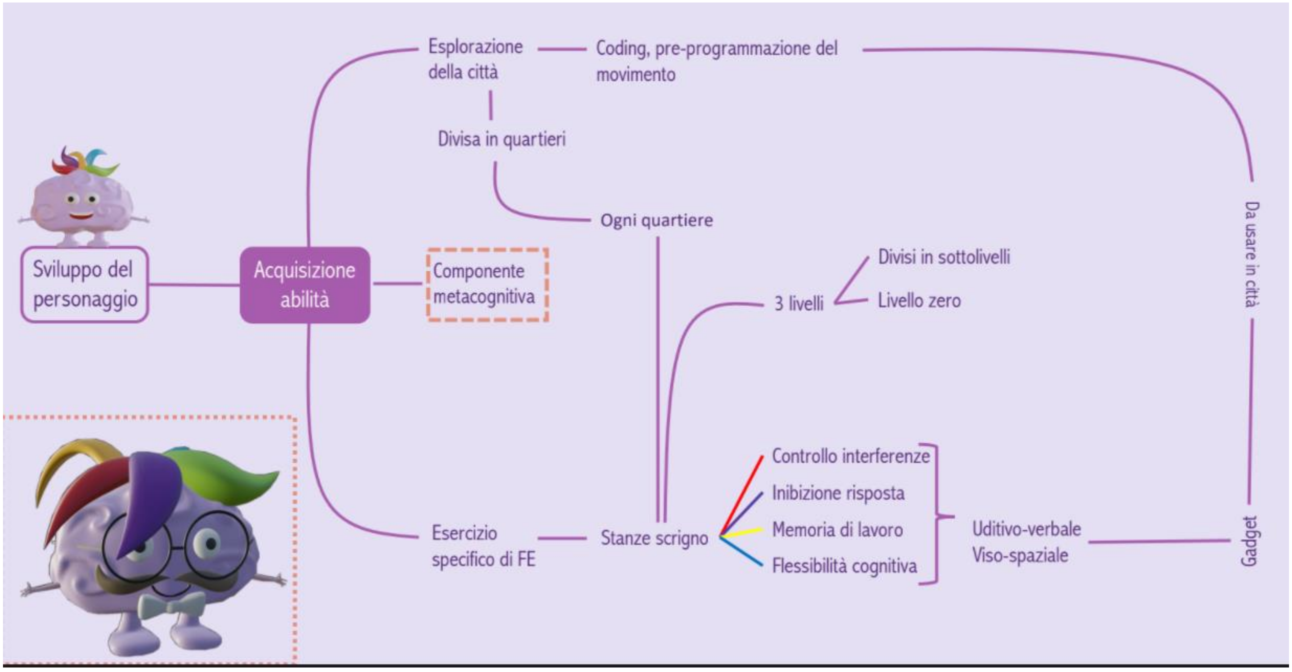
2 The Elli's World training model and its principles

"Elli's World" is a new model of EF training developed in line with the current evidence regarding the efficacy of EF training (Figure 1; see Appendix for the Italian version of the Manual). The model was developed to satisfy all the efficacy criteria that emerged from the literature and to promote the generalization of results on untrained abilities. It includes:

- school sessions promoting metacognitive reflections on EF and its utility at school and in everyday life;
- home sessions in which children train EF through a videogame;
- integrative activities to train EF at school through games and school-curriculum activities.

The innovative aspect of the present model is to integrate school-based training with computer-game-based training and to offer teachers a variety of integrative activities to support EF development. In this way, it has the advantages of school training, able to reach a large number of children regardless of the context and socioeconomic condition. In addition, thanks to the home-sessions, guarantee an adequate training intensity, which would be impossible to reach if the training was carried out exclusively at school. In addition, thanks to the integrative activities, children train EF with a multiplicity of tasks and in different situations, crucial to ensure the generalization of results.

Figure 1. Elli's world model.



The principles of the Elli's World training program are:

1) ***Gamification:*** "Elli's World" is based on the idea of gamification, which is the addition of game elements to non-game activities. Game-based training (e.g., Cogmed, Braingame) provides immediate feedback and includes animated characters, narratives, storylines, interactive environments, and player advancement through different levels to make standard

cognitive tasks more interesting (Prins et al., 2013). Adding game elements to the training environment can promote interest and motivation in the training task (Wang et al., 2019). Evidence exists regarding better results of videogame based training compared to non-videogame ones (Green & Bavelier, 2003; Mishra et al., 2011; see Cao et al., 2020 for a review). According to that evidence, the home-sessions of the "Elli's World" training appears as a videogame, in which the children guide Ello (the main character) in different games and activities to gain points and rewards. Children receive points depending on the time spent on the videogame (so they depend on the amount of training instead of performance), in order to motivate children also in case of difficulties. Every time children successfully end a "treasure room" and finish all the levels that train a specific EF, they receive a reward (i.e., a shield for interference control) that will help children in subsequent phases of the game.

2) ***Auto-adaptiveness:*** Adaptiveness is one of the core principles for cognitive training efficacy as it allows to administer to the child activities that are adequately challenging, neither too easy nor too difficult (Diamond & Ling, 2016). For this reason, all the activities proposed in the videogame include four difficulty levels, divided into 2 sub-levels, promoting the gradual increase of difficulty during the training and allowing each child to train with activities that are appropriate to his/her characteristics. To proceed in the game, it is not necessary to overcome the most difficult level, as teachers can decide which level the child must reach in order to go on. This is crucial to promote motivation and to provide a training that could be adapted to the specific characteristics of every child in the class.

3) ***Metacognition:*** metacognitive training appears to be particularly effective compared to the non-metacognitive ones, leading to greater improvements. Evidence shows that metacognitive scaffolding during training can enhance both near- and far-transfer effects, as they allow children not only to train in a task but also to increase their knowledge about

cognitive functioning and about the strategies to maximize it (Hirsh-Pasek et al., 2015; Schaeffner et al., 2021). For this reason, the school sessions of "Elli's World" training include several videos in which Big Ello, an elder brain that guides Ello, explains to the children what EFs are and how they work. The first video, at the beginning of the training, offers an overview of all EF components and explains to the children who Ello and Big Ello are. The following video focuses on the EF components that will be trained in every phase of the training. Every video will be followed by a metacognitive discussion in the classroom, in which the teacher asks the children:

- to do some new examples of the situations in which an EF component helps, both at school or in other situations of everyday life;
- to think whether they are good or not in this EF skill;
- to think about some strategies that could help to be better;
- to think about some strategies to help children with difficulties.

4) ***Inclusion and collaboration:*** the training was developed to be helpful in schools and classes that include children with different levels of abilities. The training is designed to be suitable for both typically developing children and children with special needs. EF difficulties are often present in different neurodevelopmental conditions and the focus of this training is also to help children with difficulties. For this reason, first, we include in each activity a level 0 for children that are not able to solve level 1 without an appropriate pre-training. Second, to proceed in the training is not necessary to reach the highest level - that is 3 - in each activity. If level 3 is too difficult for a child, the teacher can unlock the subsequent sets of activities, that train a new EF component, manually, to avoid frustration and provide only activities with adequate difficulties for each child. Third, we designed the training as a collaborative one: in addition to the individual activities, the training includes (not now in the prototype) some team challenges. Every child contributes to his/her team score with the

amount of time spent training himself/herself, regardless of the level reached. In this way, we tried to avoid isolation of children with difficulties, support effort and participation and tried to emphasize inclusion and collaboration between classmates.

5) ***Integrative activities:*** teachers often complain that they do not have enough time or possibility to propose training that consists of many weekly sessions at school. Home-sessions allow teachers to provide only one school session per week or to plan the number of school- sessions per week according to their own schedule. In addition, a training manual is provided to teachers with games and activities that can be easily integrated into the school routine. These activities have been developed to promote both learning skills (for example reading comprehension or mental calculation) and EF. In addition, also paper and pencil activities adapted for children with special needs are reported in the manual to provide supporting material to adapt the program to all the students. All these integrative activities are designed to provide different training modalities of EF and promote generalization.

6) ***Developmental model of EF and evidence-based activities:*** the structure of "Elli's world" and the activities are based on the developmental trajectory of EF. The training starts with interference control activities and continues with inhibition, working memory and cognitive flexibility. That is, children train first with EF components that develop first (Diamond, 2002; Letho et al., 2003). In addition, all the activities included in the videogame are based on experimental tasks used to assess and support each EF component (See Appendix for a detailed description of the activities).

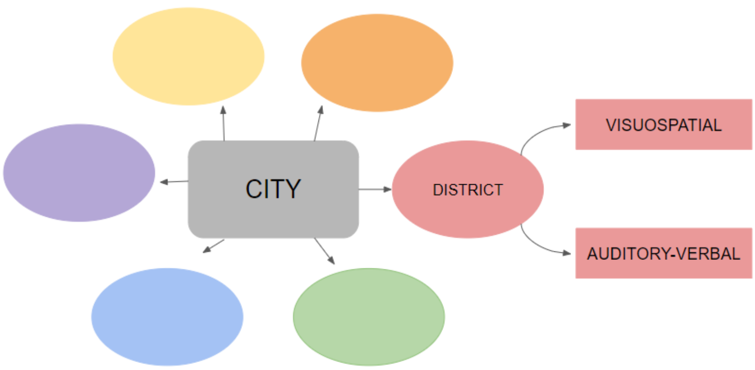
3 Storyline of the videogame

During the videogame activity, the child controls his/her avatar Ello, a young brain with poor executive functions, ready for new challenges to train his EF skills. It all happens under the guidance of Big Ello, an elder brain that helps the young Ello in his adventure.

Exploring the city

The player must help Ello explore the Elli's World, an urban scenario, similar to a city, until reaching the "treasure rooms", which are the places where the activities for the enhancement of EF are contained. The city is divided into neighborhoods, one for each EF domain, which are unlocked and become explorable as the player overcomes the different challenges (Figure 2). The game begins in a training district where the child becomes familiar with the mode of exploration of the neighborhoods and continues with the neighborhoods of the different executive functions (interference control, response inhibition, work memory, cognitive flexibility). The child moves throughout the city using coding activities, which are known to be helpful in developing EF as they require planning and management of impulsivity (Di Lieto et al., 2020). Every two weeks, regardless of the number of sessions done, a new district is unlocked, and the child has to explore it through coding. As the training goes on, coding activities gradually become more complex, and longer, with obstacles to avoid or objects to collect before reaching the destination.

Figure 2. Structure of the videogame.



Treasure rooms and EF activities

In every district (except for the first) children must find the treasure rooms, which are the places where EF activities are contained. When the children arrive in a treasure room, the activities start. First instructions appear, both written and pronounced by Big Ello. Then a practice session ensures the comprehension of the game and, if at least 60% of the practice session is solved correctly, the game starts. In every district, the child must find 2 treasure rooms with activities in auditory and visual format, respectively.

In every treasure room, activities are structured in 3 levels of increasing difficulty. Every level is also divided into 2 sublevels of slightly increasing difficulty, in order to obtain a sort of auto-adaptiveness. Auto-adaptiveness is crucial to make sure that the difficulty of each level modifies as the children play and remain in the zone of proximal development, sustaining improvement and motivation. If the children make 60% of the level correct, he/she passes to the subsequent level. In addition to the 3 levels, every room also has a level 0, which is a basic level designed for younger children or children with difficulties. This level is automatically presented to children in the first two years of primary school. From the third year, this level is not presented automatically but can be activated by the teacher, for example in the case of a child with special needs. In the same way, it can be disabled for younger children if not necessary.

Gadget

Every time a child ends a treasure room, he\she receives an energy card. When both the rooms in a district are completed, the children receive a gadget. Gadgets are objects linked to the trained EF that will help during the following coding activities. In fact, proceeding in the game, during the coding activities there will be obstacles to overcome by using the gadgets and the cards. These obstacles can be everyday situations and require the child to choose the correct gadget to solve them.

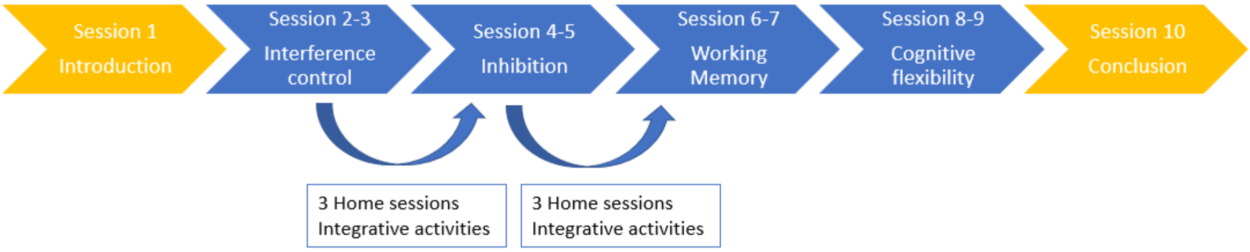
Integrative activities

To promote generalization and increase training opportunities for children, in addition to the videogames activities (coding and EF tasks in the treasure rooms), teachers are provided with classroom activities that can be administered to children at school. These activities are aimed at promoting the success of the training and the transfer of improvements in non-trained abilities. In particular, we distinguished three different kinds of integrative activities: i) activities for children with special needs. These are pencil-paper activities designed for those children who need more support and for whom the use of the videogame may not be useful, unsuitable, or not sufficient. Some children may find it difficult to cope with the challenges in the videogame. Paper and pencil activities can be administered individually or in small groups and provide a starting point for metacognitive reflection; ii) Game activities. Games can also be used to strengthen self-regulation abilities. As already mentioned, games allow children to improve their skills in a challenging and motivating way. All the game activities involve low-cost, easily available materials and can be administered during teaching hours, break time or physical education lessons; iii) School activities. Several school activities can improve EF and often teachers do not realize that these activities, if properly structured, can be a useful support to the development of EF. These activities can be defined as ecological as they are designed to be embedded in the school context and recall real life situations. In this way, the child can understand the practical usefulness of the functions trained and generalize the improvements obtained with the videogame also in everyday life activities.

4 Structure of the training

The structure of the training is presented in Figure 3. A more detailed description of each session is provided in the Appendix. The training lasts about 3 months (10 weeks). Specifically, this includes 10 weekly school sessions, one for the introductive activities in the coding district, two for each trained EF component, and one final session. Between one school session and the following one, children are required to train their executive function three times per week using the videogame. Each videogame session lasts about twenty minutes. In addition, teachers will provide the integrative activities throughout the training program.

Figure 3. Timeline of the training model.



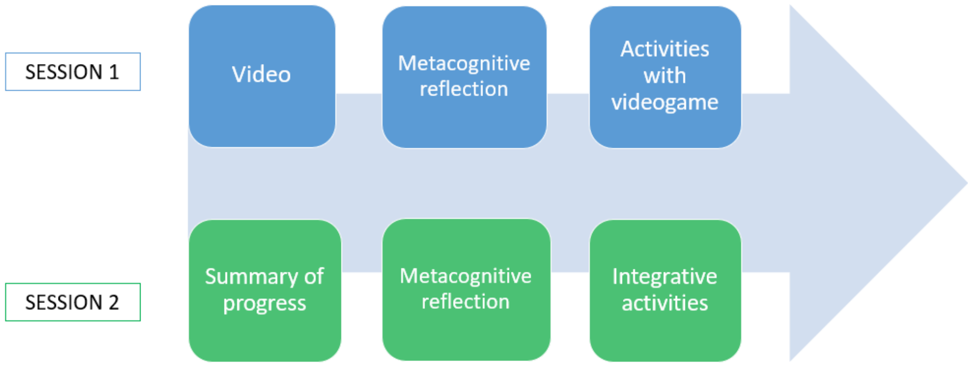
To summarize, the training switches between school-based activities and the home-based cognitive training. The general introduction to the training, as well as the introduction to each executive function (district) and the metacognitive reflection on each function are carried out at school and involve the whole class. At home, the cognitive training, which includes both the coding activities and the EF training, is carried out. In addition, during the week the teacher provides the activities and games that are described in the manual (see Appendix).

School sessions

The duration of each class session is about one hour, to ensure the right time for the different phases of the session. The structure of each school session is presented in Figure 4 and changes depending on whether it is the first or second session on a given EF dimension. It includes presentation of the new EF (video)/ summary of previous activities, metacognitive reflection, and videogame activities/integrative activities.

In case the activities with the videogame cannot be provided to children, for example because there aren't enough computers for each child, it is recommended to show the children the new videogame activities using the teacher's profile and invite them to train at home. The teacher can also use other strategies, such as dividing the children into small groups so that each group can have a try of the videogame at school. Whatever method is chosen, the teacher must ensure that any progress made at school is the same for each child.

Figure 4. Structure of school sessions.



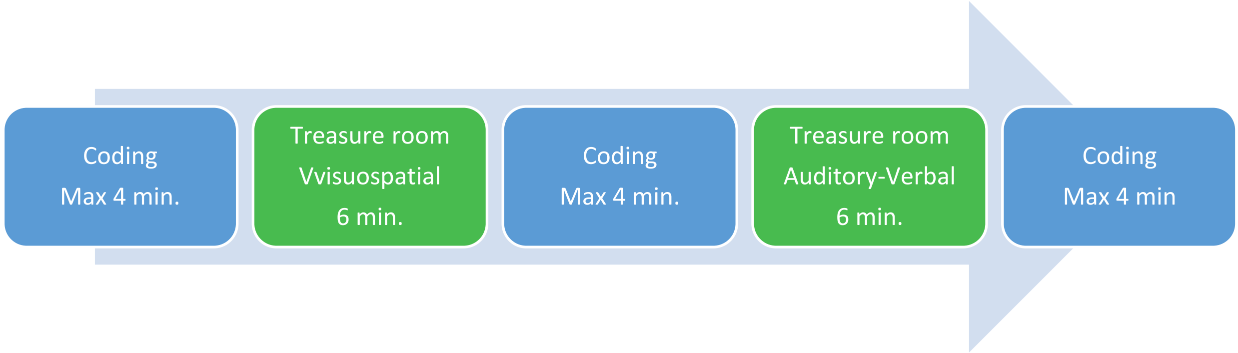
Home sessions

"Elli's World" requires that children train at home three times a week for about 20-25 minutes per session. It will be Big-Ello, at the end of the last challenge, to invite the child to close the browser. The structure of each home session is presented in Figure 5. It alternates coding activities and specific EF activities in the treasure rooms. The duration of each session is predetermined. That is, children had 4 minutes to solve the coding tasks and reach the treasure room. If the child isn't able to reach the room in this time, he/she will be "transported" in the treasure room automatically. This makes the training suitable even for children with greater difficulties or disabilities and prevent them from not being able to continue with the session.

At the first access, the child will be asked to customize his/her Ello and then start the game in the introductory district of coding. The first district has the sole purpose of allowing the child to familiarize himself with the videogame and with the navigation modes and has a duration of one week. All the other districts have a duration of two weeks, so the child will train 6 times for each executive function.

The transition from one district to another is automatic and independent of the number of sessions carried out by the child. This means that starting from the first access, the child will be for 7 days in the introductory neighborhood every time he makes an access. Starting from the eighth day it will be in the interference management district, where it will stay for 14 days. Starting from the 15th day the child will find him/herself in the neighborhood of inhibition of response for 14 days, and so on for the following neighborhoods.

Figure 5. Structure of each home session.



Summary

The training can be easily integrated into the school curriculum, thanks to its versatility and the plurality of media and activities it uses. Activities are designed to be based on collaboration rather than competition, both at the group level and at the individual level, both at school and at home. The activities are part of a well-defined program, which allows students to test themselves and experience their successes over a significant period of time, thus appreciating the gradual consolidation of their improvements and gaining confidence in themselves and in their abilities. Thanks to the levels, each activity is always an adequate challenge for the player, without ever being too easy or too difficult: in fact, the child advances with the levels after having been successful in the previous one; a zero level, comparable to a tutorial level, is provided as a starting point for children with greater difficulties. Thanks to the metacognitive reflections and the ecological activities, the child can gain a certain level of comprehension of his/her cognitive functioning that may promote generalization of the results.

5 Efficacy and feasibility of the Elli's world: a pilot study

A pilot study was conducted to investigate the efficacy and feasibility of the Ellis' World training. The study was conducted with a prototype version of the videogame in which the flexibility district was not yet active so that only interference control, response inhibition and working memory were trained. For this reason, the training lasted 8 weeks, for a total of 8 school sessions (6 with EF training, an introductive one and a final one) and 18 home sessions. In addition, only few integrative activities were provided by teachers at school. Since it was not possible to provide adequate training for teachers, the experimenter conducted the school sessions herself via videocall with the classes, due to the COVID-19 restrictions.

Materials and methods

Participants

The study involved 75 children attending the second grade in five different classes. Based on the agreement with teachers, two classes were assigned to the training group and three classes to the control group. Thus, 34 children composed the training group and 41 the control group. Thirteen children were removed from the initial training group because they did not take part in the post-test assessment (N=1), or because they completed less than half of the training sessions (<9 sessions; N=11). In addition, one child was removed because he moved to another city before the end of the study. Nine children were removed from the control group because they did not take part in the pre- or post-test assessment. The final sample included 53 children (M_{age}= 7.75, SD = 0.28, 60.4 % females) who were attending the second grade: 21 children were in the training group (M_{age}= 7.80, SD = 0.24, 71.4% females) and 32 children in the control group (M_{age}= 7.72, SD = 0.30, 53.1% females).

Procedures

The procedures used for the EF evaluation were the same used for the sample of the previous study on learning-related behavior tested in 2021. Children were assessed during 2 individual remote sessions when they were at home and connected with the experimenters through a Skype video-call. To conduct the remote evaluation, a PDF file of the task's stimuli was created and shown to the children by the experimenter by sharing her screen. Each session lasts about 30 minutes and was conducted by trained psychology students. At the end of the training, children, parents and teachers included in the training group were asked to rate an ad-hoc designed questionnaire to evaluate the training experiences.

Measures

The following tasks and questionnaires were administered. A detailed description of the tasks is presented in the previous chapter (chapter 4, paragraph 3.3).

To assess *fluid intelligence,* the Coloured Progressive Matrices Test (CPM; Raven, 1954) was administered. To assess *executive function*, two tasks for each EF domain investigated (WM and inhibition) were administered. To assess WM the *Backward digit span* (Bisiacchi et al., 2005) and the *Dual WM task* (Molina et al., 2003) were administered. To assess inhibition, the *Matching familiar figures task (MFFT;* Marzocchi et al., 2010) and the *Inhibition* subtest of the NEPSY-II (Korkman et al., 2007) were administered.

To assess *training compliance*, three different custom-made questionnaires were compiled by teachers, children and their parents respectively (see appendix). The questionnaires were adapted from the Intrinsic Motivation Inventory (IMI; Ryan, 1982; Mcauley et al., 1989) and from previous feasibility studies on game-based training (Corti et al., 2018; Görgen et al., 2020). In the self-report questionnaire, children were asked to rate to what extent they agreed with 11 statements evaluating enjoyment and satisfaction using a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). In addition, they were asked which part of the training they preferred (city exploration through coding, treasure rooms, metacognitive videos or integrative activities). The questionnaire included items regarding interest/enjoyment (e.g., ‘‘This training was fun to do’’, “I would recommend this training to friends”), perceived competence (e.g., ‘‘I think I am pretty good at this training’’), effort/importance (e.g., ‘‘It was important to me to do well at this training’’), and value/usefulness (e.g., ‘‘I believe doing this training could be beneficial to me’’). An average score was calculated for each child. In the parent-report questionnaire, parents were asked to rate 15 items using a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). The questionnaire included items regarding satisfaction (4 items), perceived satisfaction of the children (3 items) and usability (8 items regarding amount of training sessions, user friendliness of the videogame, technical issues). An average score for the three domains was calculated. In addition, they were asked to indicate the reasons why they possibly were unable to hold the three sessions per week required, if they encounter some technical issues and what aspect of the videogame would have been modified. The teacher-report questionnaire comprised 11 items to answer on the five-point Likert scale. The items evaluated satisfaction (4 items), usability (3 items) and perceived satisfaction in the children (3 items). An average score for each domain was calculated. In addition, suggestions for further videogame improvement were asked.

Statistical analysis

Statistical analyses were performed with IBM SPSS Statistics 25. To test for group differences in age, fluid intelligence, WM and inhibition at pre-test, independent samples t-tests were used. A univariate repeated measures analysis of variance (ANOVA) was conducted to evaluate significant change in EF skills from pre- to post-test. Group (TG vs. CG) was included as between-subject factor and test time point (pre-test vs. post-test) as within-subject factor. Descriptive statistics (mean and standard deviation) for each questionnaire scores and for the total score of each questionnaire (self-, parent- and teacher-report) were calculated to assess feasibility of the training. In the case of reverse items, the responses had been recoded, so that 5 indicates a positive evaluation. Additional qualitative suggestions reported by parents and teachers were screened in order to collect further information about the level of enjoyment of the training and for information on any changes to be made.

Results

First, we evaluated the rate of children in the training group who complete less than half of the home sessions. The training group initially comprised 34 children. Of these, one has moved into another city, and one has not carried out the post-test assessment. Of the 32 left, 2 (6.25%) did not have a PC capable of supporting the program (Windows 10 or above). Of the 30 left, 9 (30%) performed less than half of the required home sessions and were removed from subsequent analyses. As shown in Table 1, there were no significant differences in age, sex or cognitive functioning between groups. When differences between groups in EF abilities at pre-test were tested, some significant differences emerged (Table 2). In fact, the control group committed a significant higher number of errors in both the inhibition tasks (MFFT p= .013; Inhibition p= .009; Inhibition composite score p= .016).

Table 1. Descriptive characteristics and differences between groups.

	Total sample M(ds)	Training M(ds)	Control M(ds)	Means differences	t	*p*
Age	7.75 (0.28)	7.80 (0.24)	7.72 (0.31)	0.08	1.109	.273
CPM	71.77 (21.70)	76.43 (23.89)	68.72 (19.92)	7.71	1.225	.228
		Frequency (%)	**Male/female**		**X^2**	***p***
Sex	21 (39.6) / 32 (60.4)	6 (28.6) 15 (71.4)	15 (46.9) 17 (53.1)		1.776	.183

Training outcomes

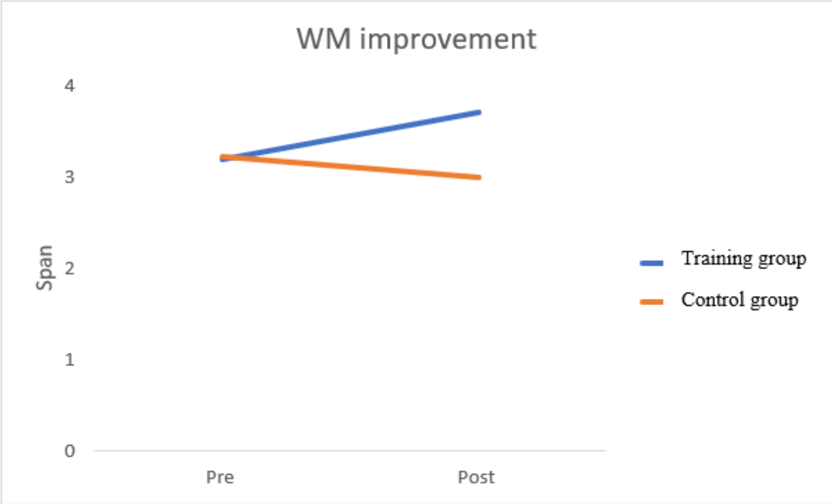
To examine pre-versus post-training changes in each task of the battery, we conducted a series of 2 (Training vs. Control Group: MT, T) × 2 (Session: pre- vs. post-intervention) ANOVAs with Intervention Group as the between-subject factor. As shown in Table 2, a significant Group x Session interaction emerged for the Span task (F=(1, 51) =17.219; *p* <.000) and a marginally significant Group x Session interaction for the Dual WM task (F(1, 51)= 3.784, *p*= .057), indicating the efficacy of the training on WM (Figure 6). Regarding the inhibition tasks, no significant effects emerges, except for the Inhibition-time score (F(1, 51)= 8.143; *p*= .006). However, in this case is the control group to improve more.

Table 2. Pre-test comparison (t-test) and training efficacy (2x2 Anova).

	Training		**Control**		**Pre-test comparison**		**Training efficacy**		
	Pre-test M(ds)	**Post-test M(ds)**	**Pre-test M(ds)**	**Post-test M(ds)**	**t**	***p***	**F**	***p***	***η2***
Span	3.19 (0.68)	3.71 (0.72)	3.22 (0.56)	3.00 (0.67)	-.166	.869	17.219	.000	.252
Dual WM task	25.76 (3.32)	28.05 (3.92)	24.76 (5.56)	25.06 (5.62)	.676	.502	3.784	.057	.069
MFFT-T	25.01 (20.96)	23.56 (17.98)	16.70 (6.88)	14.74 (6.52)	1.720	.099	.065	.799	
MFFT-E	7.90 (4.95)	7.86 (6.53)	12.79 (7.19)	10.78 (5.94)	-2.583	.013	.925	.341	
In-T	95.15 (19.24)	85.84 (25.18)	106.88 (26.45)	84.27 (14.51)	-1.704	.094	8.143	.006	.138
In-E	4.95 (3.11)	2.19 (1.54)	7.85 (4.21)	3.81 (2.48)	-2.732	.009	1.133	.292	
In-C	8.81 (2.75)	11.62 (2.46)	7.16 (2.1)	10.09 (2.18)	2.480	.016	.042	.839	

Note: In-T= Inhibition subtest part B, time; In-E= Inhibitions subtest part B, errors; In-C = Inhibitions subtest part B, combined score; MFTT-T = Matching Familiar Figure Test, time; MFTT-E = Matching Familiar Figure test, errors;

Figure 6. WM improvement post-training.



