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EXECUTIVE FUNCTION IN CHILDREN WITH TYPICAL AND ATYPICAL DEVELOPMENT: TOWARDS AN ECOLOGICAL ASSESSMENT

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SUMMARY

This research aimed to explore some salient issues regarding the domain of Executive Function (EF). EF refers to deliberate, top-down neurocognitive processes involved in the conscious, goal-directed control of thought, action and emotion processes (Miyake et al., 2000). They are crucial in novel and ambiguous situations, in everyday cognitive tasks. Executive Function is not only cognitive processes, but is also characterized in emotional responses and behavioral actions. Several elements of EF have been articulated as key components, including impulse control and self-regulation, anticipation and the deployment of attention, working memory, initiation of activity, planning ability and organisation, mental flexibility and utilisation of feedback, selection of efficient problem solving strategies, affective decision making, theory of mind and empathy. Findings about different issues in the executive domain are inconsistent. The aspects that we analyzed in the present study are the following: exploring the structure and the development of EF in typically developing children and in two developmental disorders, namely ADHD and Learning Disabilities (LD).

As far as the EF assessment is concerned, the operationalization and measurement of EF is a very important issue and traditional instruments used to measure EF are limited in ecological validity. For this reason attention is increasingly being given to alternative methods of evaluation with higher ecological validity such as empirical tests and behavior rating scales. We propose a new neuropsychological battery that included the Battersea Multitasking Paradigm, the Visuo-Spatial Reasoning Task, the Daily Planning Task, the Junior Gambling Task and the Honk Task. In Chapter 5 we analyzed its ecological validity. We also developed a new questionnaire: the Questionnaire for the assessment of EF (QuFE). In Chapter 3 evidence for reliability, internal factorial structure and clinical use of the Parent and the Teacher forms of the QuFE, was examined in a normative and clinical samples of children aged between 8 to 13 years. Results with respect to factorial structure suggested a 5-factor model for the Parent form and 3-factor model for the Teacher form. The

investigated skills were: metacognitive abilities, emotional and behavioral regulation, organization of material, shift and initiate. Internal consistency of both forms was high. As far as clinical use was concerned, the questionnaire was able to distinguish typically developing and clinical groups but it was less successful to predict clinical status of children with ADHD from those with LD.

As far as the structure and the development of EF were concerned, we administered the neuropsychological battery presented above to 343 typically developing children. There was substantial task-based variation in the developmental patterns on the various tasks. Joint Simultaneous Factor Analysis across several populations suggested a four-factor structure with Vigilance, Strategic Behaviour, Inhibition/Cognitive Flexibility and Memory as separate but interrelated dimensions that remained stable across different school-age periods and genders (Chapter 2).

Finally we studied the EF profile in children with Attentional Deficit Hyperactivity Disorder (ADHD) or Learning Disabilities (LD). Three groups of children, aged between 8 and 13 years (40 ADHD, 25 LD, 207 typically developing children) were presented with our neuropsychological battery. Our data suggested that children with ADHD or LD may overlap their strategic and inhibitory features. The two groups were characterized by memory and vigilance deficit but their extension was higher in children with ADHD. In conclusion the current study confirmed in our children with ADHD or LD the presence of executive deficits, but not in a generalized fashion (Chapter 4).

CHAPTER 1: GENERAL INTRODUCTION

1.1 DEFINITION OF EXECUTIVE FUNCTION

Despite the frequency with which it is mentioned in the literature, the concept of Executive Function (EF) is one that still awaits a formal definition. Many definitions of EF exist and the components and nomenclature vary, often depending on the specific field of study (cognitive psychology, educational psychology, neuropsychology).

EFs typically are described as integrated cognitive processes that determine goal-oriented and purposeful behavior. EFs play an important role in tasks that are fluid in nature, that require novel problem solving and place minimal demands on previous learning. EFs are also necessary in everyday tasks in which multiple steps with intermediate results are involved. These steps, intermediate results, and the related adequate responses have to be kept in mind temporarily and other information or responses have to be suppressed so they cannot interfere with the future goal. The multiple steps need to be executed in a prior order and responses need to be adjusted when the situations alter. From this description it is evident that EF domain is articulated in several elements: inhibition, selective and sustained attention, Working Memory, initiation of activity, planning and organization, mental flexibility and utilization of feedback, selection of efficient problem solving strategies. Barkley (1997) defines executive inhibition and states that inhibition is comprised of the following three interrelated processes: inhibition of a prepotent or dominant response (conflict between responses that have a history of being reinforced), stopping of an ongoing response and interference control (distractibility). Selective attention is the ability to identify specific information from environment while ignoring distracters, instead the term sustained attention refers to the ability to achieve and maintain an alert state. Working memory (WM) is the process that enable to hold information in short-memory and manipulate that information at the same time. WM originally comprised three components: 1) the phonological loop temporarily maintains and manipulates speech-based information; 2) the visuo-spatial sketch-pad holds and manipulates visuo-spatial information; 3) the central executive is a limited capacity attentional system responsible of selective attention, coordination activities, switching attention, and retrieval of information from long-term memory (Baddeley et al., 1975). More recently this model has been modified to deal with shortcomings and the episodic buffer has been included a fourth component (Baddeley, 2000); it provides a workspace for the temporary storage of information and is capable of integrating information from the slave systems and long-term memory in order to create a unitary episodic event or representation. Initiative has usually been define as the capability to begin a task or activity and independently generate ideas. Planning and organization refer to the ability to anticipate future events, set goals, develop appropriate steps to carry out associated tasks or actions, understand and communicate key concepts. Cognitive flexibility is capacity to shift between response sets, learn from mistakes, devise alternative strategies and process multiple sources of information concurrently. Finally problem solving is a mental process that involve discovering, analyzing and solving problems. Problem solving includes: identifying the problem, defining problem, forming a strategy, organizing information, allocated resources, monitoring progress and evaluating the results.

Recent research distinguished between two aspects of EF (Zelazo et al., 2002): “Cool EF” and “Hot EF”. Cool EFs are more likely to be elicited by abstract problems and they include strategic planning, organization, goal setting, behavior monitoring, problem solving, inhibition, working memory and cognitive flexibility. Hot EFs are more likely to be elicited by problems that involve the regulation of affect and motivation and the redefinition of the motivational significance of a stimulus. The domain of Hot EF includes empathy, theory of mind, emotional regulation and affective decision making. Empathy has usually been defined in two ways: the cognitive awareness of another person’s internal states (thoughts, feelings, perceptions, interactions), and the vicarious affective response to another person. Theory of mind is the ability to attribute mental states to self and others, and to predict and understand other people's behavior on the basis of their mental states. Operationally, individuals are credited with a theory of mind if they succeed in tasks designed to test their understanding that an individual may hold a false belief. Emotional regulation refers instead to the capability to modulate emotional responses. Finally affective decision making is a form of decision making that requires appraisal of the emotional and motivational significance of stimuli and involves reward, punishment, and uncertainty about future outcomes. Cool and Hot EF typically work together as part of a more general adaptive function. It remains an unresolved issue whether these aspects of executive domain are also dissociable in children or whether they become differentiated during over development.

1.2 NEUROANATOMY OF EXECUTIVE FUNCTION

Initially, in the context of human lesion studies, it was accepted that EF was submitted by frontal structures. Later, as localization models became more refined, the prefrontal cortex (PFC) was identified as the seat of these functions. In the last years it is clearly established that executive processes are associated with numerous, complex, and interrelated frontal- cortical and subcortical neural systems (Fuster 1993).

1.2.1 Neural substrate of Executive Function

The frontal lobes can be divided into three functional sectors: 1) a motor and premotor sector; 2) a paralimbic sector located in the ventral and medial sides of frontal lobe, which consists of the anterior cingulate complex (Brodman's areas 23 and 32), paraolfactory gyrus (Brodman's area 25), and posterior orbitofrontal regions; 3) a heteromodal sector including Brodman's areas 9, 10, 45, 46, and 47, and the anterior portion of Brodman's areas 11 and 12. Of these three sectors, the paralimbic and heteromodal sectors constitute the PFC. PFC can be anatomically and functionally divided into the dorsolateral PFC, orbitofrontal PFC, and the ventral PFC (Stuss et al., 2002).

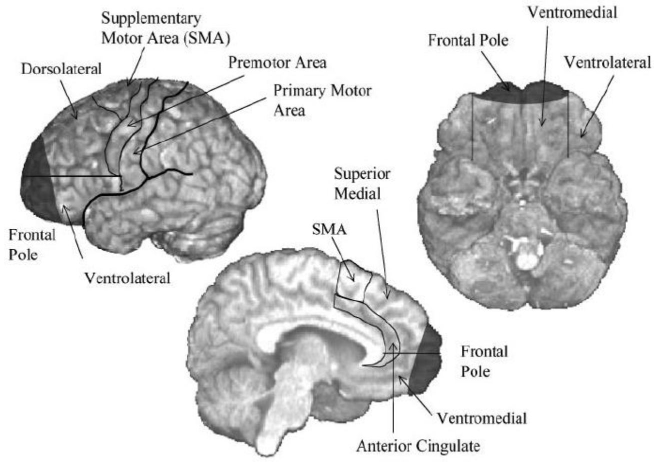


Figure 1.1: Frontal lobes

Frontal lobe is extensively interconnected with the major sensory and motor systems of the brain. There are 5 defined frontal-subcortical circuits. They are named according to their function or site of origin in the cortex. The motor circuit originating in the supplementary motor area and the oculomotor circuit originating in the frontal eye fields are involved in motor functions. The dorsolateral prefrontal, orbital frontal and anterior cingulated circuits are dedicated to EF, social behavior and motivational states in humans.

The motor circuit originates from neurons on the supplementary motor area, premotor cortex, motor cortex and somatosensory cortex. These areas project to the putamen in a topographical pattern. The putamen in turn projects to specific portions of the globus pallidus externa, interna and substantia nigra pars reticularis. The globus pallidus connects to the ventrolaterale, ventral anterior and centromedian nuclei of the thalamus which projects back to the motor cortex.

The oculomotor circuit originates in the frontal eye field and posterior parietal cortex. The fibers then project to the body of the caudate nucleus, dorsomedial globus pallidus and ventrolaterale substantia nigra. They reach the mediodorsal thalamic nuclei and close the loop by projecting back to the frontal eye field.

The dorsolateral prefrontal circuit originates in Broadmann's area 9 and 10 on the lateral surface of the anterior frontal lobe and projects to the dorsolateral head of the caudate nucleus. Neurons from this site project to the lateral part of the mediodorsal globus pallidus interna and rostrolateral substantia nigra pars reticulata as the direct pathway. The fibers from the basal ganglia project to parvocellular portions of the ventral anterior and mediodorsal thalamus. The mediodorsal thalamus sends fibers back to the circuit origin in the dorsolateral frontal cortex (Mega et al., 1994). According to Cummings (1993), dysfunction in the dorsolateral prefrontal circuit is associated with specific problems: decreased fluency, perseveration, difficulty shifting set, poor recall and retrieval of information, reduced mental control, limited abstraction ability and poor response inhibition.

The lateral orbitofrontal circuit originates in Broadmann's area 10 and 11 and sends fibers to the ventromediali caudate nucleus. Neurons form this region of the caudate project to the medial part of the mediodorsal globus pallidus interna and to rostromedial substantia nigra pars reticulata. Fibers from substantia nigra and globus pallidus connect to the ventral anterior and mediodorsal thalamus. The circuit then is closed by fibers projecting back to the orbitofrontal cortex from thalamus. a medial division of the dorsolateral circuit originates in the gyrus rectus and the medial orbital gyrus of Broadmann's area 11. The fibers go to medial aspects of the accumbens, to medial ventral pallidum and reach the mediodorsal thalamic nucleus (Mega et al., 1994). Clinical data suggest the involvement of the lateral orbitofrontal circuit in inhibition, emotion, and reward processing. Lesions specific to the circuit may result in dysinhibition and impulsivity. (Cumming et al., 1993).

Finally the anterior cingulated circuit originates in the anterior cingulated cortex (Broadmann's area 24). The neurons project to the ventral striatum, which includes the ventromediali caudate, ventral putamen, nucleus accumbens and olfactory tubercle. Projections from the ventral striatum pass to the rostromedial globus pallidus interna, ventral pallidum and rostrodorsal substantia nigra. The ventral pallidum connects to the ventral anterior nucleus of the thalamus. The anterior cingulated circuit is closed with projections from ventral anterior thalamus back to the anterior cingulated cortex (Mega et al., 1994). This circuit is involved in motivation. Lesions specific to this circuit may produce apathy, lack of motivation, decreased interest in engagement with the environment, and poor behavioral maintenance.

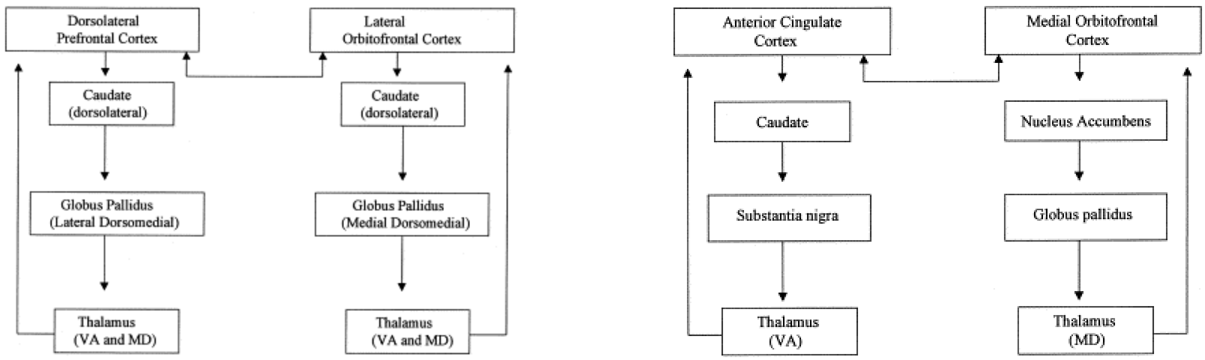


Figure 1.2: the dorsolateral prefrontal, lateral orbitofrontal and anterior cingulated circuits.

In addition to these closed frontal-subcortical loops, there are open connections of the circuits that integrate information from anatomically distant but functionally related brain areas. Major cortical afferents to the dorsolateral frontal-subcortical circuit are Broadmann area 46 and parietal area 7a, instead main efferents are to Broadmann areas 46 and 8. The orbitofrontal subcortical circuit receives open afferents from the superior temporal cortex, substantia nigra, dorsal raphe and midbrain tegmentum, instead the efferent connections of orbitofrontal circuit are to the lateral hypothalamus and the septal region. The anterior cingulated circuit receives major afferents from the perirhinal area and hippocampus and sends efferents to substantia nigra, lateral hypothalamus and subthalamic nucleus (Mega et al. 1994).

1.2.2 Association between the Frontal-subcortical circuits and specific Executive Function

A large number of studies exploring the neural substrate of executive functioning in normal subjects used task-specific analyses.

In the first series of functional neuroimaging studies, the neural substrates of EF were explored with cognitive tasks similar to those used in the clinical examination of brain damaged patients such as the Wisconsin Card Sorting Test (WCST), the Tower of London (ToL), the Random Number Generation Task and the Verbal Fluency. The data suggested that the WCST was associated with bilateral increases in cerebral activity in the dorsolateral, inferior parietal and occipital regions, and with an activation of lower intensity in the frontopolar, orbital, medial regions and temporal areas (Berman et al., 1995; Nahagama et al., 1996; Ragland et al., 1997). Researchers found for the ToL increases in cerebral activity in the left prefrontal dorsolateral cortex, the superior frontal cortex, the anterior cingulate, the right frontopolar region, and, to a lesser extent, in the precuneus, the left inferior parietal cortex, the superior parietal cortex bilaterally, and the occipital regions bilaterally (Baker et al., 1996; Dagher et al., 1999; Morris et al., 1993). The random number generation task instead was associated with significant activation of the dorsolateral prefrontal cortex, the anterior cingulate, the superior parietal cortex bilaterally, the right inferior frontal cortex, the left and right cerebellum hemispheres (Jahanshashi et al., 2000). Finally Verbal fluency was associated with the left inferior frontal gyrus, the anterior cingulate, the left middle and superior frontal gyrus, the dorsolateral prefrontal cortex, the right parahippocampal gyrus (Frith et al., 1991; Phelps et al., 1997).

Traditional cognitive tasks, used in studies presented above, have an intrinsic limitation: they involve more than one executive process and non-executive processes. Consequently, studies were undertaken to explore executive functioning using cognitive tasks considered to involve only one specific executive process. Numerous functional neuroimaging studies explored the neural substrate of updating, shifting, inhibition and dual task coordination. Updating is usually explored used the running span task for verbal material, and the n-back tasks for letter, spatial positions and non verbal material. Results obtained show that the updating process is associated with various prefrontal areas (dorsolateral, inferior and cingulate) and with parietal areas (posterior and superior) (Braver et al. 1997; Cohen et al., 1997; Jonides et al., 1997; Schumacher et al., 1996; Smith et al., 1996). Shifting has classically been studied using task-shifting paradigms, in which participants rapidly repeat the same task or alternate between different tasks. Several regions are associated with shifting processes: both posterior (parietal and occipital) and anterior areas (including the dorsolateral prefrontal cortex and anterior insula). Inhibition processes were investigated by perceptual, motor or semantic paradigms. These studies have demonstrated the involvement of various regions located in the cingulate, prefrontal, parietal and temporal areas (Bench et al., 1993; Bush et al., 1998; Chee et al., 2000; Collette et al., 2001; Garavan et al., 1999; George et al., 1994; Larrue et al., 1994; Pardo et al., 1990; Taylor et al., 1997). However, at this time, the exact role of the regions associated with inhibitory processes is not fully understood. Finally, there is still debate concerning the neural substrates of dual-task coordination. Data evidenced a left-sided fronto-parietal network involvement. This network is composed of the inferior frontal sulcus (BA 9/46 and BA 44/45), anterior prefrontal cortex (BA 10/47), posterior middle frontal gyrus (BA 6) and left inferior parietal gyrus (BA 40). Increased activity was also observed in the cerebellum (Collette et al, 2005). In summary, these studies have demonstrated that: 1) many cerebral areas are associated with the different executive processes; 2) heterogeneous regions are activated, not only by different executive processes but also by a single process, depending on the exact requirements of the tasks administered; 3) the different executive processes depend upon the intervention of both prefrontal and posterior (mainly parietal) regions during the performance of various executive tasks.

However, the functional neuroimaging studies using task-specific analyses suffer from some limitations: 1) the difficulty in isolating one specific executive process; 2) the greater number of tasks used to analyze a single executive process; 3) the difficulty in isolating the contribution of other non-executive processes. Consequently numerous functional neuroimaging studies re-examined the neural substrates of executive processes with conjunction designs. The principle of conjunction design is the search for convergence between cerebral areas activated by different tasks used to explore a single process. Findings were consistent with those of studies using task-specific analyses and were compatible with the conceptualization of executive functioning in terms of interrelationships between anterior and posterior cerebral areas (Collette et al., 2002; D’Esposito et al., 1996; Fuster, 1993; Morris, 1993; Weinberger, 1993). Interestingly, results emphasized the critical role of the parietal areas in executive functioning, since the left superior parietal cortex and the right intraparietal sulcus were activated by all executive processes (Colette et al., 2005).

In conclusion, with reference to the review of studies that deal with the neural substrates of EF, it may be argued that 1) the integrity of the PFC is necessary, but not a sufficient, condition for intact executive functioning; 2) although the importance of the prefrontal areas to EF is documented, no consensus has been reached regarding the fractionation of functions within those regions; 3) the common cerebral areas activated by all EF are the posterior regions located in the left superior parietal gyrus, the right intraparietal sulcus and the left middle and inferior frontal gyrus; 4) in addition to these common areas, each executive processes also relied on specific regions (Collette et al., 2002).

1.2.3 Development of neural substrate of Executive Function

Parallels between ongoing maturation of the frontal lobes and the emergence of EF have been reported in a number of studies. Processes such as dendritic aborisation, myelination and synaptogenesis progress during early childhood, in a largely hierarchical manner, with anterior regions the last to reach maturity (Fuster, 1993).

In this study we focused our attention on the age-group 8-13 years. Between 8 to 13 years there are significant changes in cortical gray matter development in frontal lobes. While white matter development and myelination continue to progress steadily, there is a spurt in cortical gray matter development, peaking at age 11 in girls and 12 in boys (Rapoport et al., 1999). This acceleration in frontal lobe gray matter volume will be the last during the individual's lifetime. From early adolescence onwards, gray matter volume slowly declines, firstly as part of pruning process, thought to optimize and mature frontal lobe circuitry, and later in adulthood, as a part of normal ageing process (Ge et al., 2002; Scahill et al., 2003).

1.3 CRITICAL ISSUES IN THE STUDY OF EXECUTIVE FUNCTION

Although there is general agreement about the importance of EF for adaptive functioning, the construct of EF has remained elusive. There are issues in the conceptualization of EF that have prevented clear and definitive conclusions:

- the assessment of EF;
- the structure of EF;
- the development of EF;
- the executive profile in children with specific developmental disorders.

This dissertation deals with each of these themes.

1.3.1 The assessment of Executive Function

1.3.1.1 The traditional assessment

From historical standpoint, given the initial conceptualization of EF impairment as manifestation of the “frontal lobe syndrome”, the earlier assessment instruments were developed with the goal of identifying individuals with frontal lobe lesions. The most used EF measures are: the Wisconsin Card Sorting Test, the Trial Making Test, the Tower of London, the Tower of Hanoi, and the Verbal Fluency. Two measures usually used to tap cognitive flexibility are the Wisconsin Card Sorting Test (WCST) and the Trial Making Test (TMT). The WCST requires participants to discover the principle according to which a deck of cards must be sorted. The standard material consists of cards bearing geometric figures that vary in color (red, green, blue, or yellow), shape (triangle, star, cross or circle) and number (1,2,3,4 items). Four reference cards are aligned in front of the participant throughout the test. Another deck serves as response cards. The participant is instructed to place each response card in front of 1 of the 4 reference cards, wherever he/she thinks it should go. After each response, he/she is told if the response was “right” or “wrong”, but not where the card should have gone. The sorting rule is changed during the task. The subject is not told when the rule changes. The test ends when either when the subject has reached 6 criteria or when all 128 cards have been used. Three scores are usually used as an index of subject’s performance: number of categories completed, number of perseverative errors, and number of non perseverative errors. The TMT consists of two parts (A and B) that must be performed as quickly and accurately as possible. The TMT-A requires subjects to draw lines sequentially connecting in ascending order 25 encircled numbers randomly distributed on a sheet of paper (1-2-3-etc). In the TMT-B, the subject must alternate between numbers (1-13) and letters (A-L) while connecting them (1-A-2-B-3-C etc.). The score on each part represents the amount of time required to complete the task. Equivalent measures are used to obtain information about planning: the Tower of London (ToL) and the Tower of Hanoi (ToH). The ToL (Shallice et al. 1982) consists of three pegs of different lengths mounted on a strip, and three colored balls (red, blue, and yellow) that can be manipulated on the pegs. Stating from a fixed arrangement of the balls on the pegs, the child is required to copy a series of depicted end-states by re-arranging the balls. Upon the presentation of a problem, participants were informed on the number of moves required to solve that problem correctly. Twelve problems of graded difficulty were presented and a problem is solved correctly when the end state is achieved in the prescribed number of moves. A maximum of three trials was allowed to solve each problem. Three constraints apply: 1) do not place more than the permitted number of balls one peg; 2) do not place the balls anywhere other than on a peg; 3) only move one ball at a time. The performance is described by total score (it was calculated by assigning points based on the number of trials required to solve a problem; the maximum ToL score was 36), number of moves necessary to complete the trial, number of violation and temporal measures (planning, execution and total time). For the ToH (Welsh et al., 1991), the child is presented with two wooden-based models that contain 3 equal-sized, large plastic pegs. One model is described as the examiner's, where there are 3 different color disks that are stacked on the right peg. The peg diameter is graduated, so that all three disks only fit on the peg stacked from largest to smallest. The child's model contains the same colored and sized disks as the examiner's, but arranged in a different configuration across the pegs. The child must move the three disks, one at time, among the pegs to achieve the examiner's model configuration. Different configurations result in successively more difficult problems by increasing the number of moves that the child must make to reproduce the examiner's model configuration, the end-state goal. Three constraints apply: 1) a larger disk may not be placed on the top of a smaller disk ; 2) do not place the disk anywhere other than on a peg; 3) only move one disk at a time. There are 12 ToH problems consisting of six three-disk items and six four-disk items. The three-disk problems include two 5-move, two 11-move, and two 15-move problems. Participants are given six trials for each problem, during which they have to solve the problem correctly on two consecutive trials in order to receive points for that problem. Phonemic and semantic verbal fluency are used as measures of an individual's ability to generate words. Phonemic fluency refers to the ability to generate words beginning with a specific letter, semantic fluency instead refers to the capability to generate words belonging to specific semantic category. These tests require individuals to produce words over a brief period of time, one minute.

Recently, experimental tasks are developed. The experimental tasks tend to be designed to maximized sensitivity and specificity to discrete aspects of executive function, generate normally distributed scores and are relatively resistant to previous learned skills. The tasks of this type can generally be subdivided into different categories. Experimental tasks used to assess cognitive control that share in common the need to select one of several possible responses to given stimulus. The tasks of this type are for example the Go NoGo tasks, the reversal learning tasks, the Stroop tasks. The Go/no-go paradigm (Donders, 1969) is one of paradigm that is frequently used to study response inhibition. In the Go/no-go paradigm, subjects are presented with a series of stimuli and are told to respond when a go stimulus is presented and to withhold their response when a no-go stimulus is presented. The mapping of the stimuli onto go and no-go responses is explained at the beginning of the experiment and typically remains the same throughout the experiment. Discrimination reversal learning involves repeated pairing of an action with an outcome. Subjects can learn about reward contingencies through the sensory properties of cues that predict reward availability and the actions requires to procure that reward. Operationally, the subject first learns that discriminative stimuli carry information about whether a particular response instrumentally generates a reward. Over the course of the training, subjects become proficient at providing discriminated behavior, consistent with the associative rules. The rules learned can be deterministic or probabilistic. Typically, after reaching a learning criterion for accuracy on this discrimination problem, the reversal phase is implemented, and the reward contingencies are reversed. At reversal, the trained response no longer results in reward, though it remains at least temporarily dominant because of the initial training. Stroop task consists in sets of stimuli. In half of the sets the subject is required to name the color of dots (naming task without interference). In the other sets the task consists in naming the color of the ink of the letters forming the name of a different color (naming with interference). The sets with and without interference are presented alternately. Each stimulus is presented in the center of a monitor screen. The subject is required to name the presented colors as quickly as possible. The reaction time is recorded for correct response. There are experimental tasks used to assess working memory that require participants hold information in working memory, without any conflict resolution requirement, such as the N-back tasks. In the most typical variant of this task, the subject is required to monitor a series of stimuli and to respond whenever a stimulus is presented that is the same as the one presented n trials previously. “N” is a pre-specified integer, usually 1, 2, or 3. Finally, experimental tasks that measure emotional decision making and that require that participants weigh towards a specific goal, the relative contributions of regards and punishments, such as the Iowa Gambling Test. In this task, participants are shown four decks of cards, labeled A, B, C, D. Participants are told that they could select one card at a time from any of the decks and that they can continue selecting cards until the experimenter stopped the game. When selected, each card reveal a combination of gains and losses. Participants are given a stake of 300 euros and are asked them to win as much money as possible by choosing cards. They are not told how many trials there would be. The task is designed so that choosing consistently from two of the decks (C and D) would result in a net gain, whereas choosing from two of the decks (A and B) would result in a net loss. Decks A and B deliver larger immediate rewards (10 euro) than the other two decks but C and D are advantageous in the long run because they deliver even smaller losses. In contrast to rewards, the amounts of which are fixed, losses from all decks are variable and unpredictable; in particular, two of the decks (A and B) deliver more frequent losses (50% of cards), whereas the other two decks (B and D) deliver less frequent losses (10% of cards). After 100 selections, the task stop.

1.3.1.2 Limits of the traditional assessment

Traditional assessment has inherent limitations. First, there is the impurity problem (Miyake et al., 2000). Traditional measures of EF are dependent on lower-level cognitive skills such as language, memory and attention, and it can be difficult to fractionate the influences of executive components.

Second, traditional instruments lack in ecological validity: 1) performance-based measures tap individual components of the EF over a short time frame and not the integrated, multidimensional, relativistic, priority-based decision making that is often demanded in real-world situations (Goldberg et al., 2000); 2) the structured and quite settings are unlikely to be representative of daily environments; 3) the examiner provides support and encouragement and plans and initiates activities.

Finally, with reference to developmental neuropsychology, the vast majority of the tasks were designed for adult populations. Many of these tasks may be of little interest or relevance to children, and frequently lack sufficient normative data (Anderson et al., 2002).

1.3.1.3 Towards an ecological assessment: our proposal

Given the difficulties in using only traditional performance-based measures of EF, there has been increased interest in alternative methods to improve the ecological validity.

In the present work we proposed a new comprehensive neuropsychological battery that includes empirical measures and a rating scales and evaluated executive profile of typically developing children and clinical children by it.

Empirical measures are:

1) Cool EF domain: the Battersea Multitasking Paradigm, the Daily Planning Task, the Visuo-Spatial Reasoning Task and the Honk Task;

2) Hot EF domain: the Junior Gambling Task.

The rating scales are the two forms of the Questionnaire for the assessment of Executive Function (QuFE). In Chapter 3 we proposed evidence for reliability, internal factorial structure and clinical utility of the Parent and the Teacher forms of the QuFE

1.3.2 The structure of Executive Function

It is generally accepted that EF is an umbrella term that encompasses different interrelated cognitive skills. The structure of EF and the interrelationship between EF are topic of ongoing debate.

Early attempts to conceptualize EF resulted in a unitary models such as the "Central Executive" (Baddleley, 1986) or the "Sensory Activating System" (Norman et al., 1986) that describe executive domain as un unitary flavor without including subcomponents or subfunctions. Central Executive (CE) is a limited capacity attentional system with four relevant functions. First the CE selectively attends to one stream of information while ignoring irrelevant information and distractions. Secondly, the CE enables multiple tasks to be completed concurrently by coordinating adequate working memory resources across the various tasks. The third function is important for overriding habitual or stereotyped behaviors and refers to the capability to switch attention and response set within a task or situation that requires mental flexibility. Finally, CE is responsible for the selective and temporary activation of representations from long-term memory which is important to be able to respond to demands of the environment. The Sensory Activating System (SAS) is a globally integrated system that may perform a range of processes and involve a variety of systems differentially localized within the prefrontal cortex, however Shallice and Burgess (1990) believe it represents a single system ad these subsystems are operating interactively within an overall processing system in order to achieve a common overall function.

Subsequent studies have demonstrated that a unitary structure is too reductive and that the construct is more likely to be composed of distinct but interrelated components (Baddeley, 1998).

This hypothesis is based on different data 1) clinical data: patients rarely exhibit global executive dysfunction (Pennington et al., 1996); 2) neuroanatomical data: the neuroanatomical substrates of specific executive processes vary (Collette et al., 2002; Collette et al., 2005; Collette et al., 2006); 3) psychometric data: principal component analysis and exploratory factor analysis determine that the manifest variables of neuropsychological battery can be reduced to a smaller number of underlying factors (Brocki et al., 2004; Levin et al., 1991; Welsh et al., 1991); 4) developmental data: the developmental trajectories of specific executive processes vary (Best et al., 2010, Davidson et al., 2006; Huizinga et al., 2006; Huizinga et al., 2010; Levin et al., 1991, Welsh et al., 1991). Based on these evidences, two approaches to the studies of EF have been implemented: 1) some neuropsychological models define EF as a series of 3/4 basic interrelated or not interrelated processes and describe them (Anderson et al., 2002; Barkley et al., 1997; Levin et al., 1991; Miyake et al., 2000; Welsh et al., 1991); 2) other neuropsychological models illustrate the way in which distinct executive processes operate in an integrative manner in order to solve a problem, achieve the goal state, perform a complex task (Burgess et al., 2000; Zelazo et al., 1997).

In Chapter 2 we proposed a new conceptualization of executive domain emerging by the administration of our neuropsychological battery to 343 typically developing children aged 8 to 13 years.

1.3.3 The development of Executive Function

Recent research has established that executive function skills are present early in life and improve through childhood, although the developmental profile of these executive skills is not yet fully understood (Barrash et al., 2000). Research (Anderson, 2001; Welsh et al., 1991) has begun to establish patterns of EF development in infancy, early childhood, middle childhood and adolescence.

Convergent evidence have concluded that EF skills develop early than previously believed (Alexander et al., 2000). First signs of inhibition are observed in infants. Using A-not-B task research from human infant studies has found that from 9 to 12 months of age children begin to develop the capacity to inhibit a previously learned response (Diamond, 1988; Diamond et al., 1989). This skill increases between 1 and 2 years of age. Performance on measures such as the A-not-B task exhibits developmental trajectories that tend to peak around 4 years of age (Espy, 1997). It is around 4 years that the capacity to shift between response sets first emerges and within 2 years becomes more fluent and efficient (Espy, 1997). Another executive skill observed to first emerge at 4 years of age is goal setting (Welsh et al., 1991). Between 6 and 12 years significant changes are observed in most of executive domains. EF developmental trends in this period include: 1) the improvement of inhibitory skills that mature by age 6, although incremental improvements are still observed between the ages of 6 and 8 (Becker et al., 1987; Passler et al., 1985), 2) the emergence and improvement in children's cognitive flexibility (Kelly, 2000; Welsh et al., 1991), and 3) significant development and improvement in goal-setting and planning/organization skills (Kelly, 2000; Welsh et al., 1991). Research has delineated significant functional increments in EF during early and middle childhood, where some EF skills become relatively mature by early adolescence (Becker et al., 1985; Pennington et al., 1996). In general, the investigation of executive functions in adolescence has been sparser, but research supports developmental increments of EF in adolescence (Pennington et al., 1996; Welsh et al., 1991). Based on information to date, skills more likely to improve during adolescence include complex planning and organizational skills and strategic behavior. Processing speed also increases during adolescence, resulting in faster response rates and solution times, greater output, and fewer errors (Anderson, 2001).

In Chapter 2 we described the developmental patterns on tasks included in our neuropsychological battery and investigated the stability across the school-age of emerged executive structure.

1.3.4 The executive profile in children with neurodevelopmental disorders

The last contribute of this study concerns the role of EF in accounts of developmental disorders. Several common developmental and acquired disorders such as Autism Spectrum Disorders, Tourette's Syndrome, Obsessive-Compulsive Disorder, Schizophrenia, Attentional Deficit Hyperactivity Disorder, Learning Disabilities are associated with deficits in EF. Although EF deficits often co-occur with diagnostic symptoms in these disorders, evidence indicates that they are, at least to some extent, dissociable. Extant research offers some insights into different profiles of executive dysfunction among groups of children with developmental and acquired disorders. While some of these disorders share common features of executive dysfunction, the emerging profiles of deficits within each group appear to differ (Pennington et al., 1996). Below we presented the main findings about the executive profile of these developmental disorders.

Autism Spectrum Disorders (ASD) is a group of lifelong developmental disorders characterized by poor social interaction with others, language delay or impairment, and repetitive and stereotyped behavior (Wing, 1997). While social and language impairments have long been established and well-researched in ASD, more recent evidence suggests that deficient executive processes are fundamental to the cognitive deficits in ASD (Gilotty et al., 2002). Numerous attempts have been made to delimitate the specific executive deficits in children with ASD (Geurts et al., 2004). Autistic individuals are probably impaired in planning and show a certain type of perseverative behavior, taken to indicate a deficit in mental flexibility. These individual do not exhibit impaired inhibitory control per se, they do show impaired inhibition of prepotent response in certain cases, perhaps reflecting the forced application of an arbitrary rule (Hill, 2004).

Tourette syndrome (TS) is a neurodevelopmental disorder in which the core symtomatology consists of motor and vocal tics. A range of cognitive and behavioral features is often described in conjunction with tics. There is equivocal evidence for deficits in fluency, planning, working memory and cognitive flexibility, consistent data instead suggest that TS is associated with alterations in inhibitory functioning (Channon et al., 2003; Channon et al., 2006; Crawford et al., 2005).

Traumatic brain injury (TBI) in young children is common cause of disability, and can lead to wide range of cognitive and functional deficits (O'Connor et al. 2002). TBI may interrupt or affect skills that are still developing or yet to develop and this can lead to cumulative problems, which may only become evident with time (Anderson, V.A. 1998). Examination of outcomes in specific domains of EF suggested that EF were not globally affected following TBI, with certain domains appearing more vulnerable: initiative, conceptual reasoning, planning, strategic organization, and information processing.

Within the last decades researchers focus their attention on other clinical populations: Obsessive-Compulsive Disorder, Schizophrenia and Preterm children. As far as Obsessive compulsive disorder, Schizophrenia were concerned, evidence has accumulated that frontal lobe dysfunction play a crucial role in their genesis (Liddle, 1994; Purcell et al., 1998). Studies conducted with biological high-risk populations suggest that neuropsychological and executive dysfunctions are a risk factor for and not a mere consequence of these psychiatric disorders. Obsessive compulsive disorder (OCD) is a chronically debilitating disorder characterized by two sets of symptoms: obsessions (unwanted, intrusive, recurrent thoughts or impulses) and compulsions (ritualistic, repetitive behaviors or mental acts carried out in relation to these obsessions). Findings suggest impairment in response inhibition (Chamberlain et al., 2006), attentional set shifting (Chamberlain et al., 2006), spatial working memory (van der Wee et al., 2003), and planning (Delorme et al., 2007). Schizophrenia is instead a neurodevelopmental illness which manifests with signs and symptoms that cover the entire range of human mental activity such as the ability to think creatively, to have close social relationships with other human beings, to use language and express ideas clearly, and to experience and express a variety of emotions. Deficits in EF may be central to schizophrenia and is present in adolescents at risk of developing the disease, in patients with a first outbreak of schizophrenia, and apparently in their first-degree relatives (Breton et al. 201; Freedman et al., 2011). The disorders are manifested in motor programming due to difficulties in temporal and sensory information integration, planning and maintenance of goal-oriented behavior, and behavioral flexibility. These disorders can be objectified by neuropsychological tests that evaluate different skills: conceptualization, cognitive flexibility, ability to solve complex problems, and visuo-spatial working memory (Callicott et al., 2003). With reference to Preterm children, traditionally, the focus has been on general area of function such as general intelligence and gross motor skill development. However, compared to children born a term, children born preterm have been also shown to be particularly at risk of behavioral and cognitive problems (Bhutta et al., 2002). Findings suggest that EF and attention is an area of weakness in preterm children. Consistent across the studies are deficits in verbal fluency and shifting, instead problems in attention, inhibition, planning, and phonemic fluency are influenced by age at assessment and/or gestational age at birth.

In this study we focused our attention on two specific developmental disorders: Attention Deficit Hyperactivity Disorder and Learning Disabilities. Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common neurodevelopmental disorders of childhood. It is diagnosed on the basis of persistent, developmentally inappropriate and impairing symptoms of inattention and hyperactivity/impulsivity (American Psychiatric Association, 2013). These two symptom clusters give rise to three presentations of ADHD: predominantly inattentive, predominantly hyperactive-impulsive, and a combined presentation. A review of literature suggests that EF weakness are significantly associated with ADHD but do not support the hypothesis that the EF deficits are the single necessary and sufficient cause of ADHD in all individuals with the disorder. EF difficulties appear to be one of several important weakness that comprise the overall neuropsychological etiology of ADHD. Willcutt et al. (2005) hypothesized that ADHD had deficits in executive domains such as response inhibition, planning, vigilance and working memory. The importance of executive function deficits in children with Learning Disabilities (LD) instead is becoming more appreciated only in the last years. Specific learning disorder is a type of neurodevelopmental disorder that impedes the ability to learn or use specific academic skills, which are the foundation for other academic learning. The diagnosis requires persistent difficulties in reading, writing, arithmetic, or mathematical reasoning skills during the formal years of schooling. LD includes Dyslexia, Spelling disorder and Dyscalculia. A review of literature suggests impairments in attention, response inhibition and verbal working memory in children with this neurodevelopmental disorder (Klorman et al., 1999; Nigg et al., 1999; Purvis et al., 2000; Roodenry et al.; 2001, Semrud-Clikeman et al., 2003; Semrud-Clikeman et al., 2005; Swanson et al., 1999; Weyandt et al., 1998; Willcutt et al., 2001).

Starting from these evidences, in Chapter 4 we presented an extended review of the literature and we studied the EF profile in children with ADHD and LD. Three groups of children, aged between 8 and 13 years (40 ADHD, 25 LD, 207 typically developing children) were presented with our neuropsychological battery. In Chapter 3 we described the EF profile by Questionnaire for the assessment of EF.

CHAPTER 2: STRUCTURE AND DEVELOPMENT OF EXECUTIVE FUNCTION IN CHILDHOOD

2.1 INTRODUCTION

Cognitive developmental neuropsychology has made considerable progress over the last few decades and has developed sophisticated theories and models about specific cognitive domains or processes. Despite this headway, there remain a number of theoretical issues or phenomena about which little can be said. Executive Function (EF) is one of the most widely invoked constructs in the cognitive science, neuropsychology, developmental and clinical research literature. This construct has become important in the assessment of typically developing children and special populations because of its relation to scholastic achievement and school readiness, social competence and theory of mind and behaviours associated with developmental disorders.

Executive Function refers to deliberate, top-down neurocognitive processes involved in the conscious, goal-directed control of thought, action and emotion processes (Miyake et al., 2000). These executive processes are essential for the synthesis of external stimuli, the formation of goals and strategies, the preparation of action and the verification that plan and actions have been implemented appropriately. Several elements of EF have been articulated as key components, including impulse control and self-regulation, anticipation and the deployment of attention, working memory, initiation of activity, planning ability and organisation, mental flexibility and utilisation of feedback, selection of efficient problem solving strategies. Recent research has distinguished between two aspects of EF (Zelazo et al., 2002): “Hot EF” and “Cool EF”. Cool EF is more likely to be elicited by problems and involves strategic planning, organisation, goal setting, behaviour monitoring, problem solving, inhibition, working memory and cognitive flexibility. Hot EF is more likely to be elicited by problems that involve the regulation of affect and motivation and the redefinition of the motivational significance of a stimulus. The domain of Hot EF includes empathy, theory of mind, emotional regulation and affective decision making. Cool and Hot EF typically work together as part of a more general adaptive function. Neuropsychological research with adult patients suggests that Hot and Cool EF are dissociable: Impairments in Cool EF can occur without impairments of Hot EF, and vice versa (Bechara et al. 1998). It remains an unresolved issue whether these aspects of EF are also dissociable in children or whether they become differentiated during development.

Although there is general agreement about the importance of EF for adaptive functioning, the construct of EF has remained elusive. There are three major issues in the conceptualisation of EF that have prevented clear and definitive conclusions: its structure, its development and gender differences.

2.1.1 Executive Function structure in children

The first issue concerns the question of whether EF is a unitary construct or a heterogeneous set of dissociable processes.

In the early stages of theoretical development, some authors have suggested executive control is a unitary and general domain construct that may manifest differently according to the specific contextual demand (Norman & Shallice, 1986; Baddeley, 1986). Both the Central Executive (Baddeley 1986) and Supervisory Attentional System (Norman & Shallice, 1986) had a unitary flavour, without the inclusion of any distinct subfunctions or subcomponents.