Feasibility of the training

Feasibility of the training was evaluated by three questionnaires rated by children, parents and teachers. Results are reported in Table 4**.** As questionnaires were compiled also by children (and parents) who completed less than 9 sessions, results are reported for both the total sample and the partial sample without those children. However, due to an error in implementing the online version of the self-report questionnaire, it was not possible to trace the name of 3 questionnaires. Of these, one belonged to a child who had carried out 7 sessions. This questionnaire was included in both the analysis. Given the characteristics of Likert-scale questionnaire with a neutral option (3), we reported both means and percentage of positive options (4-5) in order to have a better picture of the participant's opinion. Considering the Partial sample, enjoyment was rated on average with 3.84 (SD= 0.64). Observing the percentage of positive opinions on each statement, almost all are above 50, indicating that the children enjoyed the training, and take an effort to do it. Parents reported mean for perceived enjoyment of their children was 3.84 (SD= 0.86) and teachers reported a mean of 4.11 (SD= 0.38), confirming the results reported by the children themselves. Interestingly, teachers reported higher rate of perceived enjoyment, indicating that the children appreciated the school sessions more than the home ones. Feasibility was rated by parents with an average of 3.79 (SD= 0.65), indicating that it was possible to integrate the training into everyday life. In addition, observing the single item of the questionnaire, parents reports that instructions were understandable for the children and there was no need for an adult to support them and also that they didn't need further support during the training. However, they reported difficulties in meeting the required frequency, as well as a lack of information about the training. Teachers found that the program could be easily integrated into the curricula (M= 3.92; SD= 0.14). Finally, the mean global satisfaction score reported by parents was 3.51 (SD= 0.67). They reported that they were satisfied and that they considered the training useful. However, most parents indicated that they didn't notice changes in the child and that they would not recommend the training to others. The teachers reported a mean satisfaction score of 3.73 (0.11). All reported to be satisfied with the training and with the improvement seen in the children. However, only one indicated that she would repeat the training.

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Table 4. Feasibility outcomes

Self-report	**Total** (n=28)		**Partial** (n=21)	
	M(SD)	**% 4-5**	**M(SD)**	**% 4-5**
It was easy to stay focused during the sessions.	3.32 (0.98)	*35.7*	3.19 (0.98)	*43.3*
The training was fun.	3.79 (1.03)	*57.1*	3.86 (1.01)	*61.9*
I think it helped me do better in school.	3.96 (1.07)	*64.3*	3.86 (1.06)	*57.1*
I would happily do the training a second time.	2.79 (1.37)	*28.6*	2.76 (1.3)	*28.6*
I think I improved.	3.57 (1.1)	*64.3*	3.48 (1.17)	*57.1*
*I felt agitated/concerned while doing this activity.	3.86 (1.407)	*67.9*	3.59 (1.47)	*57.1*
I think I did well in the training	3.71 (0.763)	*60.7*	3.76 (0.77)	*66.7*
I was committed to doing well in this activity	4.11 (0.875)	*82.1*	4.1 (0.89)	*85.7*
I would recommend this game to friends	3.68 (0.983)	*60.7*	3.67 (0.97)	*61.9*
*The activities were difficult	3.57 (1.23)	*53.6*	3.48 (1.13)	*52.4*
*It was tiring to be able to do the activities at home 3 times a week.	2.61 (1.197)	*25*	2.86 (1.20)	*33.4*
Enjoyment	4.24 (0.66)		3.84 (0.64)	
Parent report	**Total** (n=23)		**Partial** (n=17)	
	M(SD)	**% 4-5**	**M(SD)**	**% 4-5**
I am satisfied to have taken part in the training project.	3.83 (0.94)	69.5	4.00 (0.71)	76.4
I would recommend this training to others	3.43 (1.12)	*34.7*	3.47 (1.01)	53
I think the training has been helpful for my child.	3.30 (0.77)	*69.5*	3.53 (0.62)	47.1
I have noticed improvements in my child.	3.78 (0.95)	*30.4*	3.06 (0.83)	29.4
Satisfaction	3.34 (0.81)		3.51 (0.67)	
The information obtained at the beginning of the training was sufficient to understand how to use the videogame	3.17 (1.37)	*47.8*	3.35 (1.32)	47.00
The instructions for the child included in the game were sufficient to understand the activities	3.70 (1.20)	*65.2*	3.94 (1.09)	70.6
*I needed to contact the research manager for further clarification on the use of the App	3.78 (1.25)	*56.3*	3.71 (1.40)	53.00
*It was difficult to be able to do all 3 scheduled weekly sessions due to time constraints	2.96 (1.52)	*34.8*	2.94 (1.56)	45.3
*It was necessary that an adult support my child during the home-sessions	3.91 (1.41)	*69.6*	3.82 (1.47)	70.6
It was difficult to get a tablet/PC to do the activities	4.52 (1.00)	*82.6*	4.65 (0.86)	88.3
There were connection problems that made it impossible to carry out the activity	4.52 (0.73)	*86.9*	4.47 (0.80)	82.3
There were technical problems with the videogame during the activities	3.57 (1.34)	*52.2*	3.41 (1.28)	47.00
Feasibility	3.77 (0.64)		3.79 (0.65)	
It was difficult to do the weekly sessions because my son/daughter was lazy, uninterested.	3.48 (1.41)	*52.2*	3.47 (1.38)	52.9
*The activities were difficult for my son/daughter.	4.26 (1.01)	*69.6*	4.29 (0.92)	70.6
My son/daughter enjoyed the activity.	3.52 (1.24)	*52.2*	3.76 (1.15)	64.7
Enjoyment-Perceived	3.75 (82.0)		3.84 (0.87)	

(continue..)

Table 4. (..continue).

Teacher report	Total (n=3) M(SD)	% 4-5
I am satisfied to have taken part in the training project.	4.67 (0.58)	100
I would recommend this training to other teachers	4.00 (0.00)	100
I would do this course again if possible	3.33 (0.58)	33.3
I have noticed improvements in the students' behavior	3.67 (0.58)	66.7
Satisfaction	3.92 (0.14)	
*It was difficult to find 30 min. per week to do the training session.	4.33 (1.15)	66.7
I was able to find time to do the additional activities.	4.00 (0.00)	100
The manual is easy to understand for the teacher	5.00 (0.00)	100
Feasibility	4.44 (0.38)	
Students were lazy and/or not very interested	4.00 (0.00)	100
Students enjoyed doing the activities.	4.33 (0.58)	100
*The activities were difficult for the students	4.00 (1.73)	66.7
Enjoyment-Perceived	4.11 (0.38)	

Note: * item reversed before analysis. A score of 5 indicates a positive opinion for all the items.

Qualitative evaluation of the program

In addition to these results, other aspects were investigated by means of questionnaires. Children reported to appreciate the videogame and its characters, specifically a positive evaluation for Ello (100%, both in the total and in the partial sample) and Big Ello (89.3% and 90.5% for the two samples, respectively) was reported. The most liked activities of the program were the city exploration and the integrative activities/metacognitive discussions in the class. Thus, the activities provided in the treasure rooms, which are those targeting EF, were less appreciated.

Parents were asked to give information about the frequency of the home sessions and about technical issues. In this case, we considered the total sample and also parents of children who did few sessions could mention difficulties to be considered. Of the 23 parents who completed the questionnaires, 19 (82.6%) reported that they were unable to perform 3 sessions per week. The main reasons were forgetfulness (30.43%) and/or impossibility to find three different moments during the week for the home sessions (56.52%). Most parents also highlighted that these difficulties were also related to the specific historical moment, during which the training was carried out, as they didn't want their children to add time using PC in a period in which children received lessons remotely via PC. A positive aspect is that only 2 parents reported that it was the child who did not want to do the sessions (8.7%). Ten of the 23 (43%) parents who completed the questionnaire reported problems with access. This was due to technical issues that emerged during the training, with the videogame that sometimes shutdown. Every time that a parent signaled the problems, it was solved in a couple of hours at most. In addition, other problems with the videogame were reported, such as slowdowns, blockages, and inaccuracy in recognizing the child's response (that is, the child clicks on an item and the system did not register it). When we asked them to tell us what they would like to change in the program, the most selected options were the usage time (39%), followed by sounds (30%) and graphics (30%). Finally, some parents suggested to add a reward system as points or feedback during the game, as this part was not yet implemented when we conducted the study.

Regarding the teachers, as the school sessions were managed by the remotely connected experimenter, no questions were asked about the technical issues related to the app. However, we asked them to tell us what they would have changed in the program. All the teachers indicated to add levels and games in the treasure rooms. In addition, two of them reported to modify the usage time for the home sessions. In contrast, no one reported difficulties in integrating sessions and integrative activities into the school curriculum.

Finally, we held a final meeting with parents and teachers to collect their impressions. Despite the technical issues and the difficulties encountered, both parents and teachers reported positive impressions. In particular, both reported that, thanks to the program, the children began to talk about executive functions with their classmates and to identify the tasks and the moments in which they were helpful, with positive effects on their self-regulation abilities.

Discussion

The first aim of the present study was to assess the feasibility of the new intervention model "Elli's World". In fact, this aspect is extremely important when designing a training program. If training is effective, but not usable, its impact will be reduced. Consequently, feasibility is the first aspect to be investigated when designing a new training program. In our case, investigating feasibility was particularly important given the complexity of the model, which includes both school and home sessions. This is one of the most innovative aspects of our model. Differently from pre-existing school-based curricula programs (i.e., Tools of the Mind), that involve only teachers and children and include only school activities, the "Elli's World" was designed to promote also parents' involvement and reduce teachers' workload. However, if on the one hand, it lightens the workload for teachers, on the other, it also requires a certain involvement by the parents. First, it was important to understand the degree of support that children needed in carrying out the home sessions and therefore the degree of commitment of parents. In this regard, parents reported that children were able to carry out the sessions in autonomy without the support of the adult as the instructions contained in the game and the difficulty of the videogame was adequate for the age of the children. Second, we wanted to verify the feasibility of the required frequency of the sessions. In this regard, parents highlighted a certain difficulty in carrying out the three weekly sessions, as demonstrated by the 9 children who played less than half of the sessions. However, this difficulty seems to be related not to a scarce engagement of the children, but to the lack of time or forgetfulness of the parents. Other aspects investigated, such as problems with the videogame and difficulties in using it, did not emerge significantly and technical issues were due to the use of a beta version of it.

It should be noted that even if home sessions have the advantage of ensuring an adequate frequency of the training, the need for a PC can be a problem for some families, especially in the case of disadvantaged socio-economic contexts. In our sample, only two children could not play the home sessions for this reason, and overall, the technical problems related to the use of the PC were few and mainly related to the use of a beta version of the video game. Moreover, the “Elli’s World” has been thought to be as flexible as possible. In the case of disadvantaged contexts, various adaptations can be made. For example, if the school has a computer classroom, home sessions can be provided during school hours. If also this is not an option, “Elli’s World” includes a variety of integrative tasks, games and metacognitive activities and, both for typically developing children and children with special needs. That is, it is designed to promote improvements even in the absence of home sessions.

Globally, parents reported to be satisfied with participation in the study. In fact, also considering the total sample, including those who had few sessions and were less satisfied, percentage of satisfied parents was 69.5, which increases to 76 for the partial sample. Results regarding teachers are limited given that only three teachers were involved in the study. In addition, given that it was a pilot study, we decided to support the teachers and not to leave them the management of the school sessions, which were conducted by the researcher. For this reason, the teacher-report questionnaire focused on the general satisfaction for the “Elli’s World”, perceived enjoyment of the students, and feasibility in terms of ease in implementing the school sessions and integrative activities in the school curriculum and user friendliness of the manual. Globally, teachers reported satisfaction, indicating a good feasibility of the training in the school setting.

Another important aspect to investigate was children’s enjoyment. In fact, even though parents’ and teachers’ perceived feasibility is important, the degree of enjoyment of children is crucial in terms of the efficacy of the training, as well. Children are the main target of the program and only if the training is pleasant and motivating there will be sufficient adherence to it and therefore effectiveness. Observing the results of the self-report questionnaire, almost all the items were rated positively by more than 50% of the sample, showing that the children had fun doing the training and would recommend it to other friends. In addition, the children reported that they were engaged in the training and perceived an improvement after training. The fact that despite the general appreciation, the children reported that they do not want to do it again, as well as the teachers, is not entirely unexpected. This result could be due to the fact that the videogame activities are repeated several times, until the child reaches a given accuracy. Repetition, which may be useful to train a cognitive skill, negatively affect enjoinment and motivation. This is also in line with the higher appreciation of integrative activities at schools, since these change every time. Finally, the perceptions of children, parents and teachers that the tasks were adequate in terms of difficulty, suggest that the adaptivity system of the program worked well and the challenge-skill balance was appropriate. The relevance of these principles has been highlighted before (Diamond & Ling, 2016; Maertens et al., 2016; Sweetser & Wyeth, 2005).

Taken together the results of the feasibility study suggest that the "Elli’s world" is feasible both at home and at school. In addition, also the preliminary data regarding efficacy are encouraging, indicating that the training was effective in improving WM. These results are in line with previous studies showing that is more likely to have an effect on WM than on inhibition (Blakey, & Carroll, 2015; Johnstone et al., 2012; Rueda et al., 2012; Thorell et al., 2009; Traverso et al., 2019). To summarize, the “Elli’s world”, thanks to the combination of school activities, home training, metacognitive reflection and integrative activities, proved to be a feasible intervention for children, parents and teachers. The preliminary data on efficacy are positive, as well.

Limitations and future directions

Some limitations must be considered. First, as a pilot study, the sample size is small and further investigations are needed to support and extend these results. The sample size did not allow us to carry out separate analyses on the group of children who completed a few sessions. In the future, the effectiveness of the training should be investigated when sessions are not carried out at home. Presumably the effect would be lower but understanding which is the individual contribution of each component of the model would be certainly useful in order to make it suitable for different contexts. Second, feasibility in the school session had to be further investigated, as in our study teachers did not conduct the sessions. Finally, our study did not include a measure of interference control, which was one of the components trained. Future efficacy studies should include this measure in order to better understand the training effects on both inhibition subcomponents. Finally, some considerations emerged from the qualitative feedback received from children, parents and teachers. Parents reported that the videogame lacked a system of rewards and feedback at the end of each session and level. This had not yet been implemented when the study was carried out but it will be implemented in the final version of the app, as also the literature confirms that, in digital game-based learning, feedback and rewards are crucial for motivation (Jamshidifarsani et al., 2019; Ke & Abras, 2013; Ronimus et al., 2014; 2019). In addition, they reported a lack of information on the intervention model and the home sessions, resulting in reduced awareness of the training goals and reduced ability in supporting their children. Given this consideration, training videos will be provided in the future to parents, as those already planned for teachers.

In conclusion, even if further improvements are possible, the integration of metacognitive reflection at school, game-based home sessions and integrative activities to be implemented in the school curricula, can be a feasibility and effective training model of EF. The home-sessions, thanks to instructions and adaptivity of the levels don’t need external help but can be performed independently in children’s home environment. In addition, the story frame makes it more enjoyable for children, increasing motivation and adherence, and school sessions centered on metacognitive reflection support training efficacy (Hirsh-Pasek et al., 2015). Finally, the addition of supplementary activities increases the probability of obtaining an effect of training and a generalization to tasks that are not trained, as it leads children to raise their EF through different materials and in various situations (Diamond & Ling, 2020).

6. GENERAL DISCUSSION AND CONCLUSION

In recent years, several types of training aimed at enhancing EF have been proposed both for clinical populations and for typical developing children (Diamond & Lee, 2011; Otero et al., 2014; see Jacob & Parkinson, 2015 and Diamond & Ling 2020 for a review). Although there are still several open questions regarding the efficacy and the generalizability of EF training (Melby-Lervåg & Hulme, 2013; Morrison & Chein, 2011; Shipstead et al., 2012), they still represent an opportunity for children at risk for specific disorders and for clinical populations. EF deficits can be considered among the core deficits underlying the symptoms of attention deficit hyperactivity disorder (Barkley et al., 1992; Shallice et al., 2002; Sonuga-Barke et al., 2002). In addition, EF disfunctions co-occur with the more specific deficit of a variety of disorders, such as Specific Learning Disorders (Peng & Fuchs, 2016; Toffalini et al., 2017; Gathercole et al., 2006), Intellectual Disability (Didanielsson et al., 2010; Fontana et al., 2021), Autistic Spectrum Disorder (Demetriou et al., 2018; Geurts et al., 2014) and Speech Disorders (Marini et al., 2020; Pauls & Archibald, 2016). Within this line of research, one area relatively unexplored is that of acquired brain injuries, and stroke in particular. Existing literature highlight the vulnerability of EF following brain lesions and in recent years the importance of including cognitive empowerment in rehabilitation programs is being recognized.

Given these premises, the present work aims to deepen both lines of research. On the one hand, it sought to deepen the relationship between FE and learning achievement, on the other hand, the functioning of FE as a result of stroke. For both areas, the aim was then to identify new improvement and intervention strategies.

Regarding executive functioning after stroke in children (see chapter 2 of the present work), the systematic review of the existing literature highlighted the vulnerability of EF. Results show that as a group, children with stroke have worse performance in EF tasks than typically developing children, that in turn are associated with behavioral difficulties in everyday life. Despite this, further investigations are needed to better understand the selective impact of stroke on the different EF domains and the role of different possible predictors such as age at stroke onset, time since stroke and lesion characteristics. In fact, results are contrasting, and it is not yet possible to draw conclusions. To contribute to deepen this relatively new and understudied topic, a study was conducted involving 30 children with a history of a stroke aged 7-12 at the time of assessment, without severe cognitive dysfunction and intelligence in the normal range. Results show that, despite the sample includes only children without severe neurological and cognitive disfunctions, almost 30% of children had a moderate or severe EF dysfunction, falling in the lower end of the average range or below. In addition, EF impairment was associated with higher symptoms of inattention and hyperactivity and more behavioural and social problems. This result is in line with previous literature and confirms that EF is particularly vulnerable to stroke and could be compromised also when cognitive and neurological functioning seems to be preserved. In addition, results show that more than 60% of the children did not show any significant EF impairment, suggesting that there is heterogeneity in EF abilities within this population of children. Given the small sample size, the conclusions regarding the potential predictors of stroke outcomes are limited. However, results appear to indicate that the major factor is the extent of the injury. This is not surprising, as EF relates to multiple brain areas and numerous structures of the central nervous system, both cortical and subcortical (Alvarez et al., 2006). Thus, a diffuse lesion led to higher impairment due to a greater network impairment. In addition, results show an association between EF impairment and language abilities. Even if this relationship has not been investigated in deep in children with stroke, these results are in line with studies involving typically developing children, in which early language skills were found to have both direct and indirect effects on children's later executive functions (Kuhn et al., 2014). Taken together, these results have several clinical implications. First, the results highlighted the importance of the cognitive evaluation of children with stroke outcomes, even when the general functioning appears not to be severely compromised. In these cases, the most evident outcome often appears to be the motor one, and consequently both assessment and rehabilitation focus on motor skills. It is clear however that it is important to consider cognitive outcomes, as well. In addition, results highlight the need to identify effective intervention strategies for these children and their families. The possibility to improve EF is well established in different clinical populations (e.g., Diamond & Lee., 2011), but not in that of children with stroke. In this vein, we conducted a pilot study to verify the feasibility of MemoRAN, a home-based training to improve EF. Results show elevated compliance and adherence to the training, indicating that both children and parents are able to carry out it in an adequate way. Despite low motivation reported from few children, and the impossibility of drawing conclusions of efficacy given the small sample size, results are globally encouraging and support the usefulness of technology for rehabilitation. Tele-rehabilitation offers important opportunities to support rehabilitation practices, as it increases the accessibility and the cost-effectiveness of services. In addition, in the case of chronic conditions such as stroke, which require frequent follow-ups to monitor recovery, telerehabilitation has a positive impact on the quality of life of the child and his/her family, reducing the time spent in a hospital or clinical service and allowing to carry out the rehabilitation at home (Edirippulige et al., 2016).

Regarding EF in typically developing children, a recent study, conducted by Gunzenhauser & Nückles (2021) suggests that executive functions can facilitate academic performance via two specific pathways, namely learning-related cognitions and learning-related behaviors. The first pathway refers to the direct implication of EF cognitive processes in math or literacy tasks. The second refers to the fact that EF supports favorable classroom behavior in young children, such as paying attention in class, following classroom rules, and completing homework (McClelland & Cameron, 2012). Thus, EF impact academic performance both directly and indirectly. However, while a great deal of research has been done on the direct role that EF have in the different school domains, little is known about its indirect role (i.e. Nesbitt et al., 2015). The first aim was to provide new knowledge about this issue. Results of our study confirm this association and the mediational role of LRBs on the link between EF and school achievement. In addition, results highlight some significant differences regarding EF and the school domain considered. Considering working memory, both direct and indirect effects are crucial in explaining school outcomes. In contrast, the association between inhibition and school achievement appears to be fully mediated by LRBs. Further investigations are needed to understand how this relationship changes during development, when learning-related behaviors have been automatized and the direct impact of EF on achievement is likely to become more significant. Given the role that EFs have in both school achievement and adjustment, the second aim was to develop a new model of intervention for EF able to increase both learning achievement and LRBs. While there is evidence that executive functions can be improved by training (Karbach & Kray, 2016) less evidence is available regarding far transfer effects (Pandey et al., 2018; Smithers et al., 2018; Smid et al., 2020), that is improvements in untrained executive function components, general cognitive abilities, or domain-specific academic achievement (e.g., in mathematics or literacy). To overcome these limitations, we develop a new model of intervention that incorporates all the most recent indications regarding cognitive training in general and for FE in particular. It includes characteristics of both school-based training, in order to maximize its ability to reach as many children as possible, and game-based and computer-based training in order to maximize the intensity of intervention, which takes place not only at school but continues at home throughout the week. It also includes school sessions designed to support metacognitive reflection about the functioning of EF in its different components to help children understand in which task EFs are needed and why. Finally, it includes a variety of integrative activities that allow the children to practice their EF in various contexts and situations. In addition, integrative activities allow teachers to train their abilities in conducting a cognitive task analysis to focus on the demands on students' executive functions when planning instructions and tasks (e.g., whether a task requires manipulating information in working memory, whether a task switching is required, or whether suppression of interfering stimuli is needed). Recently, Gunzenhauser & Nückles (2021) provided some guidelines to facilitate far transfer effects of EF training. Those guidelines confirm our idea that a new efficient training model was needed that included multiple characteristics taken from different existing training approaches. First, they claimed that EF training is more useful when the learner cannot yet rely on acquired and automatized strategies that reduce the demands for executive functions. As students proceed through school grades, and once students have accumulated large deficits about a specific school subject, it seems less likely that they might be able to close these gaps solely by improving executive functions (Duncan et al., 2007; Ahmed et al., 2019). Second, they highlight the importance to make clear to the learners which specific executive function may support the performance in more complex learning-related behavior or cognitive tasks that the training aims to improve. The training could then focus on these executive function components. Third, EF needs to be practiced within authentic contexts, that is, within those situations where the skills need to be applied. Fourth, it is important to train teachers in order to embed the scaffolding of executive functions in the instructional context and support training effects after the conclusion of the intervention. As can be seen, all these recommendations were followed in developing and implementing the new intervention model. Our results confirm the effectiveness of the "Elli's World" training model, as it results feasible for children, parents and teachers. The preliminary results about near-transfer effect are promising, as the efficacy of the training was found with respect to WM. Further investigations are needed as we used a pilot version of the videogame, which did not include the feedback and reward system, nor the cognitive flexibility section. In addition, the metacognitive sessions were conducted by the researcher. Finally, only a small amount of training was given to the teachers and not all the additional activities were already present. A new study, including a larger sample, is going to start. We hypothesize that with all the features of the model implemented, there will be higher effectiveness.

Some limitations have to be considered regarding the studies presented. First, the sample size is limited in all four studies. Considering the studies regarding childhood stroke, it is mainly due to the low prevalence of this medical condition. In addition, the sample size of all the studies has been affected by the pandemic situation, which has inevitably made it difficult for researchers to access both hospitals and schools. Second, given the multicomponential nature of EF, evaluations are complex. In all the studies, different measures for each EF component were used, to investigate the specific functioning of each of them. However, in none of the studies measures of interference-control were used. Finally, while our studies on EF after childhood stroke included children aged 7-12, covering a relatively large age range, the studies on typically developing children focused on first and second graders. We chose this age group to focus on the transition period between kindergarten and primary school, a period in which the child has not yet automatized neither learning, nor behavioural adjustment strategies. Furthermore, as far as training is concerned, we chose to focus on early intervention. However, it will be important to examine with future studies the relationship between EF, LRBs and learning changes in different samples of various ages, and how effective the intervention model can be in older children and in children with special needs.

Some general conclusions about EF evaluation and intervention can be drawn based on the results of the present studies. EF are typically considered and evaluated in those children who present primary EF disfunctions such as ADHD. Despite the growing interest on EF and the growing evidence of its impact on children development, it is relatively less considered in clinical conditions that affect cognitive functioning and brain development in general. In addition, evidence about the importance of improving EF early in the school years in order to support the transition to higher grades and prevent difficulties have not yet led to the dissemination of teaching modalities that support the development of these skills. However, the results show that low EF functioning can be present event when other cognitive or neurological disfunction are not present, and that individual differences in EF are associated to school adjustment abilities. Thus, results highlight the importance of taking EFs into account to prevent behavioral and emotional difficulties. EF evaluation would be helpful also in the school setting in order to provide useful indications to teachers and allow them to support not only those children with more severe difficulties, for which also clinicians provide suggestions to teachers, but also those who present minor difficulties, that teachers often don't know how to support.

Regrading the feasibility of computer-based training programs delivered at home, some differences emerge depending on the context. In particular, while adherence was extremely high for the clinical population, 30% of the typical children did not complete the home sessions required by the training program. This result has an important relevance also considering that the clinical sample was required to carry out 5 sessions per week, while the “Elli’s World” required only 3 sessions. Certainly, families of children with a disorder are more aware of the importance of supporting the child's cognitive development. Conversely, when a training program is proposed to children as a supportive and preventive measure, a greater effort must be made to involve parents and make them aware of the importance of adherence.

In conclusion, taken together, the results indicate that evaluation, intervention and promotion of EF should become routine both in school and in clinical practice.

References

Abgottspon, S., Steiner, L., Slavova, N., Steinlin, M., Grunt, S., & Everts, R. (2021). Relationship between motor abilities and executive functions in patients after pediatric stroke. Applied neuropsychology. Child, 1–11. Advance online publication. https://doi.org/10.1080/21622965.2021.1919111

Ahmed, S. F., Tang, S., Waters, N. E., & Davis-Kean, P. (2019). Executive function and academic achievement: Longitudinal relations from early childhood to adolescence. *Journal of Educational Psychology*, *111*(3), 446–458. https://doi.org/10.1037/edu0000296

Allan, N. P., Hume, L. E., Allan, D. M., Farrington, A. L., & Lonigan, C. J. (2014). Relations between inhibitory control and the development of academic skills in preschool and kindergarten: a meta-analysis. *Developmental psychology*, *50*(10), 2368–2379. https://doi.org/10.1037/a0037493

*Allman, C., & Scott, R. B. (2013). Neuropsychological sequelae following pediatric stroke: A nonlinear model of age at lesion effects. *Child Neuropsychology*, *19*(1), 97-107. https://doi.org/10.1080/09297049.2011.639756

Alloway, T. P., Doherty-Sneddon, G., & Forbes, L. (2012). Teachers' perceptions of classroom behaviour and working memory. *Educational Research and Reviews*, *7*(6), 138-142. DOI: 10.5897/ERR10.223

Alloway, T. P., Gathercole, S. E., Adams, A. M., Willis, C., Eaglen, R., & Lamont, E. (2005). Working memory and phonological awareness as predictors of progress towards early learning goals at school entry. *British Journal of Developmental Psychology*, *23*(3), 417-426. https://doi.org/10.1348/026151005X26804

Alloway, T. P., Gathercole, S. E., Kirkwood, H., & Elliott, J. (2009). The cognitive and behavioral characteristics of children with low working memory. *Child Development*, *80*(2), 606–621. https://doi.org/10.1111/j.1467-8624.2009.01282.x

Alloway, T.P., & Alloway, R.G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology 106*, 20–29. http://dx.doi.org/10.1016/j.jecp.2009.11.003

Alvarez, J. A., & Emory, E. (2006). Executive function and the frontal lobes: a meta-analytic review. *Neuropsychology Review*, *16*(1), 17–42. https://doi.org/10.1007/s11065-006-9002-x

*Araujo, G. C., Antonini, T. N., Anderson, V., Vannatta, K. A., Salley, C. G., Bigler, E. D., … Owen Yeates, K. (2017). Profiles of Executive Function Across Children with Distinct Brain Disorders: Traumatic Brain Injury, Stroke, and Brain Tumor. *Journal of the International Neuropsychological Society*, *23*(7), 529–538. https://doi.org/10.1017/S1355617717000364

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child neuropsychology*, *8*(2), 71-82. https://doi.org/10.1076/chin.8.2.71.8724

Anderson, S. W., Damasio, H., Jones, R. D., & Tranel, D. (1991). Wisconsin Card Sorting Test performance as a measure of frontal lobe damage. *Journal of clinical and experimental neuropsychology*, *13*(6), 909-922. https://doi.org/10.1080/01688639108405107

Anderson, V. A., Anderson, P., Northam, E., Jacobs, R., & Mikiewicz, O. (2002). Relationships between cognitive and behavioral measures of executive function in children with brain disease. Child neuropsychology, 8(4), 231-240. https://doi.org/10.1076/chin.8.4.231.13509

Andersson, U., & Lyxell, B. (2007). Working memory deficit in children with mathematical difficulties: A general or specific deficit?. *Journal of experimental child psychology*, *96*(3), 197-228. https://doi.org/10.1016/j.jecp.2006.10.001

Anthony, C. J., & Ogg, J. (2020). Executive function, learning-related behaviors, and science growth from kindergarten to fourth grade. *Journal of Educational Psychology*, *112*(8), 1563. DOI:10.1037/edu0000447

Anthony, C. J., DiPerna, J. C., & Amato, P. R. (2014). Divorce, approaches to learning, and children's academic achievement: A longitudinal analysis of mediated and moderated effects. *Journal of school psychology*, *52*(3), 249-261. https://doi.org/10.1016/j.jsp.2014.03.003

Au, J., Buschkuehl, M., Duncan, G. J., & Jaeggi, S. M. (2016). There is no convincing evidence that working memory training is NOT effective: A reply to Melby-Lervåg and Hulme (2015). *Psychonomic Bulletin & Review*, *23*(1), 331– 337. https://doi.org/10.3758/s13423-015-0967-4

Baddeley A.D. (1996). Exploring the central executive. *Quarterly Journal of Experimental Psychology, 49A*, 5-28. https://doi.org/10.1080/713755608

Badgaiyan, R. D. (2000). Executive control, willed actions, and nonconscious processing. *Human brain mapping*, *9*(1), 38-41. https://doi.org/10.1002/(sici)1097-0193(2000)9:1<38::aid-hbm4>3.0.co;2-t

Bailey, C. E. (2007). Cognitive accuracy and intelligent executive function in the brain and in business. *Annals of the New York Academy of Sciences*, *1118*(1), 122-141. https://doi.org/10.1196/annals.1412.011

Ball, K., Berch, D. B., Helmers, K. F., Jobe, J. B., Leveck, M. D., Marsiske, M., ... & ACTIVE Study Group. (2002). Effects of cognitive training interventions with older adults: a randomized controlled trial. *Jama*, *288*(18), 2271-2281. https://doi.org/10.1001/jama.288.18.2271

Ballantyne, A. O., Spilkin, A. M., Hesselink, J., & Trauner, D. A. (2008). Plasticity in the developing brain: intellectual, language and academic functions in children with ischaemic perinatal stroke. *Brain*, *131*(11), 2975-2985. https://doi.org/10.1093/brain/awn176

Barkley, R. A., Guevremont, D. C., Anastopoulos, A. D., & Fletcher, K. E. (1992). A comparison of three family therapy programs for treating family conflicts in adolescents with attention-deficit hyperactivity disorder. *Journal of Consulting and Clinical Psychology*, *60*(3), 450–462. https://doi.org/10.1037/0022-006X.60.3.450

Beauchaine, T. P., & Cicchetti, D. (2019). Emotion dysregulation and emerging psychopathology: A transdiagnostic, transdisciplinary perspective. *Development and psychopathology*, *31*(3), 799-804. https://doi.org/10.1017/S0954579419000671

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition*, *50*(1-3), 7-15. https://doi.org/10.1016/0010-0277(94)90018-3

Bechara, A., Damasio, H., Tranel, D., & Anderson, S. W. (1998). Dissociation of working memory from decision making within the human prefrontal cortex. *Journal of neuroscience*, *18*(1), 428-437. https://doi.org/10.1523/JNEUROSCI.18-01-00428.1998

Belacchi, C., Carretti, B., & Cornoldi, C. (2010). The role of working memory and updating in Coloured Raven Matrices performance in typically developing children. *European Journal of Cognitive Psychology*, *22*(7), 1010-1020. https://doi.org/10.1080/09541440903184617

Bellocchi, S., Bonifacci, P., Lami, L., Manfredini, M. (2014). Le prime prove collettive di individuazione precoce delle difficoltà di lettura e scrittura per le classi I e II primaria. Giunti Edu.

Benedek, M., Jauk, E., Sommer, M., Arendasy, M., & Neubauer, A. C. (2014). Intelligence, creativity, and cognitive control: The common and differential involvement of executive functions in intelligence and creativity. Intelligence, 46, 73 83. https://doi.org./10.1016/j.intell.2014.05.007

Ben-Soussan, T. D., Berkovich-Ohana, A., Piervincenzi, C., Glicksohn, J., & Carducci, F. (2015). Embodied cognitive flexibility and neuroplasticity following Quadrato Motor Training. *Frontiers in psychology*, *6*, 1021. https://doi.org/10.3389/fpsyg.2015.01021

Best, J. R., Miller, P. H., & Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. *Learning and individual differences*, *21*(4), 327-336. https://doi.org/10.1016/j.lindif.2011.01.007

Bierman, K. L., Domitrovich, C. E., Nix, R. L., Gest, S. D., Welsh, J. A., Greenberg, M. T., Blair, C., Nelson, K. E., & Gill, S. (2008). Promoting Academic and Social-Emotional School Readiness: The Head Start REDI Program. *Child Development*, *79*(6), 1802–1817. https://doi.org/10.1111/j.1467-8624.2008.01227.x

Bigorra, A., Garolera, M., Guijarro, S., & Hervás, A. (2015). Long-term far- transfer effects of working memory training in children with ADHD: A randomized controlled trial. *European Child & Adolescent Psychiatry*, *25*, 853– 867. https://doi.org/10.1007/s00787-015-0804-3

Birch, S. H., & Ladd, G. W. (1996). Interpersonal relationships in the school environment and children's early school adjustment: The role of teachers and peers. *Social motivation: Understanding children's school adjustment*, *15*, 199-225.

Birch, S. H., & Ladd, G. W. (1998). Children's interpersonal behaviors and the teacher-child relationship. *Developmental psychology*, *34*(5), 934–946. https://doi.org/10.1037//0012-1649.34.5.934

Bisiacchi, P. S., Cendron, M., Gugliotta, M., Tressoldi, P. E., & Vio, C. (2005). BVN 5-11: batteria di valutazione neuropsicologica per l'età evolutiva. Trento: Centro studi Erickson.

Blair, C. (2002). School readiness: Integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *American psychologist*, *57*(2), 111-127. https://doi.org/10.1037//0003-066x.57.2.111

Blair, C., & Raver, C. (2014). Closing the achievement gap through modification of neurocognitive and neuroendocrine function: Results from a cluster randomized controlled trial of an innovative approach to the education of children in kindergarten. *PLoS One, 9*(11), e112393. https://doi.org/10.1371/journal.pone.0112393

Blair, C., & Raver, C.C. (2015). School Readiness and Self-Regulation: A Developmental Psychobiological Approach. *Annual Review of Psychology*, *66*: 711-731. https://doi.org/10.1146/annurev-psych-010814-015221

Blair, C., & Razza, R.P. (2007). Relating effortful control, executive function, and false-belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78*, 647–663. http://dx.doi.org/10.1111/j.1467-8624.2007.01019.x.

Blakey, E., & Carroll, D. J. (2015). A short executive function training program improves preschoolers' working memory. *Frontiers in psychology*, *6*, 1827. https://doi.org/10.3389/fpsyg.2015.01827

Borella, E., Carretti, B., Pelgrina, S. (2010). The specific role of inhibition in reading comprehension in good and poor comprehenders. *Journal of Learning Disabilities*, *43*,541–552, http://dx.doi.org/10.1177/0022219410371676.

*Bosenbark, D. D., Krivitzky, L., Ichord, R., Jastrzab, L., & Billinghurst, L. (2018). Attention and executive functioning profiles in children following perinatal arterial ischemic stroke. *Child Neuropsychology* : A Journal on Normal and Abnormal Development in Childhood and Adolescence, 24(1), 106–123. https://doi.org/10.1080/09297049.2016.1225708

Bosenbark, D. D., Krivitzky, L., Ichord, R., Vossough, A., Bhatia, A., Jastrzab, L. E., & Billinghurst, L. (2017). Clinical predictors of attention and executive functioning outcomes in children after perinatal arterial ischemic stroke. *Pediatric neurology*, *69*, 79-86. https://doi.org/10.1016/j.pediatrneurol.2017.01.014

Brock, L. L., Rimm-Kaufman, S. E., Nathanson, L., & Grimm, K. J. (2009). The contributions of 'hot' and 'cool' executive function to children's academic achievement, learning-related behaviors, and engagement in kindergarten. *Early Childhood Research Quarterly, 24*(3), 337–349. https://doi.org/10.1016/j.ecresq.2009.06.001

Bryce, D., Whitebread, D., & Szucs, D. (2015). The relationships among executive functions, } metacognitive skills and educational achievement in 5 and 7-year-old children. Metacognition and Learning, 10, 181–198. https://doi.org/10.1007/s11409-014-9120-4

Brydges, C. R., Anderson, M., Reid, C. L., & Fox, A. M. (2013). Maturation of cognitive control: delineating response inhibition and interference suppression. *PloS one*, *8*(7), e69826. https://doi.org/10.1371/journal.pone.0069826

Brydges, C. R., Reid, C. L., Fox, A. M., & Anderson, M. (2012). A unitary executive function predicts intelligence in children. *Intelligence*, *40*(5), 458-469. https://doi.org/10.1016/j.intell.2012.05.006

Bulder, M. M. M., Hellmann, P. M., Van Nieuwenhuizen, O., Kappelle, L. J., Klijn, C. J. M., & Braun, K. P. J. (2011). Measuring outcome after arterial ischemic stroke in childhood with two different instruments. Cerebrovascular Diseases, 32(5), 463-470. https://doi.org/10.1159/000332087

Bull, R., & Lee, K. (2014.) Executive Functioning and Mathematics Achievement. *Child Development Perspectives*, *8*(1): 36-41. https://doi.org/10.1111/cdep.12059

Burgess, P. W. (1997). Theory and methodology in executive function research. In P. Rabbit (Ed.), Methodology of frontal and executive function. Psychology Press; Hove, UK: 1997. pp. 81–116.

Burke, L. A., & Hutchins, H. M. (2007). Training transfer: An integrative literature review. *Human Resource Development Review*, *6*(3), 263–296. https://doi.org/10.1177/1534484307303035

Carlson, S. M., Moses, L. J., & Hix, H. R. (1998). The role of inhibitory processes in young children's difficulties with deception and false belief. *Child Development*, *69*(3), 672–691.

Carretti, B., Borella, E., Cornoldi, C., & De Beni, R. (2009). Role of working memory in explaining the performance of individuals with specific reading comprehension difficulties: A meta-analysis. *Learning and individual differences*, *19*(2), 246-251. https://doi.org/10.1016/j.lindif.2008.10.002

Carretti, B., Borella, E., Zavagnin, M., & Beni, R. (2013). Gains in language comprehension relating to working memory training in healthy older adults. *International Journal of Geriatric Psychiatry*, *28*(5), 539–546. https://doi.org/10.1002/gps.3859

Carter, A. R., Astafiev, S. V., Lang, C. E., Connor, L. T., Rengachary, J., Strube, M. J., Pope, D. L., Shulman, G. L., & Corbetta, M. (2010). Resting interhemispheric functional magnetic resonance imaging connectivity predicts performance after stroke. *Annals of neurology*, *67*(3), 365–375. https://doi.org/10.1002/ana.21905

Castellanos, F. X., Sonuga-Barke, E. J., Milham, M. P., & Tannock, R. (2006). Characterizing cognition in ADHD: beyond executive dysfunction. *Trends in cognitive sciences*, *10*(3), 117-123. https://doi.org/10.1016/j.tics.2006.01.011

Catroppa, C., Soo, C., Crowe, L., Woods, D., & Anderson, V. (2012). Evidence-based approaches to the management of cognitive and behavioral impairments following pediatric brain injury. *Future Neurology*, *7*(6), 719-731. https://doi.org/10.2217/fnl.12.64

Caviola, S., Mammarella, I. C., Cornoldi, C., & Lucangeli, D. (2012). The involvement of working memory in children's exact and approximate mental addition. *Journal of experimental child psychology*, *112*(2), 141-160. https://doi.org/10.1016/j.jecp.2012.02.005

Champigny, C. M., Deotto, A., Westmacott, R., Dlamini, N., & Desrocher, M. (2020). Academic outcome in pediatric ischemic stroke. *Child Neuropsychology*, 1-17. https://doi.org/10.1080/09297049.2020.1712346

Chan, R. C., Shum, D., Toulopoulou, T., & Chen, E. Y. (2008). Assessment of executive functions: Review of instruments and identification of critical issues. *Archives of clinical neuropsychology*, *23*(2), 201-216. https://doi.org/10.1016/j.acn.2007.08.010

Collins, A., & Koechlin, E. (2012). Reasoning, learning, and creativity: frontal lobe function and human decision-making. *PLoS biology*, *10*(3), e1001293. https://doi.org/10.1371/journal.pbio.1001293

Conklin, H. M., Salorio, C. F., & Slomine, B. S. (2008). Working memory performance following paediatric traumatic brain injury. *Brain Injury, 22*(11), 847-857. https://doi.org/10.1080/02699050802403565

Cornoldi, C., Lucangeli, D., & Bellina, M. (2012). *AC-MT 6-11. Test di valutazione delle abilità di calcolo e soluzione dei problemi. Gruppo MT. Con CD-ROM*. Edizioni Erickson.

Cortés Pascual, A., Moyano Muñoz, N., & Quilez Robres, A. (2019). The relationship between executive functions and academic performance in primary education: Review and meta-analysis. *Frontiers in psychology*, *10*, 1582. https://doi.org/10.3389/fpsyg.2019.01582

Corti, C., Oldrati, V., Oprandi, M. C., Ferrari, E., Poggi, G., Borgatti, R., Urgesi, C., & Bardoni, A. (2019). Remote Technology-Based Training Programs for Children with Acquired Brain Injury: A Systematic Review and a Meta-Analytic Exploration. *Behavioural neurology*, *2019*, 1346987. https://doi.org/10.1155/2019/1346987

Corti, C., Poggi, G., Romaniello, R., Strazzer, S., Urgesi, C., Borgatti, R., & Bardoni, A. (2018). Feasibility of a home-based computerized cognitive training for pediatric patients with congenital or acquired brain damage: An explorative study. *PloS one*, *13*(6), e0199001. https://doi.org/10.1371/journal.pone.0199001

Cragg, L., Keeble, S., Richardson, S., Roome, H. E., & Gilmore, C. (2017). Direct and indirect influences of executive functions on mathematics achievement. *Cognition*, *162*, 12-26. https://doi.org/10.1016/j.cognition.2017.01.014

Damasio, A. R. (1994). Descartes' error: Emotion, rationality and the human brain. *New York: Putnam*, *352*.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of verbal learning and verbal behavior*, *19*(4), 450-466. https://doi.org/10.1016/S0022-5371(80)90312-6

Danielsson, H., Henry, L., Rönnberg, J., & Nilsson, L.-G. (2010). Executive functions in individuals with intellectual disability. *Research in Developmental Disabilities, 31*(6), 1299-1304. https://doi.org/10.1016/j.ridd.2010.07.012

Davidse, N. J., de Jong, M. T., Bus, A. G., Huijbregts, S. C. J., & Swaab, H. (2011). Cognitive and environmental predictors of early literacy skills. *Reading and Writing, 24*(4), 395–412. https://doi.org/10.1007/s11145-010-9233-3

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia, 44*(11), 2037–2078. https://doi.org/10.1016/j.neuropsychologia.2006.02.006

Delis, D., Kaplan, E., & Kramer, J. (2001). Delis-Kaplan executive function system (D-KEFS). *Canadian Journal of School Psychology*, *20*(1–2), 117–128. https://doi.org/10.1177/0829573506295469

Demetriou, E. A., Lampit, A., Quintana, D. S., Naismith, S. L., Song, Y., Pye, J. E., Hickie, I., & Guastella, A. J. (2018). Autism spectrum disorders: a meta-analysis of executive function. *Molecular psychiatry*, *23*(5), 1198–1204. https://doi.org/10.1038/mp.2017.75

Dempster, F. N. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review*, *12*(1), 45-75. https://doi.org/10.1016/0273-2297(92)90003-K

Desimoni, M., Pelaggi, D., Fanini S., Romano, L., Scalisi, T.G., *Dati normativi per la somministrazione delle prove PAC-SI a bambini di inizio scuola primaria*, 23 Novembre 2010

Di Lieto, M. C., Pecini, C., Castro, E., Inguaggiato, E., Cecchi, F., Dario, P., Cioni, G., & Sgandurra, G. (2020). Empowering Executive Functions in 5- and 6-Year-Old Typically Developing Children Through Educational Robotics: An RCT Study. *Frontiers in psychology*, *10*, 3084. https://doi.org/10.3389/fpsyg.2019.0308

Di Riso, D., Salcuni, S., Chessa, D., Raudino, A., Lis, A., & Altoè, G. (2010). The Strengths and Difficulties Questionnaire (SDQ). Early evidence of its reliability and validity in a community sample of Italian children. Personality and Individual Differences, 49(6), 570-575. https://doi.org/10.1016/j.paid.2010.05.005

Diamond, A. (2000). Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. *Child Development*, *71*(1), 44-56. https://doi.org/10.1111/1467-8624.00117

Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood: Cognitive functions, anatomy, and biochemistry. *Principles of frontal lobe function*, *466*, 503. DOI:10.1093/acprof:oso/9780195134971.003.0029

Diamond, A. (2012). Activities and programs that improve children's executive functions. *Current directions in psychological science*, *21*(5), 335-341. https://doi.org/10.1177/0963721412453722

Diamond, A. (2013). Executive functions. *Annual review of psychology*, *64*, 135-168. https://doi.org/10.1146/annurev-psych-113011-143750

Diamond, A. (2015). Effects of physical exercise on executive functions: going beyond simply moving to moving with thought. *Annals of sports medicine and research*, *2*(1), 1011.

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science*, *333*(6045), 959-964. https://doi.org/10.1126/science.1204529

Diamond, A., & Ling, D. S. (2020). Review of the evidence on, and fundamental questions about, efforts to improve executive functions, including working memory. https://doi.org/10.1093/oso/9780199974467.003.0008

DiPerna, J. C., Lei, P. W., & Reid, E. E. (2007). Kindergarten predictors of mathematical growth in the primary grades: An investigation using the Early Childhood Longitudinal Study--Kindergarten cohort. *Journal of Educational Psychology, 99*(2), 369-379. https://doi.org/10.1037/0022-0663.99.2.369

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., Pagani, L. S., Feinstein, L., Engel, M., Brooks-Gunn, J., Sexton, H., Duckworth, K., & Japel, C. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428–1446. https://doi.org/10.1037/0012

Duncan, J. (2013). The structure of cognition: attentional episodes in mind and brain. *Neuron*, *80*(1), 35-50. https://doi.org/10.1016/j.neuron.2013.09.015

Duncan, J., Johnson, R., Swales, M., & Freer, C. (1997). Frontal lobe deficits after head injury: Unity and diversity of function. *Cognitive Neuropsychology*, *14*, 713-741. https://doi.org/10.1080/026432997381420

Dweck, C. S., & Master, A. (2012). Self-theories motivate self-regulated learning. In Schunk, D. H., & Zimmerman, B. J. (Eds.). (2012). *Motivation and self-regulated learning: Theory, research, and applications*. Routledge.

Edirippulige, S., Reyno, J., Armfield, N. R., Bambling, M., Lloyd, O., & McNevin, E. (2016). Availability, spatial accessibility, utilisation and the role of telehealth for multi-disciplinary paediatric cerebral palsy services in Queensland. *Journal of Telemedicine and Telecare*, *22*(7), 391–396. https://doi.org/10.1177/1357633X15610720

Eslinger, P. J., Grattan, L. M., Damasio, H., & Damasio, A. R. (1992). Developmental consequences of childhood frontal lobe damage. *Archives of Neurology*, *49*(7), 764-769. https://doi.org/10.1001/archneur.1992.00530310112021

Eve, M., O'Keeffe, F., Jhuty, S., Ganesan, V., Brown, G., & Murphy, T. (2016). Computerized working-memory training for children following arterial ischemic stroke: a pilot study with long-term follow-up. *Applied Neuropsychology: Child*, *5*(4), 273-282. https://doi.org/10.1080/21622965.2015.1055563

Everts, R., Pavlovic, J., Kaufmann, F., Uhlenberg, B., Seidel, U., Nedeltchev, K., ... & Steinlin, M. (2008). Cognitive functioning, behavior, and quality of life after stroke in childhood. *Child Neuropsychology*, *14*(4), 323-338. https://doi.org/10.1080/09297040701792383

Felling, R. J., Rafay, M. F., Bernard, T. J., Carpenter, J. L., Dlamini N., Hassanein, S. M.A., Jordan, L. C., Noetzel, M. J., Rivkin, M. J., Shapiro, K. A., Slim, M., deVeber, G. (2020). Predicting Recovery and Outcome after Pediatric Stroke: Results from the International Pediatric Stroke Study. *Annuals of Neurology*, *87*(6),840-852. https://doi.org/10.1002/ana.25718

Ferriero, D. M., Fullerton, H. J., Bernard, T. J., Billinghurst, L., Daniels, S. R., DeBaun, M. R., ... & Meldau, J. (2019). Management of stroke in neonates and children: a scientific statement from the American Heart Association/American Stroke Association. *Stroke*, *50*(3), 51-96. https://doi.org/10.1161/STR.0000000000000183

Fontana, M., Usai, M. C., Toffalini, E., & Passolunghi, M. C. (2021). Meta-analysis on inhibition from childhood to young adulthood in people with Down syndrome. *Research in developmental disabilities*, *109*, 103838. https://doi.org/10.1016/j.ridd.2020.103838

Frye, D., Zelazo, P. D., & Palfai, T. (1995). Theory of mind and rule-based reasoning. *Cognitive development*, *10*(4), 483-527. https://doi.org/10.1016/0885-2014(95)90024-1

Fuchs, L. S., Compton, D. L., Fuchs, D., Paulsen, K., Bryant, J. D., & Hamlett, C. L. (2005). The Prevention, Identification, and Cognitive Determinants of Math Difficulty. *Journal of Educational Psychology*, *97*(3), 493–513. https://doi.org/10.1037/0022-0663.97.3.493

Fuchs, L. S., Fuchs, D., Hamlet, C. L., Powell, S. R., Capizzi, A. M., & Seethaler, P. M. (2006). The effects of computer-assisted instruction on number combination skill in at-risk first graders. *Journal of learning disabilities*, *39*(5), 467-475. https://doi.org/10.1177/00222194060390050701

Fuchs, L. S., Fuchs, D., Prentice, K., Burch, M., Hamlett, C. L., Owen, R., & Schroeter, K. (2003). Enhancing third-grade student'mathematical problem solving with self-regulated learning strategies. *Journal of educational psychology*, *95*(2), 306-3015. https://doi.org/10.1037/0022-0663.95.2.306

Fuchs, L.S., Fuchs, D., Compton, D.L., Powell, S.R., Seethaler, P.M., Capizzi, A.M., & Fletcher, J.M. (2006). The Cognitive Correlates of Third-Grade Skill in Arithmetic, Algorithmic Computation, and Arithmetic Word Problems. *Journal of Educational Psychology*, *98*(1), 29-43. https://doi.org/10.1037/0022-0663.98.1.29

Fuentes, A., Deotto, A., Desrocher, M., deVeber, G., & Westmacott, R. (2016). Determinants of cognitive outcomes of perinatal and childhood stroke: A review. *Child Neuropsychology*, *22*(1), 1-38. https://doi.org/10.1080/09297049.2014.969694

*Fuentes, A., Westmacott, R., Deotto, A., deVeber, G., & Desrocher, M. (2017). Working memory outcomes following unilateral arterial ischemic stroke in childhood. *Child Neuropsychology*, *23*(7), 803–821. https://doi.org/10.1080/09297049.2016.1205008

Gandolfi, E., Traverso, L., Zanobini, M., Usai, M. C., & Viterbori, P. (2021). The longitudinal relationship between early inhibitory control skills and emergent literacy in preschool children. *Reading and Writing*, 1-25. DOI:10.1007/s11145-021-10131-y

Gandolfi, E., Viterbori, P., Traverso, L., & Usai, M. C. (2014). Inhibitory processes in toddlers: a latent-variable approach. *Frontiers in psychology*, *5*, 381. DOI:10.3389/fpsyg.2014.00381

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: a review using an integrative framework. *Psychological bulletin*, 134(1), 31. https://doi.org/10.1037/0033-2909.134.1.31

Gathercole, S. E., Alloway, T. P., Willis, C., & Adams, A. M. (2006). Working memory in children with reading disabilities. *Journal of experimental child psychology*, *93*(3), 265-281. https://doi.org/10.1016/j.jecp.2005.08.003

Gathercole, S. E., Tiffany, C., Briscoe, J., Thorn, A., & ALSPAC team. (2005). Developmental consequences of poor phonological short-term memory function in childhood: A longitudinal study. *Journal of child Psychology and Psychiatry*, *46*(6), 598-611. doi:10.1111/j.1469-7610.2004.00379.x

Gathercole, S.E., Pickering, S.J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: evidence from National Curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology*, 18, 1–16. http://dx.doi.org/10.1002/acp.934.

Gerst, E. H., Cirino, P. T., Fletcher, J. M., & Yoshida, H. (2017). Cognitive and behavioral rating measures of executive function as predictors of academic outcomes in children. *Child Neuropsychology*, *23*(4), 381-407. https://doi.org/10.1080/09297049.2015.1120860

Geurts, H. M., Sinzig, J., Booth, R., & Happé, F. (2014). Neuropsychological heterogeneity in executive functioning in autism spectrum disorders. *International Journal of Developmental Disabilities*, *60*(3), 155–162. https://doi.org/10.1179/2047387714Y.0000000047

Gilmore, C., Keeble, S., Richardson, S., & Cragg, L. (2015). The role of cognitive inhibition in different components of arithmetic. *Zdm*, *47*(5), 771-782. https://doi.org/10.1007/s11858-014-0659-y

Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2000). Behavior rating inventory of executive function. *Child Neuropsychology, 6*(3), 235–238. https://doi.org/10.1076/chin.6.3.235.3152

Godefroy, O., Cabaret, M., Petit-Chenal, V., Pruvo, J. P., & Rousseaux, M. (1999). Control functions of the frontal lobes. Modularity of the central-supervisory system?. *Cortex*, *35*(1), 1-20. https://doi.org/10.1016/s0010-9452(08)70782-2

Goldberg, E., & Bilder, R. M., Jr. (1987). The frontal lobes and hierarchical organization of cognitive control. In E. Perecman (Ed.), *The frontal lobes revisited* (pp. 159–187). The IRBN Press.

Goldberg, T. E., Berman, K. F., Fleming, K., Ostrem, J., Van Horn, J. D., Esposito, G., ... & Weinberger, D. R. (1998). Uncoupling cognitive workload and prefrontal cortical physiology: a PET rCBF study. *Neuroimage*, *7*(4), 296-303. https://doi.org/10.1006/nimg.1998.0338

Golomb, M. R., MacGregor, D. L., Domi, T., Armstrong, D. C., McCrindle, B. W., Mayank, S., & DeVeber, G. A. (2001). Presumed pre-or perinatal arterial ischemic stroke: risk factors and outcomes. *Annals of Neurology*, *50*(2), 163-168. https://doi.org/10.1002/ana.1078

Gomes, A., Rinehart, N., Greenham, M., & Anderson, V. (2014). A critical review of psychosocial outcomes following childhood stroke (1995–2012). *Developmental neuropsychology*, *39*(1), 9-24. https://doi.org/10.1080/87565641.2013.827197

Goodman, R. (1997). The Strengths and Difficulties Questionnaire: a research note. Journal of child psychology and psychiatry, 38(5), 581-586. https://doi.org/10.1111/j.1469-7610.1997.tb01545.x

Görgen, R., Huemer, S., Schulte-Körne, G., & Moll, K. (2020). Evaluation of a digital game-based reading training for German children with reading disorder. *Computers & Education*, *150*. https://doi.org/10.1016/j.compedu.2020.103834

Grant, D. A., & Berg, E. (1948). A behavioral analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card-sorting problem. *Journal of experimental psychology*, *38*(4), 404-411. https://doi.org/10.1037/h0059831

Green, C. S., and Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature* 423, 534–537. https://doi.org/10.1038/nature01647

Greenham, M., Anderson, V., & Mackay, M. T. (2017). Improving cognitive outcomes for pediatric stroke. *Current opinion in neurology*, *30*(2), 127-132. https://doi.org/10.1097/WCO.0000000000000422

Greenham, M., Gordon, A. L., Cooper, A., Ditchfield, M., Coleman, L., Hunt, R. W., ... & Anderson, V. (2018). Social functioning following pediatric stroke: contribution of neurobehavioral impairment. *Developmental neuropsychology*, *43*(4), 312-328. https://doi.org/10.1080/87565641.2018.1440557

Gunzenhauser, C., & Nückles, M. (2021). Training Executive Functions to Improve Academic Achievement: Tackling Avenues to Far Transfer. *Frontiers in Psychology*, *12*, 1350. https://doi.org/10.3389/fpsyg.2021.624008

Hackman, D. A., & Farah, M. J. (2009). Socioeconomic status and the developing brain. *Trends in Cognitive Sciences*, 13(2), 65-73. https://doi.org/10.1016/j.tics.2008.11.003

*Hajek, C. A., Yeates, K. O., Anderson, V., Mackay, M., Greenham, M., Gomes, A., & Lo, W. (2014). Cognitive outcomes following arterial ischemic stroke in infants and children. *Journal of Child Neurology*, *29*(7), 887-894. https://doi.org/10.1177/0883073813491828

Hall, P. A., Crossley, M., & D'Arcy, C. (2010). Executive function and survival in the context of chronic illness. *Annals of Behavioral Medicine*, *39*(2), 119-127. https://doi.org/10.1007/s12160-010-9162-z

Härtel, C., Schilling, S., Sperner, J., & Thyen, U. (2004). The clinical outcomes of neonatal and childhood stroke: review of the literature and implications for future research. *European Journal of Neurology*, *11*(7), 431-438. https://doi.org/10.1111/j.1468-1331.2004.00861.x

Hayes, A.F., Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach, The Guilford Press, New York, 2013.