In contrast, there is also evidence for the non-unitary nature of executive functions. One line of evidence comes from clinical observations, which indicate some dissociations in performance among the executive tasks. Another line of evidence comes from a number of individual difference studies. These studies are similar in the sense that they all employed a battery of widely used executive tasks and used principal components analysis (PCA) or exploratory factor analysis (EFA) to determine whether the manifest variables could be reduced to a smaller number of underlying factors. Developmental studies using PCA or EFA have generally revealed between one and four factors of EF in preschool children (Carlson et al., 2004; Carlson et al., 2001; Espy et al., 2007; Hughes, 1998; Hughes et al., 2007; Welsh et al., 2010) and school-aged children (Brocki et al., 2004; Levin et al., 1991; Pennington et al., 1997; Welsh et al., 1991). Welsh et al. (1991) and Levin et al. (1991) performed component analyses on typically developing participants from 3 to 12 and from 7 to 12 years of age, respectively. These two studies obtained a very similar factor-analytic pattern that consisted of three different factors. The first factor in both studies could be considered a fluency dimension because it received loadings from a number of fluency measures; the second factor clearly reflected a dimension of hypothesis-testing and impulse control; and the third factor was interpreted as planning in both studies. Although they have provided useful insights, the correlational or factor analytic studies have several important weakness or limitations that limit the conclusion about the nature of EF that can be drawn from these studies: task impurity problems, low internal and test retest reliability and construct validity problems. Latent variable analysis (CFA) could alleviate at least some of the problems that have plagued the typical individual differences approach. CFA extracts the common variance to executive tasks that are presupposed to call on the same underlying executive function. Miyake and colleagues (2000) used CFA to test one theoretical framework that suggests that the EF construct consists of interrelated but distinct components: Shifting, Inhibition and Updating of Working memory. Shifting refers to the ability to move between alternative sets of mental operations. Inhibition refers to the ability to resist interference from competing or prepotent responses or processes. Updating refers to the ability to refresh and maintain information in working memory in the presence of new information. They focused on these three components because 1) they are well-circumscribed, lower-level functions that can be operationalized in a fairly precise manner; 2) they can be studied using commonly used tasks, and 3) they have been implicated in the performance of more complex EF tasks, such as the Wisconsin Card Sorting Task and theTower of London. The authors tested healthy adults on multiple tasks that tapped Working Memory, Shifting and Inhibition, and several standard but complex neuropsychological tasks, including the Wisconsin Card Sorting Task and the Tower of Hanoi. The results showed that, although moderately correlated, Working Memory, Shifting and Inhibition were separable constructs. To explain the correlations between factors, the authors proposed that updating requires discarding irrelevant incoming information and suppressing obsolete information. Shifting requires the deactivation or suppression of an obsolete mental set in favour of the new one. Accordingly, poor behavioural inhibition would lead to secondary deficiencies in EF.

Many developmental studies have adopted the multifactorial framework of Miyake and colleagues, but few have provided an empirical or theoretical justification for the suitability of the model for a child population. Despite early evidence that suggests that EF can be divided into the same dimensions in children (Lehto et al., 2003, Wu et al., 2011), findings from more recent studies are equivocal. A number of studies failed to find evidence for differentiation into the same three subtypes (Huizinga et al., 2006; Van der Sluis et al., 2007, Lee et al., 2013). Lehto and colleague (2003) seemed to show support for Miyake's model in children aged 8 to 13 years. Three tasks from the Cambridge Neuropsychological Test Automated Battery (CANTAB), two tasks from Developmental Neuropsychological Assessment Battery (NEPSY) and some additional EF tests were administered to 108 children. EFA and CFA yielded three interrelated factors labelled Working Memory, Inhibition and Shifting. Similar results with CFA were reported by Wu and colleagues (2011): subtests from the Test of Everyday Attention for Children and other EF tests were administered to 185 children aged 7 to 14 years. Structural equation modelling results indicated that three first-order EF components—Shifting, Working memory and Inhibition—were the best. Both Huizinga and colleagues (2006) and Van der Sluis and colleagues (2007) instead supported a two-factor structure. Huizinga and colleagues (2006) examined the performance on standard but complex neuropsychological EF tasks in four age groups (7, 11, 15, 21 years). CFA yielded two common factors: Working memory and Shifting. Huizinga and colleagues (2006) did not find evidence for a separate inhibition process. Van der Sluis and colleagues (2007) also failed to detect a common factor for Inhibition in children aged 9 to 12. The authors suggested that the failure to distinguish a common Inhibition factor did not necessarily indicate that there was no such thing as "inhibitory ability". This construct may exist, but there might not be large sources of reliable individual differences; it could be very difficult to measure or be highly correlated with other constructs. Lee and colleagues (2013) proposed an integrative point of view. Using a cohort-sequential design, this study analysed executive functioning in children aged 6 to 15 years. Findings from this study are similar to Huizinga and colleagues (2006) and Van der Sluis and colleagues (2007), who found a separation between Working Memory and Shifting across early childhood. The authors proposed a process of differentiation from a two-factor structure in early childhood to a three-factor structure in the teenage years. Data from the 11 and 14 years children suggested a period of transition during which the two- and three-factor models vacillated in their ability to provide the best description for the data. Signs of early differentiation emerged at age 11 and reached some stability at age 15.

In conclusion, the above studies support the non-unitary hypothesis of EF. EF is conceptualised as discrete functions that operate in an integrative manner. With reference to the school-age population, data converge towards a model with two (Working Memory and Cognitive flexibility) or three factors (Working Memory, Cognitive flexibility and Inhibition).

2.1.2 Development of Executive Function

A growing body of research had indicated that the development of EF is protracted process that extends into early adulthood. Evidence has suggested both quantitative (Munakata et al. 2001) and qualitative (Zelazo et al., 2003) EF development. Much of the change appears to be quantitative and gradual, although the change may be more rapid in the early years. Some change appears to be qualitative, suggesting changes in brain organisation as the site of brain activities shifts during development (Scherf et al. 2006). In addition, there is sufficient evidence to suggest that specific executive processes arise at different ages and exhibit variable developmental trajectories.

Our current understanding of EF development, in the age group object of our study (8-13 years), is based on various developmental and normative studies: Levin and colleagues (1991), Welsh and colleagues (1991), Huizinga and colleagues (2006), and Best and colleagues (2009). Levin and colleagues (1991) concluded that adult-level performance on tasks that assessed the formation of concepts was achieved at 12 years, and adult-level performance on tasks that tapped planning and inhibition was reached at 15 years. Welsh and colleagues (1991) reported similar developmental trajectories. The authors concluded that adult-level performance on different executive function tasks was achieved at three different ages: 6 years for speed responding and simple forms of planning, 10 years for inhibition and 12 years for problem solving and planning. Huizinga and colleagues (2006) focused their attention on working memory (WM), shifting and inhibition of responses, and they concluded that an adult level of performance in WM, switching and inhibitory tasks was not reached until the age of 15. Consistent with prior studies, they found that adult-level performance in WM tasks was not reached before the age of 12, the cost of shifting decreased with age, and inhibition improved rapidly until the age 11, and at this age, performance did not differ from 15-year-olds or 21-year-olds. Similar results were obtained in other studies (Lehto et al., 2003, Davidson et al., 2006, Lee et al. 2013). An interesting review was conducted by Best and colleagues (2010). This review focused on large age ranges and outlined the development of the same EF investigated by Huizinga and colleagues (2006). The authors inferred that 1) inhibition improved strikingly particularly during the preschool years and changed less later and 2) working memory showed a more gradual linear improvement throughout development as did shifting.

In conclusion, EF emerges early in childhood, but a significant period of development occurs before it is fully functional. EF develops rapidly throughout childhood, which suggests that progression is not necessarily linear but may occur in spurts. Furthermore, it appears that components of EF might demonstrate different developmental trajectories. As far as school-age was concerned, inhibition and cognitive flexibility a reached mature level, and working memory and planning/organisation were characterised by significant increases.

2.1.3 Gender differences in structure of Executive Function

Available data seem to suggest that only a small amount of variance in the performance of EF tasks was actually accounted for by gender differences. There was some mention of gender differences for select components of executive function in the literature, possibly mediated by hormonal factors and by gender related differences in brain structure (Kolb et al., 1991; Gurr et al., 1999; Gurr et al., 2000; De Bellis et al., 2001, Goldstein et al., 2001; Lenroot et al., 2010). Anderson and colleagues (2001) and Ardila and colleagues (1994) proposed gender differences in normal children. Males were found to excel on planning and organisation, vigilance and speed of processing tasks, whereas a gender crossover effect with increasing age has been found for working memory. In their study, De Luca and colleagues (2003) failed to replicate the findings of a gender crossover in executive domains; in fact, executive skills came "on-line" simultaneously for both genders and progressed at equal rates. Males were consistently seen to outperform females in measures of visuo-spatial working memory, planning and attentional set shifting. Gurr and colleagues (2012) also found significant gender differences in the overall performance and in age group related variation, but they were small compared to age group effects. The hypothesised differences that favour females on memory and social cognition tests and males on spatial and motor tests were supported. The authors found few age-gender interactions in spatial memory, non-verbal reasoning and social cognition tests. All of these interactions indicated that gender differences became more pronounced in the age groups that follow mid-adolescence. Across almost all domains, females reached a plateau before males, so there was earlier maturation in females.

In conclusion, the above studies suggest there are gender differences in the performance of specific tests designed to assess specific executive processes. Areas in which girls have been reported to outperform boys include verbal working memory and attention. In contrast, boys have performed better than girls on spatial reasoning/working memory and cognitive flexibility.

2.1.4 Aims of the study

This study has three main goals:

1. The first aim is to examine the structure of EF in typically developing children. Consistent with prior studies, we hypothesised that EF would be characterised as separable but related functions. In contrast to prior studies, we supposed that the executive domain would be more articulated than was proposed by Miyake and colleagues (2000), who proposed that the taxonomy of executive functioning consists of three basic functions: shifting, updating and inhibiting. We assumed that this theoretical framework could be, in part, explained by the tests used. For example, Miyake and colleagues (2000) employed rather simple measures designed to probe predetermined latent EF. We hypothesised that in addition to these basic functions, there may be a more complex executive domain that is a core of executive functions.

2. Second, the development of executive function in school-age children age 8 to 13 years would be examined. Consistent with prior studies, we hypothesised developmental changes in the performance of all executive domains. We assumed there would be contained and non-linear changes in all hypothesised executive domains. We hypothesised that basic functions, such as inhibition and vigilance, could reach mature levels during school-age years instead of more complex ones continuing their development in adolescence.

3. Third, gender differences in various EF components would be examined. Behavioural, structural neuroimaging and functional imaging measures suggested differences in individual performance but not in the structure of the executive domain. Consistent with developmental and normative studies, we supposed that boys and girls would have different performance in specific tasks used to tap EF. In particular, it is possible to assume that girls outperform boys in tasks used to tap the attentional domain, and boys perform better than girls in tasks used to evaluate visuo-spatial reasoning and cognitive flexibility.

2.2 METHOD

2.2.1 Participants

Participants in the study included 343 children (157 boys, 186 girls) with a mean age of 10.47 years (SD=1.71; range 8-13). The decision to limit the youngest group to 8-year-olds was based on the consideration that the tasks were most likely too difficult for children younger than 8 years of age. *Table 2.1* shows the distribution of boys and girls across the age groups.

Children were representative of the 8- to 13-year-old population and came from public schools in Lombardy, Piedmont, Veneto and Sardinia.

The eligibility criteria for children were the following: no diagnoses of any neurological, psychiatric or developmental disorders and no history of brain damage or sensory deficit. All participants spoke Italian as their first language.

Both teachers and parents were informed about the study aims. Parental consent was obtained for all participating children.

Table 2.1 Distribution of boys and girls across the age groups.

Age	Boys	Girls	Total
8 years	26	31	57
9 years	28	38	66
10 years	31	21	52
11 years	21	25	46
12 years	31	41	72
13 years	20	30	50
Total	157	186	343

2.2.2 Materials

We developed a comprehensive test battery that included tasks that measure working memory, retrospective episodic memory, cognitive flexibility, inhibition, planning and organisation of behaviour, affective decision making, and visuo-spatial reasoning. The battery includes the following tasks: the Battersea Multitasking Paradigm, the Daily Planning Task, the Visuo-Spatial Reasoning Task, the Junior Iowa Gambling Task and the Honk Task.

- Battersea Multitasking Paradigm (adapted from Mackinlay et al., 2006)

The Battersea Multitask Paradigm (BMP) is a children's task designed following the principles of the Greenwich Multitask Test for adults (Burgess et al., 2000). The BMP makes demands upon three constructs: retrospective memory, planning and prospective memory.

The BMP consists of 3 interleaved but very simple tasks that children must perform in a time limit of 6 minutes. The performance constrained by four rules. The object of the game is to score a maximum of points without breaking any rules. The optimal way to perform the game is to fill up small clusters of yellow items in all 3 tasks. The 3 tasks are bead sorting, counter sorting and caterpillar colouring. In the bead sorting task, children sort blue and yellow beads from a large box into 8 smaller transparent containers of varying forms. Half the containers are marked for blue beads and half for yellow beads. In the caterpillar task, children colour parts of blue and yellow caterpillars presented on an A3 sheet of paper. Each caterpillar is constructed of circles. There are 12 caterpillars of varying length. In the counter sorting task, children sort blue and yellow discs from large box onto 10 grids of varying size. Half the grids are marked for yellow counters, and half for blue. Task performance is governed by 4 rules: 1) Try all 3 games before the sand runs out, 2) yellow items get more points than blue, 3) full clusters get extra points, and 4) items must only be picked or coloured one-by-one. The BMP is administered in a five-stage invariant behavioural sequence. Each stage generated a dependent variable. The sequence of administration is the following: learn, plan, execution, monitor and memory. In the Learning section, after the rules had been explained and demonstrated, the child was asked to freely recall them. To test cue rule recall, the child was asked 9 questions about the rules. The composite score of *Learning* ranged from 0-13 points. In Planning , the child was asked to generate a plan of how he/she intended to perform the task, gaining as many points as possible without breaking any rules. The composite score *Planning* ranged from 0-12. In Execution, the child performed the task in the 6-minute time limit. The maximum composite score *Execution* is 78. In Monitoring, the child was asked to tell and show the experimenter what he/she had done and why. The composite score of *Monitoring* ranged from 0-17. In Memory, the child was asked to freely recall the 4 rules of the paradigm. The possible range of the composite score *Memory* was 0-4.

- <u>Daily Planning Task</u> (adapted from Schweiger and Marzocchi, 2008)

The Daily Planning Task (DPT) is a semi-ecological children's task designed following the principles of the Multiple Errands Test (Shall et al. 1991). The DPT assesses retrospective and working memory, planning and temporal estimation.

The DPT is proposed in 2 versions, a version for children aged 8-10 years and a version for subjects aged 11-14 years. The DPT is administered according to a 3-stage invariant sequence. Each stage generated 1 dependent variable. The sequence of administration is the following: a Learning task, a Temporal Estimation task and a Planning task. In the Learning task, after ten activities had been explained, the child was asked to freely recall them. The *Learning* score ranged from 0-10 points. In the Temporal Estimation task, the child was asked to estimate the duration of each activity. The *Temporal estimation* score ranged from 0-10 points. Finally, in the Planning task, the child was asked to order the 10 activities following logical and chronological constraints and minimising the number of movements (the minimum number of movements was 8) in a time limit of 20 minutes. This stage generated the dependent variable *Activities*, the number of activities organised in the correct way, and its score ranged from 0-10 points.

- Visuo-spatial Reasoning Task (adapted from Burgess et al., 1997; Shallice et al., 2002)

The Visuo-spatial Reasoning Task (VSRT) is a rule attainment task that gives information about visuo-spatial reasoning, working memory and cognitive flexibility.

Participants were presented with a 55-page stimulus booklet. Each page contained 10 circles, 9 blue circles and 1 red circle that changed in position from one page to the next. The changes were governed by 7 simple rules that varied without warning. Participants were presented with one page at a time and were required to point to where they thought the red circle would be on the next page based on the pattern of rules inferred from the previous pages. Errors were classified as *Perseverations* or *Non perseverative errors*. The first dependent variable referred to all errors that could be attributed to some form of perseveration, either of reproducing the current stimulus or the preceding response, or of the application of the rule that immediately preceded the current one to either the current stimulus or the previous response. The second dependent variable referred to all other error responses. The composite score ranged from 0-48 errors.

- Junior Gambling Task (adapted from Bechara et al., 1994)

The Junior Gambling Task (JGT) is designed to assess affective decision making. In this task, participants were shown 4 decks of cards, labelled A, B, C, or D. Participants were told that they could select 1 card at a time from any of the decks and that they could continue selecting cards until the experimenter stopped the game. When selected, each card revealed a combination of gains and losses. Participants were given a stack of 300 euros and were asked to win as much money as possible by choosing cards. They were not told how many trials there would be. The task was designed so that choosing consistently from 2 of the decks (C and D) would result in a net gain, whereas choosing from the other 2 decks (A and B) would result in a net loss. Decks A and B delivered larger immediate rewards (10 euro) than the other 2 decks, but C and D were advantageous in the long run because they delivered even smaller losses. In contrast to rewards, the amounts of which were fixed, losses from all decks were variable and unpredictable; in particular, two of the decks (A and B) delivered more frequent losses (50% of cards), whereas the other 2 decks (B and D) delivered less frequent losses (10% of cards). After 100 selections, the task stopped. For each block, the number of disadvantageous choices was subtracted from the number of advantageous choices. A mean score (*Total*) was calculated.

- Honk Task (Marzocchi et al., 2013)

The Honk Task (HT) is a children's computerised task designed following the principles of the Change Task paradigm (Sergeant and Oosterlaan, 1998). The Honk Task is designed to assess vigilance, inhibition and cognitive flexibility.

The Honk Task consists of 3 sessions of trials: Go, Stop and Change sessions. Each session consists of 160 trials.

The *GO session* is used to build up a prepotent motor response. Children were presented with a red car on the screen of a computer. The car was presented in the left or in the right part of the screen. Using the right hand, children were asked to press as fast as possible the “N” button on the keyboard every time the red car was displayed on the left side of the screen and were asked to press the “M” button every time the red car was presented on the right side (main task).

In the *STOP session,* a stop signal tone (honk) was presented in 25% of the trials (40 trials). Stop trials were presented randomly within the session to discourage children from anticipating the presentation of the stop trials. In the stop trial, children were asked to initiate the same response as in go trials (main task), but after hearing the stop signal, children were asked to inhibit their response.

In the *CHANGE session*, a signal tone indicated that an alternative response should be executed. Signal tones were presented in 25% of trials (40 trials). Children were required to initiate the same response as on G*o* trials (the main task), but after hearing the signal tone, children were required to press the “X” button on the keyboard using the left hand.

For the three sessions, children had 2000 ms to respond. The time interval between the response and the next stimulus was 1000 ms.

The Honk Task has six dependent variables 1) *Median RTs*: the mean of the Median RTs of the main task in the three sessions (GO, STOP and CHANGE) was calculated; 2) *Total omissions*: the total number of omissions committed by the children in the main task of the three sessions (GO, STOP and CHANGE) was calculated; 3) *STOP session errors*: numbers of times in which the child did not inhibit the answer after hearing the stop signal in the STOP session (range: 0 - 40); 4) *CHANGE session errors*: number of times in which the child does not press the “X” button after hearing the signal tone in the CHANGE session (range: 0 - 40); 5) *GO session SD of RTs*: this variable is the standard deviation of the responses of each children the GO session; and 6) *Mean SD of RTs*: since the STOP and CHANGE sessions required inhibition of responses (the GO session did not) we separated the consistency of performance calculating the mean of SD of RTs in the STOP and CHANGE sessions.

2.2.3 Procedure

Experimenters were instructed to test children in one session. On average, the battery of tests took approximately 75 minutes to administer. The tasks were administered in a fixed order to minimise any error due to participants by order interaction. The children were tested individually in a separate room within the school environment.

2.2.4 Data analyses

The study hypotheses were tested using different sets of analyses.

As far as first aim was concerned, we focused our attention on the structure of the executive domain and on similarities and differences in the factor structures between groups (age groups and male vs female). We studied the correlations between the tests of the battery by conducting a Joint Simultaneous Factor Analysis across several populations (SIFASP). SIFASP, based on correlation matrices (correlation matrices calculated separately for each population), were conducted using LISREL. The fit of model to the data was evaluated by examining multiple fit indices: the chi square statistic, the root mean square error of approximation (RMSEA), Bentler's comparative fit index-CFI, and the non-normed fit index fit index (NNFI). RMSEA is a measure of the discrepancy between the model and the data per degree of freedom. RMSEA values below 0.08 indicate satisfactory fit (Browne et al., 1993). The CFI range between 0 and 1, and values greater than 0.90 indicate a good fit (Byrne, 1994). NNFI measures the relative improvement in fit by comparing a target model with a baseline model with respect to the degree of freedom. It ranges from 0 to 1, with values greater than 0.90 implying a good fit (Bentler et al., 1980).

Developmental trajectories and gender differences were assessed using multivariate analyses of variance (MANOVA). The alpha level was set at 0.05. Significant findings were followed up with Tukey Honestly Significant Differences post hoc tests. We focused our attention on the performance in each task and on the executive factors that resulted from Joint Simultaneous Factor Analysis across several populations.

2.3 RESULTS

2.3.1 Descriptive results

We screened all measures for missing values, outliers and normality of distribution and screened data from different tasks separately.

Because our first aim was to investigate the cognitive structure of executive functioning, in further CFA, all participants were treated as a single group. The means and standard deviations for different tests are reported in *Table 2.2*.