He, B. J., Snyder, A. Z., Vincent, J. L., Epstein, A., Shulman, G. L., & Corbetta, M. (2007). Breakdown of functional connectivity in frontoparietal networks underlies behavioral deficits in spatial neglect. *Neuron*, *53*(6), 905-918. https://doi.org/10.1016/j.neuron.2007.02.013

Herrero, M. T., Barcia, C., & Navarro, J. (2002). Functional anatomy of thalamus and basal ganglia. *Child's Nervous System*, *18*(8), 386-404. https://doi.org/10.1007/s00381-002-0604-1

Hirsh-Pasek, K., Zosh, J. M., Golinkoff, R. M., Gray, J. H., Robb, M. B., & Kaufman, J. (2015). Putting education in "educational" apps: lessons from the science of learning. *Psychological science in the public interest : a journal of the American Psychological Society*, *16*(1), 3–34. https://doi.org/10.1177/1529100615569721

Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. Trends in cognitive sciences, 16(3), 174-180. https://doi.org/10.1016/j.tics.2012.01.006

How, T. V., Hwang, A. S., Green, R., & Mihailidis, A. (2017). Envisioning future cognitive telerehabilitation technologies: a co-design process with clinicians. *Disability and rehabilitation. Assistive technology*, *12*(3), 244–261. https://doi.org/10.3109/17483107.2015.1129457

Hughes, C., & Ensor, R. (2007). Executive function and theory of mind: Predictive relations from ages 2 to 4. Developmental psychology, 43(6), 1447. https://doi.org/10.1037/0012-1649.43.6.1447

Hughes, C., & Ensor, R. (2008). Does executive function matter for preschoolers' problem behaviors? *Journal of Abnormal Child Psychology. 36*, 1–1. http://dx.doi.org/10.1007/s10802-007-9107-6.

Hughes, C., Dunn, J. (1998). Understanding mind and emotion: longitudinalassociations with mental-state talk between young friends. *Developmental Psychology*, 34,1026–1037, http://dx.doi.org/10.1037/0012-1649.34.5.1026.

Hughes, C., Russell, J., & Robbins, T. W. (1994). Evidence for executive dysfunction in autism. *Neuropsychologia*, *32*(4), 477-492. https://doi.org/10.1016/0028-3932(94)90092-2

Huttenlocher, P. R. (1990). Morphometric study of human cerebral cortex development. *Neuropsychologia*, *28*(6), 517-527. https://doi.org/10.1016/0028-3932(90)90031-i

Ide, S., Kakeda, S., & Korogi, Y. (2015). Anatomy of the thalamus. *Brain and nerve= Shinkei kenkyu no shinpo*, *67*(12), 1459-1469. https://doi.org/10.11477/mf.1416200323

Isquith, P. K., Roth, R. M., & Gioia, G. (2013). Contribution of rating scales to the assessment of executive functions. *Applied Neuropsychology: Child*, *2*(2), 125-132. https://doi.org/10.1080/21622965.2013.748389

Jacob, R., & Parkinson, J. (2015). The potential for school-based interventions that target executive function to improve academic achievement: A review. *Review of Educational Research*, *85*(4), 512–552. https://doi.org/10.3102/0034654314561338

Jamshidifarsani, H., Garbaya, S., Lim, T., Blazevic, P., and Ritchie, J. M. (2019). Technology-based reading intervention programs for elementary grades: an analytical review. *Comput. Edu.* 128, 427–451. https://doi.org/10.1016/j.compedu.2018.10.003

Johnstone, S. J., Roodenrys, S., Blackman, R., Johnston, E., Loveday, K., Mantz, S., Barratt, M. F. (2012). Neurocognitive training for children with and without AD/HD. *Attention Deficit and Hyperactivity Disorders, 4*(1), 11-23. https://doi.org/10.1007/s12402-011-0069-8

Karbach, J., & Kray, J. (2016). *Executive functions. In Cognitive training.* New York city, NY: Springer, 93–103.

Karbach, J., & Unger, K. (2014). Executive control training from middle childhood to adolescence. *Frontiers in psychology*, *5*, 390. https://doi.org/10.3389/fpsyg.2014.00390

Karbach, J., & Verhaeghen, P. (2014). Making working memory work: a meta-analysis of executive-control and working memory training in older adults. *Psychological science*, *25*(11), 2027-2037. https://doi.org/10.1177/0956797614548725

Ke, F., Abras, T. (2013). Games for engaged learning of middle school children with special learning needs. *British Journal of Educational Technology*, *44*, 225–242. https://doi.org/10.1111/j.1467-8535.2012.01326.x

Kesler, S. R., Lacayo, N. J., & Jo, B. (2011). A pilot study of an online cognitive rehabilitation program for executive function skills in children with cancer-related brain injury. *Brain injury*, *25*(1), 101–112. https://doi.org/10.3109/02699052.2010.536194

Khng, K. H., & Lee, K. (2009). Inhibiting interference from prior knowledge: Arithmetic intrusions in algebra word problem solving. *Learning and Individual Differences*, *19*(2), 262-268. https://doi.org/10.1016/j.lindif.2009.01.004

Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlström, K., Gillberg, C. G., Forssberg, H., & Westerberg, H. (2005). Computerized training of working memory in children with ADHD--a randomized, controlled trial. *Journal of the American Academy of Child and Adolescent Psychiatry*, *44*(2), 177–186. https://doi.org/10.1097/00004583-200502000-00010

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of clinical and experimental neuropsychology*, *24*(6), 781–791. https://doi.org/10.1076/jcen.24.6.781.8395

*Kolk, A., Ennok, M., Laugesaar, R., Kaldoja, M. L., & Talvik, T. (2011). Long-term cognitive outcomes after pediatric stroke. *Pediatric neurology*, *44*(2), 101-109. https://doi.org/10.1016/j.pediatrneurol.2010.08.012

Korkman, M., Kirk, U., & Kemp, S. (2007). *NEPSY II: Clinical and interpretive manual*. Harcourt Assessment, PsychCorp.

*Kornfeld, S., Yuan, R., Biswal, B. B., Grunt, S., Kamal, S., Rodríguez, J. A. D., ... & Steinlin, M. (2018). Resting-state connectivity and executive functions after pediatric arterial ischemic stroke. *NeuroImage: Clinical*, *17*, 359-367. doi : 10.1016/j.nicl.2017.10.016

Kueider, A. M., Parisi, J. M., Gross, A. L., & Rebok, G. W. (2012). Computerized cognitive training with older adults: a systematic review. *PloS one*, *7*(7), e40588. https://doi.org/10.1371/journal.pone.0040588

Kuhn, L. J., Willoughby, M. T., Wilbourn, M. P., Vernon-Feagans, L., Blair, C. B., & Family Life Project Key Investigators. (2014). Early communicative gestures prospectively predict language development and executive function in early childhood. *Child development*, *85*(5), 1898-1914. https://doi.org/10.1111/cdev.12249

Ladd, G. W. (1989). Children's social competence and social supports: Precursors of early school adjustment?. In *Social competence in developmental perspective* (pp. 277-291). Springer, Dordrecht.

Ladd, G. W., Kochenderfer, B. J., & Coleman, C. C. (1996). Friendship quality as a predictor of young children's early school adjustment. *Child development*, *67*(3), 1103–1118.

Lan, X., Legare, C. H., Ponitz, C. C., Li, S., & Morrison, F. J. (2011). Investigating the links between the subcomponents of executive function and academic achievement: a cross-cultural analysis of Chinese and American preschoolers. *Journal of experimental child psychology*, *108*(3), 677–692. https://doi.org/10.1016/j.jecp.2010.11.001

Lansing, A. E., Max, J. E., Delis, D. C., Fox, P. T., Lancaster, J., Manes, F. F., & Schatz, A. (2004). Verbal learning and memory after childhood stroke. *Journal of the International Neuropsychological Society*, *10*(5), 742-752. https://doi.org/10.10170S1355617704105122

Lantrip, C., Isquith, P. K., Koven, N. S., Welsh, K., & Roth, R. M. (2016). Executive function and emotion regulation strategy use in adolescents. Applied Neuropsychology: Child, 5(1), 50-55. https://doi.org/10.1080/21622965.2014.960567

Laski, E. V., & Dulaney, A. (2015). When prior knowledge interferes, inhibitory control matters for learning: The case of numerical magnitude representations. *Journal of Educational Psychology*, *107*(4), 1035. https://doi.org/10.1037/edu0000034

Lee, K., Bull, R., & Ho, R. M. (2013). Developmental changes in executive functioning. *Child development*, 84(6), 1933-1953. https://doi.org/10.1111/cdev.12096

Lehto, J. (1996). Are executive function tests dependent on working memory capacity?. *The quarterly journal of experimental psychology section A*, *49*(1), 29-50. https://doi.org/10.1080/713755616

Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology*, *21*(1), 59-80. https://doi.org/10.1348/026151003321164627

Leisman, G., Braun-Benjamin, O., & Melillo, R. (2014). Cognitive-motor interactions of the basal ganglia in development. *Frontiers in systems neuroscience*, *8*, 16. https://doi.org/10.3389/fnsys.2014.00016

Levin, H. S., Fletcher, J. M., Kufera, J. A., Harward, H., Lilly, M. A., Mendelsohn, D., ... & Eisenberg, H. M. (1996). Dimensions of cognition measured by the Tower of London and other cognitive tasks in head-injured children and adolescents. *Developmental Neuropsychology*, *12*(1), 17-34. https://doi.org/10.1080/87565649609540638

Li, L., & Liu, J. (2013). The effect of pediatric traumatic brain injury on behavioral outcomes: a systematic review. Developmental Medicine & Child Neurology, 55(1), 37-45. https://doi.org/10.1111/j.1469-8749.2012.04414.x

Liebermann, D., Ploner, C. J., Kraft, A., Kopp, U. A., & Ostendorf, F. (2013). A dysexecutive syndrome of the medial thalamus. *Cortex*, *49*(1), 40-49. https://doi.org/10.1016/j.cortex.2011.11.005

Li-Grining, C. P., Raver, C. C., & Pess, R. A. (2011). Academic impacts of the Chicago School Readiness Project: Testing for evidence in elementary school. In *biennial meeting of the Society for Research in Child Development*, Montreal, QC, Canada.

Linden, M., Hawley, C., Blackwood, B., Evans, J., Anderson, V., & O'Rourke, C. (2016). Technological aids for the rehabilitation of memory and executive functioning in children and adolescents with acquired brain injury. *Cochrane Database of Systematic Reviews, 7*(7), CD011020. https://doi.org/10.1002/14651858.

*Long, B., Anderson, V., Jacobs, R., Mackay, M., Leventer, R., Barnes, C., & Spencer-Smith, M. (2011). Executive function following child stroke: The impact of lesion size. *Developmental neuropsychology, 36*(8), 971-987. https://doi.org/10.1080/87565641.2011.581537

*Long, B., Spencer-Smith, M. M., Jacobs, R., Mackay, M., Leventer, R., Barnes, C., & Anderson, V. (2011). Executive function following child stroke: the impact of lesion location. *Journal of Child Neurology*, *26*(3), 279-287. https://doi.org/10.1177/0883073810380049

Lowe, C., & Rabbitt, P. (1997). Cognitive models of aging and frontal lobe deficits. In P. Rabbit (Ed.), *Methodology of frontal and executive function* (pp. 39–59). London: Psychology Press.

Lunt, L., Bramham, J., Morris, R. G., Bullock, P. R., Selway, R. P., Xenitidis, K., & David, A. S. (2012). Prefrontal cortex dysfunction and 'Jumping to Conclusions': Bias or deficit? *Journal of Neuropsychology*, 6(1), 65–78. http://dx.doi.org/10.1111/jnp.2012.6.issue-1

Lurija A. R. (1973). The Working Brain: An Introduction to Neuropsychology. London: Penguin Press.

Mackey, A. P., Hill, S. S., Stone, S. I., & Bunge, S. A. (2011). Differential effects of reasoning and speed training in children. *Developmental science, 14*(3), 582-590. https://doi.org/10.1111/j.1467-7687.2010.01005.x

Maertens, B., De Smedt, B., Sasanguie, D., Elen, J., & Reynvoet, B. (2016). Enhancing arithmetic in pre-schoolers with comparison or number line estimation training: Does it matter? *Learning and Instruction*, *46*, 1–11. https://doi.org/10.1016/j.learninstruc.2016.08.004

Manly, T., Anderson, V., Nimmo-Smith, I., Turner, A., Watson, P., & Robertson, I. H. (2001). The differential assessment of children's attention: The Test of Everyday Attention for Children (TEA-Ch), normative sample and ADHD performance. *The Journal of Child Psychology and Psychiatry and Allied Disciplines*, *42*(8), 1065-1081. https://doi.org/10.1111/1469-7610.00806

Marini, A., Piccolo, B., Taverna, L., Berginc, M., Ozbič, M. (2020) The complex relation between executive functions and language in preschoolers with Developmental Language Disorders. *International Journal of Environmental Research and Public Health, 17*, 1772. https://doi.org/10.3390/ijerph17051772.

Marzocchi, G. M., Re, A. M., & Cornoldi, C. (2010). *BIA. Batteria italiana per l'ADHID per la valutazione dei bambini con deficit di attenzione-iperattività* [Italian battery for the evaluation of children with attention deficit hyperactivity disorder]. Edizioni Erickson.

Masten, A. S., Herbers, J. E., Desjardins, C. D., Cutuli, J. J., McCormick, C. M., Sapienza, J. K., ... & Zelazo, P. D. (2012). Executive function skills and school success in young children experiencing homelessness. *Educational Researcher, 41*(9), 375-384. https://doi.org/10.3102/0013189X12459883

*Max, J. E., Bruce, M., Keatley, E., & Delis, D. (2010). Pediatric stroke: plasticity, vulnerability, and age of lesion onset. *The Journal of neuropsychiatry and clinical neurosciences*, *22*(1), 30-39. https://doi.org/10.1176/appi.neuropsych.22.1.30

Max, J. E., Mathews, K., Lansing, A. E., Robertson, B. A., Fox, P. T., Lancaster, J. L., ... & Smith, J. (2002). Psychiatric disorders after childhood stroke. *Journal of the American Academy of Child & Adolescent Psychiatry*, 41(5), 555-562. https://doi.org/10.1097/00004583-200205000-00013

*Max, J. E., Mathews, K., Manes, F. F., Robertson, B. A., Fox, P. T., Lancaster, J. L., ... & Collings, N. (2003). Attention deficit hyperactivity disorder and neurocognitive correlates after childhood stroke. *Journal of the International Neuropsychological Society*, *9*(6), 815-829. https://doi.org/10.10170S1355617703960012

Mazzocco, M. M., & Kover, S. T. (2007). A longitudinal assessment of executive function skills and their association with math performance. *Child neuropsychology*, *13*(1), 18-45. https://doi.org/10.1080/09297040600611346

McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: A confirmatory factor analysis. *Research quarterly for exercise and sport*, *60*(1), 48-58. https://doi.org/10.1080/02701367.1989.10607413

McAuley, T., Chen, S., Goos, L., Schachar, R., & Crosbie, J. (2010). Is the Behavior Rating Inventory of Executive Function more strongly associated with measures of impairment or executive function? *Journal of the International Neuropsychological Society*, *16*(3), 495–505. https://doi.org/10.1017/S1355617710000093

McCarthy, R.A., & Warrington, E.K., (1992). Neuropsicologia cognitiva. Un’introduzione clinica, Milano, Raffaello Cortina Editore.

McClelland, M. M., & Cameron, C. E. (2012). Self-regulation in early childhood: Improving conceptual clarity and developing ecologically valid measures. *Child Development Perspectives*, *6*(2), 136–142. https://doi.org/10.1111/j.1750-8606.2011.00191.x

McClelland, M. M., Cameron, C. E., Connor, C. M., Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. *Developmental psychology*, *43*(4), 947. https://doi.org/10.1037/0012-1649.43.4.947

McClelland, M. M., Morrison, F. J., & Holmes, D. L. (2000). Children at risk for early academic problems: The role of learning-related social skills. *Early childhood research quarterly*, *15*(3), 307-329. DOI:10.1016/S0885-2006(00)00069-7

McDermott, P. A., Rikoon, S. H., & Fantuzzo, J. W. (2014). Tracing children’s approaches to learning through head start, kindergarten, and first grade: Different pathways to different outcomes. Journal of Educational Psychology, 106(1), 200–213. https://doi.org/10.1037/a0033547

McKenna, R., Rushe, T., & Woodcock, K. A. (2017). Informing the structure of executive function in children: a meta-analysis of functional neuroimaging data. *Frontiers in human neuroscience*, *11*, 154. https://doi.org/10.3389/fnhum.2017.00154

McTeague, L. M., Huemer, J., Carreon, D. M., Jiang, Y., Eickhoff, S. B., & Etkin, A. (2017). Identification of common neural circuit disruptions in cognitive control across psychiatric disorders. *American Journal of Psychiatry*, *174*(7), 676-685. https://doi.org/10.1176/appi.ajp.2017.16040400

Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental psychology*, *49*(2), 270-291. https://doi.org/10.1037/a0028228

Miller, H.V., Barnes, J.C., Beaver, K.M. (2011). Self-control and health outcomes in anationally representative sample. *American Journal of Health Behavior*, *35* (1), 15–27, http://dx.doi.org/10.5993/AJHB.35.1.2.

Miller, M. R., Giesbrecht, G. F., Müller, U., McInerney, R. J., & Kerns, K. A. (2012). A latent variable approach to determining the structure of executive function in preschool children. *Journal of Cognition and Development*, *13*(3), 395-423. https://doi.org/10.1080/15248372.2011.585478

Mishra, J., Zinni, M., Bavelier, D., and Hillyard, S. A. (2011). Neural basis of superior performance of action videogame players in an attention-demanding task. *J. Neurosci.* 31, 992–998. doi: 10.1523/JNEUROSCI.4834-10.2011

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive psychology*, *41*(1), 49-100. https://doi.org/10.1006/cogp.1999.0734

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., Houts, R., Poulton, R., Roberts, B. W., Ross, S., Sears, M. R., Thomson, W. M., & Caspi, A. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(7), 2693–2698. https://doi.org/10.1073/pnas.1010076108

Moffitt, T.E.. (2012). Childhood self-control predicts adult health, wealth, and crime. In: Multi-Disciplinary Symposium Improving the Well-Being of Children and Youth, Copenhagen.

Monette, S., Bigras, M., & Guay, M-C. (2011) The Role of the Executive Functions in School Achievement at the End of Grade 1. *Journal of Experimental Child Psychology, 109*(2), 158-173. https://doi.org/10.1016/j.jecp.2011.01.008

Moreno-Alcázar, A., Ramos-Quiroga, J. A., Radua, J., Salavert, J., Palomar, G., Bosch, R., ... & Pomarol-Clotet, E. (2016). Brain abnormalities in adults with Attention Deficit Hyperactivity Disorder revealed by voxel-based morphometry. *Psychiatry Research: Neuroimaging*, *254*, 41-47. https://doi.org/10.1016/j.pscychresns.2016.06.002

Morrison, A. B., & Chein, J. M. (2011). Does working memory training work? The promise and challenges of enhancing cognition by training working memory. *Psychonomic Bulletin & Review*, *18*(1), 46–60. https://doi.org/10.3758/s13423-010-0034-0

Morrison, F. J., Ponitz, C. C., & McClelland, M. M. (2010). Self-regulation and academic achievement in the transition to school. In S. D. Calkins & M. A. Bell (Eds.), *Child development at* *the intersection of emotion and cognition* (pp. 203–224). American Psychological Association. https://doi.org/10.1037/12059-011

Murias, K., Brooks, B., Kirton, A., & Iaria, G. (2014). A review of cognitive outcomes in children following perinatal stroke. *Developmental neuropsychology*, *39*(2), 131-157. https://doi.org/10.1080/87565641.2013.870178

*Murphy, L. K., Compas, B. E., Gindville, M. C., Reeslund, K. L., & Jordan, L. C. (2017). Cognitive functioning over 2 years after intracerebral hemorrhage in school-aged children. *Developmental Medicine & Child Neurology*, *59*(11), 1146-1151. https://doi.org/10.1111/dmcn.13547

Nadeau, S. E. (2008). The thalamus and working memory. *Journal of the International Neuropsychological Society*, *14*(5), 900-901. https://doi.org/10.1017/S1355617708081149

Nagin, D., & Tremblay, R. E. (1999). Trajectories of boys' physical aggression, opposition, and hyperactivity on the path to physically violent and nonviolent juvenile delinquency. *Child development*, *70*(5), 1181-1196. https://doi.org/10.1111/1467-8624.00086

Nayfeld, I., Fuccillo, J., & Greenfield, D.B. (2013). Executive Functions in Early Learning: Extending the Relationship Between Executive Functions and School Readiness to Science. *Learning and Individual Differences*, *26*: 81-88. https://doi.org/10.1016/j.lindif.2013.04.011

Nesbitt, K. T., Farran, D. C., & Fuh, M. W. (2015). Executive function skills and academic achievement gains in prekindergarten: contributions of learning-related behaviors. *Developmental Psychology, 51,* 865–878. doi:10.1037/dev0000021

Neuenschwander, R., Röthlisberger, M., Cimeli, P., & Roebers, C. M. (2012). How do different aspects of self-regulation predict successful adaptation to school? *Journal of Experimental Child Psychology*, *113(*3), 353–371. https://doi.org/10.1016/j.jecp.2012.07.004

Niendam, T. A., Laird, A. R., Ray, K. L., Dean, Y. M., Glahn, D. C., & Carter, C. S. (2012). Meta-analytic evidence for a superordinate cognitive control network subserving diverse executive functions. *Cognitive, Affective, & Behavioral Neuroscience*, *12*(2), 241-268. https://doi.org/10.3758/s13415-011-0083-5

Norman, D. A., & Shallice, (1986). Attention to Action. Willed and automatic control of behaviour. In R.. J. Davidson, G.E. Schwartz, D. Shapiro (Eds.), Consciousness and selfregulation, 1-17. Plenum Press, New York.

*O'Keeffe, F., Ganesan, V., King, J., & Murphy, T. (2012). Quality-of-life and psychosocial outcome following childhood arterial ischaemic stroke. *Brain injury*, *26*(9), 1072-1083. https://doi.org/10.3109/02699052.2012.66111

*O'Keeffe, F., Liégeois, F., Eve, M., Ganesan, V., King, J., & Murphy, T. (2014). Neuropsychological and neurobehavioral outcome following childhood arterial ischemic stroke: Attention deficits, emotional dysregulation, and executive dysfunction. *Child Neuropsychology*, *20*(5), 557–582. https://doi.org/10.1080/09297049.2013.832740

O'Keeffe, F., Stark, D., Murphy, O., Ganesan, V., King, J., & Murphy, T. (2017). Psychosocial outcome and quality of life following childhood stroke–A systematic review. *Developmental neurorehabilitation*, *20*(7), 428-442. https://doi.org/10.1080/17518423.2017.1282052

Obradović, J., Bush, N. R., Stamperdahl, J., Adler, N. E., & Boyce, W. T. (2010). Biological sensitivity to context: The interactive effects of stress reactivity and family adversity on socioemotional behavior and school readiness. *Child development*, *81*(1), 270-289. https://doi.org/10.1111/j.1467-8624.2009.01394.x

Olson, S. L., Sameroff, A. J., Kerr, D. C., Lopez, N. L., & Wellman, H. M. (2005). Developmental foundations of externalizing problems in young children: The role of effortful control. *Development and psychopathology*, *17*(1), 25-45. https://doi.org/10.1017/s0954579405050029

Otero, T. M., Barker, L. A., & Naglieri, J. A. (2014). Executive function treatment and intervention in schools. *Applied Neuropsychology: Child*, *3*(3), 205–214. https://doi.org/10.1080/21622965.2014.897903

Owen, A. M., McMillan, K. M., Laird, A. R., & Bullmore, E. (2005). N-back working memory paradigm: A meta-analysis of normative functional neuroimaging studies. *Human brain mapping*, *25*(1), 46-59. https://doi.org/10.1002/hbm.20131

Owen, A. M., Downes, J. J., Sahakian, B. J., Polkey, C. E., & Robbins, T. W. (1990). Planning and spatial working memory following frontal lobe lesions in man. *Neuropsychologia*, *28*(10), 1021–1034. https://doi.org/10.1016/0028-3932(90)90137-d

Pandey, A., Hale, D., Das, S., Goddings, A. L., Blakemore, S. J., & Viner, R. M. (2018). Effectiveness of universal self-regulation-based interventions in children and adolescents: a systematic review and meta-analysis. *JAMA Pediatrics* 172, 566–575. https://doi.org/10.1001/jamapediatrics.2018.0232

Pasolunghi, M. C., Cornoldi, C., & De Liberto, S. (1999). Working memory and intrusions of irrelevant information in a group of specific poor problem solvers. *Memory & Cognition*, *27*(5), 779-790. https://doi.org/10.3758/bf03198531

Passolunghi, M. C., & Siegel, L. S. (2001). Short-term memory, working memory, and inhibitory control in children with difficulties in arithmetic problem solving. *Journal of experimental child psychology*, *80*(1), 44-57. https://doi.org/10.1006/jecp.2000.2626

Pauls, L. J., & Archibald, L. M. D. (2016). Executive functions in children with specific language impairment: A meta-analysis. Journal of Speech, Language, and Hearing Research, 59, 1074–1086. https://doi.org/10.1044/2016_JSLHR-L-15-0174

Pavlovic, J., Kaufmann, F., Boltshauser, E., Mori, A. C., Mercati, D. G., Haenggeli, C. A., ... & Perez, E. R. (2006). Neuropsychological problems after paediatric stroke: two year follow-up of Swiss children. *Neuropediatrics*, *37*(01), 13-19. https://doi.org/10.1055/s-2006-923932

Peng, P., & Fuchs, D. (2016). A meta-analysis of working memory deficits in children with learning difficulties: Is there a difference between verbal domain and numerical domain? *Journal of Learning Disabilities*, *49*(1), 3–20. https://doi.org/10.1177/0022219414521667

Pennington, B. F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of child psychology and psychiatry*, *37*(1), 51-87. https://doi.org/10.1111/j.1469-7610.1996.tb01380.x

Pintrich, P. R., & Zusho, A. (2002). The development of academic selfregulation: The role of cognitive and motivational factors. In A. Wigfield & J. S. Eccles (Eds.), A Vol. in the educational psychology series. Development of achievement motivation (pp. 249–284). San Diego, CA, US: Academic Press. https://doi.org/10.1016/B978-012750053-9/50012-7

Ponitz, C., McClelland, M., Jewkes, A., Connor, C., Farris, C., & Morrison, F. (2008). Touch your toes! Developing a direct measure of behavioral regulation in early childhood. *Early Childhood Research Quarterly, 23*(2), 141–158. https://doi.org/10.1016/j.ecresq.2007.01.004

Price, B. H., Daffner, K. R., Stowe, R. M., & Mesulam, M. M. (1990). The comportmental learning disabilities of early frontal lobe damage. *Brain*, *113*(5), 1383-1393. https://doi.org/10.1093/brain/113.5.1383

Prins, P. J., Brink, E. T., Dovis, S., Ponsioen, A., Geurts, H. M., De Vries, M., et al. (2013). “Braingame Brian”: toward an executive function training program withgame elements for children with ADHD and cognitive control problems. *Games Health J.* 2, 44–49. doi: 10.1089/g4h.2013.0004

Raven, J., Raven, J.C., Court, J.H. (1998). Raven manual, Section 2 (Coloured Progressive Matrices). Oxford, England: Oxford Psychologist Press

Raver, C. C., Jones, S. M., Li-Grining, C. P., Metzger, M., Champion, K. M., & Sardin, L. (2008). Improving preschool classroom processes: Preliminary findings from a randomized trial implemented in Head Start settings. *Early Childhood Research Quarterly*, *23*(1), 10–26.

Raver, C. C., Jones, S. M., Li-Grining, C., Zhai, F., Bub, K., & Pressler, E. (2011). CSRP’s impact on low-income preschoolers’ preacademic skills: self-regulation as a mediating mechanism. *Child development*, *82*(1), 362-378. https://doi.org/10.1111/j.1467-8624.2010.01561.x

Resch, C., Rosema, S., Hurks, P., de Kloet, A., & van Heugten, C. (2018). Searching for effective components of cognitive rehabilitation for children and adolescents with acquired brain injury: a systematic review. *Brain injury*, *32*(6), 679-692. https://doi.org/10.1080/02699052.2018.1458335

Ribner, A. D., Willoughby, M. T., Blair, C. B., & Family Life Project Key Investigators. (2017). Executive function buffers the association between early math and later academic skills. *Frontiers in psychology*, *8*, 869. https://doi.org/10.3389/fpsyg.2017.00869

Riggs, N. R., Jahromi, L. B., Razza, R. P., Dillworth-Bart, J. E., & Mueller, U. (2006). Executive function and the promotion of social–emotional competence. *Journal of Applied Developmental Psychology*, *27*(4), 300-309. https://doi.org/10.1016/j.appdev.2006.04.002Get

Rivella, C., & Viterbori, P. (2020). Executive function following pediatric stroke. A systematic review. *Child Neuropsychology*, 1-23. https://doi.org/10.1080/09297049.2020.1820472

Robbins, T. W. (1996). Dissociating executive functions of the prefrontal cortex. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *351*(1346), 1463-1471.