Table 2.2 Descriptive statistics for Executive Function measures

MEASURE	Mean	SD	Skewness	Kurtosis
Battersea Multitasking Paradigm				
Learning	12.03	1.04	-1.28	2.20
Planning	8.61	0.93	-3.51	15.21
Execution	44.90	16.81	-0.30	-0.52
Monitoring	12.73	4.32	-1.84	4.61
Memory	3.07	0.84	-0.48	-0.60
Daily Planning Task				
Learning	8.11	1.47	-1.19	2.97
Temporal estimation	7.21	1.91	-0.65	0.31
Activities	9.03	1.83	-2.62	7.11
Visuo-spatial reasoning task				
Perseverations	3.15	2.09	1.39	5.71
Non perseverative errors	12.67	9.21	0.24	-0.62
Junior Gambling Task				
Total	-0.46	5.67	0.34	0.44
Honk Task				
GO session SD of RTs	150	68.27	1.14	1.40
STOP session errors	17.87	11.40	0.61	-0.69
CHANGE session errors	15.04	9.19	0.74	0.05
Mean SD of RTs	284	80.02	0.72	0.50
Median RTs	622	153	1.02	1.58
Total omissions	8.86	10.08	2.92	12.36

Legend: 1) Mean SD of RTs: mean of SD of RTs in main task of STOP and CHANGE sessions; 2) Median RTs: median RTs in main task of GO, STOP and CHANGE sessions; 3) Total omissions: total number of omissions committed in main task of GO, STOP and CHANGE sessions.

2.3.2 Factor structure

Because EF tasks share different cognitive processes, in this section, we presented the results of the analysis of correlations, Explorative and Simultaneous Factor Analysis across several populations.

The results of the analysis of correlations are shown in *Table 2.3*. In general, the correlation coefficients between the different tasks were rather low ($r < 0.4$). Despite the overall weak connections, our findings reveal interesting relationships between the measures.

Correlations were found between the SD of RTs in the Go session of the Honk Task and almost all variables. In the literature, this variable could be assumed to tap vigilance. These results showed the key role played by vigilance in all tasks. Consistent with Anderson and colleagues (2002), attentional effort greatly influences the functioning of the other executive domains.

The correlations also allowed us to analyse the relationship between Hot and Cool EF in children. Junior Iowa Gambling requires the flexible appraisal of motivationally significant stimuli and therefore was chosen to investigate Hot EF. In contrast, the Battersea Multitask Paradigm, the Daily Planning Task, the Visuo-Spatial Reasoning Task and the Honk Task were chosen to measure Cool EF. Our data seem to suggest the presence of interactions between the two types of executive processes. There were significant correlations between the total score in the Junior Gambling Task and measures of the Battersea Multitasking Paradigm, the Daily Planning Task and the Honk Task.

Table 2.3: Correlations between executive measures

MEASURE	1.	2.	3.	4.	5.	6.	7.	8.	9	10	11	12	13	14	15	16	17
1BMP.Learning																	
2.BMP Planning	**0.109***																
3.BMP Execution	**0.376*****	**.185*****															
4.BMP Monitoring	0.025	**0.147****	**-0.206*****														
5.BMP Memory	**0.373*****	**0.144****	**0.327*****	0.047													
6.DPT Learning	**0.128***	**0.112***	0.036	**0.206*****	**0.218*****												
7.DPT Temporal estimation	**0.137***	0.008	0.014	**0.111***	**0.182****	**0.175****											
8.DPT Activities	0.062	**0.155****	0.072	0.104	**0.172****	**0.192*****	**0.120***										
9 VSRT Perseverations	-0.06	-0.010	-0.042	-0.052	**-0.111***	-0.064	-0.104	-0.095									
10.VSRT Non perseverative errors	**-0.336*****	**-0.221*****	**-0.556*****	0.082	**-0.239*****	0.014	0.020	0.027	0.020								
11.JGT Total	**0.174****	0.065	**0.377*****	-0.073	**0.182****	**0.112***	0.016	0.003	0.034	**-0.386*****							
12.HT GO session SD of RTs	**-0.174****	**-0.147****	**-0.270*****	-0.030	**-0.237*****	**-0.146****	**-0.108***	**-0.140****	**0.123***	0.096	**-0.161****						
13.HT STOP session errors	**-0.120***	-0.050	-0.026	-0.084	-0.082	-0.039	**-0.112***	-0.021	**0.161****	-0.005	-0.034	**0.192*****					
14.HT CHANGE session errors	-0.012	0.031	0.058	-0.068	-0.062	**-0.177****	**-0.108***	-0.068	0.064	**-0.204*****	**0.120***	**0.190****	**0.455*****				
15.HT Mean SD of RTs	-0.096	-0.035	**-0.139****	0.037	**-0.108***	**-0.107***	**-0.111***	-0.056	0.063	0.025	-0.044	**0.437****	0.011	0.041			
16.HT Mean RTs	**-0.142****	-0.096	**-0.207*****	0.101	**-0.135****	-0.011	-0.048	**-0.158****	0.015	0.105	**-0.137***	**0.503*****	**-0.213*****	**-0.194*****	**0.405**		
17.HT Total omissions	-0.065	-0.020	**-0.125***	0.042	-0.099	-0.067	-0.053	-0.057	0.097	0.024	-0.026	**0.539*****	0.027	**0.142****	**0.382****	**0.481*****	

Legend: - * p<0.05 ** p<0.01 ***p<0.001;

- BMP=Battersea Multitasking Paradigm; DPT=Daily Planning Task; VSRT= Visuo-Spatial Reasoning Task; JGT=Junior Gambling Task; HT=Honk Task

- Mean SD of RTs: mean of SD of RTs in main task of STOP and CHANGE sessions; 2) Median RTs: median RTs in main task of GO, STOP and CHANGE sessions; 3) Total omissions: total number of omissions committed in main task of GO, STOP and CHANGE sessions.

To obtain the general dimensions of executive functioning, we conducted preliminary EFA to examine the entire sample of subjects. Seventeen critical variables were entered into the EFA (maximum likelihood). The analysis produced four factors, which were rotated using the Promax method.

Regarding the results of the structure analysis, first, we were interested in testing whether the four-factor model would fit the data that described the performance in the different age groups. We conducted constrained factor analyses to verify the goodness of fit of the four-factor model with the data from children in primary school and children in middle school. The results were satisfactory: chi-square=310.94 (d.f. =242), RMSEA=0.036, CFI=0.950, and NFI=0.80. We conducted the same analyses for gender to verify whether the four-factor model would fit the data that described the performance of boys and girls. SIFASP (loadings and correlations were fixed to be same to ensure metric and construct invariance) gave an acceptable solution. Several indices of model fit were considered: chi-square=328.45 (d.f. =243), RMSEA=0.041, CFI=0.950, and NFI=0.82.

Because the preliminary analyses did not reveal statistically significant evidence of qualitative changes throughout ages, we conducted a SIFASP (loadings and correlations were fixed to be the same so that there was metric and construct invariance). Several indices of model fit were considered. The full four-factor solution showed acceptable fit indices: chi-square=633.07 (d.f.=517), RMSEA=0.046, CFI=0.910, and NFI=0.66. The solutions were accettable.

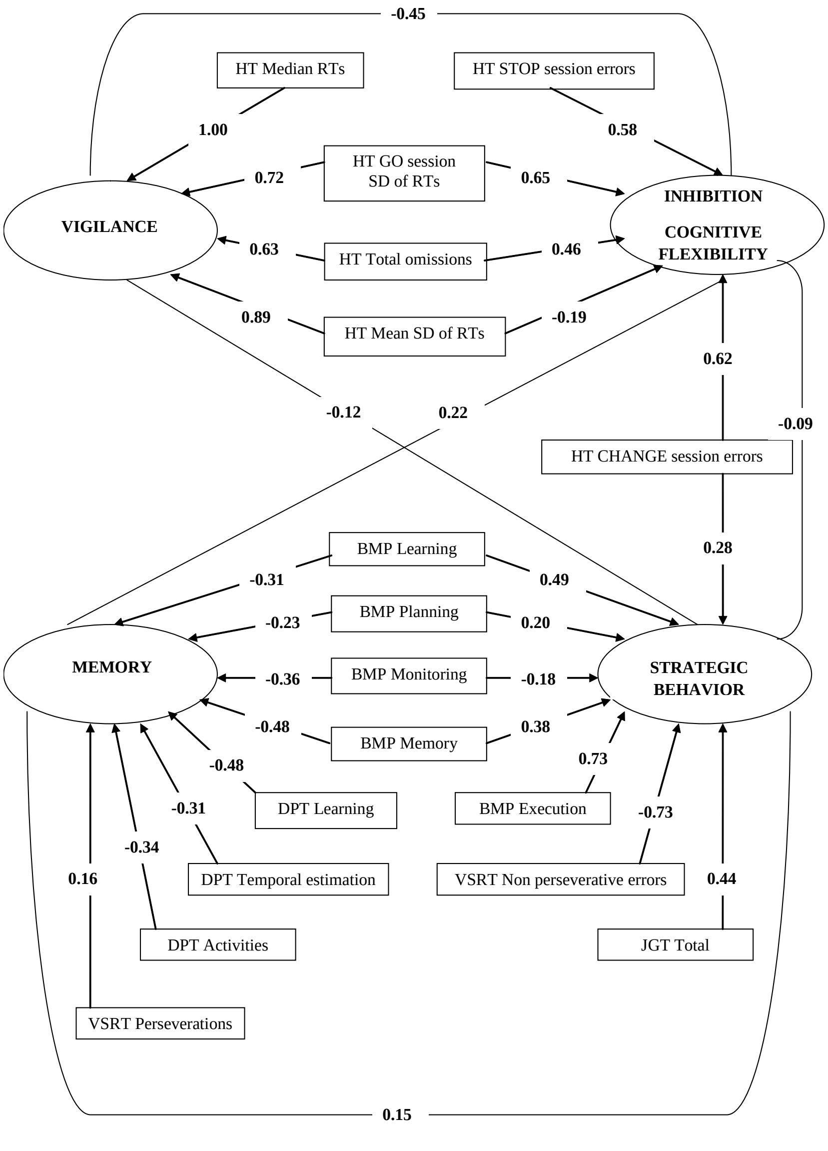
The full four-factor model, complete with the estimated factor loadings, is illustrated in *Figure 2.1*.

The correlations between factors are shown in *Table 2.4.*

Table 2.4: Correlations between EF factors

	Vigilance	Strategic Behavior	Inhibition/cognitive flexibility	Memory
Vigilance	-			
Strategic behavior	-0.13	-		
Inhibition/cognitive flexibility	-0.45	-0.07	-	
Memory	0.00	0.13	0.21	-

Figure 2.1: Full Four-factor model of Executive Function



Legend: - BMP=Battersea Multitasking Paradigm; DPT=Daily Planning Task; VSRT= Visuo-Spatial Reasoning Task; JGT=Junior Gambling Task; HT=Honk Task

- 1) Mean SD of RTs: mean of SD of RTs in main task of STOP and CHANGE sessions; 2) Median RTs: median RTs in main task of GO, STOP and CHANGE sessions; 3) Total omissions: total number of omissions committed in main task of GO, STOP and CHANGE sessions.

2.3.3 Age-related and gender differences

We conducted analyses of variance to verify whether some tests of the EF battery were able to detect age-related changes and gender differences.

The dependent variables were the following: Learning, Planning, Execution, Monitoring, Memory in the Battersea Multitasking Paradigm, Learning, Temporal estimation, Activities in Daily Planning Task, Non perseverative errors, Perseverations in the Visuo-Spatial Reasoning Task, Total in the Junior Gambling Task, GO session SD of RTs, STOP session errors, CHANGE session errors, Total omissions, Mean SD of RTs in STOP and CHANGE sessions and Median RTs in GO, STOP and CHANGE sessions in the Honk Task.

All 17 variables were submitted to a MANOVA with Age (six levels) and Gender (two levels) as the between-subjects variables. The means and standard deviations of the scores of each task for each age group and the results of MANOVA are reported in *Table 2.5.*

An age effect was found to be significant for almost all measures of the EF battery. Significant findings were tested using post-hoc analysis (Tukey).

According to the level of performance, we identified two different subgroups of children—children aged 8-10 and 11-13 years—for the following three variables: Execution in the Battersea Multitasking Paradigm and the Median RTs in the Honk Task. The younger children had poorer performance than the oldest children on these three measures: They had lower Execution scores, higher reaction times and greater variability in reaction times.

Second, three subgroups of children were found to be significantly different—i.e., children aged 8 vs 9-10 vs 11-13 years—for the six following variables: Planning in the Battersea Multitasking Paradigm, Non perseverative errors in the Visuo-Spatial Reasoning Task, Learning and Temporal estimation in the Daily Planning Task, Total in Junior Gambling Task and GO session SD of RTs in the Honk Task. Over the course of development, the number of items correctly planned and recalled increased, and the number of errors and the variability in reaction times decreased.

We found three subgroups—children aged 8-9 vs 10-11 vs 12-13 years—for the following four variables: Learning and Memory in the Battersea Multitasking Paradigm and STOP session errors and CHANGE session errors in the Honk Task. Over the course of development, the number of items correctly recalled increased, and the number of errors decreased.

We found also three subgroups—children aged 8-9 vs 10-11-12 vs 13 years—for Mean SD of RTs in the Honk Task; the variability of performance decreased between 8/9 and 10/12 years, and then, it increased again.

Finally, as far as Total omissions in the Honk Task were concerned, post hoc comparisons showed that children aged 8 years committed more errors than children in other age groups.

The gender effect was found to be significant for Execution in the Battersea Multitasking Paradigm, Temporal estimation in the Daily Planning Task, Total in the Junior Gambling Task and CHANGE session errors in the Honk Task because girls outperformed boys in the first three variables, whereas males outperformed girls on the errors in Change session of the Honk Task.

The Age by Gender interaction effect was found to be significant for Temporal estimation in the Daily Planning Task and Perseverations in the Visuo-Spatial Reasoning Task. As far as Perseverations in the Visuo-Spatial Reasoning Task was concerned, boys and girls had opposite developmental trajectories during primary school: the performance of girls worsened between 8 and 9 years of age and improved between 9 and 10 years of age; the opposite trend was found in boys. Boys and girls instead showed similar developmental trajectories during middle school. There was no a clear trend for Temporal estimation in the Daily Planning Task.

Table 2.5 Descriptive statistics for EF measures and Age, Gender, Age by Gender interaction Effects

	8 years (n =58)		**9 years** (n=66)		**10 years** (n=54)		**11 years** (n=49)		**12 years** (n=54)		**13 years** (n=71)		**Age Effect**		**Male** (n=)		**Female** (n=)		**Gender Effect**		**Interaction Age X Gender**	
MEASURE	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	F(5,338)	P	M	SD	M	SD	F(1,342)	p	F(5,338)	p
Battersea Multitask Paradigm																						
Learning	11.57	1.14	11.88	1.13	12.01	1.14	11.93	0.15	12.36	0.12	12.35	0.15	5.179	**0.000**	11.95	0.08	12.09	0.07	1.480	0.225	1.408	0.221
Planning	8.23	0.12	8.58	0.12	8.61	0.13	8.77	0.14	8.78	0.11	8.66	0.14	2.658	**0.023**	8.59	0.07	8.61	0.07	0.008	0.928	0.956	0.445
Execution	36.50	2.10	41.48	1.96	40.22	2.23	45.34	2.33	50.75	1.88	52.09	2.28	8.601	**0.000**	42.50	1.28	46.30	1.19	4.743	**0.030**	0.551	0.737
Monitoring	12.14	0.58	13.17	0.54	12.86	0.62	13.06	0.64	12.12	0.52	13.04	0.63	0.722	0.607	12.65	0.35	12.81	0.33	0.109	0.742	1.844	0.104
Memory	2.69	0.11	2.95	0.10	2.95	0.11	3.05	0.12	3.25	0.09	3.48	0.12	6.119	**0.000**	3.01	0.07	3.12	0.06	1.540	0.215	1.299	0.264
Daily Planning Task																						
Learning	7.44	0.19	8.13	0.18	7.92	0.21	8.19	0.22	8.47	0.17	8.30	0.21	3.655	**0.003**	7.93	0.12	8.22	0.11	3.289	0.071	1.543	0.176
Temporal estimation	6.25	0.24	7.09	0.23	7.38	0.26	7.17	0.27	7.82	0.22	7.60	0.26	5.344	**0.000**	7.02	0.15	7.42	0.14	4.120	**0.043**	2.474	**0.032**
Activities	8.47	0.24	9.18	0.23	8.96	0.26	8.90	0.27	9.30	0.22	9.42	0.26	1.950	0.086	8.97	0.15	9.11	0.14	0.489	0.485	0.595	0.704
Visuo-Spatial Reasoning Task																						
Perseverations	3.53	0.28	3.21	0.26	3.13	0.29	3.35	0.31	2.71	0.25	2.71	0.30	1.488	0.193	3.14	0.17	3.07	0.16	0.091	0.763	2.460	**0.033**
Non perseverative errors	16.04	1.20	13.56	1.13	13.91	1.28	12.15	1.34	10.41	1.08	11.61	1.30	2.893	**0.014**	12.44	0.73	13.45	0.68	1.013	0.315	0.527	0.756
Junior Gambling Task Total	-2.72	0.73	-0.56	0.68	-1.45	0.77	-0.86	0.81	0.59	0.65	1.14	0.79	3.616	**0.003**	-1.51	0.44	0.22	0.41	8.204	**0.004**	1.024	0.404
Honk Task																						
GO session SD of Rts	204.75	8.24	167.06	7.72	156.71	8.76	133.54	9.17	127.83	7.38	112.64	8.95	15.833	**0.000**	146	5.02	155	4.67	2.035	0.155	0.885	0.491
STOP session errors	20.13	1.45	21.28	1.36	18.62	1.54	16.36	1.62	15.56	1.29	12.83	1.58	4.605	**0.000**	17.36	0.88	17.57	0.82	0.030	0.862	0.385	0.859
CHANGE session errors	16.74	1.20	16.89	1.13	14.84	1.28	13.94	1.34	15.41	1.08	10.61	1.31	3.401	**0.005**	13.72	0.73	15.76	0.68	4.166	**0.042**	0.333	0.893
Mean SD of RTs	307.20	10.17	314.98	9.62	271.33	10.78	266.15	11.04	251.50	9.03	296.60	10.99	6.769	**0.000**	285	6.07	284	5.81	0.028	0.867	0.281	0.923
Median RTs	716.93	18.93	669.52	17.73	650.22	20.12	609.60	21.07	543.82	16.94	557.90	20.55	13.120	**0.000**	622.74	11.53	626.59	10.72	0.060	0.807	0.295	0.915
Total omissions	16.78	1.27	9.48	1.19	7.74	1.35	7.15	1.42	7.02	1.14	4.73	1.38	10.535	**0.000**	8.28	0.78	9.35	0.72	1.015	0.314	0.428	0.829

Legend: 1) Mean SD of RTs: mean of SD of RTs in main task of STOP and CHANGE sessions; 2) Median RTs: median RTs in main task of GO, STOP and CHANGE sessions; 3) Total omissions: total number of omissions committed in main task of GO, STOP and CHANGE sessions.

2.4 DISCUSSION

This study aimed to examine Executive Function in children ages 8 to 13 years. First, we were interested to examine EF structure in school-age children; second, we were interested in analysing the type of EF development in school-aged children; finally, we focused our attention on gender differences in EF.

To achieve these aims, we administered a battery of tasks assessing different aspects of EF (Zelazo, 2004). The Junior Gambling Task (JGT) requires the flexible appraisal of motivationally significant stimuli and therefore was chosen to investigate Hot EF. In contrast, the Battersea Multitask Paradigm (BMP), the Daily Planning Task (DPT), the Visuo-Spatial Reasoning Task (VSRT) and the Honk Task (HT) were chosen to measure Cool EF.

As far as the structure of EF was concerned, consistent with prior studies, we hypothesised that EF would be characterised as separable but related functions. However, we supposed that the executive domain would be more articulate than was proposed in recent cognitive developmental neuropsychology studies (Huizinga et al., 2006, Lee et al., 2013, Letho et al., 2003, Miyake et al., 2000, van der Sluis et al., 2007, Wu et al., 2011). Recent findings converge towards a model with two (Working Memory and Cognitive flexibility) or three factors (Working Memory, Cognitive flexibility and Inhibition). We assumed that these results could be partially explained by the tests used. For example, Miyake and colleagues (2000) employed rather simple measures designed to probe predetermined latent EF. For this reason, we have proposed a more articulate, complex and ecological battery.

We extracted four distinct but correlated executive components that we have identified as Vigilance, Strategic Behaviour, Inhibition/Cognitive Flexibility and Memory. Vigilance included measures of the Honk Task (Median RTs, Go session SD of RTs, Mean SD of RTs and Total omissions), and it referred to the capability to attend to specific stimuli and maintain attention for a prolonged period. Strategic Behaviour included measures of the BMP (Learning, Execution and

Memory), the VSRT (Non perseverative errors) and the JGT (Total). This factor represented the core of EF and reflected the ability to initiate, plan, organise, sustain future-oriented problem solving in working memory, self-manage tasks and monitor one's own performance. Inhibition/cognitive flexibility included errors in Stop and Change sessions of the HT, and it referred to the capability to control interference, to suppress prepotent responses and to make a fast and accurate choice between two or more competing responses. Finally, Memory included measures of the BMP (Monitoring), the DPT (Learning, Temporal estimation and Activities) and the VSRT (Perseverations). At first blush, the measures converging on this factor seem to be quite diverse; however, after closer analysis, important similarities emerge among tasks. The tasks required retrospective (Monitoring in the BMP, Learning and Temporal estimation in the DPT), perspective and working memory (Perseverations in the VSRT and Activities in the DPT). In particular, these tasks require the learning of task parameters, analysis and synthesis, strategy generation without external stimuli and maintaining in mind constraints formerly used strategies.