Roebers, C. M. (2017). Executive function and metacognition: Towards a unifying framework of cognitive self-regulation. *Developmental review*, *45*, 31-51. https://doi.org/10.1016/j.dr.2017.04.001

Ronimus, M., Kujala, J.V., Tolvanen, A., & Lyytinen, H. (2014). Children's engagement during digital game-based learning of reading: The effects of time, rewards, and challenge. *Computers and Education.*, *71*, 237-246. https://doi.org/10.1016/j.compedu.2013.10.008

Rushworth, M. F. S., Walton, M. E., Kennerley, S. W., & Bannerman, D. M. (2004). Action sets and decisions in the medial frontal cortex. *Trends in cognitive sciences*, *8*(9), 410-417. https://doi.org/10.1016/j.tics.2004.07.009

Rutherford, T., Buschkuehl, M., Jaeggi, S. M., & Farkas, G. (2018). Links between achievement, executive functions, and self-regulated learning. *Applied Cognitive Psychology*, *32*(6), 763-774. https://doi.org/10.1002/acp.3462

Ryan, R. M. (1982). Control and information in the intrapersonal sphere: An extension of cognitive evaluation theory. *Journal of personality and social psychology*, *43*(3), 450. https://doi.org/10.1037/0022-3514.43.3.450

Sasser, T. R., Bierman, K. L., & Heinrichs, B. (2015). Executive functioning and school adjustment: The mediational role of pre-kindergarten learning-related behaviors. *Early childhood research quarterly*, *30*, 70-79. https://doi.org/10.1016/j.ecresq.2014.09.001.

Scarpa, P., Piazzini, A., Pesenti, G., Brovedani, P., Toraldo, A., Turner, K., Scotti, S., Dal Lago, C., Perelli, V., Brizzolara, D., Canger, R., Canevini, M. P., & Bottini, G. (2006). Italian neuropsychological instruments to assess memory, attention and frontal functions for developmental age. *Neurological Sciences, 27*(6), 381-396. https://doi.org/10.1007/s10072-006-0717-5

Schachar, R. J., Tannock, R., & Logan, G. (1993). Inhibitory control, impulsiveness, and attention deficit hyperactivity disorder. *Clinical Psychology Review*, *13*(8), 721-739. https://doi.org/10.1016/S0272-7358(05)80003-0

Schaeffner, S., Chevalier, N., Kubota, M., & Karbach, J. (2021). Metacognitive training. In *Cognitive Training* (pp. 255-270). Springer, Cham. https://doi.org/ 10.1007/978-3-030-39292-5_18

*Schatz, J., & Buzan, R. (2006). Decreased corpus callosum size in sickle cell disease: relationship with cerebral infarcts and cognitive functioning. *Journal of the International Neuropsychological Society*, *12*(1), 24-33. https://doi.org/10.10170S1355617706060085

*Schatz, J., Craft, S., Koby, M., Siegel, M. J., Resar, L., Lee, R. R., Chu, J. Y., ... & Le DeBaun, M. R. (1999). Neuropsychologic deficits in children with sickle cell disease and cerebral infarction: Role of lesion site and volume. *Child Neuropsychology*, *5*(2), 92-103. https://doi.org/10.1076/chin.5.2.92.3170

Schmeler, M. R., Schein, R. M., McCue, M., & Betz, K. (2009). Telerehabilitation clinical and vocational applications for assistive technology: research, opportunities, and challenges. *International journal of telerehabilitation*, *1*(1), 59–72. https://doi.org/10.5195/ijt.2009.6014

Shallice, T. (1988). From neuropsychology to mental structure; trad. It. Neuropsicologia e struttura della mente, Bologna, Il Mulino, 1990.

Shallice, T. I. M., & Burgess, P. W. (1991). Deficits in strategy application following frontal lobe damage in man. *Brain*, *114*(2), 727-741. https://doi.org/10.1093/brain/114.2.727

Shallice, T., Burgess, P. W., Schon, F., & Baxter, D. M. (1989). The origins of utilization behaviour. *Brain*, *112*(6), 1587-1598. https://doi.org/10.1093/brain/112.6.1587

Shallice, T., Marzocchi, G. M., Coser, S., Del Savio, M., Meuter, R. F., & Rumiati, R. I. (2002). Executive Function Profile of Children With Attention Deficit Hyperactivity Disorder. *Developmental Neuropsychology*, *21*(1), 43–71. https://doi.org/10.1207/S15326942DN2101_3

Shaul, S., & Schwartz, M. (2014). The role of the executive functions in school readiness among preschool-age children. *Reading and Writing*, *27*(4), 749-768. https://doi.org/10.1007/s11145-013-9470-3.

Sherman, V., Martino, R., Bhathal, I., DeVeber, G., Dlamini, N., MacGregor, D., ... & Moharir, M. (2021). Swallowing, Oral Motor, Motor Speech, and Language Impairments Following Acute Pediatric Ischemic Stroke. *Stroke*, *52*(4), 1309-1318. https://doi.org/10.1161/STROKEAHA.120.031893

Shipstead, Z., Redick, T. S., & Engle, R. W. (2012). Is working memory training effective? *Psychological Bulletin*, *138*(4), 628–654. https://doi.org/10.1037/a0027473

Shrout, P. E., & Bolger, N. (2002). Mediation in experimental and nonexperimental studies: new procedures and recommendations. *Psychological methods*, *7*(4), 422. https://doi.org/10.1037/1082-989X.7.4.422

Siegler, R.S., & Pyke, A.A. (2013). Developmental and Individual Differences in Understanding of Fractions. *Developmental Psychology*, *49*(10): 1994. https://doi.org/10.1037/a0031200

Sjö, N. M., Spellerberg, S., Weidner, S., & Kihlgren, M. (2010). Training of attention and memory deficits in children with acquired brain injury. *Acta paediatrica*, *99*(2), 230-236. https://doi.org/10.1111/j.1651-2227.2009.01587.x

Slomine, B., & Locascio, G. (2009). Cognitive rehabilitation for children with acquired brain injury. *Developmental Disabilities Research Reviews*, *15*(2), 133-143. https://doi.org/10.1002/ddrr.56

Smid, C. R., Karbach, J., &Steinbeis, N. (2020). Toward a science of effective cognitive training. *Current Directions in Psychological Science*, 29, 1–7. https://doi.org/10.1177/0963721420951599

Smithers, L. G., Sawyer, A. C. P., Chittleborough, C. R., Davies, N., Smith, G. D., and Lynch, J. (2018). A systematic review and meta-analysis of effects of early life non-cognitive skills on academic, psychosocial, cognitive and health outcomes. *Nature Human Behaviour*, 2, 867–880. https://doi.org/10.1038/s41562-018-0461-x

Sølsnes, A. E., Skranes, J., Brubakk, A.-M., & Løhaugen, G. C. C. (2014). Executive functions in very-low-birth-weight young adults: A comparison between self-report and neuropsychological test results. *Journal of the International Neuropsychological Society*, *20*(5), 506–515. https://doi.org/10.1017/S1355617714000332

Sonuga-Barke, E. J., Cortese, S., Fairchild, G., & Stringaris, A. (2016). Annual Research Review: Transdiagnostic neuroscience of child and adolescent mental disorders–differentiating decision making in attention-deficit/hyperactivity disorder, conduct disorder, depression, and anxiety. *Journal of Child Psychology and Psychiatry*, *57*(3), 321-349. https://doi.org/10.1111/jcpp.12496

St. Clair-Thompson, H.L., & Gathercole, S.E. (2006). Executive Functions and Achievements in School: Shifting, Updating, Inhibition, and Working Memory. *Quarterly Journal of Experimental Psychology*, *59*(4): 745-759. https://doi.org/10.1080/17470210500162854

Stevens, W. D., & Spreng, R. N. (2014). Resting state functional connectivity MRI reveals active processes central to cognition. *Wiley Interdisciplinary Reviews: Cognitive Science*, *5*(2), 233-245. https://doi.org/10.1002/wcs.1275

Stipek, D. (2006). Accountability comes to preschool: Can we make it work for young children?. *Phi Delta Kappan*, *87*(10), 740-744. https://doi.org/10.1177/003172170608701007

Stipek, D., Newton, S., & Chudgar, A. (2010). Learning-related behaviors and literacy achievement in elementary school-aged children. *Early Childhood Research Quarterly*, *25*(3), 385-395. https://doi.org/10.1016/j.ecresq.2009.12.001

*Studer, M., Boltshauser, E., Mori, A. C., Datta, A., Fluss, J., Mercati, D., ... & Ramelli, G. P. (2014). Factors affecting cognitive outcome in early pediatric stroke. *Neurology*, *82*(9), 784-792. https://doi.org/10.1212/WNL.0000000000000162

Stuss, D. T. (2011). Functions of the frontal lobes: relation to executive functions. *Journal of the international neuropsychological Society*, *17*(5), 759-765. https://doi.org/10.1017/S1355617711000695

Sung, J., & Wickrama, K. A. S. (2018). Longitudinal relationship between early academic achievement and executive function: Mediating role of approaches to learning. Contemporary Educational Psychology, 54, 171–183. https://doi.org/10.1016/j.cedpsych. 2018.06.010

Swanson, H. L., & Jerman, O. (2007). The influence of working memory on reading growth in subgroups of children with reading disabilities. *Journal of experimental child psychology*, *96*(4), 249-283. https://doi.org/10.1016/j.jecp.2006.12.004

Sweetser, P. & Wyeth, P. (2005). GameFlow: a model for evaluating player enjoyment in games. *Computers in Entertainment. 3*(3). https://doi.org/10.1145/1077246.1077253

Tavares, J. V. T., Clark, L., Cannon, D. M., Erickson, K., Drevets, W. C., & Sahakian, B. J. (2007). Distinct profiles of neurocognitive function in unmedicated unipolar depression and bipolar II depression. *Biological psychiatry*, *62*(8), 917-924. https://doi.org/10.1016/j.biopsych.2007.05.034

Teuber, H. L. (1972). Unity and diversity of frontal lobe functions. *Acta Neurobiologiae Experimentalis*, 32, 615-656.

Thorell, L. B., Lindqvist, S., Bergman Nutley, S., Bohlin, G., & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental science, 12*(1), 106–113. https://doi.org/10.1111/j.1467-7687.2008.00745.x

Toffalini, E., Giofrè, D., & Cornoldi, C. (2017). Strengths and weaknesses in the intellectual profile of different subtypes of specific learning disorder: A study on 1,049 diagnosed children. *Clinical Psychological Science*, *5*(2), 402–409. https://doi.org/10.1177/2167702616672038

Toplak, M. E., West, R. F., & Stanovich, K. E. (2013). Practitioner review: Do performance-based measures and ratings of executive function assess the same construct?. *Journal of child psychology and psychiatry*, *54*(2), 131-143. https://doi.org/10.1111/jcpp.12001

Tranel, D., & Eslinger, P. J. (2000). Effects of early onset brain injury on the development of cognition and behavior: Introduction to the special issue. *Developmental neuropsychology, 18*(3), 273-280. https://doi.org/10.1207/S1532694201Tranel

Tranel, D., Anderson, S. W., & Benton, A. (1994). Development of the concept of "executive function" and its relationship to the frontal lobes. In F. Boller & J. Grafman (Eds.), Handbook of Neuropsychology (Vol. 9, pp. 125-148). Amsterdam: Elsevier.

Traverso, L., Viterbori, P., & Usai, M. C. (2019). Effectiveness of an executive function training in Italian preschool educational services and far transfer effects to pre-academic skills. *Frontiers in psychology*, *10*, 2053. https://doi.org/10.3389/fpsyg.2019.02053

Usai, M. C., Viterbori, P., Traverso, L., & De Franchis, V. (2014). Latent structure of executive function in five-and six-year-old children: A longitudinal study. *European Journal of Developmental Psychology*, *11*(4), 447-462. https://doi.org/10.1080/17405629.2013.840578

Van Aken, L., Kessels, R. P., Wingbermühle, E., Van Der Veld, W. M., & Egger, J. I. (2016). Fluid intelligence and executive functioning more alike than different?. *Acta neuropsychiatrica*, *28*(1), 31–37. https://doi.org/10.1017/neu.2015.46

Van Der Werf, Y. D., Jolles, J., Witter, M. P., & Uylings, H. B. (2003). Contributions of thalamic nuclei to declarative memory functioning. *Cortex*, *39*(4-5), 1047-1062. https://doi.org/10.1016/S0010-9452(08)70877-3

Verhelst, H., Vander Linden, C., Vingerhoets, G., & Caeyenberghs, K. (2017). How to train an injured brain? A pilot feasibility study of home-based computerized cognitive training. *Games for Health Journal*, *6*(1), 28-38. https://doi.org/10.1089/g4h.2016.0043

Vitaro, F., Barker, E. D., Brendgen, M., & Tremblay, R. E. (2012). Pathways explaining the reduction of adult criminal behaviour by a randomized preventive intervention for disruptive kindergarten children. *Journal of Child Psychology and Psychiatry*, *53*(7), 748-756. https://doi.org/10.1111/j.1469-7610.2011.02517.x

Viterbori, P., Traverso, L., & Usai, M. C. (2017). The role of executive function in arithmetic problem-solving processes: A study of third graders. *Journal of cognition and Development*, *18*(5), 595-616. https://doi.org/10.1080/15248372.2017.1392307

Viterbori, P., Usai, M. C., Traverso, L., & De Franchis, V. (2015). How preschool executive functioning predicts several aspects of math achievement in Grades 1 and 3: A longitudinal study. *Journal of Experimental Child Psychology*, *140*, 38-55. https://doi.org/10.1016/j.jecp.2015.06.014

Volckaert, A. M. S., & Noël, M. P. (2015). Training executive function in preschoolers reduce externalizing behaviors. *Trends in Neuroscience and Education*, *4*(1-2), 37-47. https://doi.org/10.1016/j.tine.2015.02.001

Vu, T., Magis-Weinberg, L., Jansen, B.R.J. *et al.* Motivation-Achievement Cycles in Learning: a Literature Review and Research Agenda. *Educ Psychol Rev* (2021). https://doi.org/10.1007/s10648-021-09616-7

Vukovic, R. K., Fuchs, L. S., Geary, D. C., Jordan, N. C., Gersten, R., & Siegler, R. S. (2014). Sources of individual differences in children's understanding of fractions. *Child development*, *85*(4), 1461-1476. https://doi.org/10.1111/cdev.12218

Waber, D. P., Gerber, E. B., Turcios, V. Y., Wagner, E. R., & Forbes, P. W. (2006). Executive functions and performance on high-stakes testing in children from urban schools. *Developmental Neuropsychology, 29,* 459–477. https://doi.org/10.1207/s15326942dn2903_5.

Wade, S. L., Walz, N. C., Carey, J. C., & Williams, K. M. (2008). Preliminary efficacy of a Web-based family problem-solving treatment program for adolescents with traumatic brain injury. *The Journal of head trauma rehabilitation*, *23*(6), 369-377. https://doi.org/10.1097/01.HTR.0000341432.67251.48

Wade, S. L., Walz, N. C., Carey, J., Williams, K. M., Cass, J., Herren, L., ... & Yeates, K. O. (2010). A randomized trial of teen online problem solving for improving executive function deficits following pediatric traumatic brain injury. *The Journal of head trauma rehabilitation*, *25*(6), 409-415. https://doi.org/ 10.1097/HTR.0b013e3181fb900d

Wang, C.-C., Alderman, B., Wu, C.-H., Chi, L., Chen, S.-R., Chu, I. H., et al. (2019). Effects of acute aerobic and resistance exercise on cognitive function and salivary cortisol responses. *J. Sport Exerc. Psychol*. 41, 73–81. https://doi.org/10.1123/jsep.2018-0244

Ward, L. M. (2013). The thalamus: gateway to the mind. *Wiley Interdisciplinary Reviews: Cognitive Science*, *4*(6), 609-622. https://doi.org/10.1002/wcs.1256

Wechsler, D. (2003). Wechsler intelligence scale for children–Fourth Edition (WISC-IV). San Antonio, TX: The Psychological Corporation.

Welsh, J. A., Nix, R. L., Blair, C., Bierman, K. L., & Nelson, K. E. (2010). The Development of Cognitive Skills and Gains in Academic School Readiness for Children from Low-Income Families. *Journal of educational psychology*, *102*(1), 43–53. https://doi.org/10.1037/a0016738

Welsh, M. C., & Pennington, B. F. (1988). Assessing frontal lobe functioning in children: Views from developmental psychology. *Developmental neuropsychology*, *4*(3), 199-230. https://doi.org/10.1080/87565648809540405

Welsh, M. C., Pennington, B. F., & Groisser, D. B. (1991). A normative-developmental study of executive function: A window on prefrontal function in children. *Developmental neuropsychology*, *7*(2), 131-149. https://doi.org/10.1080/87565649109540483

*Westmacott, R., Askalan, R., Macgregor, D., Anderson, P., & deVeber, G. (2010). Cognitive outcome following unilateral arterial ischaemic stroke in childhood: Effects of age at stroke and lesion location. *Developmental Medicine & Child Neurology*, *52*(4), 386–393. https://doi.org/10.1111/j.1469-8749.2009.03403.x

Westmacott, R., MacGregor, D., Askalan, R., & deVeber, G. (2009). Late emergence of cognitive deficits after unilateral neonatal stroke. *Stroke*, 40(6), 2012-2019. https://doi.org/10.1161/STROKEAHA.108.533976

*Westmacott, R., McDonald, K. P., deVeber, G., MacGregor, D., Moharir, M., Dlamini, N., … Williams, T. S. (2018). Neurocognitive outcomes in children with unilateral basal ganglia arterial ischemic stroke and secondary hemidystonia. *Child Neuropsychology*, *24*(7), 923–937. https://doi.org/10.1080/09297049.2017.1353073

*Westmacott, R., McDonald, K. P., Roberts, S. D., deVeber, G., MacGregor, D., Moharir, M., … Williams, T. S. (2018). Predictors of cognitive and academic outcome following childhood subcortical stroke. *Developmental Neuropsychology*, *43*(8), 708–728. https://doi.org/10.1080/87565641.2018.1522538

Wiebe, S. A., Espy, K. A., & Charak, D. (2008). Using confirmatory factor analysis to understand executive control in preschool children: I. Latent structure. *Developmental psychology*, *44*(2), 575. https://doi.org/10.1037/0012-1649.44.2.575

Wiebe, S. A., Sheffield, T., Nelson, J. M., Clark, C. A., Chevalier, N., & Espy, K. A. (2011). The structure of executive function in 3-year-olds. *Journal of experimental child psychology*, *108*(3), 436-452. https://doi.org/10.1016/j.jecp.2010.08.008

*Williams, T. S., Roberts, S. D., Coppens, A. M., Crosbie, J., Dlamini, N., & Westmacott, R. (2018). Secondary attention-deficit/hyperactivity disorder following perinatal and childhood stroke: impact on cognitive and academic outcomes. *Child Neuropsychology*, *24*(6), 763-783. https://doi.org/10.1080/09297049.2017.1333091

Willoughby, M. T., Blair, C. B., Wirth, R. J., & Greenberg, M. (2012). The measurement of executive function at age 5: psychometric properties and relationship to academic achievement. *Psychological assessment*, *24*(1), 226. https://doi.org/10.1037/a0025361

Willoughby, M., Holochwost, S. J., Blanton, Z. E., & Blair, C. B. (2014). Executive functions: Formative versus reflective measurement. *Measurement: Interdisciplinary Research & Perspectives*, *12*(3), 69-95. https://doi.org/10.1080/15366367.2014.929453

Wise, S. P., Murray, E. A., & Gerfen, C. R. (1996). The frontal cortex-basal ganglia system in primates. Critical Reviews in Neurobiology, 10, 317-356. https://doi.org/10.1615/CritRevNeurobiol.v10.i3-4.30

Xu, F., Han, Y., Sabbagh, M. A., Wang, T., Ren, X., & Li, C. (2013). Developmental differences in the structure of executive function in middle childhood and adolescence. *PloS one, 8*(10), e77770. https://doi.org/10.1371/journal.pone.0077770

Yakovlev, P.A., & Lecours, I.R. (1967). The myelogenetic cycles of regional maturation of the brain. In A. Minkowski (Ed.), *Regional development of the brain in early life* (pp. 3– 70). Oxford: Blackwell.

Zampolini, M., Todeschini, E., Bernabeu Guitart, M., Hermens, H., Ilsbroukx, S., Macellari, V., Magni, R., Rogante, M., Scattareggia Marchese, S., Vollenbroek, M., & Giacomozzi, C. (2008). Tele-rehabilitation: present and future. *Annali dell'Istituto superiore di sanita*, *44*(2), 125–134.

Zelazo, A. Carter, J. S. Reznick, & D. Frye (1997). Early development of executive function: A problem-solving framework. *Review of General Psychology.* https://doi.org/10.1037/1089-2680.1.2.198

Zelazo, P. D. (2020). Executive function and psychopathology: A neurodevelopmental perspective. *Annual Review of Clinical Psychology*, 16, 431-454. https://doi.org/10.1146/annurev-clinpsy-072319-024242

Zelazo, P. D., & Cunningham, W. A. (2007). Executive function: Mechanisms underlying emotion regulation. In J. Gross (Ed.), *Handbook of emotion regulation* (pp. 135–158). New York: Guilford Press.

Zelazo, P. D., Blair, C. B., & Willoughby, M. T. (2016). Executive Function: Implications for Education. NCER 2017-2000.*Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Research.*

Zelazo, P. D., Reznick, J. S., & Piñon, D. E. (1995). Response control and the execution of verbal rules. *Developmental Psychology*, *31*(3), 508. https://doi.org/10.1037/0012-1649.31.3.508

Zelazo, P.D., & Muller, U. (2002). Executive function in typical and atypical development. In U. Goswami (Ed.), *Handbook of childhood cognitive development* (445-469). Blackwell, Oxford.

Zenon, A., & Olivier, E. (2014). Contribution of the basal ganglia to spoken language: is speech production like the other motor skills. *Behav Brain Sci*, *37*(6), 576. https://doi.org/10.1017/S0140525X13004238

Zimmerman, B. J. (2008). Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. *American educational research journal*, *45*(1), 166-183. https://doi.org/10.3102/0002831207312909

Appendix

IL MONDO DEGLI ELLI

Un nuovo modello di intervento per il potenziamento delle funzioni esecutive

PREFAZIONE

Questo manuale presenta un nuovo modello di intervento cognitivo, inerente nello specifico le Funzioni Esecutive, un insieme di abilità cruciali per la regolazione del comportamento e più in generale per lo svolgimento di compiti complessi e finalizzati ad un obiettivo.

Negli ultimi anni si è assistito ad un crescente interesse verso il potenziamento di queste abilità, che si sono dimostrate predittive del successo scolastico e della qualità di vita in generale. Numerose sono le modalità di potenziamento che sono state proposte, tra cui quelli specifici, centrati su un aspetto specifico del funzionamento esecutivo, e quelli generali, pensati per potenziare le funzioni esecutive in modo globale. Nonostante le evidenze di efficacia, pochi sono i percorsi che mostrano una generalizzazione, ovvero un miglioramento non solo delle abilità allenate, ma anche degli ambiti ad esse associate, come gli apprendimenti o la qualità della relazione con i pari e gli insegnanti.

Il mondo degli elli offre un nuovo modello di intervento globale che oltre all'allenamento mirato alle FE, prevede una serie di attività integrative ecologiche volte a favorire la generalizzazione.

Il videogame "Il mondo degli Elli" è stato ideato nel contesto del progetto regionale POR-FESR EMILIA ROMAGNA 2018 COMPRENDO (COMponenti tecnologiche PeR l'inclusionE Nella Didattica e nella fOrmazione).

CAP 1: INTRODUZIONE

1.1 Il ruolo delle funzioni esecutive nel contesto scolastico

L'apprendimento rappresenta una sfida costante per gli studenti e un compito tutt'altro che semplice. Per affrontare con successo ed entusiasmo il percorso scolastico sono necessarie numerose competenze e abilità. La scuola è un ambiente complesso, che richiede ai bambini di regolare il proprio comportamento, le proprie emozioni, la propria attenzione e, ovviamente, di concentrarsi sugli apprendimenti. Rimanere seduti durante la spiegazione di un nuovo argomento è già di per sé un compito impegnativo, riuscirci senza farsi distrarre da ciò che accade nell'ambiente circostante può esserlo ancora di più. Molti sono i bambini che, soprattutto all'ingresso della scuola primaria, manifestano difficoltà di adattamento al contesto scolastico e non riescono a far fronte a tutte queste richieste. In questi casi, frustrazione e demotivazione possono scoraggiare l'alunno e avere conseguenze negative sia sulla sua esperienza scolastica, sia sull'immagine di sé. L'instaurarsi di questo circolo vizioso può deteriorare i rapporti con i compagni e i docenti incidendo significativamente sul futuro dello studente (Mischel, Shoda e Peake 1988; McClelland et al. 2013; Moffit et al., 2011).

Per aiutare gli alunni a costruire un'esperienza positiva e incoraggiante della propria vita scolastica, insieme a compagni e insegnanti, è quindi importante sviluppare le abilità che consentono di adattarsi con successo alle sfide che caratterizzano il percorso di apprendimento scolastico. Per questa ragione è fondamentale il lavoro di potenziamento delle funzioni esecutive (FE), ossia un insieme di processi cognitivi che entrano in gioco in tutte le situazioni nuove o complesse, in cui i comportamenti automatici o quelli precedentemente appresi non sono sufficienti a raggiungere l'obiettivo, ma è necessaria una regolazione attiva e consapevole del proprio comportamento.

Il percorso di potenziamento "Il mondo degli Elli" trae il proprio fondamento teorico dal modello elaborato da Miyake e collaboratori, il quale suddivide le funzioni esecutive in tre processi di base (Miyake e Friedman, 2012; Friedman e Miyake, 2017; Diamond, 2013): inibizione, memoria di lavoro e flessibilità cognitiva, alle quali si aggiungono in età più avanzata funzioni più complesse, come la pianificazione e il *problem solving*. L'inibizione si articola in due componenti, l'inibizione della risposta impulsiva e la gestione dell'interferenza. La prima si riferisce alla capacità di sopprimere comportamenti automatici e impulsivi quando questi non sono utili per il compito e il contesto in cui ci si trova; la seconda si riferisce invece alla capacità di non farsi distrarre da stimoli distraenti e non utili per il compito. La memoria di lavoro è responsabile del mantenimento e dell'elaborazione delle informazioni in memoria; la flessibilità riguarda la capacità di adattarsi a nuovi compiti in maniera rapida e flessibile e di osservare le situazioni da più punti di vista differenti, rendendo capace il bambino di modificare in modo funzionale il suo comportamento quando questo non produce i risultati richiesti o desiderati, senza perseverare nell'errore.

Queste abilità hanno un ruolo fondamentale nell'adattamento e nel successo scolastico: grazie ad esse, gli alunni riescono a rimanere seduti al proprio posto, stare attenti, ricordare le istruzioni dell'insegnante e ad adottare nuove prospettive durante i compiti (Zelazo, Blair e Willoughby 2017). I bambini che approdano alla scuola primaria con buone funzioni esecutive imparano più facilmente, hanno un miglior rendimento e dimostrano maggiore intraprendenza. Questo comporta una serie di effetti indiretti, come un maggiore interesse verso la scuola e una maggiore motivazione ad affrontare compiti sempre più difficili, creando così un circolo virtuoso di successi e motivazione ad apprendere Viceversa, i bambini che non dispongono di buone funzioni esecutive faticano a regolare il proprio comportamento e a mantenere l'attenzione per tutto il tempo richiesto. Sperimentano quindi maggiori insuccessi, che vanno a minare la motivazione ad apprendere e ad incrementare così le difficoltà. Anche le relazioni con i compagni e con le insegnanti risultano spesso compromesse in bambini con difficoltà di regolazione, in quanto ricevono spesso richiami negativi e faticano ad interagire in maniera adeguata con i compagni. Appare quindi sempre più evidente il ruolo di primo piano giocato dalle funzioni esecutive nell'esperienza scolastica del bambino.

Le ricerche in questo ambito mettono in evidenza come le funzioni esecutive risultino un fattore predittivo per la riuscita scolastica, la qualità della vita quotidiana dello studente e, più in generale, per i processi di apprendimento e adattamento che contraddistinguono l'intero arco di vita della persona (Mischel, Shoda e Peake, 1988; McClelland et al., 2013; Moffit et al., 2011; Zelazo, Blair e Willoughby, 2017). In particolare, buone abilità di memoria di lavoro, inibizione e flessibilità cognitiva rappresentano le fondamenta che permettono alla lettura, alla scrittura e alla matematica di evolversi. Fortunatamente, la scuola costituisce il contesto ideale per allenare le funzioni esecutive ed è un primo punto di osservazione per valutarne fragilità e potenzialità.

Per quanto riguarda la matematica, ad esempio, la memoria di lavoro riveste un ruolo centrale nella risoluzione dei problemi. Infatti, essa permette di selezionare le informazioni importanti e inibire quelle superflue (irrilevanti ai fini della risoluzione) e di aggiornare costantemente la domanda finale del problema per rivedere i propri piani e decidere come agire durante lo svolgimento del problema. Buone funzioni esecutive permettono inoltre di monitorare il processo di risoluzione del problema, individuare eventuali errori nell'esecuzione e correggerli al fine di arrivare alla corretta soluzione (Passolunghi e Siegel, 2001; Passolunghi, 2004; Swanson, Jerman e Zheng, 2008). Difficoltà di memoria di lavoro sono spesso associate a difficoltà e scarso rendimento in matematica, con ricadute negative sul vissuto emotivo degli studenti, fino a sviluppare una vera e propria ansia per la matematica. Il rischio è che lo studente ritiri ogni tipo di investimento nei confronti della materia e accetti il fallimento come inevitabile.