Our findings are in line with contemporary views that EFs are simultaneously uniform and diverse (Miyake et al., 2000). Our findings do not support antecedent EF models that included two or three separated factors, because our best model was composed of four factors. However, unity meant that significant correlations among these EF factors could be found. Consistent with Miyake and colleagues (2000), we found Memory and Inhibition to be executive components. As far as Memory was concerned, consistent with Miyake and colleagues (2000), we supposed that Memory went beyond the simple maintenance of task-relevant information in its requirement to dynamically manipulate the contents of working memory. This executive component requires monitoring and coding incoming information for relevance to the task at hand and then appropriately revising the items held in working memory by replacing old, no longer relevant information with newer, more relevant information. As far as Inhibition was concerned, our findings were not completely in line with Miyake and colleagues (2000). Our concept of Inhibition was more articulated because we supposed that Inhibition referred to the ability to deliberately inhibit dominant, automatic or prepotent responses when necessary; moreover, we focused our attention on other two aspects: interference control and making a fast and accurate choice between two or more competing responses. Our factor seems to tap both Inhibition and Shifting, as described by Miyake and colleagues (2000). Consistent with Anderson (2002), we found attentional effort, which included the capacity to maintain attention over time and monitor a situation in which significant events may occur. Maintaining performance over time requires sustained attention to a target, the organisation of appropriate responses to signals, and the inhibition of inappropriate responses. The main finding of our study was the discovery of a fourth factor: Strategic Behaviour. The factor Strategic Behaviour referred to different components: initiative, planning, organisation and auto-regulation. Initiation included the ability to begin a task or activity independently and generate ideas, responses, or problem solving strategies. Planning implied the capability to imagine or develop a goal or end state and then strategically determine the most effective method or steps to attain that goal. Organisation involved the skills to bring order to information and appreciate the main idea or key concepts when learning or communicating information. Finally, monitoring concerned the ability to access performance during or shortly after finishing a task to ensure the appropriate attainment of a goal.

Second, we focused our attention on developmental trajectories. We examined changes in different executive components across multiple ages to find similarities and differences in developmental trends. Consistent with prior studies, we hypothesised developmental changes in performance in all tasks used to tap executive domains. In particular, we hypothesised greater differences between children who attended primary school than children who attended middle school, and we expected there were different developmental profiles. We hypothesised that different executive components would have different maturation rates and that they would reach adult levels at different ages. We also examined whether the four-factor structure fit the data in different age groups.

Analyses revealed that performance in all tasks improved with age. In general, children aged 12/13 outperformed children aged 8/9 in all tasks, and for many variables, a slowdown was observed in the growth of performance between 10 and 11 years. We also found four different developmental profiles. According to the level of performance, we could infer the presence of more linear and gradual developmental changes for some variables (when we found three subgroups according to levels of performance) and the presence of growth spurts for others (Execution in the BMP and Median RTs, Mean SD of RTs and Total omissions in the HT).

All these findings were consistent with previous studies (Best et al., 2009, Davidson et al., 2006, Huizinga et al. 2006). As far as drops in performance were concerned, this age-related dip has been documented in the literature (McGiven et al., 2002) and may represent functional markers of the phase shift between proliferation and onset of pruning that affect the neural substrate of EF in this period of life. Notably, with reference to this population, our results were not consistent with the suggestion that Cool EF emerges earlier. The variable used to describe the performance on the tasks that tap Hot EF (the JGT) had a developmental trajectory similar to that of other variables.

The current study also added a developmental dimension to the EF model fitting and suggested that the structure of EF remained stable during the school-age years. In fact, the model presented in *Figure 2.1* provided an adequate description of task performance in different age groups (children who attended primary school and children who attended middle school).

Finally, we analysed the effect of gender on executive performance. We hypothesised that boys and girls would have different performance in specific executive tasks but a similar structure of executive domain.

Our data indicated that the performances of boys and girls were similar on 13 of 17 measures. We found a statistically significant gender effect for four variables: on Execution in the

BMP, Temporal estimation in the DPT and Total in the JGT girls outperformed boys instead on CHANGE session errors in the HT boys outperformed girls. Data were consistent with the literature: previous studies suggested gender differences in the performance on specific tests designed to assess specific executive processes. In particular, data suggested different performances in specific tasks used to tap verbal and visual-spatial working memory, attention, cognitive flexibility and visuo-spatial reasoning. In line with the literature (Gurr et al., 2012), boys had better performances than girls in measures of inhibition/cognitive flexibility. Information about the Junior Gambling Task was contradictory: in contrast with Reavis and colleagues (2001), we found that girls outperformed boys. Our data were in line with Hooper and colleagues (2004): in this study, girls did show a stronger preference than boys for decks that yielded infrequent punishment.

Our study confirms that the structure of EF is similar across gender. We found similarities in the factor structures in males and females.

2.5 CONCLUSION

The results of the current study provide support for the non-unitary, multi-faced nature of EF. Four latent factors, Vigilance, Strategic Behaviour, Inhibition and Memory, were distinguishable but related. With reference to this population (children aged 8 to 13 years), the executive structure was stable across school-age and gender. The study also provides evidence that documents developmental differences for various EF skills throughout childhood and pre-adolescent periods. All these data converge in support of a multistage interpretation of EF development with some skills growing continuously at early ages of 8 and 9 years old, possibly reaching a plateau at 12 to 13 years (Vigilance). Other skills continue to growth during adolescence (Memory).

Data excluded structural executive differences across gender. We found differences only in specific performance.

2.6 LIMITATIONS OF THE STUY

The tests used in this study involved rather complex executive tasks that may require several latent EFs. This impurity of EF tasks has been an issue frequently addressed in theoretical discussions. For this reason, it is important that future research will analyse the validity of these instruments, combining basic tests to distinguish between executive and non-executive processes.

CHAPTER 3: A NEW QUESTIONNAIRE FOR THE ASSESSMENT OF EXECUTIVE FUNCTION IN CHILDREN

3.1 INTRODUCTION

The operationalization and measurement of EF is a very important issue that directly impacts the inferences we can make about these competencies. The procedures traditionally used to operationalize EF in clinical and research settings employ performance-based measures. Performance-based tests are usually administered in highly standardized conditions. Stimulus presentation is carefully constrained so that each child experiences and completes the task in the same way as other children. traditionally tasks are typically based on accuracy, response time and speed of responding under a time constriction. While these tests offer the advantages of strong internal validity, control over extraneous variables, and the potential to fractionate and examine components of EF separately, they are necessarily limited in their ecological validity or predictive value of functioning in the everyday environment. These tasks may relieve the demands on the executive functions and thereby reduce the opportunities to observe critical processes associated with them (Bernstein et al., 1990). More complex, multi-step tasks in daily life may require more complicated series of responses, including goal and sub-goal setting, prioritization of sub-goals, triggering prospective memory to initiate sub-tasks when the conditions for them become ripe, and inhibiting irrelevant and inappropriate actions during different sub-tasks.

Given the challenges of ecologically valid assessment of executive function, attention is increasingly being given to alternative methods of evaluation with greater ecological validity. Rating measures of EF were developed to provide an ecologically valid indicator of competences in complex, everyday problem solving situations. Rating measures of EF involve reporting information on difficulties with performing everyday tasks. Only a few standardized psychometric instruments designed to measures executive problems in children have recently became available.

These include the Childhood Executive Functioning Inventory (Thorell et al., 2008) and the Dysexecutive Questionnaire for Children (Emslie et al., 2003), but the most commonly used rating scale of EF has been the Behavior Rating Inventory of Executive Function (Gioia et al., 2000). The Child Behavior Questionnaire (CBQ) could also be interpreted in terms of EF behavior as it also includes subscales assumed to tap inhibitory control, impulsivity and the ability to focus. The Childhood Executive Functioning Inventory (CHEXI) was developed to focus specifically on different types of executive control rather than using more general statements or items included in the symptom criteria for Attentional Deficit Hyperactivity Disorder (ADHD). The CHEXI includes four subscales, which were created based on Barkley's (1997) hybrid model in which inhibition, working memory, regulation and planning are regarded as constituting the major EF deficits in children with ADHD. The Dysexecutive Questionnaire for Children (DEX-C) is a 20-item questionnaire based on the Dysexecutive Questionnaire for the Behavioral Assessment of the Dysexecutive Syndrome (BADS). The questionnaire was constructed to reflect the range of problems usually associated with Dysexecutive Syndrome. The questions probe four broad areas of possible difficulty: emotional/personality, motivational, behavioral and cognitive. The DEX-C is designed to be completed by a parent and/or teacher who has frequent contact with the child. The DEX-C was designed to assess Dysexecutive Syndrome symptoms, such as abstract thinking problems, impulsivity, confabulation, planning problems, euphoria, temporal sequencing problems, lack of insight and social awareness, apathy, dysinhibition, disturbed impulse control, dysinhibition of affective response, aggression, lack of concern, perseveration, restlessness, mobility to inhibit response, knowledge response dissociation, distractibility, loss of decision making ability, and unconcern for social rules.

We focused our attention in particular on the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000). In contrast with the questionnaire presented above, the BRIEF focuses less on psychopathology and focuses more on everyday behaviors associated with executive functioning. The BRIEF includes a total of 86 items that describe difficulties in everyday activities. Each item is rated on whether difficulties are encountered never, sometimes or often. The only constraint given is to report on behaviors that have been problematic in the last 6 months. The BRIEF is composed of 8 individual scales: Inhibition, Shift, Emotional Control, Working Memory, Plan/Organize, Organization of Materials, and Initiation and Monitor. The Inhibition scale assesses inhibitory control and the ability to stop one's own behavior at an appropriate time. The Shift scale assesses the ability to move freely from one situation, activity or aspect of a problem to another as the circumstances demand. The Emotional Control scale assesses a child's ability to modulate emotional responses. The Initiation scale assesses the ability to begin a task or activity as well as independently generate ideas, responses or problem solving strategies. The Working Memory (WM) scale measures the capability to hold information in mind for the purpose of completing a task. WM is essential to perform multistep activities, complete mental arithmetic or follow complex instructions. The Plan/Organize scale measures the child's ability to manage current and future-oriented task demands. Plan refers to the ability to anticipate future events, set goals and develop appropriate steps ahead of time to perform a task or activity. Organization refers to ability to bring order to information and to appreciate ideas or key concepts when learning or communicating information. The Organization of Materials scale measures the orderliness of work and play storage spaces and assesses the manner in which children order and organize their world and belongings. The Monitor scale assesses work checking habits, a personal monitoring function. Item content of the Monitor scale was re-examined and hypothesized to reflect two distinct dimensions: monitoring of task-related activities and monitoring of personal behavioral activities. The BRIEF also provides three summary indices: the Behavioral regulation index (BRI), the Metacognitive index (MI) and the Global score (the GEC). The Inhibition, Shift, Emotional control and Self-monitoring scales compose the Behavioral regulation index (BRI). The Initiation, Working memory, Plan/organize, organization of materials and Task monitoring scales compose the Metacognitive index (MI). The

BRI and the MI can be combined to form an overall Global executive index (GEC). Finally, there are two validity scales to assess the inconsistency and negativity of ratings. Inconsistency score can indicate the extent to which the respondent answered similar BRIEF items in an inconsistent way. The Negativity scale measures the extent to which the respondent answered selected BRIEF items in an unusually negative manner. Further studies on the validity of the BRIEF (Gioia et al., 2002; Peters et al., 2012) suggest that the best fitting model is one comprising three factors: Behavioral Regulation (Inhibition and Self-Monitor scales), Emotional Regulation (Emotional Control and Shift scales) and Metacognition (Initiation, Working Memory, Plan/Organize, Organization of Materials, and Task-Monitor scales).

The BRIEF was used to obtain data useful to address two issues in the study of EF: 1) the postnatal development of EF and 2) the role of EF in cases of developmental disorders such as Attention Deficit Hyperactivity Disorder (ADHD) and Learning Disabilities (LD). As far as development of EF was concerned, Gioia and colleagues (2000) described a decrease in executive function problems when children grow older. The distribution of the BRIEF scales and the index scores for boys and girls across the age span (5-18 years) were examined to determine the most appropriate age groupings. Unique developmental trends were found on each form. The relevant developmental trends were best represented by the formation of four groups for each of the two BRIEF versions: ages 5-7, 8-10, 11-13 and 14-18 for the parent form and ages 5-6, 7-8, 9-13, and 14-18 years for the teacher form. Huizinga and colleagues (2011) replicated the above data. Second, researchers used the BRIEF to delineate different executive profiles in clinical populations. The BRIEF was selected because it is effective at detecting EF deficits among different clinical populations, sensitive and specific in detecting salient executive deficits among different clinical groups not readily identified or detected by neuropsychological EF laboratory measures and an instrument potentially well suited to investigating the domain of social adaptive behavior. Only a handful of studies have used the BRIEF in children and adolescents with ADHD and LD. The executive profiles of both clinical populations were analyzed by Pratt and colleagues (2000) and Gioia and colleagues (2002). While there were similarities in some aspects of executive function between the groups, there were also logical and consistent differences where they might be expected. Pratt (2000) examined parent reports for 212 children ages 6 to 11 that had either a diagnosis of ADHD only, LD only, ADHD and LD or no diagnosis. They found that children with ADHD had significantly higher elevations on all BRIEF scales than control children. Children with LD had more deficits on the Working Memory and Plan/Organize scales than control children. The children in the comorbid group were not distinguishable from the children with ADHD only. Shifting the focus on ADHD subtypes, children with the Combined subtype (ADHD-C) had significantly higher elevations on the Inhibition, Emotional Control, and Self-Monitor scales than children with the Inattentive subtype (ADHD-I). Gioia and colleagues (2002) confirmed the results above. They suggested that children with ADHD-C exhibited high elevations across all scales of the BRIEF and they demonstrated the most severe difficulties in both the Metacognition and Behavioral regulation (inhibitory control, emotional modulation) domains of EF. Children with ADHD-I and LD exhibited greater difficulties with the metacognitive aspects of EF, including working memory, planning, organization and self-monitoring, but not inhibiting, shifting, or regulating emotions. Results suggested that the ADHD-I and LD groups exhibited a similar pattern of metacognitive executive deficits but the deficits were significantly more elevated, or severe, in ADHD-I children and adolescents. ADHD-I children also had inhibitory and emotional control deficits, but their level of difficulty was not as severe as children with ADHD-C. With reference to single scales, the Working Memory scale proved effective in distinguishing the ADHD groups from the non-ADHD group, whereas the Inhibit scale was able to distinguish between subtypes.

Other research groups analyzed the executive profile of children and adolescents with ADHD and other clinical disorders such as Tourette's Syndrome (TS; Mahone et al., 2002; McCandless et al., 2007). A study by Mahone and colleagues (2002) investigated groups of children with ADHD, Tourette's Syndrome (TS), comorbid ADHD and TS and controls and found that the BRIEF successfully differentiated the groups from one another. The ADHD and TS and ADHD groups were significantly more impaired on all scales of the BRIEF relative to controls and children with TS. There were no differences on the BRIEF between children with ADHD and TS and children with ADHD only. Consistent with studies by Gioia and colleagues and Pratt and colleagues, McCandless and colleague (2007) suggested that the MI and associated scales may be most useful in ruling in a diagnosis of ADHD, whereas ratings on the BRI, and particularly the Inhibition scale, may be most useful in determining ADHD subtype.

3.1.1 Aims of the study

Research using the BRIEF has shown that it is a reliable and valid measure of everyday executive function in typically developing children and clinical populations (Kenworthy et al., 2008, Mahone et al., 2002; Mangeot et al., 2002; Nadebaum et al., 2007; Toplack et al., 2009). However, its use has been limited to English-speaking countries. Other language versions of the BRIEF are lacking. We propose a new questionnaire inspired by the factorial structure of the BRIEF, the Questionnaire for the assessment of Executive Function (QuFE). The present research is divided into two studies.

The aim of Study 1 was twofold:

1) First we analyzed the factor structure and the psychometric properties of the QuFE. We performed item analysis of the parent and teacher ratings using Exploratory Factor Analysis and Confirmatory Factor Analysis. We speculated that the taxonomy of the QuFE consists of at least of three basic domains: Metacognition, Behavior and Emotional Regulation and Organization of Materials.

2) The second aim of the research involved the analysis of the age and gender differences with respect to the latent variables that the QuFE purports to measure. Consistent with prior studies, we supposed that executive problems would decrease when children grow older.

The aim of Study 2 was to investigate the executive profiles of children with ADHD and LD and evaluate the clinical use of the QuFE. Consistent with the literature, we hypothesized that children with LD would exhibit difficulties with metacognitive aspects of EF, particularly working memory, planning, organization, and self-monitoring, but no difficulties with Inhibitory control, shifting sets, or emotional modulation. We further hypothesized that children with ADHD would exhibit more general executive difficulties with both metacognitive and behavioral/emotional aspects.

3.2 STUDY 1: STRUCTURE AND PSYCHOMETRIC PROPERTIES OF THE QuFE

3.2.1 METHOD

3.2.1.1 Participants

A total of 862 (448 boys, 414 girls) children with a mean age of 10.38 years (SD=1.72; range 8-13) took part in this research.

Children were diverse in their background characteristics and were approximately representative of the 8-13 year-old population. Children came from public schools in Lombardy, Piedmont, Veneto and Sardinia. The eligibility criteria for children included the following: no diagnoses of any neurological, psychiatric or developmental disorders and no history of brain damage or sensory deficit. All participants spoke Italian as their first language.

Both teachers and parents were informed about the study aims. Parental consent was obtained for all participating children.

Table 3.1 shows the distribution of boys and girls across the age groups.

Table 3.1 Distribution of boys and girls across the age groups.

Age	Boys	Girls	Total
8 years	91	78	169
9 years	70	78	148
10 years	78	51	129
11 years	72	63	135
12 years	80	82	162
13 years	57	62	119
Total	**448**	**414**	**862**

To investigate the factorial structure, the samples were divided as follows:

538 children participated in the Exploratory Factor Analysis, and 324 children instead participated in the Confirmatory Factor Analysis. In the two samples, the distributions of gender and age were maintained.

3.2.1.2 Material

- Questionnaire for the assessment of Executive Function (QuFE)

The Questionnaire for the assessment of Executive Function is a questionnaire that concerns specific behaviors relating to executive functioning in children. The QuFE enables professionals to assess executive function behaviors in the home and school environments.

The questionnaire is completed by raters (parent and/or teacher) who indicate how often a given behavior has occurred in the past 6 months on a 5point Likert scale (1 = never; 5 = usually). High scores on an individual subscale correspond to better functioning in that domain. The Parent and the Teacher forms of the QuFE each contain 32 items. Some of the items included in the two versions are different and specific to the home and school environments. The instructions to the parent and the teacher emphasize the importance of responding to all items on the form. The QuFE will take approximately 10 minutes to complete.

The QuFE is inspired by the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000). We focused our attention on the 8 executive dimensions investigated by the BRIEF and we proposed for each of them four items that enable assessing the skill in daily life. The executive dimensions are:

1) *Inhibition:* control impulses; appropriately stop own behavior at the proper time. Example: respect his/her turn to speak.

2) *Shift:* move freely from one situation, activity, or aspect of a problem to another as the situation demands; transition; solve problems flexibly. Example: he/she calmly faces a new situation.

3) *Emotional control:* modulate emotional responses appropriately. Example: he/she rarely becomes irritated.

4) *Initiate:* begin a task or activity; independently generate ideas. Example: he/she individually starts his/her activities.

5) *Working memory/Attention:* hold information in mind for the purpose of completing a task; stay with, or stick to, an activity. Example: he/she maintains focus for an extended period of time.

6) *Plan/organization:* anticipate future events; set goals; develop appropriate steps ahead of time to perform an associated task or action. Example: he/she performs goal-oriented activities.

7) *Organization of materials:* keep workplace, play area, and materials in an orderly manner. Example: he/she leaves his/her room in order (parent version); he/she has an ordered school desk.

8) *Monitor:* check work; assess performance during or after finishing a task ensuring attainment of a goal. Example: he/she is precise and accurate in his/her activities.

3.2.1.3 Procedure

Parents and teachers completed the QuFE. The QuFE will take approximately 10 minutes to complete.

3.2.1.4 Data analyses

First we analyzed the factor structure and the psychometric properties of the QuFE.

To investigate the factor structure of the QuFE, we performed Exploratory (EFA) and Confirmatory (CFA) Factor Analysis for both forms of the QuFE. First, 32 items of both ratings were entered into the EFA (Maximum likelihood) using the Statistical Package for Social Science 20.0 (SPSS; 2012). The analysis produced factors that were rotated using the Promax method. Second, we performed a series of CFAs of the parent and teacher ratings on the 32 items to establish the factor structure that fit the items well. A series of CFAs, based on the covariance matrices, were conducted using Analysis of Moment Structures 20 (AMOS; Arbuckle, 2012). The fit of each model to the data was evaluated by examining multiple fit indices: the chi-square statistic, the root mean square error of approximation (RMSEA), Bentler's comparative fit index (CFI), the normed fit index (NFI) and the Akaike Information Criterion (AIC). To investigate the reliability of the QuFE, we analyzed internal consistency. Internal consistency was evaluated by calculating Cronbach's alpha (α) for the identified clinical scales. In addition item-total correlations of each item with the total score were calculated.

Second, we focused our attention on age and gender differences in both versions of the QuFE. Age group differences and gender differences were investigated with a multivariate analysis of variance (MANOVA). The dependent variables included the identified clinical scales and total score in both versions of the QuFE. Age and Gender were included as between-subjects factors. Alpha level was set at 0.05. Significant findings were followed up with Tukey Honest Significant Difference post hoc tests.

3.2.2 RESULTS

3.2.2.1 THE PARENT FORM OF THE QuFE

3.2.2.1.1 Exploratory Factor Analysis and psychometric properties

To obtain the executive dimensions analyzed by the QuFE, we conducted EFA. All 32 items were entered into the EFA (Maximum likelihood). The analysis produced five factors, which were rotated using the Promax method. This solution accounted for 58.69 % of the total variance. Item loadings and correlations between scales are given in *Tables 3.2* and *3.3,* respectively.

Twelve items had the highest loadings on the first factor. The common denominator for the items loading on the first factor might be the requirement of metacognition. These items refer to the ability to begin a task or activity; generate ideas, responses or problem solving strategies; manage current and future-oriented task demands; anticipate future events; set goals and develop appropriate steps ahead of time to perform a task or activity; bring order to information and appreciate ideas or key concepts; and maintain concentration and attention for a prolonged period of time. The first factor was named *Metacognition*.

Nine items had the highest loadings on the second factor. The common denominator for the items loading on this factor might be the requirement to regulate emotions and behavior. These items refer to the ability to stop one's own behavior at an appropriate time and modulate emotional responses. The second factor was named *Emotional and behavioral regulation*.

Three items had the highest loadings on the third factor. The common denominator for the items loading on this factor might be the requirement to organize materials. These items assess the orderliness of work and play storage spaces and the manner in which children order and organize their world and belongings. The third was named *Organization of materials*.

Four items had the highest loadings on the fourth factor. The common denominator for the items loading on this factor might be the requirement to shift. These items refer to the ability to move freely from one situation, activity or aspect of a problem to another as the circumstances demand. The fourth factor was named *Shift.*

Four items had the highest loadings on the last factor. The common denominator for the items loading on this factor might be the requirement to initiate. These items measure the capabilities to begin a task or activity and independently generate ideas, responses or problem solving strategies. The firth factor was named *Initiation.*

The Cronbach's α coefficients of the scales are shown in *Table 3.3.* A commonly accepted rule of thumb is that an α of 0.6-0.7 indicates acceptable reliability, and 0.8 or higher indicates good reliability (Cronbach, 2004). Cronbach's α of the five scales ranged from 0.670 to 0.922. Thus, the internal consistency of this version of the QuFE was good.

For the item-total correlations, a value of 0.3 is generally regarded as satisfactory (Nunally et al., 1994). The values ranged from 0.422 to 0.696.

Table 3.2: Factor loadings for items

	Metacognition	Emotional/behavioral regulation	Organization of materials	Shift	Initiation
1-He/she is self-starter	**0.646**				0.447
4-He/she maintains attention for a long time	**0.700**	0.429			
5-He/she carefully preserve the school supplies	**0.664**		0.572		
7- He/she focused on schoolwork and domestic chores	**0.778**	0.421			
8- He/she is precise and accurate in activities	**0.750**		0.494		
11- He/she performs a task for a long time	**0.751**	0.435			
17- His/her written work is well organized	**0.753**	0.378			
18- He/she starts a task	**0.626**				0.491
20- He/she schedules homework	**0.702**		0.443		
22- He/she performs necessary actions to achieve a goal	**0.602**				0.561
25- He/she carries out his/her tasks	**0.732**				0.540
26- He/she is ordered in his/her activities	**0.749**		0.570		
9- He/she waits his/her turn	0.438	**0.595**			
10- He/she controls outbursts of anger		**0.764**		0.529	
15- He/she maintains control	0.469	**0.593**			
16- He/she know when his/her behavior provokes negative reactions		**0.523**			0.489
19- He/she controls mood		**0.679**		0.467	
23- He/she behaves in a quite and orderly manner	0.569	**0.728**			
24- He/she stops when he/she performs inadequate actions		**0.751**			0.414
28- He/she calibrates the reactions		**0.622**		0.535	
32- He/she hardly becomes irritated		**0.588**		0.402	
2-He/she keeps in order games	0.436		**0.799**		
12- He/she leaves his/her room in order	0.435		**0.875**		
31- He/she keeps objects in order	0.477		**0.812**		
3-He/she quietly confronts new situations		0.415		**0.710**	
6- He/she reacts calmly to changes in plan		0.562		**0.705**	
13- He/she adapts easily to new situations		0.437		**0.724**	
29- He/she accepts changes in routine, food, place…		0.367		**0.565**	
14- He/she has good ideas	0.593				**0.629**
21- He/she knows his/her strengths and weaknesses	0.400				**0.543**
27- He/she takes the initiative	0.455				**0.576**
30- He/she has idea about what to do during free time				0.358	**0.480**
α Cronbach	0.922	0.867	0.870	0.778	0.670

Table 3.3: Correlations among the five factors

	Metacognition	Emotional/behavioral regulation	Organization of materials	Shift	Initiation
Metacognition	-				
Emotional/behavioral regulation	0.543	-			
Organization of materials	0.525	0.340	-		
Shift	0.382	0.547	0.227	-	
Initiation	0.495	0.406	0.189	0.347	-

3.2.2.1.2 Confirmatory Factor Analysis

To determine the QuFE structure, we tested the model obtained by EFA and four different theoretical models proposed by Gioia and colleagues (2002). In the first model, all items were constrained to load on one latent factor. The second model was defined as a 2-factor model with a Metacognition factor (Initiation, WM, Plan/organization, Organization of materials and Task monitor) and a Behavioral/emotional regulation factor (Inhibition, Shift, Emotional control and Self-Monitor) as latent factors. In the third model, there were three latent factors: Metacognition (Initiation, WM, Plan/organization, Organization of materials and Task monitor), Behavior regulation (Inhibition, Self-monitor) and Emotional regulation (Shift and Emotional control). The fourth model included a 4-factor solution with Internal Metacognition (Initiation, WM, Plan/organization), External Metacognition (Organization of materials, Task monitor), Behavior regulation (Inhibition, Self-monitor) and Emotional regulation (Shift and Emotional control) as latent factors.

Table 3.4 summarizes the fit indices for the five models. The 5-factors model appeared to better fit the data. The RMSEA was acceptable, whereas the CFI and NFI were slightly below threshold.

Table 3.4: Summary of fit indices for five nested the QuFE models

	χ^2 statistic	**RMSEA**	**CFI**	**NFI**	**AIC**
1-factor *	2549.862 (464)	0.118	0.590	0.543	2677
2-factors *	1931.866 (463)	0.099	0.711	0.654	2061
3-factors *	1879.201 (461)	0.098	0.721	0.663	2013
4-factors *	1527.813 (458)	0.085	0.790	0.726	1667
5-factors ^	**1202.566 (454)**	**0.071**	**0.853**	**0.785**	**1350**

Notes: RMSEA, Root mean square error of approximation; CFI, Comparative fit index; NFI, Normed fit index; AIC, Akaike's information criterion; * theoretical models; ^ empirical model.

3.2.2.1.3 Age-related and gender differences

We conducted analyses of variance to verify if scales of the Parent form of the QuFE are able to detect age-related changes and gender differences.

The dependent variables were the Total score and the five latent factors obtained above (Metacognition, Emotional and behavioral regulation, Organization of materials, Shift, and Initiation).

All six variables were submitted to a MANOVA with Age (six levels) and Gender (two levels) as between-subjects variables. The MANOVA resulted in main effects of Age and Gender.

The MANOVA showed that the main effect of Age was significant on only one scale (Organization of materials). This significant finding was followed up with a post hoc Tukey HSD test (alpha level was set at 0.05). Post hoc testing showed significantly higher scores in children 8 years old than in children 12 years old. The developmental trajectory was not linear.

The MANOVA showed that the main effect of Gender was significant on all scores, except for Shift. Girls showed better executive skills than boys. Specifically, girls scored higher on all scores.

The Age group and gender interaction was not significant.

Table 3.5 shows descriptive statistics for each scale in the QuFE and the Age, Gender, and Age by Gender effects.

Table 3.5: Descriptive statistics for the QuFE scores and Age, Gender, Age by Gender interaction Effects

	8 years (n =169)		**9 years** (n=148)		**10 years** (n=129)		**11 years** (n=135)		**12 years** (n=162)		**13 years** (n=119)		**Age Effect**		**Male** (n=448)		**Female** (n=414)		**Gender Effect**		**Interaction Age X Gender**	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	F(5,857)	P	M	SD	M	SD	F(1,861)	p	F(5,857)	P
Metacognition	3.89	0.06	3.82	0.06	3.87	0.07	3.80	0.06	3.82	0.06	3.84	0.07	0.31	0.905	3.66	0.03	4.01	0.04	49.69	**0.000**	1.43	0.211
Emotional/behavior regulation	3.76	0.05	3.64	0.06	3.57	0.06	3.74	0.06	3.69	0.05	3.77	0.06	1.72	0.128	3.61	0.03	3.78	0.03	11.98	**0.001**	1.57	0.17
Organization of materials	3.45	0.08	3.11	0.08	3.28	0.09	3.20	0.09	2.99	0.08	3.13	0.09	3.920	**0.002**	3.07	0.05	3.32	0.05	11.69	**0.001**	0.39	0.857
Shift	3.86	0.06	3.75	0.06	3.71	0.07	3.79	0.07	3.79	0.06	3.71	0.07	0.87	0.503	3.72	0.04	3.82	0.04	3.66	0.056	1.86	0.099
Initiation	4.04	0.05	3.98	0.06	3.93	0.06	3.93	0.06	3.99	0.05	3.93	0.06	0.73	0.598	3.91	0.03	4.03	0.03	6.95	**0.009**	0.87	0.504
Total	122.39	1.41	118.79	1.50	118.93	1.64	119.76	1.58	119.20	1.44	119.88	1.68	0.85	0.512	116.20	0.87	123.45	0.91	33.16	**0.000**	1.37	0.233

3.2.2.2 THE TEACHER FORM OF THE QuFE

3.2.2.2.1 Exploratory Factor Analysis and psychometric properties

To obtain general dimensions of executive functioning, 32 items were entered into the Exploratory Factor Analysis (Maximum likelihood). The analysis produced three factors, which were rotated using the Promax method. This solution accounted for 72.178 % of the total variance. Item loadings and correlations between the scales are given in *Tables 3.6* and *3.7*, respectively.

Fourteen items had the highest loadings on the first factor. The common denominator for the items loading on the first factor might be the requirement of metacognition. These items refer to the ability to begin a task or activity; generate ideas, answers or problem solving strategies; manage current and future-oriented task demands; anticipate future events; set goals and develop appropriate steps ahead of time to perform a task or activity; bring order to information and to appreciate ideas or key concepts; and maintain concentration and attention for a prolonged period of time. The first factor named *Metacognition.*

Thirteen items had the highest loadings on the second factor. The common denominator for the items loading on this factor might be the requirement of regulating emotions and behavior. These items refer to ability to stop one's own behavior at an appropriate time; modulate emotional responses; move freely from one situation, activity or aspect of a problem to another as the circumstances demand and monitor personal behavioral activities. The second factor named *Emotional and behavioral regulation.*

Four items had the highest loadings on the third factor. The common denominator for the measures loading on this factor might be the requirement to organize materials. These items assess the orderliness of work and play storage spaces and the manner in which children order and organize their world and belongings. The third factor named *Organization of materials.*

The Cronbach's α coefficients of the scales are shown in *Table 3.6.* A commonly accepted rule of thumb is that an α of 0.6-0.7 indicates acceptable reliability, and 0.8 or higher indicates good reliability (Cronbach, 2004). The Cronbach's αs of the 3 scales ranged from 0.932 to 0.969. Thus, the internal consistency of the QuFE was very good.

For the item-total correlations, a value of 0.3 is generally regarded as satisfactory (Nunally et al., 1994). The values ranged from 0.694 to 0.845.

Table 3.6: Factor loadings for items

	Metacognition	**Emotional/behavioral regulation**	**Organization of materials**
1-He/she is self-starter	**0.798**		
2- He/she has good ideas	**0.982**		
5- He/she maintains attention for a long time	**0.581**		
9-He/she focused on schoolwork and domestic chores	**0.653**		
10-He/she is creative in solving daily problems	**0.925**		
11-He/she plans the right time	**0.717**		
12- He/she performs a task for a long time	**0.590**		
19-He/she carries out his/her activities	**0.742**		
22-He/she starts homework and domestic chores	**0.670**		
23- He/she schedules homework	**0.643**		
25-He/she takes the initiative	**0.919**		
27-If he/she is distracted, he/she remembers what he/she was doing	**0.656**		
31-He/she has good ideas	**0.890**		
3- He/she quietly confronts new situations		**0.551**	
6- He/she reacts calmly to changes in plan		**0.718**	
7-He/she has stable mood		**0.717**	
13-He/she understands that actions may annoy		**0.686**	
15-He/she aware of his/her behavior in group		**0.700**	
16-He/she waits for his/her turn to talk		**0.694**	
17-He/she is controlled and moderate		**0.853**	
18- He/she know when his/her behavior provokes negative reactions		**0.742**	
20-He/she reacts in an appropriate manner		**0.598**	
21-He/she accepts changes in teachers and class		**0.572**	
24-He/she is calm and controlled		**0.876**	
26-He/she easily recovers disappointment	0.416	**0.575**	
28- He/she stops when he/she performs inadequate actions		**0.871**	
29- He/she calibrates the reactions		**0.842**	
32- He/she controls outbursts of anger		**0.825**	
4-He/she has ordered desk			**0.790**
8- He/she carefully preserve the school supplies			**0.897**
14-He/she maintains in order the school supplies			**0.853**
30-He/she is able to find his/her own objects			**0.630**
α Cronbach	0.969	0.957	0.932

Table 3.7: Correlations among the three factors

	Metacognition	Emotional/behavioral regulation	Organization of materials
Metacognition	-		
Emotional/behavioral regulation	0.688	-	
Organization of materials	0.691	0.693	-

3.2.2.2.2 Confirmatory Factor Analysis

To determine the QuFE structure, we tested the model obtained by EFA and four different theoretical models proposed by Gioia and colleague (2002). In the first model, all items were constrained to load on one latent factor. The second model was defined as a 2-factor model with a Metacognition factor (Initiation, WM, Plan/organization, Organization of materials and Task monitor) and a Behavioral/emotional regulation factor (Inhibition, Shift, Emotional control and Self-Monitor) as latent factors. In the third model, there were three latent factors: Metacognition (Initiation, WM, Plan/organization, Organization of materials and Task monitor), Behavior regulation (Inhibition, Self-monitor) and Emotional regulation (Shift and Emotional control). The fourth model included a 4-factor solution with Internal Metacognition (Initiation, WM, Plan/organization), External Metacognition (Organization of materials, Task monitor), Behavior regulation (Inhibition, Self-monitor) and Emotional regulation (Shift and Emotional control) as latent factors.

Table 3.8 summarizes the fit indices for the five models. The 3-factor model obtained by EFA appeared to better fit the data. The RMSEA was acceptable, whereas the CFI and NFI were slightly below threshold.

Table 3.8: Summary of fit indices for five nested the QuFE models

	χ^2 statistic	RMSEA	CFI	NFI	AIC
1-factor *	3826.853 (464)	0.150	0.728	0.702	3954
2-factors *	2561.112 (463)	0.118	0.830	0.801	2691
3-factors *	2343.684 (461)	0.112	0.848	0.818	2477
4-factors *	1962.248 (458)	0.101	0.879	0.879	2096
3-factors ^	**1952.825 (461)**	**0.100**	**0.879**	**0.879**	**2092**

Notes: RMSEA, Root mean square error of approximation; CFI, Comparative fit index; NFI, Normed fit index; AIC, Akaike's information criterion; * theoretical models; ^ empirical model

3.2.2.2.3 Age-related and gender differences

We conducted analyses of variance to verify if scales of the Teacher form of the QuFE are able to detect age-related changes and gender differences.

The dependent variables were the three latent factors obtained above (Metacognition, Emotional and behavioral regulation, Organization of materials) and the Total score.

All four variables were submitted to a MANOVA with Age (six levels) and Gender (two levels) as between-subjects variables. The MANOVA resulted in main effects of Age and Gender.

The MANOVA showed that the main effect of Age was significant on all scores, except for Metacognition. Significant findings were followed up with post hoc Tukey HSD tests (alpha level was set at 0.05). With reference to Emotional/behavioral regulation, post hoc testing showed 1) significantly lower scores in children 8 years old than in children 9 years old; 2) significantly higher scores in children 9 years old than in children 8 and 10 years old; 3) significantly lower scores in children 10 years old than in children 12 and 13 years old. As far as Organization of materials was concerned, post hoc testing showed significantly higher scores in children 9 years old than in children 10 years old.

The MANOVA showed that the main effect of Gender was significant on all scores. Girls showed better executive skills than boys. Specifically, girls scored higher on all scales.

The Age group and gender interaction was absent.

Table 3.9 shows descriptive statistics for each scale in the QuFE and the Age, Gender, and Age by Gender effects.

Table 3.9: Descriptive statistics for the QuFE scores and Age, Gender, Age by Gender interaction Effects

	8 years (n =169)		**9 years** (n=148)		**10 years** (n=129)		**11 years** (n=135)		**12 years** (n=162)		**13 years** (n=119)		**Age Effect**		**Male** (n=448)		**Female** (n=414)		**Gender Effect**		**Interaction Age X Gender**	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	F(5,857)	P	M	SD	M	SD	F(1,861)	p	F(5,857)	P
Metacognition	3.71	0.07	3.89	0.07	3.67	0.08	3.65	0.08	3.72	0.07	3.68	0.08	1.39	0.229	3.54	0.04	3.90	0.05	32.43	**0.000**	0.30	0.914
Emotional/behavior regulation	3.76	0.06	4.03	0.07	3.63	0.07	3.81	0.07	3.85	0.06	3.89	0.08	3.70	**0.003**	3.62	0.04	4.04	0.04	56.98	**0.000**	0.47	0.798
Organization of materials	3.79	0.07	4.06	0.08	3.68	0.09	3.86	0.08	3.88	0.08	3.95	0.09	2.45	**0.033**	3.58	0.05	4.17	0.05	78.46	**0.000**	0.50	0.774
Total	119.73	1.97	127.33	2.10	116.87	2.30	120.12	2.21	121.60	2.01	121.92	2.35	2.58	**0.025**	114.58	1.22	127.94	1.27	57.32	**0.000**	0.30	0.911

3.2.2.3 Rating consistency

To evaluate the consistency in ratings provided by the parents and teachers of the same child, we analyzed the correlations between the two informants (parents and teachers).

The scores correlated with one another significantly and the values of correlation ranged from 0.081 to 0.497. Despite the weakness of the relationships, our findings revealed interesting relationships: 1) correlations were found between Metacognition of the Parent form and all factors of the Teacher form of the QuFE; and 2) there were correlations between the scores that tapped the same executive skills in both forms, in particular metacognitive and regulatory ability.

Table 3.10 shows the correlations.

Table 3.10: Correlations between the Parent and the Teacher forms of the QuFE

		Teachers			
		Metacognition	**Emotional and behavior regulation**	**Organization of materials**	**Total score**
Parents	**Metacognition**	**0.497**	0.369	0.464	0.486
	Emotional and behavioral regulation	0.226	**0.342**	0.253	0.305
	Organization of materials	0.105	0.081	**0.185**	0.114
	Shift	0.141	0.190	0.096	0.170
	Initiation	0.253	0.187	0.184	0.233
	Total score	0.388	0.373	0.377	**0.412**

For all correlations (r values) p=0.000

3.2.3 DISCUSSION

The Behavioral Rating Inventory of Executive Function (BRIEF) is a suitable questionnaire to measure everyday executive function behaviors in children between 8 and 13 years of age. The current study was conducted to investigate the structure and the psychometric properties of a new EF questionnaire, the QuFE, and to examine whether this instrument could be used as a reliable and valid measure of EF in an Italian sample of children. Moreover, our study examined the age-related and gender differences with respect to the latent variables of the QuFE the Parent and the Teacher versions.

With regards to factor structure, we found that different factor models fit the Parent and Teacher forms of the QuFE. For the Parent version, the underlying structure was more articulated. A five-factor model fit the Parental ratings on the 32 items. The five factors were named Metacognition, Emotional/behavioral regulation, Organization of materials, Shift and Initiation. Metacognition implicates the ability to develop new initiatives, plan actions in advance and approach activities in an efficient and strategic manner, stick to activities for an age-appropriate amount of time and complete them, and evaluate resources and limits. Emotional and behavioral Regulation involve the ability to modulate and exercise control over emotions, behaviors and their consequences. Organization of materials assesses the orderliness of work and play storage spaces and the manner in which children order and organize their world and belongings. The Shift scale provides information about the capacity to accept changes and react in an appropriate manner to them. Finally, the Initiation scale refers to the capabilities to begin a task or activity as well as independently generate ideas, responses or problem solving strategies. In contrast a three-factor model fit the Teacher ratings on the 32 items best. The three factors were named Metacognition, Emotional and behavioral regulation and Organization of materials. As with the parental version, Metacognition represents the child's ability to initiate, plan, organize and sustain performance and future-oriented problem solving in working memory. Emotional and behavioral regulation refers to the child's ability to shift cognitive set and modulate emotions and behavior via appropriate inhibitory control, efficiently monitor their own performance and learn from mistakes. Finally, Organization of materials assesses the manner in which the child orders or organizes his/her scholastic world and belongings. Interestingly, in contrast with Gioia and colleagues (2002), Egeland and colleague (2010), and Peters and colleagues (2012), in both versions of the QuFE, the Inhibitory behavior control dimension was not differentiated from the emotional control dimension.

That is, our study indicated only one aspect of regulatory control. Another element common to the two forms of the QuFE and in contrast with prior literature (Gioia et al., 2002 and Huizinga et al., 2011) concerned the Organization of materials. This executive dimension was differentiated from the metacognitive domain in our research.

As far as the reliability of questionnaire was concerned, the finding in this study showed that the internal consistency of both versions of the QuFE was high to very high. Cronbach's alphas of the five clinical scales in the parent version ranged from 0.670 to 0.922, and the alpha coefficients of the three clinical scales in the teacher version ranged from 0.932 to 0.969. These results were equivalent to the original version of the BRIEF (Gioia et al., 2000). The reliability of the QuFE was also supported by the significant correlations between the descriptions provided by parents and teachers. Correlations between scores that tap the same executive domains in the parent and teacher forms of the QuFE were statistically significant and greater than 0.3. Interestingly, correlation values were higher for items that give information about cognitive and metacognitive dimensions, while they were more moderate when more practical and contextualized aspect of EF were taken into consideration. Based on these findings, we concluded that the QuFE is a reliable tool to assess EF in children.