Fin qui si è parlato dell'importanza di potenziare le FE al fine di promuovere un migliore rendimento scolastico. Ma le FE rivestono un ruolo importante anche per quanto riguarda la regolazione delle emozioni e le relazioni sociali. Le FE permettono infatti non solo di regolare il comportamento in termini di mantenimento dell'attenzione e inibizione di comportamenti impulsivi, ma permettono di avere risposte emotive adeguate. Ad esempio, un bambino che non è in grado di auto-regolarsi, fatica a gestire la frustrazione che può scaturire dopo aver perso una gara, o la rabbia che si può provare per un litigio, o ancora la frustrazione che deriva da un compito difficile da risolvere. In tutte queste situazioni possono avere crisi di rabbia, sono difficili da calmare e possono diventare aggressivi. Questo incide negativamente soprattutto sulla relazione con i compagni, che tendono ad isolarlo proprio per via delle sue difficoltà.

Infine, il percorso qui presentato può avere anche un ruolo abilitativo\riabilitativo, in quanto le FE risultano compromesse in numerosi disturbi del neurosviluppo. Deficit delle FE sono infatti presenti in bambini con disturbo da deficit di attenzione/iperattività (ADHD), disturbi specifici dell'apprendimento (DSA), disabilità intellettive (DI), disturbo dello spettro autistico (ASD) e disturbi del linguaggio.

Le difficoltà di regolazione sono il principale sintomo dell'ADHD. I bambini che presentano questo disturbo hanno difficoltà a bloccare comportamenti impulsivi e inappropriati per il compito e faticano a mantenere l'attenzione per periodi di tempo prolungati in quanto facilmente distraibili da elementi distraenti della realtà. Diversamente, nel caso dei DSA il principale deficit riguarda la memoria di lavoro, con una conseguente difficoltà nell'automatizzazione dei processi di lettura e scrittura e una generale difficoltà a mantenere e rielaborare in memoria grandi quantità di informazioni. e difficoltà di organizzazione e pianificazione. Ancora, una compromissione delle abilità di inibizione e di flessibilità cognitiva è spesso presente nei bambini con disturbi dello spettro autistico e questo è, ad esempio, alla base della rigidità di pensiero e della difficoltà a modificare routine e a gestire i cambiamenti di programma.

I profili citati – e in generale tutta la categoria BES (Bisogni educativi speciali) – sono stati posti al centro di questo progetto di potenziamento. Per sostenere lo sviluppo delle funzioni esecutive di questi alunni sono state approntate misure specifiche sia sul piano cognitivo che su quello sociale.

Il programma di intervento "Il mondo degli Elli" promuove un approccio integrato e inclusivo, per mezzo del quale i bambini possono trarre giovamento dal potenziamento in un contesto ludico, finalizzato a favorire la socializzazione attraverso la cooperazione.

1.2 Il mondo degli Elli

Alla luce di quanto detto fino a qui, appare evidente l'importanza di uno strumento adeguato per potenziare le funzioni esecutive dei bambini. Uno strumento che possa dispiegarsi tra l'attività scolastica e quella domestica per favorire la generalizzazione di quanto appreso ai vari contesti di vita degli alunni, come misura preventiva e, allo stesso tempo, di promozione del benessere individuale.

Gamification

Il programma di potenziamento delle funzioni esecutive, "Il mondo degli Elli" si presenta come un videogame, ma è molto più che un semplice gioco. Alla base vi è l'idea della Gamification, ovvero l'utilizzo del gioco in contesti e per obiettivi non ludici. I percorsi di potenziamento, così come le attività didattiche, sono spesso mal digerite dagli alunni, soprattutto da quelli con più difficoltà che ne avrebbero invece più bisogno. Se un percorso di potenziamento è noioso, mal tollerato, questo sarà sicuramente poco efficace. Al contrario, i videogame sono molto apprezzati proprio per la loro capacità di divertire e motivare. L'idea alla base della Gamification è proprio quella di inserire all'interno di un contesto ludico e motivante delle attività che pur apparendo tali, sono appositamente pensate e strutturate per essere allenanti e generare un potenziamento cognitivo. Tutta le sfide che il bambino si trova ad affrontare, pur essendo divertenti e proposte sotto forma di gioco, sono in realtà attività scelte in quanto altamente richiestive in termini di funzionamento esecutivo, proprio allo scopo di allenare il bambino in queste abilità. Il risultato è che il bambino si allena senza quasi rendersene conto e soprattutto divertendosi, con effetti positivi sulla motivazione e sull'aderenza al percorso.

Generalizzazione e metacognizione: il ruolo dell'insegnante

Quando si propone un percorso di promozione e potenziamento delle abilità cognitive, il risultato che si deve raggiungere è quello di ottenere un miglioramento non solo nelle attività proposte all'interno del percorso, ma anche e soprattutto un miglioramento nelle situazioni di vita quotidiana, che sia osservabile da genitori ed insegnanti. In questo senso, se ad esempio un'attività del percorso richiede di tenere a mente e ripetere in ordine inverso un certo numero di parole, ci aspettiamo che ripetendo nel tempo questa attività il bambino riesca man mano a ricordare correttamente un numero sempre maggiore di parole. Se poi, questo miglioramento si riflette anche in altri compiti non direttamente allenati, come ad esempio la risoluzione di compiti matematici o il fare la spesa (in cui la memoria è cruciale), allora si può parlare di generalizzazione.

Per favorire la generalizzazione, le attività proposte nel videogioco "il mondo degli Elli" devono sempre essere accompagnate da momenti di riflessione metacognitiva, ovvero di presentazione dei processi cognitivi che verranno allenati e di riflessione su di essi, sulla loro utilità e sui modi in cui si possono utilizzare al meglio. Per supportare gli insegnanti in queste attività di riflessione metacognitiva, il percorso è costellato da brevi contenuti video con esemplificazioni tratte dalla vita quotidiana circa il funzionamento di ogni funzione esecutiva da allenare. Inoltre, nella sezione successiva del manuale sono contenute delle domande e risposte guida che l'insegnante può utilizzare per guidare e sostenere la riflessione.

Sempre allo scopo di promuovere lo sviluppo delle funzioni esecutive e la generalizzazione dei miglioramenti alla vita quotidiana, il percorso prevede che le/gli insegnanti propongano durante l'orario scolastico e nelle modalità e nei tempi che preferiscono, attività supplementari a quelle proposte nel videogioco. Tali attività, descritte nella sezione successiva del manuale, consistono in attività carta-matita, attività motorie e giochi e attività scolastiche che richiedono l'utilizzo di una o più funzioni esecutive, e che quindi ne promuovono lo sviluppo.

Compito delle/gli insegnanti è quindi quello di guidare i bambini lungo tutto il percorso, favorendo la riflessione sulle abilità che vengono allenate tramite il gioco e sulla loro utilità nella vita di tutti i giorni. In questo senso, il ruolo delle insegnanti è quello di favorire la consapevolezza metacognitiva, ovvero la conoscenza circa la natura e il funzionamento dei processi mentali. Avere un'adeguata conoscenza metacognitiva delle funzioni esecutive permette infatti di comprendere a cosa servono e come possono essere utilizzate, inoltre favorisce la messa in atto di comportamenti adeguati e il monitoraggio del proprio comportamento. Riconoscere che alla base di tutti i nostri comportamenti complessi vi siano abilità di inibizione, mantenimento in memoria delle informazioni rilevanti e la capacità di modificare flessibilmente il proprio comportamento e il proprio punto di vista è un primo passo fondamentale per poter migliorare queste abilità. Il compito del docente è quello di stimolare gli alunni affinché riconoscano nell'attività videoludica e ludica le funzioni esecutive e rinforzare la generalizzazione.

La cornice narrativa

Il mondo degli Elli è un programma di potenziamento delle funzioni esecutive che utilizza il videogame in combinazione con attività di gioco, nel contesto del gruppo-classe, ed è corredato da momenti di riflessione metacognitiva. Durante l'attività videoludica, il bambino assume il controllo del piccolo Ello, il protagonista, un giovane cervellino con scarse funzioni esecutive, pronto a vivere nuove sfide nel mondo degli Elli per allenare le proprie abilità. Il tutto avviene sotto lo sguardo di Big Ello, un saggio cervello che si prepara a guidare il giovane Ello nella sua avventura.

Compito del giocatore è aiutare Ello ad esplorare il mondo degli Elli, uno scenario urbano, simile a una città, fino a raggiungere le stanze scrigno, ovvero i luoghi dove sono contenute le attività per il potenziamento delle funzioni esecutive. La città da esplorare è suddivisa in quartieri, uno per ogni funzione esecutiva da allenare, che si sbloccano e divengono esplorabili via via che il giocatore supera le diverse sfide. Il gioco inizia in un quartiere di allenamento in cui i bambini familiarizzano con le modalità di esplorazione dei quartieri e prosegue con i quartieri delle diverse funzioni esecutive (inibizione della risposta, memoria di lavoro, flessibilità cognitiva).

Il coding

Lo spostamento all'interno della città e dei suoi quartieri avviene attraverso attività di coding, che promuovono l'abilità di pianificazione e di risoluzione di problemi. Il bambino infatti, per potersi muovere e raggiungere l'obiettivo, dovrà pianificare gli spostamenti da fare, capire di quante caselle spostarsi e quali frecce utilizzare. Solo alla fine, premendo il via, si potrà spostarsi e verificare di aver pianificato correttamente . Lo scopo è quello di superare un certo numero di percorsi con l'uso del coding per arrivare a raggiungere la "Stanza Scrigno" e iniziare così le attività di allenamento.

I quartieri e le stanze scrigno

Sono previste due stanze scrigno per ogni funzione esecutiva da allenare (memoria di lavoro, inibizione, gestione dell'interferenza, flessibilità cognitiva), che contengono rispettivamente attività in formato uditivo-verbale e visuospaziale.

L'allenamento nelle stanze scrigno è individuale e avviene per la maggior parte nelle 3 sessioni settimanali da svolgere a casa (si veda capitolo successivo). Il bambino si mette alla prova e – in base alle proprie capacità - affronta i livelli in solitaria, per migliorare le proprie capacità nella funzione esecutiva corrispondente.

All'ingresso di ogni nuovo quartiere (ad ogni nuova funzione esecutiva da allenare) è previsto un video in cui Big Ello illustra al giocatore la funzione che si apprestano ad allenare tramite esempi e riferimenti alla sua utilità a scuola e nella vita quotidiana. Conclusa la visione del video, l'insegnante dovrà promuovere un momento di riflessione metacognitiva tra gli studenti.

Conclusi gli esercizi presenti nelle stanze scrigno, verrà vinto un gadget – specifico per ogni funzione esecutiva – utile per rispondere a un quiz relativo all'uso delle funzioni esecutive nella vita quotidiana
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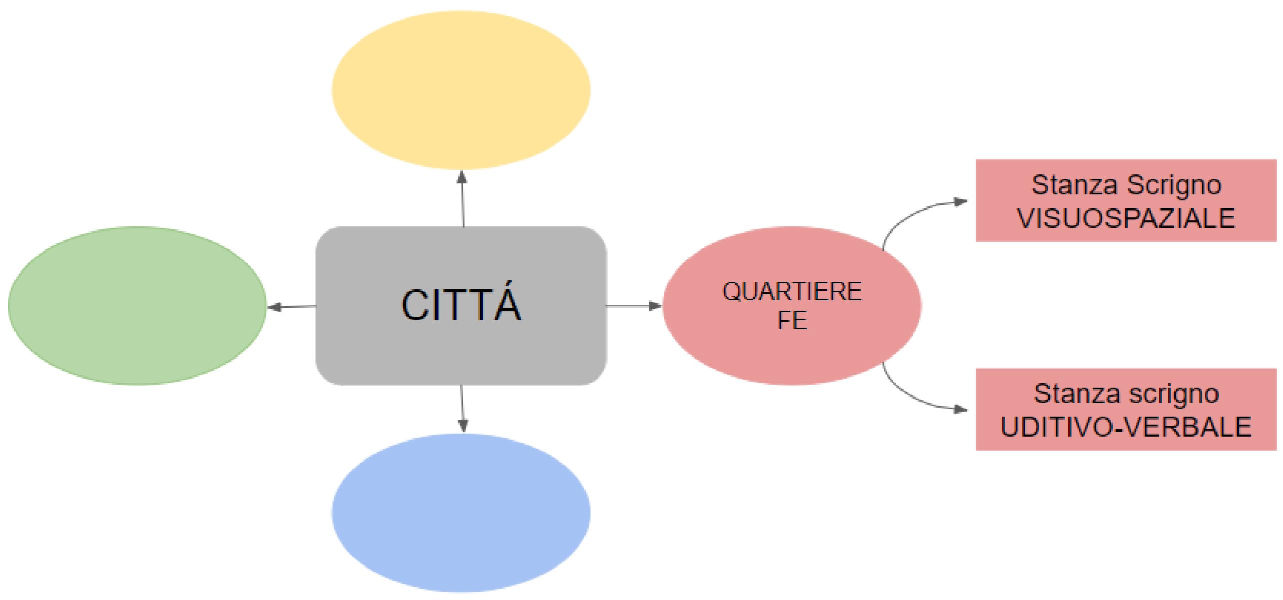


Difficoltà incrementale

Le attività di coding, così come quelle all'interno delle stanze scrigno, aumentano di complessità via via che il bambino si allena. Per quanto riguarda il coding, i percorsi da pianificare divengono via via più complessi, più lunghi e con più curve. Le attività delle stanze scrigno sono strutturate in tre livelli di difficoltà crescente, più un livello base che chiameremo livello 0, funzionale all'allenamento, specie per i bambini che mostrano maggiori difficoltà in una specifica funzione. Il livello zero è stato realizzato per offrire ai bambini più piccoli, o con difficoltà, un punto di partenza facilitato in cui mettersi alla prova e cominciare a familiarizzare con le richieste del compito presentato nella stanza scrigno. Il livello è attivabile manualmente da parte dell'insegnante attraverso la piattaforma di monitoraggio. È consigliato avvalersi del livello zero quando i bambini dimostrano di essere in difficoltà nel compito oppure hanno specifiche disabilità che compromettono la prestazione nei livelli più avanzati. In questo modo, il percorso si adatta naturalmente anche ai bambini con condizioni psicopatologiche o in difficoltà, permettendogli di giocare con gli altri e contribuendo alle sessioni di squadre affrontando sfide di difficoltà adeguata. Il docente curatore del progetto e l'insegnante di sostegno possono coordinarsi per costruire e definire il percorso e gli obiettivi per ogni bambino.

La presenza di diversi livelli di difficoltà permette ad ogni bambino di allenarsi con attività che risultino adeguate alle sue personali caratteristiche, senza essere né troppo facili né troppo difficili. Infatti, per procedere nel gioco non è necessario superare per forza il livello di gioco più difficile, in quanto gli insegnanti possono decidere quale livello deve essere raggiunto dal bambino per poter avanzare nel gioco.

Attività integrative

In affiancamento alle attività proposte dal videogame, il percorso prevede diverse tipologie di attività integrative volte a favorire il successo del percorso ed il trasferimento dei miglioramenti ottenuti al contesto di vita quotidiano. Per ognuna di queste, la parte operativa del manuale fornisce diversi esempi. Queste attività, descritte nel dettaglio di seguito, possono essere proposte all'interno delle sessioni in classe, ma sono pensate soprattutto per un utilizzo separato dalla sessione stessa. L'insegnante potrà quindi scegliere i momenti più opportuni nel corso delle settimane.

Attività di potenziamento per bambini con difficoltà

Si tratta di attività carta-matita sono pensate per quei bambini che necessitano di maggiore supporto, per i quali l'utilizzo del videogioco potrebbe essere non funzionale o non sufficiente. Alcuni bambini potrebbero infatti trovarsi in difficoltà di fronte alle sfide proposte nel videogame. Le attività di potenziamento, da proporre in maniera individuale a singoli alunni o a piccoli gruppi, vogliono essere attività semplificate che insegnanti di classe, di sostegno o educatori potranno utilizzare al fine di favorire l'adattabilità del percorso ad ogni bambino. Inoltre, queste attività forniscono uno spunto di partenza per la riflessione metacognitiva (es. quanto ti è sembrata difficile l'attività? come mai? quale strategia hai usato?).

Attività ludiche

Oltre alle attività di potenziamento, anche le attività ludiche possono essere sfruttate per il potenziamento delle capacità di regolazione. Come già detto, sfruttare il gioco permette di favorire l'acquisizione di competenze in un contesto stimolante e motivante. Le attività ludiche proposte dal manuale possono essere usate sia durante le ore di didattica, sia nei momenti di ricreazione o durante l'ora di educazione fisica. Risultano particolarmente fruibili in quanto questo genere di proposte richiede poche risorse e tutte solitamente già disponibili a scuola (cancelleria e giochi), trasformandole in attività di potenziamento per supportare l'allenamento svolto con il videogioco del mondo degli Elli.

Attività ponte con la didattica

Le attività ponte con la didattica sono attività pensate per il potenziamento delle funzioni esecutive attraverso attività già tipicamente presenti nei programmi curriculari e nella didattica. Infatti, spesso non si è consapevoli di quanto le attività didattiche che proponiamo ai bambini, se strutturate in modo corretto, possono essere un utile supporto allo sviluppo delle capacità di regolazione. Queste attività si possono definire ecologiche in quanto pensate per essere inserite nel contesto di vita del bambino e richiamare situazioni di vita reale. In questo modo si aiuta il bambino a comprendere l'utilità pratica delle funzioni allenate, favorendo la generalizzazione dei miglioramenti ottenuti con il videogame anche appunto nella vita di tutti i giorni.

La dimensione sociale

"Il mondo degli Elli" non vuole essere un percorso di allenamento individuale, dove ognuno lavora per sé. Né tantomeno vuole essere un gioco competitivo, dove chi è più bravo ottiene più punti e vince a discapito degli altri. Al contrario si vuole favorire il più possibile la socializzazione e la cooperazione durante l'esecuzione del percorso.

Questo viene promosso attraverso:

- Attività metacognitive: la riflessione è intesa di gruppo, ogni bambino deve essere incentivato a offrire il suo punto di vista, a descrivere esperienze personali e a trovare insieme ai compagni strategie per migliorare e per aiutare i compagni a migliorare.
- Attività ecologiche: le attività ecologiche sono in parte di gruppo, e favoriscono così socializzazione e collaborazione.

Durante tutto il percorso poi, socialità e cooperazione possono essere promossi affiancando i bambini più capaci a quelli con maggiori difficoltà, stimolando cooperazione e prosocialità.

Per concludere

"Il mondo degli Elli" costituisce una proposta facilmente integrabile nel programma scolastico, grazie alla sua versatilità e alla pluralità di *media* di cui si avvale. Attraverso le attività videoludiche e ludiche, i bambini potranno esercitarsi nel potenziamento delle funzioni esecutive per mezzo di attività improntate alla collaborazione anziché alla competizione, sia in gruppo che da soli, sia a scuola che a casa. Le attività proposte si inseriscono in un percorso di lunga durata, che permette agli studenti di mettersi alla prova e sperimentare i propri successi in un arco di tempo significativo, apprezzando così il consolidarsi graduale dei propri miglioramenti e guadagnando fiducia in se stessi e nelle proprie capacità. Grazie ai livelli, ogni attività costituisce sempre una sfida adeguata per il giocatore, senza mai essere troppo facili o troppo difficili: infatti, si avanza con i livelli solo dopo aver avuto successo nel precedente; un livello zero, equiparabile a un livello tutorial, può inoltre essere proposto come punto di partenza ai bambini con maggiori difficoltà.

CAP 2 GUIDA PRATICA PER L’INSEGNANTE

<table>
<tr><th colspan="2">INTRODUZIONE</th></tr>
<tr><td>In classe
1h</td><td>Presentazione del percorso alla classe
Visione del video introduttivo
Riflessione metacognitiva sull’utilizzo delle FE a scuola e nella vita quotidiana</td></tr>
<tr><td></td><td>-</td></tr>
<tr><th colspan="2">SESSIONE1
IL CODING</th></tr>
<tr><td>In classe
1h</td><td>Presentazione della città degli Elli
Attività di coding cartacee\motorie
Attività di coding tramite app</td></tr>
<tr><td>A casa
3x20 min</td><td>Allenamento quartiere introduttivo</td></tr>
<tr><td>In classe
Momenti
a scelta</td><td>Attività integrative: Potenziamento per bambini con difficoltà
Ludiche
Ponte con la didattica</td></tr>
<tr><th colspan="2">SESSIONE2
Gestione interferenza</th></tr>
<tr><td>A scuola
1h</td><td>Sblocco nuovo quartiere
Visione video
Riflessione metacognitiva
Attività di esempio tramite app</td></tr>
<tr><td>A casa
3x20 min</td><td>Allenamento quartiere</td></tr>
<tr><td>In classe
Momenti
a scelta</td><td>Attività integrative: Potenziamento per bambini con difficoltà
Ludiche
Ponte con la didattica</td></tr>
<tr><th colspan="2">SESSIONE 3
Gestione interferenza</th></tr>
<tr><td>A scuola
1h</td><td>Riepilogo avanzamenti fatti
Riflessione metacognitiva
Attività di esempio tramite app
Attività integrative</td></tr>
<tr><td>A casa
3x20 min</td><td>Allenamento quartiere
Ottenimento gadget di fine quartiere</td></tr>
<tr><td>In classe
Momenti
a scelta</td><td>Attività integrative: Potenziamento per bambini con difficoltà
Ludiche
Ponte con la didattica</td></tr>
<tr><th colspan="2">SESSIONE 4
Inibizione della risposta</th></tr>
<tr><td>A scuola
1h</td><td>Sblocco nuovo quartiere
Visione video
Riflessione metacognitiva
Attività di esempio tramite app</td></tr>
</table>

A casa 3x20 min	Allenamento quartiere
In classe Momenti a scelta	Attività integrative: Potenziamento per bambini con difficoltà Ludiche Ponte con la didattica
SESSIONE 5 **Inibizione della risposta**	
A scuola 1h	Riepilogo avanzamenti fatti Riflessione metacognitiva Attività di esempio tramite app Attività integrative
A casa 3x20 min	Allenamento quartiere Ottenimento gadget di fine quartiere
In classe Momenti a scelta	Attività integrative: Potenziamento per bambini con difficoltà Ludiche Ponte con la didattica
SESSIONE 6 **Memoria di lavoro**	
A scuola 1h	Sblocco nuovo quartiere Visione video Riflessione metacognitiva Attività di esempio tramite app
A casa 3x20 min	Allenamento quartiere
In classe Momenti a scelta	Attività integrative: Potenziamento per bambini con difficoltà Ludiche Ponte con la didattica
SESSIONE 7 **Memoria di lavoro**	
A scuola 1h	Riepilogo avanzamenti fatti Riflessione metacognitiva Attività di esempio tramite app Attività integrative
A casa 3x20 min	Allenamento quartiere Ottenimento gadget di fine quartiere
In classe Momenti a scelta	Attività integrative: Potenziamento per bambini con difficoltà Ludiche Ponte con la didattica
SESSIONE 8 **Flessibilità cognitiva**	
A scuola 1h	Sblocco nuovo quartiere Visione video Riflessione metacognitiva Attività di esempio tramite app
A casa 3x20 min	Allenamento quartiere
In classe Momenti a scelta	Attività integrative: Potenziamento per bambini con difficoltà Ludiche Ponte con la didattica
SESSIONE 9	

Flessibilità cognitiva	
A scuola 1h	Riepilogo avanzamenti fatti Riflessione metacognitiva Attività di esempio tramite app Attività integrative
A casa 3x20 min	Allenamento quartiere Ottenimento gadget di fine quartiere
In classe Momenti a scelta	Attività integrative: Potenziamento per bambini con difficoltà Ludiche Ponte con la didattica
CONCLUSIONE	
A scuola 1h	Riepilogo avanzamenti fatti Riflessione metacognitiva Riepilogo e chiusura del percorso

2.1. Modi e tempi del percorso

Come riassunto in tabella il percorso alterna momenti di attività a scuola a momenti di allenamento a casa. L’introduzione generale al percorso, così come l’introduzione ad ogni funzione esecutiva (quartiere) e la riflessione metacognitiva sulla funzione di ognuna di esse sono svolte a scuola e coinvolgono tutto il gruppo classe. A casa invece viene svolto l’allenamento attraverso le attività contenute nella stanza scrigno, alternate ad attività di coding. Per questa ragione è possibile e del tutto normale che i giocatori raggiungano livelli diversi nel corso dell’attività: qualcuno completerà prima la stanza scrigno e qualcun altro impiegherà più tempo. In aggiunta a questi due momenti (sessione a scuola e sessione a casa) ogni settimana il percorso dovrà essere integrato con le apposite attività proposte dal manuale.

La durata delle sessioni in classe deve essere di un’ora, per garantire il giusto spazio alle diverse fasi della sessione: presentazione del percorso, riepilogo di quanto fatto fino a quel momento, presentazione della nuova attività, riflessione metacognitiva e inizio dell’allenamento.

E’ prevedibile che non sempre la scuola disponga di un computer per ogni bambino. In questi casi, si consiglia di lavorare in classe solo attraverso il profilo dell’insegnante per mostrare i video e superare alcuni livelli di prova insieme ai bambini. Si lasci invece che i bambini utilizzino il proprio profilo individuale solo a casa. In questo modo si evita che alcuni bambini inizino la sessione a scuola ed altri no. L'insegnante è comunque libera di trovare altre modalità, come per esempio la suddivisione in piccolo gruppo e l’esecuzione delle attività in momenti differenti, ma qualunque modalità scelta deve garantire che l’eventuale avanzamento avuto a scuola sia uguale per ogni bambino.

L’allenamento per ogni funzione esecutiva ha la durata complessiva di 2 settimane. Nel corso delle due settimane di allenamento, l’insegnante può (e deve) integrare l’allenamento che i bambini svolgono a casa tramite il videogioco con le attività integrative descritte in questo manuale. Si tratta di attività carta-matita, attività scolastiche o giochi e attività motorie, pensate per allenare le diverse funzioni esecutive. L'utilizzo di queste attività garantisce una migliore efficacia del percorso e favorisce la generalizzazione dei risultati al contesto di vita quotidiano.

2.2 Le sessioni di allenamento a casa

Il percorso richiede che i bambini si allenino a casa tre volte a settimana per circa 20 minuti a sessione. Sarà BigEllo, al termine dell'ultima sfida, a segnalare la fine della sessione invitando il bambino a chiudere il browser.

Al primo accesso verrà chiesto al bambino di personalizzare il proprio Ello per poi dare il via al gioco nel quartiere introduttivo di coding. Il primo quartiere, avendo il solo scopo di permettere al bambino di familiarizzare con il videogioco e con le modalità di navigazione in esso, ha la durata di una settimana. Tutti gli altri quartieri invece hanno una durata di due settimane, per cui il bambino si allenerà 6 volte per ogni funzione esecutiva.

Il passaggio da un quartiere ad un altro avviene in maniera automatica e indipendente dal numero di sessioni svolte dal bambino. Questo vuol dire che a partire dal primo accesso, il bambino si troverà per 7 giorni nel quartiere introduttivo ogni volta che farà un accesso. A partire dall'ottavo giorno si troverà invece nel quartiere di gestione dell'interferenza, dove rimarrà per 14 giorni. A partire dal 15° giorno si troverà nel quartiere dell'inibizione della risposta, dove rimarrà per altri 14 giorni, e così via per i quartieri successivi.

2.3 Le attività integrative

In aggiunta alle 9 sessioni da svolgere in classe una volta a settimana, l'insegnante dovrà individuare i modi e i tempi per proporre alla classe le attività integrative. Per quanto riguarda le attività di potenziamento, queste possono essere svolte dal bambino insieme all'insegnante di sostegno o di potenziamento, individualmente o in piccolo gruppo. Le attività ludiche e quelle ponte per la didattica invece possono essere proposte in qualunque momento , sottolineando il loro collegamento con il percorso e l'abilità che con queste vogliamo allenare.

In aggiunta, tutte le attività integrative possono essere sfruttate nel corso di tutte le seconde sessioni riguardanti una certa FE, ovvero le sessioni 3,5,7 e 9.

2.3 Istruzioni di accesso e utilizzo

Docenti e studenti accedono con la propria credenziale e password dal sito internet http://mondoelli.anastasis.it/

Una volta effettuato l'accesso il gioco si avvia automaticamente.

Al termine della sessione, indicata dal personaggio guida big Ello, sarà sufficiente chiudere il browser.

2.4 Monitoraggio del percorso

I/le docenti avranno accesso ad una piattaforma per il monitoraggio del percorso di ogni alunno (xxx link). Le credenziali…xxx

La piattaforma permette di sapere a che punto del percorso si trova il bambino (in quale quartiere si sta allenando), quante sessioni sono state svolte, quale livello di difficoltà è stato raggiunto, oltre ad una serie di informazioni aggiuntive sulla prestazione e sui tempi di esecuzione. Questa appare molto utile per comprendere la risposta degli alunni al percorso e per intervenire nel caso emergessero delle difficoltà da parte di alcuni alunni. Inoltre, la piattaforma permette di spostare gli alunni da un quartiere ad un altro. Questo è particolarmente utile in quanto è fondamentale che l'allenamento dell'alunno prosegua di pari passo con le riflessioni metacognitive in classe e con i quartieri e le FE affrontate in classe. Qualora l'insegnante rilevasse che per qualche motivo un bambino si sta allenando in un quartiere diverso da quello affrontato in classe, deve quindi spostarlo nel quartiere corretto, indipendentemente dal numero di sessioni svolte.