In addition to examining the psychometric properties, we examined age and gender differences in both versions of the QuFE. We observed main effects of age and gender in both forms of the QuFE. As far as the Parent version was concerned, we found significant differences between age groups in Organization of Materials. The highest scores were reported by children 8 years old because they were rated as more accurate in the management of their personal space and materials. We observed a slight drop between 10 and 11 years and a subsequent stabilization. Finally, boys showed significantly more executive problems than girls. With regards to the Teacher form, we found significant differences between age groups on two scales, Emotional and behavioral regulation and Organization of Materials, and on the Total score. We observed non-linear development. We found two growth spurts between 8 and 9 years and between 10 and 11 years and a slowdown between 9 and 10 years. Finally, girls had better executive functioning than boys. Data relating to developmental trajectories were in line with the indications that emerged from the evaluation of performance: in all tasks and for many variables, a slowdown in the growth of performance was observed between 10 and 11 years, which may represent a functional marker of the phase shift between proliferation and the onset of pruning that affects the neural substrate of EF in this period of life. Studies that utilized the BRIEF have instead documented different results (Gioia et al., 2001, Huizinga et al. 2011): both research groups showed a linear decrease in executive function problems when children become older. The findings about the gender effect were not new because converging results (Gioia et al., 2001 and Huizinga et al., 2011) consistently support this hypothesis.

3.3 STUDY 2: CLINICAL USE OF THE QuFE

3.3.1 METHOD

3.3.1.1 Participants

A total of 803 children with ADHD, LD or typical development (TD) took part in this study, including 697 TD children (children randomly selected from the original sample of 862 used in Study 1), 65 children with ADHD and 41 children with LD.

The eligibility criteria for both the control and clinical children included the following: 1) being between 8 and 13 years old; 2) having an IQ equal to or higher than 85; and 3) speaking Italian as their first language.

Typical developing children

A total of 697 children (448 boys, 249 girls) with a mean age of 10.35 years (SD=1.73; range 8-13) and mean full scale IQ of 114.95 (SD=16.00) took part in this research.

Children were representative of the 8- to 13-year-old population and came from public schools in Lombardy, Piedmont, Veneto and Sardinia.

The eligibility criteria for children were the following: no diagnoses of any neurological, psychiatric or developmental disorders and no history of brain damage or sensory deficit. All participants spoke Italian as their first language.

Both teachers and parents were informed about the study aims. Parental consent was obtained for all participating children.

Children with ADHD or LD

A total of 106 children (70 boys, 36 girls) with a mean age of 9.97 years (SD=1.78; range 8-13) took part in this research, including 65 children with ADHD and 41 children with LD. Children in the clinical groups met International Classification of Diseases (ICD-10) criteria for Attentional Deficit Hyperactivity Disorder (ADHD) or Learning Disabilities (LD). Clinical participants were recruited from specialist assessment and diagnostic services for children and adolescents with neurodevelopmental disorders in Bergamo, Milan (Fatebenefratelli Hospital, Niguarda Hospital and San Paolo Hospital) and Venice (San Donà di Piave Hospital).

Children with ADHD were diagnosed using a diagnostic interview (K-SADs-PL; Kaufman et al., 2004), neurological exam, and clinical observation. To confirm impairment in several contexts, the Conners Rating Scales for Parent and Teacher were completed (Nobile et al., 2007). Children with ADHD were required to obtain a T score above 65 on the ADHD subscale from both parents and teachers. None of the children had received a diagnosis of any chronic neurological illnesses and none was using medication during the testing. Three children took methylphenidate; it was mandatory for medication to be discontinued for 24 hours before testing took place to allow a complete wash-out.

Learning disabilities included Dyslexia, Spelling disorder and Dyscalculia. Dyslexia was diagnosed by an Italian standardized test, *reading words* (subtest 2 of Battery for the Assessment of Developmental Dyslexia and Dysorthography, Sartori et al., 2007). In order to be classified as Dyslexic, children had to obtain a score at least 2 SDs below the mean (Speed and Accuracy). Spelling disorder was diagnosed by an Italian standardized test, *dictation of text* (Battery for the Evaluation of Writing and Spelling skills, Tressoldi et al., 2000). In order to be classified as spelling impaired, children had to obtain a score of at least 2 SDs below the mean (Accuracy). Dyscalculia was diagnosed by Italian standardized battery, *Battery for Developmental Dyscalculia* (Biancardi et al., 2004). Triplets, mental math and written calculations were administered. In order to be classified as having Dyscalculia, children were required to obtain calculation standard scores and numerical standard scores below 70.

None of the children had received a diagnosis of any chronic neurological illness.

In order to ensure that there was no comorbidity of ADHD and LD in our groups, all ADHD children were required not to have scored 2 SDs below the mean on the lists of words (Sartori et al., 2007) or on the dictation of text (Tressoldi et al., 2000), and they were required not to have calculation and numerical standard scores below 70 (Biancardi et al., 2004). Moreover, children with LD were required to obtain a T-score less than 65 on the ADHD subscales of both the parents and teachers for the Conners' Rating Scales (Nobile et al., 2007).

Table 3.11 presents the means and SDs for age, IQ, ADHD symptoms according to the parent and the teacher ratings, reading, writing and computing performance. Reading and writing performance are reported as z-scores; thus, scores below zero mean poor performance.

Table 3.11: Clinical characteristics of sample, IQ and reading, writing and computing performance

	TD (N=697)		**ADHD** (N=65)		**LD** (N=41)	
	Mean	SD	Mean	SD	Mean	SD
Age	10.35	1.73	9.83	1.81	10.20	1.74
Full Scale IQ	114.95	16.00	112.28	12.05	107.96	9.90
<u>Symptoms</u>						
Conners ADHD parent (T score)	50.30	4.22	74.85	6.22	51.30	4.82
Conners ADHD teacher (T score)	51.60	5.42	73.40	4.81	48.30	4.97
<u>School Learning</u>						
Reading words: Speed (z score)	0.55	0.11	-0.48	0.10	-2.10	3.73
Reading words: Accuracy (z score)	0.21	0.69	-0.24	0.98	-2.51	2.67
Dictation of text: Accuracy (z score)	0.42	0.25	0.40	0.57	-2.70	2.82
Numeric IQ (standard score)	93.15	5.25	85.30	12.12	80.28	31.76
Calculation IQ (standard score)	95.45	5.65	79.52	14.01	76.88	27.09

3.3.1.2 Materials

3.3.1.2.1 Intelligence measure

- WISC-III

Three subtests of the *WISC-III* were administered: Vocabulary, Block Design and Digit Span. Vocabulary and Block Design were used to estimate Verbal, Performance and Total IQ. Verbal IQ was obtained by multiplying the value of the weighted score on the Vocabulary subtest by a factor of 5. Performance IQ was obtained by multiplying the value of the weighted score on the Block Design subtest by a factor of 5. Total IQ was derived by converting the sum of Verbal and Performance IQ (Wechsler et al., 2006).

3.3.1.2.2 Symptoms measure

- Conners' ratings scales

The *Conners' Rating Scales* (Nobile et al., 2007) for parents and teachers were administered. The Conners' Rating Scales comprise a research and clinical tool for obtaining parental and teacher reports of childhood behavioral problems (age range: 3-17). The Conners' Rating Scales evaluate problem behaviors, ADHD and comorbid disorders (Oppositional Defiant Disorder, Conduct Disorder, Cognitive Disorder, depression and anxiety), as reported by teachers and parents. The parent version includes 80 items, and the teacher version includes 59 items.

3.3.1.2.3 School learning measures

- Reading tasks (Sartori et al., 2007)

All children were presented with four lists of 28 words of different lengths and frequencies. Children were asked to read as quickly and accurately as possible. The number of errors and the time to read the lists were recorded.

- Dictation (Tressoldi et al., 2000)

All children recorded dictated texts that differed according to age. The texts normally take a maximum of 20-25 minutes to write, according to age and length. The lengths of the texts were variable, ranging from 139 words to 250 words. Phonological errors and non-phonological errors were recorded.

- Calculation task (Biancardi et al, 2004)

Triplets: All children were presented with triplets of numbers. Children were asked to choose the greatest number as quickly and accurately as possible. The number of errors and the time of execution were recorded.

Mental calculation: Children were asked to mentally perform 16 multiplication operations. The number of errors was recorded.

Written calculation: Children were asked to perform four addition, four subtraction and four multiplication operations of increasing complexity. The number of errors was recorded.

3.3.1.2.4 Executive function measures

- Questionnaire for the assessment of Executive Function (QuFE)

In Study 2 we used the questionnaire presented in Study 1.

3.3.1.3 Procedure

The subtests of the WISC-III, reading words, dictation of text, triplets, mental and written calculation were administered. On average, these tests took approximately 30 minutes

Parents and teachers completed the QuFE. The QuFE will take approximately 10 minutes to complete.

3.3.1.4 Data Analyses

First, we analyzed the executive profile obtained by the two different QuFE forms (parent and teacher versions). Data were analyzed using multivariate analyses of variance (MANOVA) using group (3 levels) as a between-subjects factor. Alpha level was set at 0.05. Significant differences were followed up with post hoc Tukey HSD tests if the group effect was significant for some variable.

Second, exploratory discriminant analyses were also performed to investigate the contribution of executive processes to possible differences between the clinical groups and the control group.

3.3.2 RESULTS

3.3.2.1 Diagnosis differences

Univariate analysis did not find a significant differences by Age, $F(5,798)=1.605$, $p=0.156$. A Chi-square test was then run to compare the distribution of Gender. The Chi-square test revealed no difference in distribution of Gender, $\chi^2(2)=1.768$, $p=0.413$.

We conducted analyses of variance to verify if children with ADHD and LD have executive problems in comparison with the typically developing children and if the two disorders can be distinguished on the basis of an executive profile that emerged from the parent or teacher forms of the QuFE. The 5 subscales of the Parent form (Metacognition, Emotional and behavioral regulation, Organization of materials, Shift, Initiation), the 3 subscales of the Teacher form (Metacognition, Emotional and behavior regulation, Organization of materials) and both Total scores were submitted to a MANOVA with Group (three levels) as the between-subjects variable.

The MANOVA showed that for all scores Group effect was significant.

According to a post hoc test, the children with ADHD and LD had specific executive deficits.

The children with ADHD exhibited significantly lower scores than matched TD on all subscales according to parents' and teachers' evaluations on the QuFE.

Children with LD exhibited significantly lower scores than TD on 1) all subscales except for Organization of materials on the Parent form and 2) all subscales except for Emotional and Behavioral Regulation on the Teacher form.

Numerous subscale in both versions differentiated the LD and ADHD groups. On the Parent form, children with ADHD exhibited significantly lower scores than children with LD on Metacognition, Emotional and Behavioral Regulation and Total score. On the Teacher form, children with ADHD exhibited significantly lower scores than children with LD on all scales.

Means and standard deviations of all scores for each group are reported in *Table 3.12*.

Table 3.12: Descriptive statistics for scores in the Parent and the Teacher forms of the QuFE and group differences

	TD (n =697)		**ADHD** (n=65)		**LD** (n=41)		**Effect of group** F (2, 801)		**Contrast between groups**
	M	SD	M	SD	M	SD	F	P	Tukey post-hoc
Parent form of QuFE									
Metacognition	3.79	0.75	2.63	0.66	2.98	0.76	89.68	**0.000**	ADHD < LD < TD
Emotional and behavioral regulation	3.67	0.69	2.92	0.70	3.40	0.67	36.93	**0.000**	ADHD < LD < TD
Organization of materials	3.18	1.04	2.77	1.11	2.88	0.98	5.78	**0.003**	ADHD < TD
Shift	3.77	0.76	3.36	0.82	3.13	0.80	20.26	**0.000**	ADHD, LD < TD
Initiation	3.69	0.67	3.29	0.65	3.58	0.77	33.67	**0.000**	ADHD, LD < TD
Total score	118.99	18.95	92.78	17.66	101.82	18.87	69.70	**0.000**	ADHD < LD < TD
Teacher form of QuFE									
Metacognition	3.67	0.94	2.53	0.77	3.17	0.67	50.19	**0.000**	ADHD < LD < TD
Emotional and behavioral regulation	3.76	0.86	2.73	0.76	3.76	0.59	44.83	**0.000**	ADHD < LD, TD
Organization of materials	3.78	1.04	2.48	1.13	3.37	1.07	47.23	**0.000**	ADHD < LD < TD
Total score	119.30	27.01	83.72	21.42	111.05	19.14	55.31	**0.000**	ADHD < LD, TD

3.3.2.2 Exploratory discriminant analyses

Exploratory discriminant analyses were performed to investigate the contributions of the investigated executive domains to possible differences between the clinical and typically developing children. In these analyses subscales in both versions of the QuFE were used to predict group membership. Specifically, we used 5 scores from the Parent form (Metacognition, Emotional and behavioral regulation, Organization of materials, Shift, Initiation), 3 scores from the Teacher form (Metacognition, Emotional and behavior regulation, Organization of materials) and both Total scores. To investigate the capability of the questionnaire to detect membership to specific clinical groups, the sample was divided into three groups: TD, ADHD and LD. 70% of cases were correctly classified: 70.2% of the normative children, 70.8% of the children with ADHD, and 61% of the children with LD. The results of the group classification are reported in *Table 3.13*.

Table 3.13: Classification results

	TD	**ADHD**	**LD**
TD	**70.2**	14.6	15.2
ADHD	6.2	**70.8**	23.1
LD	26.8	12.2	**61.0**

3.3.2.3 Rating consistency in clinical populations

To evaluate the consistency in ratings provided by parents and teachers of the same child with a clinical diagnosis, we analyzed the correlations between the two informants.

Some subscales correlated with one another significantly, and in general the values of correlation ranged from 0.002 to 0.579. Despite the weakness of some relationships, for the ADHD group, our findings revealed interesting correlations between subscales that provide information about the same executive skills in the two forms of the QuFE. For the LD group, the values of correlations were in general lower, but the correlation between the Metacognition subscales in the two forms was moderate and significant. *Tables 3.14 and 3.15* show the correlations.

Table 3.14: Correlations between forms of QuFE in ADHD evaluation.

		Teachers			
		Metacognition	Emotional/behavior regulation	Organization of materials	Total score
Parents	Metacognition	**0.296***	0.114	0.419**	0.287*
	Emotional and behavioral regulation	0.296*	**0.469****	0.294*	0.449**
	Organization of materials	0.188	0.287*	**0.507****	0.347**
	Shift	-0.090	0.091	0.002	0.006
	Initiation	0.088	-0.028	0.080	0.043
	Total score	0.270*	0.285*	0.399**	**0.361****

* p<0.05 ** p<0.01

Table 3.15: Correlations between two forms of QuFE in LD evaluation.

		Teachers			
		Metacognition	Emotional/ behavior regulation	Organization of materials	Total score
Parents	Metacognition	**0.579****	0.304	0.339*	0.480**
	Emotional and behavioral regulation	0.295	**-0.005**	0.070	0.147
	Organization of materials	0.464**	0.220	**0.220**	0.362*
	Shift	0.021	0.029	0.284	0.087
	Initiation	0.459**	0.172	0.271	0.349*
	Total score	0.525**	0.212	0.313*	**0.407****

* p<0.05 ** p<0.01

We were also interested in verifying if there were significant differences in the degree of agreement between parents and teachers in the two clinical groups. Using the Fisher r-to-z transformation, we calculated z value that can be used to assess the significance of the difference between two correlation coefficients. The consistencies in the descriptions provided by parents and teachers for Emotional and Behavioral Regulation and Organization of materials were significantly greater in the ADHD group, while the consistency was significantly greater in the LD group for Metacognition. *Table 3.16* shows these findings.

Table 3.16: Degree of agreement between parents and teachers

	R Parents version	R Teachers version	Z	p
Metacognition	0.296	0.579	-6.88	**0.000**
Emotional and Behavioral Regulation	0.469	-0.005	9.93	**0.000**
Organization of material	0.507	0.220	6.47	**0.000**
Total score	0.361	0.407	-1.04	0.298

3.3.4 DISCUSSION

The purpose of this study was to investigate the clinical use of the QuFE and diagnostic group differences in terms of parent and teacher ratings on the QuFE. We focused our attention on ADHD and LD groups. In general, the results of the present examination of executive profiles in specific clinical groups were consistent with our expectations based on the literature. While there were similarities in some executive domains between groups, there were also reasonable and consistent differences where they might be expected. Children with ADHD were characterized by more severe general executive weaknesses in both cognitive and regulatory domains than children with LD.

In general, prior work that used similar questionnaires (such as the CHEXI and the BRIEF) has shown that children with ADHD have a compromised executive profile. Thorell and colleagues (2010) collected parent and teacher ratings on the CHEXI. Their results showed that children in the ADHD group differed significantly from the children in the typically developing group on both the CHEXI composite scores and Inhibition and Working memory. Numerous studies have instead used the BRIEF to investigate executive functioning in children with ADHD. Results from different studies are consistent. Compared with their typically developing peers, children with ADHD have lower scores on almost all examined executive domains. Gioia and colleagues (2002) suggested that children with ADHD had worse scores than typically developing children on Initiation, Working memory, Plan/organization, Monitor, Emotional control, Organization of materials and Inhibition subscales. Only children with the combined form of ADHD had worse scores than typically developing children on the Shift subscale. More recent work that focused its attention only on 4 subscales of the BRIEF has shown that ratings on the working memory, Inhibition, shift, plan and organization scales were good predictors of ADHD status (Toplak et al., 2009). As far as clinical utility and sensitivity of individual subscales of the BRIEF are concerned, there is agreement about two findings: 1) the working memory subscale is particularly sensitive to the diagnosis of ADHD and 2) the Inhibition scale reliably differentiates between subtypes of the disorder (Gioia et al., 2000; Mahone et al., 2002, Pratt et al., 2000; Toplak et al. 2009). Consistent with the findings presented above and with the expectation of pervasive and general executive dysfunction with ADHD, our sample exhibited general executive weakness in both home and school environments. In line with the literature, cognitive and metacognitive deficits were useful in ruling in a diagnosis of ADHD. Children in our ADHD sample had the lowest scores on scales that tap the ability to begin a task or activity and independently generate ideas; to hold information in mind for the purpose of completing a task; to maintain attention for a prolonged time; to anticipate future events, set goals and develop appropriate steps ahead of time to perform an associated task or action; and to check work and performance during or after finishing a task, ensuring attainment of a goal. In our work the subtypes of ADHD were not differentiated so we had no data to confirm or deny the role of Inhibition. However, our data suggested the presence of regulatory weakness. Children with ADHD had the lowest scores on scales that give information about the capability to control impulses and stop one's own behavior at the proper time; move freely between situations, activities or aspects of problem; and modulate emotional responses appropriately. Finally, children with ADHD seemed to have problems with practical abilities, such as keeping their workspace, play areas, and materials in an orderly manner. Referring to a similar subscale in the BRIEF, the available data were inconsistent. Other researchers described a significant weakness (Gioia et al., 2002), while others (Shimoni et al., 2012; Sullivan et al., 2007) excluded a problem with this skill in the home environment. Different results can be possibly be explained by parent/teacher subjectivity. It is possible that organizing materials does not depend on executive abilities but on familial habits or parents' attitude. Finally, as far as the consistency between parent and teacher reports was concerned, the executive profiles that emerged in the two contexts were substantially overlapping. The consistency was higher for Emotional and behavioral regulation and Organization of materials. For Metacognition the agreement was lower. These data replicated findings presented above in Study 1. In general, executive weakness was higher in the school environment.

The executive profile for children with LD was more subtle than that of ADHD. In previous works, deficits in the metacognitive domains of working memory, planning and organization, and monitoring were generally found, but the frequency of problematic behaviors in these areas and the overall level of executive dysfunction were significantly lower than in those with ADHD (Gioia et al., 2000). Our data were in line with these findings. Compared with ADHD, LD had the same cognitive impairment but its intensity was significantly lower in both domestic and scholastic environments. Children with LD had difficulties with sustained attention, planning and organization, monitoring of activity and behavior, and initiation. An interesting additional finding in our study was the relative regulatory difficulties at home. Children with LD had lower scores than typically developing children in the Emotional and behavioral regulation subscale that gives information about emotional control, behavior flexibility and inhibition. A similar weakness was not recognized in the school setting: in the teacher report, children with LD had scores in line with typically developing children. Differences in parent and teacher reports likely reflect differences in child behavior across settings. Parents may have the opportunity to observe problems with behavioral control, whereas teachers are more likely to notice the cognitive impairments, given the higher demands on cognition and the more structured context of observation. Finally, in the domestic environment, parents did not report problems in Organization of materials. The underlying factor that might explain the lack of agreement between parents and teachers in rating organization skill is that Organization of materials relies on external support. According to our findings, there was consistency between parents' and teachers' descriptions only in the cognitive domain: both parents and teachers reported significant weakness.

To investigate the clinical use and discriminant power of the QuFE, we analyzed group differences and the sensitivity (correct identification of clinical children) and specificity (correct identification of typically developing children) of the questionnaire. As far as group differences were concerned, in the parent form, Metacognition and Emotional/behavioral regulation significantly differentiated the ADHD and LD groups, while for the teacher form, there were significant differences on all subscales. Children with ADHD had the lowest scores on all subscales. Compared with studies investigating the discriminant validity of similar questionnaires, our results are similar with regard to specificity. One study that did determine specificity and sensitivity using discriminant function analyses was conducted by McCandless and colleagues (2007). They studied the BRIEF in a group of children diagnosed with different ADHD subtypes and a comparison group and found an overall classification rate of 77.1% for the ADHD versus non-ADHD comparison, with a sensitivity of 77.8% and a specificity of 76.0%. Compared with studies investigating the discriminant validity of neuropsychological EF tests, these results are similar for specificity, but neuropsychological tests have generally been shown to have poorer sensitivity (Barkley et al., 1994; Doyle et al., 2000; Perugini et al., 2000). The QuFE correctly classified 70% of children, with 70.2% specificity and sensitivity between 61% and 70.8%. In conclusion, our findings supported the clinical use of the QuFE. Almost all subscales in both forms were able to distinguish typically developing and clinical groups, even if the discriminating power was greater for the ADHD group. The scales were less successful at predicting the presence of ADHD or LD.

3.4 GENERAL CONCLUSION

Executive Function (EF) is one of the most widely invoked constructs in cognitive science, neuropsychology, and developmental and clinical research literatures. This construct has become important in the assessment of typically developing children and special populations because of its relationships with scholastic achievement and school readiness, social competence and theory of mind and behaviors associated with developmental disorders.