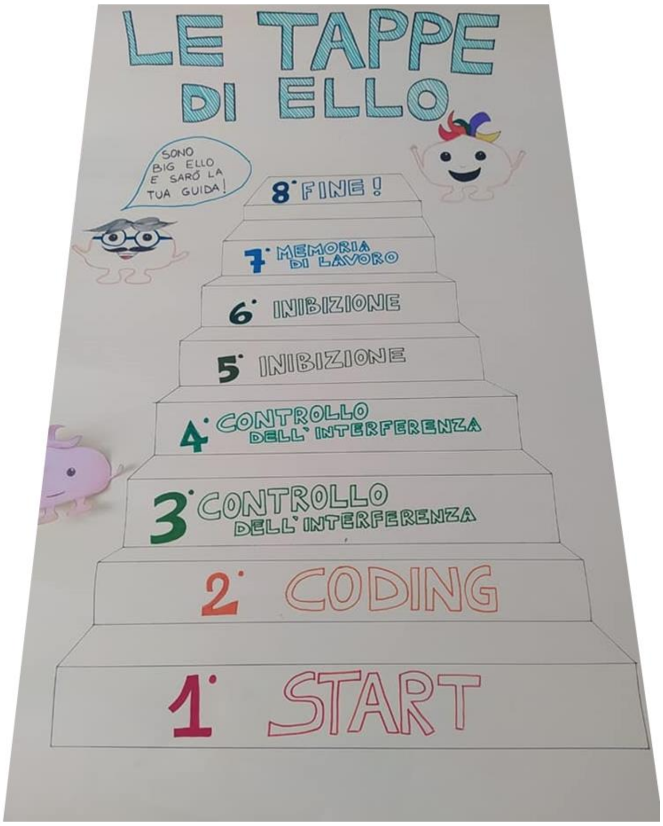
2.5 Strutturazione degli incontri

Per garantire il successo del percorso di potenziamento è importante assicurarsi che i bambini comprendano i contenuti e gli scopi del percorso. In particolare è importante che riescano a cogliere un filo conduttore che unisce i diversi incontri, e che questi siano ben connotati come facenti parte di un percorso di potenziamento che ha un suo inizio ed una fine e che segue una progressione logica.

Per fare questo è utile adottare questi due accorgimenti:

1. Preparare un cartellone dove siano indicati i diversi incontri del percorso, ed un piccolo Ello che si sposterà lungo il percorso incontro per incontro, indicando così in che quartiere si trovano i bambini. Inoltre questo aiuterà a ricordare quanto è già stato fatto e ad avere chiaro ciò che avverrà in futuro e quanto manca alla fine del percorso.
2. Adottare una struttura fissa per ogni incontro in classe: mantenere sempre la stessa struttura degli incontri facilita la comprensione del percorso e permette di associare l'incontro al percorso stesso. E' importante che ogni incontro in classe inizi con un chiaro riferimento al "mondo degli Elli" ed al potenziamento delle funzioni esecutive. Iniziare quindi con un riepilogo di quanto fatto fino a quel momento e, con l'utilizzo del cartellone, far avanzare Ello sull'incontro attuale. Solo dopo aver chiesto agli alunni cosa ricordano di quanto fatto fino a quel momento e averli aiutati a ricapitolare le abilità allenate, potremo passare alla parte

centrale dell’incontro in cui mostrare i video metacognitivi o riflettere sull’andamento delle sessioni di allenamento a casa (nel caso dei secondi incontri per quartiere). Infine, nella parte conclusiva, ricapitolare quanto fatto e invitare i bambini a proseguire l’allenamento a casa.



INTRODURRE IL PERCORSO ALLA CLASSE

Questa fase iniziale è di cruciale importanza, il docente ha il delicato compito di proporre ai suoi alunni il progetto promuovendo il gioco come un’attività interessante e capace di motivare i bambini. Contemporaneamente, bisogna che curi anche l’aspetto metacognitivo, attraverso una riflessione consapevole esplicativa rispetto al valore concreto delle attività che la classe si appresta ad intraprendere.

Nel video introduttivo , Big Ello, la guida del piccolo Ello, spiega al giocatore cosa sono le funzioni esecutive (inibizione, memoria di lavoro e flessibilità cognitiva) attraverso esempi e situazioni di vita quotidiana in cui queste entrano in gioco Il video si conclude con una serie di domande poste da Big Ello direttamente ai bambini.

A questo punto è importante che l'insegnante predisponga uno spazio di riflessione metacognitiva, per favorire la riflessione degli alunni rispetto alle occasioni quotidiane in cui emerge l’uso della funzione esecutiva discussa. A questo punto, attraverso il dialogo, i bambini si confrontano e discutono, estendono la propria conoscenza, individuano insieme esempi concreti. L’obiettivo è promuovere una maggiore consapevolezza sia delle caratteristiche della funzione esecutiva analizzata, sia dei propri punti di forza e debolezza rispetto ad essa. Questo lavoro è fondamentale per favorire una comprensione delle funzioni esecutive nella vita di tutti i giorni. Inoltre, favorisce e supporta i processi di generalizzazione dal videogioco alla quotidianità. L’insegnante può cogliere l’occasione per apprezzare i punti di vista personali dei suoi alunni e da essi può ricevere molte informazioni utili a calibrare il proprio intervento.

Un altro aspetto di cruciale importanza da affrontare in occasione di questo incontro è la struttura del videogioco e la modalità di allenamento. E’ necessario spiegare gli alunni che il videogioco che andranno ad utilizzare non è come quelli a cui potrebbero essere abituati, perché è fatto apposta per aiutarli ad allenarsi. Bisognerà quindi spiegare loro che allenarsi vuol dire ripetere tante volte un esercizio in modo da diventare via via sempre più bravi. Per questo motivo, il videogioco è strutturato in quartieri, ognuno….

Per iniziare

Ciao bambini! Oggi inizieremo una nuova avventura! Entreremo nel mondo degli Elli, un mondo dove vivono tanti giovani cervelli che hanno proprio la vostra età! Loro hanno bisogno del nostro aiuto, perchè sono dei grandi pasticcioni! Quando sono a scuola, non riescono a stare attenti, si distraggono, facilmente, si dimenticano le cose che dice la maestra…….spesso dimenticano i compiti o i materiali… e anche fuori scuola le cose non vanno molto meglio….sono stanchi di

fare pasticci e hanno deciso di allenarsi per diventare più bravi, li aiutiamo a superare tutte le sfide dell'allenamento??? *Ora vediamo un video, ci aiuterà a capire insieme che cosa alleneremo!* (visione del video e riflessione metacognitiva)

Riflessione metacognitiva

Comprensione	
Secondo voi, a cosa servono queste capacità? *A cosa serve non farsi distrarre, saper resistere agli impulsi e pensare prima di fare qualcosa o tenere a mente tante cose?*	*-Memoria di lavoro: per fare la spesa, per ricordarmi le cose da fare, per preparare lo zaino di scuola o sportivo senza dimenticare nulla, per ricordare tutti i passaggi per fare qualcosa (una ricetta, una mossa di karate, un ballo di danza…), ricordare gli impegni. E' vero che a volte la mamma o il papà ci aiutano, ma non sarebbe più bello riuscire a ricordarci le cose da soli?* *-Inibizione: stare seduto durante i pasti o al ristorante, non agitarsi e correre quando non si può, rispettare il turno quando si gioca, ascoltare e stare attenti senza distrarci quando mamma o papà ci parlano o quando siamo con il maestro di sport. controllare che il semaforo sia verde e non ci siano macchine prima di attraversare...etc….* *E' vero che sarebbe più bello poter correre al ristorante, è noioso stare fermi ad aspettare, però pensate a cosa succede se correndo inciampiamo sul cameriere facendogli cadere la pizza! sarebbe un bel guaio!*
Come le chiamereste?	*Sono state chiamate funzioni esecutive perchè sono abilità che ci servono per eseguire le azioni più complesse, per decidere cosa dobbiamo fare e quali passaggi dobbiamo fare per riuscirci. Sono abilità che si possono allenare.*
Secondo te a cosa ti serve a scuola?	*-Memoria di lavoro: nei compiti di matematica (es: ricordare tutti i passaggi di un problema, di una operazione, fare calcoli a mente); nei compiti di lettura di testi (devo ricordare quello che ho letto prima e aggiornare l'idea che mi faccio di un personaggio via via che vado avanti); per avere sempre tutti i materiali, libri quaderni che mi servono.* *- Inibizione: stare seduto anche se vorrei alzarmi e giocare, stare attento senza farmi distrarre da quello che succede attorno, fare quello che dice la maestra e non quello che vorrei fare io, alzare la mano prima di parlare, regolare le emozioni e gestire la rabbia\frustrazione senza "usare le mani"* *-Flessibilità: quando bisogna cambiare materia, quindi cambiare quaderno e materiali e smettere di pensare alla materia precedente; quando non riesco a risolvere il compito e devo cambiare strategia\procedura; in matematica, quando devo svolgere in modo alternato addizioni, operazioni e sottrazioni, cambiando quindi sempre procedura ad ogni operazione; quando devo capire il punto di vista di un mio*

	amico (es: penso che mi abbia rotto apposta il gioco, invece lo ha calpestato per sbaglio).
Valutazione	
La usi spesso?	*Partendo dagli esempi riportati dai bambini, aiutarli a capire se si sentono capaci o se in effetti gli capita spesso di non riuscire in alcune delle cose dette. Farli riflettere su cosa succede quando non riescono ad esempio a stare attenti, cosa pensano, e cosa succede e cosa pensa chi invece ci riesce.* *Riflettere su quanto sarebbe bello a volte fare cose senza usare le FE, e sulle conseguenze che però questo comporta*
Quanto è difficile per te utilizzarla?	
Perché?	
Riflessione	
Come potresti migliorare?	*Allenandosi e impegnandosi,usando degli aiuti (post it, per la memoria, clessidre che mi dicono quanto tempo stare concentrato e quando fare una pausa), contare fino a 3 prima di fare\dire qualcosa.* *Si può aiutare un compagno evitando di distrarlo, ricordandogli le cose, facendogli vedere come si fa….*
Come potresti aiutare un tuo compagno a migliorare nell'usare questa funzione esecutiva?	
Quali strategie potreste utilizzare?	
Generalizzazione	
Le strategie varrebbero sia a scuola che a casa?	*In parte sono le stesse….ma posso trovare strategie diverse a seconda di dove mi trovo*
Se la risposta è no, come potrebbero cambiare a seconda del contesto?	

Per concludere

Bravissimi bimbi! Abbiamo iniziato a capire insieme cosa sono le funzioni esecutive e come funzionano: come fare a stare attenti, essere flessibili e ricordare le cose importanti!
Adesso che abbiamo capito che cosa alleneremo, vi spiego come funzionerà: una volta a settimana vedremo insieme la sfida che Big Ello ci propone. Poi voi dovrete allenarvi a casa almeno 3 volte in una settimana. La settimana dopo ci alleneremo con una nuova sfida e così via fino a superarle tutte!
In più, in classe faremo molti giochi ed attività tutti assieme che ci aiuteranno a migliorare. La settimana prossima affronteremo la prima sfida!

SESSIONE 1
CODING

Dopo aver concluso la visione del video introduttivo sulle funzioni esecutive, la classe può dare il via al proprio percorso alla scoperta del mondo degli Elli. La prima attività richiede ai bambini di familiarizzare con le procedure di movimento all'interno della città in cui è ambientato il videogioco. Il movimento all'interno della città è possibile attraverso attività di coding: l'avatar del giocatore deve raggiungere un obiettivo, per farlo il giocatore dovrà muoverlo sullo schermo pianificando il percorso da compiere, facendo attenzione agli ostacoli che incontrerà sul proprio cammino.

Il coding favorisce lo sviluppo delle funzioni esecutive, specie della pianificazione, una delle FE più avanzate. La pianificazione consente di individuare un obiettivo e stabilire in modo strategico i passaggi necessari al suo raggiungimento. Inoltre, consente di monitorare i progressi ottenuti e valutarli in relazione al piano stabilito per conseguire l'obiettivo prefissato.

Prima ancora di mettersi all'opera nelle stanze scrigno, Ello dovrà farsi strada per le vie del mondo degli Elli. Il giocatore stabilisce un percorso per condurre Ello a destinazione, per fare ciò utilizza le frecce di comando. I tracciati diverranno più lunghi e complessi via via che si procede con l'allenamento, per cui il giocatore dovrà diventare sempre più abile nel pianificare i propri spostamenti sulla mappa.

Il bambino, inizialmente, dovrà raggiungere e raccogliere dei fulmini collocati in diverse punti della città, successivamente dovrà cimentarsi in veri e propri percorsi via via sempre più complessi. In una prima fase, ogni volta che il giocatore sceglie una freccia, vedrà l'ombra di ello muoversi lungo il percorso nella direzione corrispondente, Questo garantisce un monitoraggio costante per mezzo del quale, il bambino potrà riconsiderare le proprie scelte e correggere le proprie decisioni, fino ad arrivare correttamente a destinazione. Questa funzione scomparirà in seguito, con l'avanzamento del gioco, il bambino arriverà a vedere se ha selezionato l'itinerario correttamente solo dopo aver dato il via ad Ello. Come precisato in precedenza, anche per le attività di coding i compiti proposti saranno di difficoltà crescente: soltanto quando il giocatore avrà conseguito un numero sufficiente di successi potrà accedere a percorsi di complessità più elevata. L'attività di coding verrà richiesta più volte durante il gioco, ogni volta che il giocatore, terminato l'allenamento in una stanza scrigno, dovrà muoversi per la città per raggiungere la stanza scrigno successiva.

Per iniziare

Ciao bambini! Vi ricordate cosa abbiamo fatto la volta scorsa? chi si ricorda di cosa abbiamo parlato?
Oggi finalmente cominciamo ad esplorare la città degli Elli! Siete pronti! Vediamo insieme come funziona!

(Attività tramite videogioco + attività motorie)

Per concludere

Bravissimi ! Non è facilissimo muoversi in questa città: bisogna pensare bene a quali sono le frecce da usare, controllare di aver scelto quelle giuste e in caso di errore riprovare. Vedrete che diventerete sempre più bravi! *Adesso Big Ello ci saluta, ma ricordatevi di allenarvi a casa!*

SESSIONE 2
GESTIONE DELL'INTERFERENZA

Obiettivi

Obiettivo generale del quartiere sulla gestione dell'interferenza, è quello di imparare a concentrarsi su ciò che è rilevante per il compito ignorando il resto.

Nel corso dei livelli il giocatore deve concentrarsi su uno specifico suono ed escludere tutti gli altri rumori (compiti uditivo-verbali) oppure focalizzarsi su uno stimolo visivo senza farsi distrarre dagli altri (compiti visuo-spaziali).

Per iniziare

Ciao bambini! Siete stati bravissimi e avete imparato a muovervi pianificando i percorsi e scegliendo le frecce giuste! Ora siamo arrivati nel primo quartiere! Ora vediamo insieme un video, il nostro amico BigEllo ci spiega in cosa ci alleneremo! *(*Visione video) *Avete capito bambini? Ci alleneremo a stare attenti e non farci distrarre !* (Riflessione metacognitiva)

Spunti per la riflessione metacognitiva

Riflessione su di sé: fragilità e potenzialità	
Secondo voi a cosa serve questa abilità? perchè è utile? *Far riflettere su cosa succede quando ci si distrae.*	*Rimanere concentrati, non farsi distrarre…* *Pensate se la maestra/mamma vi sta raccontando una storia e voi vi distraete. Perderete un pezzo di storia! La stessa cosa se state guardando un film, ascoltando le istruzioni di un gioco, ascoltando la maestra. Se ci distraiamo non sappiamo come giocare o*

	cosa rispondere alla maestra.
Ti capita spesso di perdere l'attenzione e distrarti? Quando ti distrai più facilmente?	*Es: quando una cosa è noiosa, quando è difficile, quando un compito è troppo lungo...quando ho il mio migliore amico vicino, quando sono vicino alla finestra, se faccio i compiti con la TV accesa, se il mio gatto entra in camera, quando sono a calcio, a scuola, a casa….*
Secondo te, perché?	*Perchè ci sono più persone, più rumore, perché sono stanco, perché se una cosa è noiosa o difficile è più difficile rimanere concentrati, perché se vedo un pallone penso che voglio giocare e mi distraggo…..*
Analisi: individuare possibilità per il cambiamento	
Come potresti distrarti di meno? Perché?	*Evitare le cose che distraggono (rumori, finestra, giochi etc), facendo delle pause tra un compito e un altro…..*
Come potresti aiutare un tuo compagno a rimanere attento?	*Non devo distrarlo, devo aiutarlo a capire se è distratto, fare le cose assieme*
Cosa potrebbe fare un tuo compagno per aiutarti a recuperare l'attenzione persa?	
Pensa insieme ai tuoi compagni ad alcuni trucchi per rimanere attento a scuola	
Analisi: generalizzare le nuove prassi	
A casa i trucchi a cui avete pensato sarebbero altrettanto efficaci?	
Pensate a dei suggerimenti da dare ai vostri insegnanti per aiutare a rimanere più concentrati durante le lezioni.	

Per concludere

Abbiamo capito che cosa è la gestione dell'interferenza e come fare a non farci distrarre! A casa potrete allenarvi e superare tante sfide per diventare sempre più bravi, buon lavoro!

Livelli -Stanza scrigno visuospaziale

LV.0 – *Il giocatore deve aiutare Ello a scorgere tra i numerosi oggetti che scorrono su di un nastro trasportatore, quello che è indicato sullo schermo. Attenzione: l'oggetto cambierà nel corso del livello.*

> **LV. 0.1** – Il giocatore seleziona l'oggetto indicato su schermo tra quelli trasportati sul nastro. Ogni volta che il giocatore commette un errore nella selezione dell'oggetto target, una bomba esploderà e il fumo prodotte dall'esplosione invaderà parte dello schermo;
>
> **LV. 0.2** – Le interferenze aumentano. Gli oggetti si somigliano per forma, colore, uso; potrebbero esserci suoni distraenti; il nastro potrà inclinarsi aumentando o diminuendo la velocità con cui gli oggetti si spostano.

LV.1 – *La velocità con cui scorrono gli oggetti sul nastro trasportatore aumenta, così come il numero di oggetti presenti sul nastro. Il livello ripresenta tutte le caratteristiche già viste nel precedente e ne inserisce alcune inedite, come la comparsa di bolle di sapone o palline sullo schermo, fumo, luci distraenti, pioggia...*

> **LV. 1.1** – Il giocatore deve selezionare lo stimolo target in mezzo ai distrattori. Inizialmente lo stimolo target che cambia dopo un certo numero di risposte corrette. Poi il compito diventa più complesso e gli stimoli target diventano 2.
>
> **LV. 1.2** – Lo scatolone in cui sono stati raccolti gli oggetti selezionati nel corso del livello 1.1 è stato rovesciato. Ora gli oggetti scorrono dall'alto verso il basso. Sullo schermo vengono visualizzati 6 stimoli target che il giocatore dovrà selezionare in mezzo a tutti gli stimoli distrattori

LV.2 – *Qualcuno ha spento la luce e ora non si distinguono più i colori. Sul nastro scorrono lische di pesce bianche e nere che differiscono tra loro per colore o forma. Ello deve continuare il suo compito e cercare di selezionare la lisca indicata ignorando le altre.*

> **LV. 2.1** – In assenza di colori il grado di interferenza aumenta, gli oggetti infatti appaiono come stimoli neutri e maggiormente simili tra loro, generando maggiore confusione a livello visivo. Tutto risulta appiattito e difficile da distinguere. Il livello si presenta come il livello uno, con l'eccezione che anche gli effetti speciali (esplosioni) sono in bianco e nero.
>
> **LV. 2.2** – Lo scatolone in cui sono stati raccolti gli oggetti selezionati nel corso del livello 1.1 è stato rovesciato. Ora gli oggetti scorrono dall'alto verso il basso. Sullo schermo vengono visualizzati 3 stimoli target che il giocatore dovrà selezionare in mezzo a tutti gli stimoli distrattori. Sebbene gli stimoli target, a differenza del lv. 1.2, non siano 6 ma ridotti a 3, la difficoltà risulta comunque più elevata data la maggiore somiglianza degli stimoli in bianco e nero.

LV.3 – Ora Ello dovrà riconoscere figure geometriche tridimensionali.

LV.3.1 – La struttura del livello è uguale a quelle dei livelli 1.1 e 2.1, ma la difficoltà è maggiore.

LV.3.2 – La struttura del livello è uguale a quelle dei livelli 1.2 e 2.2, ma la difficoltà aumenta.

Livelli- stanza scrigno uditivo verbale

LV.0 – Al giocatore viene mostrato un cellulare e viene fatta ascoltare la sua suoneria. Il compito sarà quello di *riconoscere il proprio telefono tra una manciata di altri cellulari che suonano su un tavolo.* Compito del giocatore è quello di selezionare il suo cellulare, cliccandoci sopra, ogni qual volta lo sente suonare; non deve fare niente quando a squillare sono gli altri telefoni

> **LV. 0.1** : i cellulari squillano uno dopo l'altro senza mai sovrapporsi.
>
> **LV. 0.2** : ora i telefoni potranno suonare contemporaneamente, rendendo il compito più difficile

LV.1 – *Ello ha smarrito il suo telefono! Fortunatamente è stato ritrovato e consegnato all'ufficio oggetti smarriti del mondo degli Elli, al piccolo protagonista non resta che recarsi là e cercarlo. Anche qui, il compito del giocatore è selezionare il proprio cellulare ogni volta che lo sente squillare, ignorando gli altri telefoni. Rispetto al livello 0, il numero di cellulari presenti sul tavolo aumenta, le suonerie si somigliano maggiormente, ci sono suoni distraenti come voci e fuochi d'artificio*

> **LV. 1.1 -** Il giocatore dovrà selezionare il più rapidamente il proprio cellulare tra gli altri presenti su schermo riconoscendolo in base alla sua suoneria. Suona un solo telefono alla volta.
>
> **LV. 1.2** – Ora suonano più telefoni contemporaneamente e le suonerie si somigliano.

LV.2 – *Ello è finalmente riuscito a rientrare in possesso del suo cellulare, ma i guai non sono ancora finiti! I responsabili dell'ufficio oggetti smarriti stanno per fare un'importante comunicazione a tutti i presenti. Purtroppo c'è molta confusione. Ello dovrà fare del suo meglio per concentrarsi e capire chi sta parlando tra i diversi personaggi che affollano l'ufficio.*

> **LV. 2.1** – Sullo schermo compare il responsabile dell'ufficio, che ogni tanto fa una comunicazione. Il bambino deve cliccare sul responsabile ogni volta che parla, senza farsi distrarre dai rumori dell'aeroporto e dalle voci degli avvisi che vengono dati da altre persone
>
> **LV. 2.2** – Il giocatore dovrà capire che cosa ha detto il responsabile dell'ufficio scegliendo tra quattro vignette che illustrano diverse situazioni.

LV.3 – *Ello cercherà di capire di quale oggetto sta parlando uno dei due responsabili impegnati in una conversazione. Una volta individuato, il giocatore cliccherà sull'icona dell'oggetto corrispondente.*
LV. 3.1 – Sullo schermo appariranno due responsabili intenti a comunicare qualcosa ai presenti, sotto di essi comparirà una lista di oggetti. Uno dei responsabili verrà incorniciato di rosso, il giocatore dovrà discriminare l'oggetto a cui si riferisce il personaggio contrassegnato in rosso e selezionare quello giusto scegliendo tra quelli presenti nella lista sottostante. La cornice si alternerà in modo imprevedibile tra i due personaggi.
LV. 3.2 – Al precedente livello si aggiungeranno una serie di rumori interferenti che rendono il compito più impegnativo.

SESSIONE 3
GESTIONE DELL'INTERFERENZA

Per iniziare

Ciao bambini! vi siete allenati nel primo quartiere, bravissimi! Come sta andando l'allenamento?

Spunti per la riflessione metacognitiva

Riflessione su di sé: fragilità e potenzialità	
Come sta andando l'allenamento?	
Come vi sembrano le attività? facili/difficili?	
Quali attività sono più difficili? perchè?	
Analisi: individuare possibilità per il cambiamento	
Cosa potresti fare per fare meno fatica?	
Che strategie potrebbero essere utili?	
Analisi: generalizzare le nuove prassi	
Come pensi che questi giochi ti aiutino a stare più attento e concentrato?	

Per concludere

Avete visto, nelle sfide che avete superato vi siete allenati a guardare bene gli oggetti, trovare quello giusto e non farvi distrarre da tutte le altre cose che comparivano sullo schermo. Vi siete anche allenati a non farvi distrarre dai suoni o dalle parole delle persone che vogliono distrarvi. Continuate ad allenarvi per scoprire le nuove sfide di Big Ello

SESSIONE 4

INIBIZIONE DELLA RISPOSTA AUTOMATICA

5.1 Obiettivi

Scopo generale delle stanze scrigno Inibizione è quello di allenare la capacità di inibire una risposta impulsiva e automatica, inadeguata per il compito, in favore di quella richiesta dal compito stesso. Per farlo, al bambino viene chiesto ad esempio di ascoltare una frase e poi di selezionare l'immagine che non rappresenta il significato della frase stessa (incongruente), inibendo l'impulso di selezionare l'immagine corrispondente alla frase ascoltata (congruente). Oppure, nella stanza visuospaziale, si chiede di selezionare l'immagine opposta rispetto a quella vista.

Per iniziare

Eccoci di nuovo nel mondo degli Elli! Vi siete divertiti fin qui? Che cosa abbiamo imparato? Quale abilità abbiamo allenato fino ad ora? *Esatto! Ci siamo allenati a non farci distrarre, né da quello che vediamo né da quello che sentiamo! Ora siete davvero bravissimi a non farvi distrarre e a concentrarvi e stare attenti sulle cose importanti. Possiamo lasciare il quartiere della gestione dell'interferenza e avventurarci in una nuova parte di città! BigEllo è tornato a farci visita, vediamo che cosa ci spiega oggi.* (visione video) *Avete visto cosa è successo a questi bambini? ci alleneremo a non essere impulsivi, che vuol dire imparare a pensare prima di agire, imparare a non fare tutto quello che ci passa per la testa.*

4.2 Spunti per la riflessione metacognitiva

Riflessione su di sé: fragilità e potenzialità	
Secondo voi a cosa serve questa abilità? perchè è utile? *Far riflettere su cosa succede quando facciamo le cose senza pensare se è il momento o la cosa giusta.*	*Serve altrimenti faremmo sempre tutto quello di cui abbiamo voglia, senza pensare se in quel momento è la cosa giusta*
Ti capita spesso di agire d'impulso? Quando ti accade più facilmente?	*Es: rispondere alle domande senza alzare la mano, risolvere un esercizio senza leggere la consegna, parlare sopra agli altri, non aspettare il proprio turno in un gioco, alzarsi e muoversi quando non si dovrebbe.*

Secondo te, perché?	*spesso ci sono cose un po' noiose, come stare seduti ad ascoltare, stare seduti a tavola, ascoltare le istruzioni di un gioco, e ci viene voglia di fare qualcosa di più divertente*
Analisi: individuare possibilità per il cambiamento	
Come potresti valutare meglio la situazione prima di agire?	
Come potresti aiutare un tuo compagno a riflettere prima di fare qualcosa di avventato?	
Cosa potrebbe fare un tuo compagno per aiutarti a non fare le cose di fretta?	
Pensa insieme ai tuoi compagni ad alcuni trucchi per pensare prima di agire quando siete a scuola?	
Analisi: generalizzare le nuove prassi	
A casa i trucchi a cui avete pensato sarebbero altrettanto efficaci?	
Pensate a dei suggerimenti da dare ai vostri insegnanti per aiutare a rimanere più concentrati durante le lezioni.	

Per concludere

Oggi abbiamo scoperto che cos'è l'impulsività! Abbiamo visto la prima sfida che Ello deve superare! Mi raccomando, allenatevi a casa, superate questa sfida e scoprite cosa vi aspetta dopo!

Livelli- stanza scrigno visuospaziale

LV.0 – *Il giocatore dovrà aiutare Ello a premere la barra spaziatrice solo quando appariranno solo quando appariranno degli animali uguali alla figura target presente sullo schermo. In caso contrario, quando l'animale non risulta essere lo stesso di quello nel riquadro blu, il giocatore dovrà selezionare la leva per passare alla figura successiva oppure attendere senza digitare nessun tasto. Attenzione: la figura target cambierà nel corso del livello*

> **LV. 0.1** – In questa prima sfida, il bambino dovrà premere sul dispositivo solo quando sullo schermo apparirà l'animale target, se compaiono altri animali dovrà, invece, premere la leva per passare alla successiva o non fare niente.

LV. 0.2 – Questa volta il bambino dovrà fare attenzione anche allo sfondo della figura bersaglio: solo per le figure con sfondo bianco si può schiacciare il bottone, nel caso lo sfondo fosse colorato dovrà tirare la leva o non premere nulla.

LV.1 – *Ello sarà impegnato in una particolare caccia al dettaglio, ma – come in precedenza – non dovrà cliccare il dettaglio corretto bensì quello errato, il tutto il più rapidamente possibile.*

LV. 1.1 – Sullo schermo appaiono Ello e BigEllo, lo scenario si modifica nel corso del livello presentando vari dettagli, per esempio: è notte, gli Elli beveno un tè caldo, Ello è felice e così via. Insieme alla figura vengono presentati due pulsanti che rappresentano due icone riferite ai dettagli dello scenario mostrato, il giocatore dovrà selezionare l'icona incongruente (ossia quella scorretta), rispetto a quanto osservato. Il tempo per rispondere è di sei secondi.

LV. 1.2 – Questo livello funziona come il precedente, ma aggiunge un dettaglio grafico che scandisce il tempo di risposta (sempre sei secondi): una bomba che esplode quando il tempo esaurisce.

LV.2 –*Un altro Ello è in difficoltà! Qualcuno deve avergli fatto uno scherzetto: tutti i comandi sono invertiti! Aiuta questo Ello a tornare a casa!*

LV. 2.1 – Il giocatore dirigerà l'altro Ello su un reticolato fino all'obiettivo segnato sulla griglia grazie al coding, la stessa dinamica che utilizza per spostarsi all'interno della città ma con una differenza: dovrà digitare i comandi inversi rispetto a quelli che utilizzerebbe normalmente (per andare a destra dovrà scegliere il tasto che indica a sinistra!). Ad ogni modo, nella prima parte il suo compito sarà agevolato dalla presenza di istruzioni a schermo che lo guideranno nell'esercizio, il giocatore si baserà su quanto osservato, ma dovrà comunque digitare i comandi opposti rispetto a quanto presente a schermo.

LV. 2.2 – Il livello è identico al precedente, ma non sono più presenti istruzioni a schermo. Il bambino dovrà programmare autonomamente il percorso da fare.

LV.3 – *Ora Ello dovrà rintracciare le immagini che non si assomigliano, potrà sembrare che siano tutte uguali, ma attenzione ai piccoli dettagli!*

LV.3.1 – Il bambino ha un tempo limite per stabilire se gli occhiali, le scarpe e il cappello di mamma e baby Ello sono tutti diversi nelle due immagini presentate, in caso affermativo cliccherà l'apposito pulsante, altrimenti tirerà la leva per far arrivare una nuova immagine da confrontare. In caso di errore verrà sottratto del tempo dal cronometro.

LV.3.2 – Questo livello è uguale al precedente, ma il giocatore noterà un cronometro con un tempo di cinque secondi che fissa il limite di tempo che ha a disposizione per scegliere se l'immagine assomiglia oppure no.

Livelli- stanza scrigno uditivo-verbale

LV.0 – *Ello deve affrontare un nuovo compito individuando l'immagine che non corrisponde a quella pronunciata da Big Ello. Dovrà essere veloce e selezionare la risposta corretta prima che la bomba esploda.*

> **LV. 0.1** – Il giocatore ascolta una parola e deve selezionare il più velocemente possibile da una coppia di immagini quella che non corrisponde alla parola stimolo precedentemente udita.
>
> **LV. 0.2** – Il gioco non cambia, ma la difficoltà sarà incrementata e gli stimoli visivi saranno più difficili da discriminare.

LV.1 – Il giocatore, similmente al livello precedente, aiuterà Ello a individuare lo stimolo corretto prima che la bomba esploda. Attenzione: la risposta giusta è quella che non corrisponde allo stimolo proposto, perciò dovrà sopprimere l'istinto e rispettare la consegna.

> **LV. 1.1 –** Lo schermo mostrerà due immagini che rappresentano una frase, la quale verrà udita dal giocatore contemporaneamente alla presentazione delle immagini. Il giocatore ha il compito di selezionare, il più rapidamente possibile, quella che non corrisponde alla frase ascoltata, ossia l'immagine non congruente.
>
> **LV. 1.2** – In questa sfida il giocatore dovrà porre particolare attenzione allo sfondo e selezionare l'immagine congruente alla frase se lo sfondo che appare è a righe, altrimenti dovrà premere sull'immagine non congruente (come aveva fatto in precedenza) se lo sfondo è bianco. A schermo è presente un piccolo cronometro che scandisce il tempo previsto per la seleziona dell'immagine.

LV.2 – *Una nuova sfida attende Ello e, come per quelle precedenti, il giocatore dovrà completare la frase udita con lo stimolo non congruente, ossia quello che risulta inappropriato al completamento della frase anziché quello giusto.*

> **LV. 2.1** – Il giocatore completerà la frase ascoltata con la parola mancante scegliendo tra due immagini quella che risulta…scorretta! Il tutto nel minor tempo possibile (anche per questo livello è presente il cronometro). Per le classi fino alla terza primaria le opzioni a schermo saranno due immagini, mentre per le classi dalla quarta in su gli stimoli saranno parole scritte sullo schermo. A lato dello schermo è presente una bomba la cui miccia ha una durata di cinque secondi, dopodiché la bomba esploderà.
>
> **LV. 2.2** – Ora Ello dovrà prestare molta attenzione alle voci. Se a parlare sarà una voce dal tono femminile, allora dovrà selezionare l'immagine o la parola giusta (congruente allo

stimolo mostrato); se a parlare sarà una voce dal tono maschile, allora bisognerà selezionare l'immagine o la parola scorretta (incongruente allo stimolo presentato). Anche qui è presente un conto alla rovescia di cinque secondi per la bomba posta al centro dello schermo.

LV.3 – *Adesso Ello ascolterà una storia, ma non resterà con le mani in mano: ogni volta che sentirà il narratore pronuncerà una determinata parola, il giocatore dovrà selezionare una parola sullo schermo.*

LV. 3.1 – Quando il narratore dirà gatto, il giocatore dovrà selezionare la parola cane e viceversa; quando il narratore pronuncerà scuola, il giocatore dovrà selezionare casa e viceversa. Ogni altra parola dovrà essere ignorata. Lo studente agirà il più rapidamente possibile.

LV. 3.2 – Rispetto al precedente livello la difficoltà aumenta, alle parole vengono aggiunti degli aggettivi che identificano il colore di oggetti e animali incrementando così la difficoltà nel compito inibitorio. Quando il narratore leggerà casa gialla, il giocatore selezionerà casa rossa e viceversa; se il narratore leggerà macchina blu, il giocatore selezionerà macchina rosa e viceversa.

SESSIONE 5
INIBIZIONE DELLA RISPOSTA AUTOMATICA

Per iniziare

Non è facile non fare qualcosa quando questo ci viene spontaneo e automatico, ma voi vi siete allenati e siete migliorati molto! Come sta andando l'allenamento?

Spunti per la riflessione metacognitiva

Riflessione su di sé: fragilità e potenzialità	
Come sta andando l'allenamento?	
Come vi sembrano le attività? facili/difficili?	
Quali attività sono più difficili? perchè?	
Analisi: individuare possibilità per il cambiamento	
Cosa potresti fare per fare meno fatica?	
Che strategie potrebbero essere utili?	
Analisi: generalizzare le nuove prassi	

Come pensi che questi giochi ti aiutino a stare più attento e concentrato?	

Per concludere

Nelle sfide che vi ha proposto Big Ello nel quartiere dell'inibizione vi siete allenati a fare cose che non vi vengono spontanee, come scegliere l'immagine opposta rispetto a quello che ascoltate. Vi siete quindi allenati a pensare prima di fare qualcosa, in modo da svolgere correttamente la sfida. Continuate ad allenarvi per diventare ancora più bravi!

SESSIONE 6

MEMORIA DI LAVORO

Obiettivo

Nelle due stanze scrigno dedicate alla memoria di lavoro, il bambino dovrà allenare la sua capacità di tenere a mente, elaborare e manipolare delle informazioni sia in modalità uditiva che in modalità visiva.

Per iniziare

Quanta strada abbiamo fatto! Vi ricordate quali abilità abbiamo allenato nelle scorse settimane? Giusto!Abbiamo aiutato Ello ad imparare a non farsi distrarre dai suoni e dalle cose che gli succedono attorno. Lo abbiamo aiutato a non essere impulsivo, a pensare e fare la cosa giusta. E adesso che altra sfida ci aspetta? Ascoltiamo il nostro amico Big Ello e scopriamo una nuova parte di città! (video) *Big Ello ci ha chiesto di aiutare Ello ad allenare la sua memoria di lavoro, siete pronti? Raggiungiamo la prossima stanza scrigno!*

5.2 Spunti per la riflessione metacognitiva

Riflessione su di sé: fragilità e potenzialità	
Secondo voi a cosa serve questa abilità? perchè è utile? *Far riflettere su cosa succede dimentichiamo le cose*	*E' utile quando dobbiamo ricordarci cosa mettere in cartella, o dobbiamo svolgere tutti i passaggi per risolvere un problema, o capire un brano.*
Ti capita spesso di dimenticare quello che dovevi fare?Quando ti capita più facilmente?	

Secondo te, perché?	*Capita più spesso quando si è stanchi, quando ci sono tante cose da fare o da ricordare, quando non si è fatto attenzione al momento della memorizzazione (es mamma mi dice cosa comprare ma io non ascolto bene e mi dimentico)*
Analisi: individuare possibilità per il cambiamento	
Come potresti fare ordine nella tua mente per ricordare meglio? Perché?	
Come potresti aiutare un tuo compagno a ricordare meglio?	
Cosa potrebbe fare un tuo compagno per aiutarti a organizzare meglio le cose che devi ricordare?	
Pensa insieme ai tuoi compagni ad alcuni trucchi per organizzare le informazioni da tenere a mente?	
Analisi: generalizzare le nuove prassi	
A casa i trucchi a cui avete pensato sarebbero altrettanto efficaci?	
Pensate a dei suggerimenti da dare ai vostri insegnanti per aiutare a rimanere più concentrati durante le lezioni.	

Per concludere

Anche avere buona memoria è importante! Con le prossime sfide imparerete a tenere a mente tantissime cose! Buon allenamento!

Livelli - stanza scrigno visuospaziale

LV.0 – *Ello si appresta a cimentarsi in una nuova prova. Questa volta dovrà aguzzare la vista e avere buona memoria per ricostruire le sequenze di stimoli visivi che gli saranno presentati.*

> **LV. 0.1** – Il giocatore vedrà su schermo alcune icone che si illumineranno in un certo ordine, non appena riceverà il via dal gioco (semaforo verde) dovrà cliccare sulle icone nell'ordine in cui le ha viste accendersi. La lunghezza delle sequenze aumenta nel corso del livello.

LV. 0.2 –L’esercizio è il medesimo del precedente ma stavolta le icone disposte sul primo nastro trasportatore scompariranno!

LV.1 – *Ello prosegue la sua avventura con una nuova sfida di memoria tra i nastri trasportatori.*

LV. 1.1 – Gli oggetti sui nastri trasportatori scorrono a una velocità contenuta. Non appena il semaforo diventa verde, il giocatore dovrà selezionare, rispettando l’ordine di accensione, gli oggetti dal primo all’ultimo.

LV. 1.2 – Il livello è simile al precedente, ma l’ordine di selezione degli oggetti dovrà essere inverso (dall’ultimo al primo) rispetto a quanto osservato sul nastro.

LV.2 – *Continua la sfida di Ello, ma le insidie si fanno sempre maggiori e gli oggetti trasportati dai nastri si assomigliano sempre di più.*

LV. 2.1 – Gli oggetti trasportati sui nastri questa volta sono davvero simili gli uni agli altri e possono anche cambiare la propria posizione nel corso della prova. Il giocatore dovrà selezionare gli oggetti nell’ordine in cui si sono illuminati.

LV. 2.2 – Il livello è uguale al precedente, con l’eccezione che la selezione dovrà essere compiuta all’inverso rispetto all’ordine di accensione degli oggetti (dall’ultimo al primo).

LV.3 – L’ultima sfida metterà alla prova la capacità di memoria di lavoro di Ello perché non appena il semaforo diventa verde Ello non dovrà solo selezionare, rispettando l’ordine di accensione, gli oggetti dal primo all’ultimo come nei precedenti esercizi ma dovrà prestare attenzione anche alle ruote del nastro trasportatore! Infatti, alcune di queste ruote saranno ferme mentre gli oggetti bersaglio vengono illustrati e il giocatore dovrà cliccare anche su di esse nella fase di selezione.

LV.3.1 – Il giocatore dovrà fare fronte a due compiti in contemporanea: porre attenzione agli oggetti che si illuminano e, contemporaneamente, osservare quali ruote del nastro trasportatore restano ferme. La difficoltà, rappresentata dal numero di ruote ferme e di stimoli bersaglio, aumenterà sensibilmente con lo scorrere dell’esercizio!

LV.3.2 – Il livello finale è simile al precedente, ma sono presenti delle forme geometriche che il giocatore dovrà selezionare in ordine inverso di illuminazione. Inoltre, dovrà sempre individuare le ruote rimaste ferme!

Livelli - stanza scrigno uditivo verbale

LV.0 – *Ello deve ricordare l’ordine di apparizione di un numero crescente di oggetti denominati da Big Ello.*

LV. 0.1 – Sullo schermo appaiono per qualche secondo diversi oggetti in rapida successione, accompagnati dalla voce di Big Ello che pronuncia il nome di ognuno. Dopodiché l'intera serie si ripresenta sullo schermo. Appena scatta il semaforo verde, il giocatore dovrà selezionare gli oggetti in ordine di apparizione. Il numero di oggetti da ricordare varia in base al punteggio nel corso del livello. In caso di errore si usufruisce di una seconda possibilità ma la posizione degli oggetti viene modificata e la stringa precedente non viene più riproposta!

LV. 0.2 – Questo livello ricalca il precedente, ma aumentano i distrattori

LV.1 – *Ello dovrà memorizzare gli oggetti presentati nella sfida e ricostruire le sequenze che gli sono state sottoposte. Il tempo per rispondere è limitato e sono presenti dei distrattori!*

LV. 1.1 – Gli oggetti vengono nominati uno alla volta, non appena scatterà il semaforo verde il giocatore dovrà selezionare gli oggetti nello stesso ordine.

LV. 1.2 – Questa volta il giocatore dovrà selezionare gli oggetti in ordine inverso rispetto a quanto udito.

LV.2 – *Le cose si complicano, Ello dovrà cominciare a tenere a mente alcune nuove regole per superare questo livello. Al giocatore vengono presentate cinque categorie di oggetti differenti, l'esercizio prevede di tenere traccia dell'ultimo oggetto mostrato per una o più categorie. Gli oggetti vengono presentati solo vocalmente uno alla volta e successivamente appaiono contemporaneamente sul nastro trasportatore: il bambino deve costantemente aggiornare la propria memoria per ricordare qual è l'ultimo oggetto nominato e presente sul nastro che appartiene alla categoria indicata e, contemporaneamente, ignorare gli stimoli distraenti presentati. In caso di errore si usufruisce di una seconda possibilità ma la posizione degli oggetti viene modificata e la stringa precedente non viene più riproposta!*

LV. 2.1 –LV. 2.1 – Inizialmente al giocatore viene presentata e ricordata la categoria bersaglio degli oggetti che deve discriminare uditivamente al fine di selezionare successivamente l'ultimo oggetto nominato presente sul nastro. La categoria target cambierà e sarà presentata all'inizio di ogni sfida. In base al punteggio la difficoltà può aumentare: il giocatore dovrà discriminare uditivamente non più uno solo ma ben due oggetti appartenenti alla categoria bersaglio della sfida e li dovrà selezionare sul nastro, nell'ordine in cui sono stati nominati.

LV. 2.2– Il livello è simile al precedente, la complessità della sfida è accresciuta dal fatto di dover ricordare tutti gli oggetti nominati selezionandoli nell'ordine di presentazione. Superata la prima fase dovrà essere selezionato l'ultimo oggetto nominato della categoria bersaglio della sfida.

LV.3 – *Questo livello vedrà il giovane Ello impegnato tra lettere e numeri nel tentativo di sistemarli secondo le istruzioni impartite da Big Ello.*

LV. 3.1 – Il giocatore sentirà alcune lettere e numeri pronunciati in un certo ordine, il suo compito sarà quello di ordinarli all'inverso di come sono stati presentati. In caso di errore si usufruisce di una seconda possibilità: comparirà il tasto play in alto a destra che, se premuto, consentirà di riascoltare la voce. La difficoltà aumenterà man mano che l'esercizio va avanti!

LV. 3.2 –Stavolta il giocatore dovrà rispondere ad alcune domande su quanto udito, ossia selezionare solo alcuni stimoli in base alla regola (Es: seleziona solo i numeri pari uditi precedentemente). La regola cambierà nel corso dell'esercizio!

SESSIONE 7
MEMORIA DI LAVORO

Per iniziare

Eccoci di nuovo pronti ad aiutare Ello! Avete migliorato la vostra memoria? *Come sta andando l'allenamento?*

Spunti per la riflessione metacognitiva

Riflessione su di sé: fragilità e potenzialità	
Come sta andando l'allenamento?	
Come vi sembrano le attività? facili/difficili?	
Quali attività sono più difficili? perchè?	
Analisi: individuare possibilità per il cambiamento	
Cosa potresti fare per fare meno fatica?	
Che strategie potrebbero essere utili?	
Analisi: generalizzare le nuove prassi	
Come pensi che questi giochi ti aiutino a stare più attento e concentrato?	

Per concludere

Nelle sfide che vi ha proposto Big Ello nel quartiere della memoria di lavoro vi state allenando a

tenere a mente tante informazioni da usare per superare le sfide . Continuate così e diventerete dei campioni!

SESSIONE 8

FLESSIBILITA' COGNITIVA

Obiettivo

La flessibilità cognitiva è quella funzione esecutiva per mezzo della quale lo studente è in grado di pensare e riflettere su un dato problema o situazione adottando una pluralità di differenti prospettive.E' fondamentale per risolvere problemi o imprevisti. E' inoltre cruciale per riuscire a passare da un compito ad un altro senza perseverare. Le sfide proposte nel quartiere della flessibilità, siano esse in modalità uditiva o visuo spaziale, richiedono al bambino svolgere le sfide seguendo regole sempre diverse a seconda dei criteri definiti dal gioco..

Per iniziare

Quanta strada abbiamo fatto! Vi ricordate quali abilità abbiamo allenato nelle scorse settimane? Siete pronti a scoprire che altra sfida ci aspetta? Ascoltiamo il nostro amico Big Ello e scopriamo una nuova parte di città! (video) *Big Ello ci ha chiesto di aiutare Ello ad allenare la sua flessibilità cognitiva, siete pronti? Raggiungiamo la prossima stanza scrigno!*

5.2 Spunti per la riflessione metacognitiva

Riflessione su di sé: fragilità e potenzialità	
Secondo voi a cosa serve questa abilità? perchè è utile? *Far riflettere su cosa succede se pensiamo solo al nostro punto di vista / se non ci accorgiamo che sono cambiate le regole del compito*	
Ti capita spesso di non riuscire a trovare modi diversi di affrontare un problema?	
Secondo te, perché?	
Analisi: individuare possibilità per il cambiamento	

Come potresti fare ordine nella tua mente per riuscire a trovare nuovi punti di vista? Perché?	
Come potresti aiutare un tuo compagno?	
Cosa potrebbe fare un tuo compagno per aiutarti?	
Pensa insieme ai tuoi compagni ad alcuni trucchi per essere più flessibili?	
Analisi: generalizzare le nuove prassi	
A casa i trucchi a cui avete pensato sarebbero altrettanto efficaci?	
Pensate a dei suggerimenti da dare ai vostri insegnanti per aiutarvi a essere più flessibili	

Per concludere

Anche essere flessibili è importante! Con le prossime sfide imparerete a tenere a mente tantissime cose! Buon allenamento!

SESSIONE 9

FLESSIBILITA' COGNITIVA

Per iniziare

Eccoci di nuovo pronti ad aiutare Ello! Avete migliorato la vostra flessibilità? *Come sta andando l'allenamento?*

Spunti per la riflessione metacognitiva

Riflessione su di sé: fragilità e potenzialità	
Come sta andando l'allenamento?	
Come vi sembrano le attività? facili/difficili?	
Quali attività sono più difficili? perchè?	
Analisi: individuare possibilità per il cambiamento	
Cosa potresti fare per fare meno fatica?	

Che strategie potrebbero essere utili?	
Analisi: generalizzare le nuove prassi	
Come pensi che questi giochi ti aiutino a stare più attento e concentrato?	

Per concludere

Nelle sfide che vi ha proposto Big Ello nel quartiere della flessibilità vi state allenando a cambiare rapidamente regola di gioco. Continuate così e diventerete dei campioni!

ATTIVITÀ SUPPLEMENTARI

ATTIVITA' DI POTENZIAMENTO

Schede di coding carta-matita (si vedano gli allegati)

Schede "Dov'è Ello": scheda carta-matita. Compito del bambino è trovare l'oggetto target

Schede di barrage : schede con tanti elementi, i bambini devono tirare una riga su tutti gli oggetti target indicati dalla scheda e ignorare gli altri.

Scheda trova la figura identica/diversa: I bambini devono dire quale tra le figure è identica a quella presentata. Compreso il compito, le alternative di risposta aumentano.

Il compito può anche essere svolto con il target sulla lim e le figure alternative sul banco di ogni bambino. Ognuno dovrà scegliere quali delle sue carte corrisponde a quella target.

Il livello di difficoltà può variare in termini di complessità delle figure. Inoltre si può decidere se lasciare la figura target in vista sulla lim o se rimuoverla dopo averla fatta osservare per un certo periodo di tempo, inserendo anche un carico di memoria. Può essere proposta anche in formato uditivo, ovvero la figura target non viene mostrata ma descritta oralmente.

Si può anche aggiungere una componente motoria: ad ogni bambino si da una carta, che può essere o meno uguale a quella target. Si mostra l'immagine target sulla lim e si chiede ai bambini che pensano di avere la carta con la figura identica di alzarsi. Si andrà poi a controllare se i bambini hanno agito correttamente.

Scheda Riproduci la matrice: viene proiettata a tutta la classe una matrice, e ogni bambino ha la sua griglia. L'esercizio è costituito da matrici che contengono dei simboli. Il bambino viene invitato ad osservare la matrice per pochi secondi e a ricordare l'esatta posizione dei simboli per poi ricostruire una identica senza poter guardare quella di riferimento. La tabella viene nascosta dopo

essere stata osservata dalla classe. Inizialmente si può prevedere un tempo di esposizione alla matrice più lungo, ma una volta allenati, ridurre il più possibile il tempo di esposizione.
Modificare la difficoltà: si può ridurre o aumentare la difficoltà modificando il tempo di esposizione della matrice; la grandezza della matrice (2x2 3x3 ecc..); il numero di bersagli nella matrice; il tipo di bersaglio (può essere un simbolo, un disegno, lettere o numeri); la presenza di distrattori fuori dalla griglia.

ATTIVITA' LUDICHE

Coding motorio: con dello scotch creare una griglia 5x5 sul pavimento. Indicare con una X il punto di partenza e il punto di arrivo. Preparare un certo numero di frecce di 4 colori diversi per indicare le 4 direzioni. A turno, chiedere ad un bambino di pianificare il percorso e ad un altro di eseguirlo una volta concluso. Verificare se il percorso è corretto.
Il gioco si può fare anche dividendo i bambini a gruppi: ogni gruppo deve pianificare un percorso e scegliere un membro che lo esegua per verificarne la correttezza.
Incremento/decremento della difficoltà: modificare la lunghezza dei percorsi, grandezza della griglia, presenza di elementi da evitare o da raccogliere lungo il percorso, presenza di curve.
Funzioni esecutive: questo gioco allena la pianificazione, ovvero la capacità di organizzare un piano d'azione e di monitorare l'esecuzione al fine di raggiungere l'obiettivo
Battaglia di cori: la classe viene divisa in due gruppi, ognuno dei quali guidato da un insegnante. Il primo gruppo intona la prima strofa di una canzone, non appena la strofa viene terminata, anche il secondo gruppo comincia a cantare la stessa canzone ripetendo la prima strofa mentre il primo gruppo prosegue con la seconda. L'obiettivo di ogni gruppo è quello di non lasciarsi confondere dall'altro e continuare a cantare correttamente la canzone.
Modificare la difficoltà: aumentare o ridurre il numero di gruppi, mischiare i gruppi (far sedere nello stesso spazio i bambini di gruppi differenti così ogni bambino è attorniato da persone che cantano strofe diverse).
Funzioni esecutive: in questo gioco i bambini devono riuscire a gestire i numerosi stimoli interferenti che vengono prodotti attraverso il canto sfalsato delle strofe e trovare strategie adattive per concentrarsi sulla strofa corretta.
Che ore sono Signor Lupo?: l'insegnante porta la classe in giardino o in palestra e sceglie uno degli studenti per vestire i panni del Signor Lupo. Dopodiché il resto della classe (come in un due tre… stella!) si dispone dietro una linea in direzione opposta al luogo della conta in cui si trova il

Signor Lupo. A questo punto, il Signor Lupo si volta dall'altra parte. I bambini – prima di muoversi – gli pongono in coro questa domanda: "Che ore sono Signor Lupo?", il Lupo risponde esclamando ad alta voce un numero e i bambini si muovono di un numero di passi equivalente a quelli del numero pronunciato. Il gioco prosegue così sino a quando il Signor Lupo pensa che i bambini siano abbastanza vicini a lui, a questo punto la sua risposta cambia e diventa: "L'ora di cena!". Il Signor Lupo si volta e comincia a correre per acchiappare i bambini, il primo che tocca lo sostituisce nel ruolo del Signor Lupo.

Modificare la difficoltà: il bambino preso può salvarsi se ricorda l'ultimo numero urlato dal Signor Lupo; Il bambino può salvarsi se ricorda l'ordine preciso di tutti i numeri pronunciati dal Signor Lupo.

Funzioni esecutive: il gioco coniuga la dimensione motoria a quella cognitiva, infatti i bambini allenano le proprie funzioni esecutive avendo la possibilità di scaricare le energie fisiche e l'esuberanza. Il bambino a cui è affidato il ruolo del Signor Lupo deve inibire il desiderio di girarsi e correre dietro ai compagni per acchiapparli fino a che non sono abbastanza vicini a lui, altrimenti rischia di avere meno possibilità di prenderli. Il resto della classe invece dovrà tenere controllo il proprio desiderio di diventare il Signor Lupo e non lasciarsi prendere, altrimenti il gioco è rovinato. Inoltre con le regole aggiuntive che incrementano il livello di difficoltà del gioco, viene coinvolta anche la memoria di lavoro attraverso un doppio compito: scappare e tenere a mente i numeri detti dal Signor Lupo.

La danza del ghiacciolo: il docente avvia la musica e i bambini si mettono a ballare, non appena la musica si ferma tutti i bambini devono restare immobili nella posizione in cui si trovano. Chi non riesce dovrà proseguire il gioco stando in ginocchio, se non si ferma in tempo nel turno successivo dovrà proseguire da seduto e poi da sdraiato. Se riesce a fermarsi in tempo, allora può recuperare e tornare alla precedente posizione, per esempio: se un bambini fallisce per due volte di seguito, dalla posizione in piedi disputerà le successive manche in ginocchio e poi seduto; ma se riesce a vincere la successiva dalla posizione seduta tornerà a quella in ginocchio. Il gioco termina quando rimane un solo bambino.

Modificare la difficoltà: regolare il tempo tra uno stop e l'altro, far partire tutti i bambini inginocchiati, aggiungere regole a piacere (es: ad un certo punto del gioco si inverte la regola e i bambini devono stare fermi mentre c'è la musica e ballare quando non c'è; i bambini devono muovere solo specifiche parti del corpo; utilizzando delle palette colorate, associare ad ogni colore una azione. Es: giallo= salto, blu= batto le mani…) .

Funzioni esecutive: i bambini devono riuscire a resistere all'impulso motorio provocato dalla musica e adottare strategie efficaci per fermarsi o recuperare la posizione eretta. Nella versione più complessa con aggiunta di regola, devono ricordare e mettere in atto al momento giusto l'azione associata ad ogni colore.

Il gioco dei colori: in questo gioco i bambini devono regolare il loro comportamento a seconda dello stimolo che vedono. Prima si mostra un quadrato rosso o uno blu e i bambini devono saltare quando c'è il rosso e stare fermi quando c'è il blu. Poi a ognuno viene assegnato uno dei due colori e devono saltare quando compare il loro e stare fermi quando compare l'altro.

Modificare la difficoltà: possono essere aggiunti altri simboli con altre regole. Si può dare ad ogni bambino un cartoncino con il colore assegnato o farlo tenere a mente. Si possono usare due palette rosse e blu e chiedere ad uno dei bambini di condurre il gioco alzando in maniera casuale e alternata una delle due palette. Ad un altro bambino si può assegnare il compito di controllore per verificare se tutti i bambini hanno fatto correttamente.

Sacco pieno\sacco vuoto: chi conduce il gioco usa i pollici e dice "sacco pieno" a pollici alzati oppure "sacco vuoto" a pollici abbassati. I bambini devono stare in piedi quando i pollici sono alzati e sentono "sacco pieno" e devono accucciarsi quando i pollici sono abbassati e sentono "sacco vuoto".

Modificare la difficoltà: usare solo i pollici senza pronunciare nulla; chiedere ai bambini di basarsi solo sui pollici e pronunciare "sacco pieno" e "sacco vuoto" a volte in modo congruente ai pollici a volte in modo incongruente (abbasso i pollici e dico "sacco pieno": i bambini devono abbassarsi); gioco al contrario: pollici su e "sacco pieno" indicano accucciarsi, mentre pollice giù e "sacco vuoto" indica alzarsi.

Giochi con le parole\numeri: la maestra dice una serie di numeri e chiede al bambino di ripeterli in ordine crescente, decrescente, solo i pari, solo i dispari. Con le parole si può invece chiedere al bambino di ripetere solo gli animali (es: casa, palla, topo, chiave, cane), solo la frutta, solo i 3 animali più piccoli (es: cavallo, mosca, elefante, formica, gatto).

Modificare la difficoltà: aumentare il numero di parole o numeri detti.

Sequenze motorie da ricordare: la maestra fa una sequenza di movimenti (braccio in alto, braccio in avanti, braccio a destra) e una volta terminata chiede ai bambini di ripeterla.

Modificare la difficoltà: modificare la lunghezza delle sequenze, usare più parti del corpo, chiedere di ripetere nell'ordine inverso, chiedere di ricordare un percorso.