The operationalization and measurement of EF is a very important issue that directly impacts the inferences we can make about these competencies. Assessment of EF has historically been confined to laboratory-based performance tests. These instruments are limited in ecological validity and predictive value of functioning in the everyday environment. Accordingly, attention is increasingly being given to alternative methods of evaluation with greater ecological validity. Rating measures of EF were developed to provide an ecologically valid indicator of competences in complex, everyday, problem solving situations. In our research we proposed a new EF questionnaire: the Questionnaire for the assessment of Executive Function (QuFE). We aimed to analyze the factor structure and the reliability of the QuFE, the capability of this questionnaire to detect changes in executive functioning during childhood and adolescence and its clinical use.

With reference to the structure of the QuFE, an interesting finding in our study was the different structure that fit data from the parent and teacher forms. Five dimensions described the executive profile in the parent form: Metacognition, Emotional and behavioral regulation, Organization of materials, Shift and Initiation. However, three domains defined executive behavior in the teacher version: Metacognition, Emotional and behavioral regulation and Organization of materials. Additionally, the current study showed that the QuFE is a reliable measure of EF. The finding in this study showed that the internal consistency of both version of the QuFE was generally high, and correlations between scores that tap same executive domains in the Parent and the Teacher form of the QuFE were statistically significant and greater than 0.3.

Results with respect to age revealed that the QuFE, in particular the parent version, was not very sensitive. In the Parent version, different scores were essentially stable from 8 to 13 years. In the Teacher version, two scales, Emotional and behavioral regulation and Organization of materials, had non-linear development during primary school, and the scores gradually increased during middle school. The underlying factor that might explain the lack of age-related changes in the parents' and teachers' evaluations is their different expectations for the growth of a child.

As far as clinical use was concerned, the QuFE is a multi-domain measure that brings an ecologically valid dimension to executive profiles in typically developing and clinical children. The QuFE offers a view of children's executive function profiles in everyday environments, but it was not intended as a tool for independently diagnosing specific disorders. The questionnaire was able to distinguish typically developing and clinical groups, but it was less successful at discriminating children with ADHD from those with LD; therefore, the executive profiles that emerged from the QuFE were not sufficiently specific for a diagnosis of ADHD or LD.

3.5 LIMITATIONS OF THE STUDY AND FUTURE PERSPECTIVES

The QuFE is a new instrument. For this reason, it is important that future research will confirm its construct, concurrent and ecological validity. It would be useful to conduct new confirmatory factor analyses on a sample of different children, verify relationships with other EF questionnaires or performance-based measures and collect normative data from a large number of children at various ages to determine specific cutoffs so that the QuFE can be used in clinical practice. It is also important that future studies will verify its clinical validity. The results need to be replicated using larger clinical samples, and it also needs to be determined whether the QuFE can be used to discriminate between children with various pathological conditions. Finally, future studies should investigate the discriminant validity of the QuFE with a longitudinal perspective. More specifically, it would be valuable to study whether the QuFE can be used to discriminate between preschool children with high levels of ADHD who will show continuing behavior problems and children whose behavior problems are more transient in nature.

CHAPTER 4: VIGILANCE, STRATEGIC BEHAVIOR, INHIBITION AND MEMORY IN CHILDREN WITH ADHD AND LEARNING DISABILITIES

4.1 INTRODUCTION

EF deficits play a part in several developmental and neurological disorders, including Autism, Attentional-Deficit Hyperactivity Disorder (ADHD), Tourette Syndrome (TS), and Learning Disabilities (LD). These findings have raised the "discriminant validity question" (Pennington et al., 1996): it is important to clarify precisely which functions are impaired in each disorder. In examining the discriminant validity problem, the goal of the researchers often has been to find the primary neurocognitive deficit for each disorder, with "primary" referring to a deficit that is universal, specific, necessary and sufficient to cause the symptoms of the disorder.

4.1.1 Executive Function profile in children with ADHD

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common neurodevelopmental disorders of childhood. It is diagnosed on the basis of persistent, developmentally inappropriate and impairing symptoms of inattention and hyperactivity/impulsivity (American Psychiatric Association, 2013). These two symptom clusters give rise to three presentations of ADHD: a predominantly inattentive, a predominantly hyperactive-impulsive, and a combined presentation.

Heterogeneity in children with ADHD symptoms is a well-known phenomenon. Empirically, this heterogeneity is evident in at least three different respects: expression of the two symptom domains (inattention and hyperactivity/impulsivity), neuropsychological impairments, and comorbid disorders. Considerable research has been conducted in recent decades to try to understand the neuropsychology behind ADHD symptoms. Recent research has identified the effects of several neuropsychological processes in children with ADHD (Solanto et al., 2001), which implies that it is unlikely that researchers will find a single core deficit. Some multiple-deficit models have proposed independent or additive effects of separate neuropsychological deficits that characterize subgroups of children with ADHD symptoms (Nigg et al., 2005; Sonuga-Barke 2005). Other models suggest that ADHD symptoms could be explained by the interactive effects of several cognitive deficits (Castellanos et al., 2006, Willcutt et al., 2005).

However, neuropsychological studies of ADHD have mainly focused on EF impairments. The reason for this concentration is based on the observation that frontal and prefrontal lesions in patients sometimes produce hyperactivity, distractibility or impulsivity, separately or in combination, similar to the behavioral symptoms seen in children with ADHD. Concerning the relation between impaired EF and ADHD symptoms in children, one of the most influential neuropsychological theories is Barkley's model of ADHD (Barkley, 1997). In Barkley's model, ADHD is proposed to derive from poor EF, with poor inhibitory control as a core deficit. This neuropsychological model catalyzed a literature, much of it focused on inhibition as the core deficit in ADHD (Castel et al., 2011, Geurts et al., 2004, Nigg et al., 2002, Oosterlaan et al., 1998, Purvis et al., 2000, Rubia et al., 2008, Willcutt et al., 2001, Willcutt at al., 2005). Among different types of inhibitory processes, only the executive motor inhibition deficit has clear, replicated evidence in ADHD (Nigg et al., 2001). Go-NoGo paradigm is traditionally used to measure executive motor inhibition ability. Trommer and colleagues (1988) conducted a study in which ADHD children made more commission, omission and multiple omission errors than controls. These findings were replicated in a study by Shue and colleagues (1992). Other variables of this paradigm that were included in the analysis of performance were Stop Signal Reaction Time (SSRT), Reaction Time (RT) and RT variability. Two meta-analyses (Lijffijt et al., 2005; Willcutt et al., 2005) reported significantly longer SSRT, slower RTs to Go stimuli and greater Go stimulus RT variability in ADHD children.

Explaining executive dysfunction in ADHD entirely in terms of poor inhibition may be an oversimplification. Zelazo and colleagues (2002) proposed that ADHD should be considered a disorder of cool EF. In contrast, Castellanos and colleagues (2006) suggested a differentiation: inattention symptoms may be associated with deficits in cool EF whereas hyperactivity/impulsivity symptoms will be found to reflect hot EF deficits. This hypothesis gives rise to the possibility that individuals with ADHD would manifest primarily hot EF dysfunction, whereas others will show mainly cool EF deficits, and others both types.

Most of the studies in the literature, in line with Zelazo and colleagues, have focused on cool EF. Individuals with ADHD have been widely reported to have impairments in cognitive flexibility (Bental et al., 2007; Pennington et al., 1996; Shallice et al., 2002; Willcutt et al., 2005), in planning (Marzocchi et al., 2008; Oosterlaan et al., 2005; Willcutt et al., 2005), in visuo-spatial working memory and executive central processes (Cornoldi et al., 2001; Martinussen et al., 2005; Roodenrys et al., 2001).

Cognitive flexibility is usually measured by the Wisconsin Card Sorting Test (WCST). As far as WCST perseverative errors are concerned, the majority of the studies analyzed by Willcutt and colleagues in their meta-analysis (2005) did not detect significant differences between children with and without ADHD. The authors speculated that a weakness in cognitive flexibility is a poor candidate for the primary neuropsychological deficit in ADHD. Some studies instead have found deficits in performance on WCST and have focused attention on completed categories and perseverative errors. Children with ADHD completed fewer categories (Pennington et al., 1996) and committed more perseverative errors (Bental et al., 2007) than controls. Another rule-attainment test based on the WCST has recently been used to measure cognitive flexibility: the Brixton Spatial Anticipation Test. Interesting contrasts in results have been obtained in different studies. For example Shallice and colleagues (2002) found that, on the Brixton Spatial Anticipation Test, children with ADHD performed more poorly than controls because they produced an excess of perseverative response. In contrast, Bayliss and colleagues (2000) stated that children with ADHD may have difficulty with the Brixton Spatial Anticipation Test, but the number of errors made fail to discriminate between the groups. The authors speculated that the children with ADHD were no more impulsive or perseverative in their responding than the other children.

Planning is usually assessed by the Tower of London (ToL) or the Tower of Hanoi (ToH). Willcutt and colleagues in their meta-analysis (2005) argued that results were stronger and more consistent on the Tower of Hanoi than the Tower of London. There is no clear position about planning capabilities in children with ADHD. Some authors found that ADHD was associated with poor performance in planning tasks. Oosterlaan and colleagues (2005) argued that ADHD status predicted a low ToL score, a high number of errors, and fast planning times (despite normal execution times). Children with ADHD also had planning times that remained similar across difficulty levels. In other words, these children did not adjust their planning times as difficulty levels increased. Taken together, these results suggest that children with ADHD performed poorly on the ToL because they made their first moves before they had successfully generated an appropriate solution to the problem. In line with these data, Marzocchi and colleagues (2008) found that children with ADHD were characterized by shorter delays in response initiation following instructions at the beginning of task execution and a larger number of rule violations. In contrast, other research groups have not found drops in performance on the ToL or the ToH (Geurts et al., 2004; Wu et al., 2002).

Working memory is a limited-capacity, multicomponent cognitive system that allows us to hold and manipulate information on-line for a few seconds, focus attention, resist distraction, and guide decision making during complex daily activities. Working memory has recently been proposed as a potential cognitive endophenotype for ADHD (Castellanos et al., 2002), but empirical findings are inconsistent. In order to identify the core memory deficit in children with ADHD, most researchers have focused their attention on the functioning of the central executive system of WM and on the use of learning strategies. Some studies have confirmed this hypothetical deficit. Roodenrys and colleagues (2001) suggested that ADHD was associated with poorer performance on tasks that require memory updating. Children with ADHD had trouble changing from the simple rehearsal strategy used when no updating was required to the more complex processes involved when updating was required. Cornoldi and colleagues (2001) described overlapping ADHD profiles with a similar WM task. Interestingly, Martinussen and colleagues (2005) conducted a meta-analyses and focused their attention on each separate WM component. (The number of available studies varied by component, ranging from 7 for the central executive to 16 for verbal storage.) Results indicated that WM in children with ADHD was impaired relative to control children on all components. They confirmed a deficit in the central executive system and suggested that differences in the verbal domain were moderate in magnitude, whereas those in the visuo-spatial domain were large. Group differences in WM were larger in those studies that controlled for reading and language impairments.

The results of research on learning strategies in children with ADHD are controversial. Some researchers have suggested that children with ADHD use less efficient strategies and that they are impaired in learning material that requires organized, deliberate rehearsal strategies, sustained strategic effort and careful consideration of response alternatives (O'Neill et al., 1991; Douglas et al., 1990). In contrast, Mahone and colleagues (2001) suggested that children with ADHD are not impaired in the application of semantic strategies.

Recently, researchers have begun to investigate hot EF in children with ADHD. Different studies have investigated affective decision making based on the performance of children/adolescents with ADHD on the Iowa Gambling Task (IGT) or a variant of the IGT. Different studies (Daugherty et al., 1991; Garon et al., 2006; Hobson et al. 2011; Humphreys et al., 2011; Luman et al., 2008; Matthys et al., 1998) have reported that children/adolescents clearly display riskier behavior than do normally developing children. Garon and colleagues (2006) found that children with ADHD less often chose the advantageous decks than controls. The controls also made more advantageous decisions as the task progressed, whereas the children with ADHD did not show this pattern and did not choose the advantageous decks more often than would be predicted by chance. Hobson and colleagues (2011) found that individuals with ADHD made riskier choices than controls. Three studies (Geurts et al., 2006; Masunami et al., 2009; Toplak et al., 2005) found no abnormalities in the degree of risk taking on the IGT in children/adolescents with ADHD. A study by Geurts and colleagues (2006) revealed no differences between children with ADHD and controls with regard to net score: both groups more often chose the advantageous decks as the task progressed, with this pattern emerging sooner in the reversed condition. Masunami and colleagues did not find abnormalities in the number of advantageous choices. Finally, Toplak and colleagues (2005) found no group differences in financial outcomes and, in line with Geurts and colleagues (2006), similar total scores in controls and children with ADHD.

In recent years, researchers have aimed to elucidate the performance of children with ADHD in multitasking situations. These situations involve the prioritization of competing demands, the organization and execution of a number of different tasks within a given period, and the ability to create, maintain and activate delayed intentions. Many of the more recent studies aimed at describing the executive profile of children and adolescents with ADHD have used the Six Element Test (SET; Shallice et al., 1991). Clarck and colleagues (2000) performed a study utilizing this task with adolescents with ADHD (12-15 years). They found that adolescents with ADHD performed significantly worse on SET than controls. Indeed, individuals with ADHD attempted significantly fewer tasks than controls but did not commit more rule breaks. Siklos and colleagues (2004) described a similar profile in children with ADHD.

A review of the literature presented above suggests that EF weakness are significantly associated with ADHD but do not support the hypothesis that the EF deficits are the necessary and sufficient cause of ADHD in all individuals with the disorder. EF difficulties appear to be one of several important weaknesses that comprise the overall neuropsychological etiology of ADHD.

4.1.2 Executive Function profile in children with Learning Disabilities

Learning disabilities (LD) have been defined in various ways over the time. The diagnosis requires persistent difficulties in reading, writing, arithmetic, or mathematical reasoning skills during the formal years of schooling. Symptoms may include inaccurate or slow and effortful reading, poor written expression that lacks clarity, difficulties remembering numerical facts, and inaccurate mathematical reasoning. (American Psychiatric Association, 2013).

Although deficits in groups with LD are most pronounced in the areas of listening, speaking, reading, writing, spelling, reasoning and mathematics, individuals with LD also have weaknesses in several other neurocognitive domains. Children with LD have been hypothesized to show difficulties with attention that may interfere with their neuropsychological functioning (Lyon, 1996, Whyte, 1994, Semrud-Clikeman et al., 2005, Willcutt et al., 2001). There is evidence for weakness in executive function domains such as verbal working memory (Roodenry et al., 2001, Semrud-Clikeman et al., 2003, Semrud-Clikeman et al., 2005, Swanson et al., 1999, Whyte, 1994, Willcutt et al., 2001), set shifting (Weyandt et al., 1998), planning (Klorman et al., 1999) and response inhibition (Purvis et al., 2000, Willcutt et al., 2001).

Children with LD frequently present with poor verbal WM despite having intact visual WM (Baddeley et al., 1994). Many authors suggest that the phonological loop is impaired in this population (Roodenrys et al., 2001): children with LDs have difficulties in span tasks. Subvocal rehearsal mechanisms have been found to be intact (McDougall et al., 2002, Rucklidge et al., 2002; Willcutt et al., 2001). Data on the central executive and visuo-spatial sketchpad are inconsistent. As far as shifting is concerned, a recent meta-analytic study found that shifting was significantly associated with children's performance in both reading and math (Yeniad et al., 2013). Data about the performance of children with LD in tasks traditionally used to evaluate shifting are inconsistent. The Wisconsin Card Sorting Test (WCST) and the Trail Making Test (TMT)-part B are often used to measure this executive domain. Studies that have used the WCST have revealed that individuals with LDs commit more perseverative (Marzocchi et al., 2008) and non-perseverative errors (Helland et al., 2000) and complete fewer categories (Menghini et al., 2010) than normally developing individuals. Narhi and colleagues (1997) described the impaired performance of children with LD on TMT-B; data reporting the opposite effect have been published by other research groups (Reiter et al., 2005; van der Sluis et al., 2004). Some studies ultimately used the Brixton Spatial Anticipation Test to obtain information about cognitive flexibility. Neither Bayliss and colleagues (2000) nor Shallice and colleagues (2002) found significant impairments in performance on this task. Planning is another executive domain on which researchers have focused their attention. Studies testing the planning ability of children with LD have yielded inconsistent findings. Reiter and colleagues (2005) used the ToL to measure differences in planning abilities between children with LD and typically developing children. They found that the groups did not differ in the number of problems solved but that the planning time was significantly longer in the LD group. Marzocchi and colleagues (2008), using the same task, did not find significant group differences in total scores, planning time, or execution time. Inhibition is usually studied using the Go NoGo and Change paradigms in children with LD. Available data are not unequivocal. Purvis and colleagues (2000) and Willcutt and colleagues (2001) demonstrated that children with LD have executive disabilities in their inhibitory processes; the LD group had longer Stop Signal Reaction Times in both paradigms. In contrast, Gooch and colleagues ruled out any deficit in the Go NoGo paradigm task.

Although the data reported above suggest that impairments in specific executive domains are present in children with LD, other authors, such as Cutting and colleagues (2003), have report that these areas are not well understood in children with diagnoses of LD who do not have ADHD.

There may be soft signs of executive dysfunction that are not well documented in children with LD but without ADHD.

In conclusion, the importance of executive function deficits in children with LD is becoming more appreciated. The review of literature presented above suggests impairments in attention, response inhibition and verbal working memory in children with this neurodevelopmental disorder.

In the current study, we analyzed inhibition, cognitive flexibility, planning, memory, strategic behavior and affective decision making through a neuropsychological battery including the Battersea Multitasking Paradigm, the Daily Planning Task, the Visuo-Spatial Reasoning Task, the Junior Iowa Gambling Task and the Honk Task. We studied the executive profiles of children with ADHD and LD. Other research groups have studied these processes in these clinical populations using the same or different tasks. The general consensus emerging from the research is that executive functioning is impaired in ADHD, but there is dissent about the precise nature of the deficits and their specificity to ADHD. Instead, only recent studies suggest that individuals with LD have weaknesses in several neurocognitive domains, including executive functions.

4.1.3 Aims of the study

This study sought to determine whether executive impairments exist in children with Attention Deficit Hyperactivity Disorder (ADHD) or Learning Disabilities (LD) in comparison with a healthy control group. Consistent with prior studies, we hypothesized the following.

1) Both neurodevelopmental disorders, ADHD and LD, would be characterized by impaired executive functioning.

2) There is only partial overlap in executive impairments in children with Attention Deficit Hyperactivity Disorder and Learning Disabilities. Children with ADHD would be characterized by deficits in both cool and hot executive function. Children with LD would be

characterized by circumscribed executive impairment, in particular, in working memory and attention.

4.2 METHOD

4.2.1 Participants

272 children with conditions characterized by ADHD, LD or typical developing took part in this study: 207 typically developing children, 40 children with ADHD and 25 children with LD.

The eligibility criteria for both the control and clinical children included the following: 1) an age between 8 and 13 years; 2) an IQ equal to or greater than 85; and 3) Italian spoken as their first language.

Typical developing children

207 children (157 boys, 50 girls) with a mean age of 10.21 years (SD=1.69; range: 8-13) and a mean full-scale IQ of 114.95 (SD=16.00) took part in this research. The children came from public schools in Lombardy, Piedmont, Veneto and Sardinia.

The eligibility criteria specific to the control children included the following: no diagnoses of any neurological, psychiatric or developmental disorders and no history of brain damage or sensory deficits.

Both teachers and parents were informed about aims of the study. Written parental consent was obtained from all participating children.

Children with ADHD or LD

65 children (50 boys, 15 girls) with a mean age of 10.0 years (SD=1.68; range: 8-13) took part to this research: 40 children with ADHD and 25 children with LD. Children belonging to the clinical groups met International Classification of Diseases (ICD-10) criteria for Attentional Deficit/Hyperactivity Disorder (ADHD) or Learning Disabilities (LD). Clinical participants were recruited from specialized assessment and diagnostic services for children and adolescents with neurodevelopmental disorders in Bergamo, Milan (Fatebenefratelli Hospital, Niguarda Hospital and San Paolo Hospital) and Venice (San Donà di Piave Hospital).

Children with ADHD were diagnosed using a diagnostic interview (K-SADs-PL; Kaufman et al., 2004), a neurological exam, and clinical observation. In order to confirm impairment in several contexts, the Conners' Rating Scales for Parents and Teachers were completed (Nobile et al., 2007). Children with ADHD were required to obtain a T-score greater than 65 on the ADHD subscales of both the parents and teachers. None of the children had received a diagnosis of any chronic neurological illness, and none was taking medication during the testing. Three children consumed methylphenidate; however, it was mandatory for medication to be discontinued for 24 hours before testing took place to allow a complete wash-out.

Learning disabilities included Dyslexia, Spelling disorder and Dyscalculia. Dyslexia was diagnosed by an Italian standardized test, *reading words* (subtest 2 of Battery for the Assessment of Developmental Dyslexia and Dysorthography, Sartori et al., 2007). In order to be classified as Dyslexic, children had to obtain a score at least 2 SDs below the mean (Speed and Accuracy). Spelling disorder was diagnosed by an Italian standardized test, *dictation of text* (Battery for the Evaluation of Writing and Spelling skills, Tressoldi et al., 2000). In order to be classified as spelling impaired, children had to obtain a score of at least 2 SDs below the mean (Accuracy). Dyscalculia was diagnosed by Italian standardized battery, *Battery for Developmental Dyscalculia* (Biancardi et al., 2004). Triplets, mental math and written calculations were administered. In order to be classified as having Dyscalculia, children were required to obtain calculation standard scores and numerical standard scores less than 70.

None of the children had received a diagnosis of any chronic neurological illness.

In order to ensure that there was no comorbidity of ADHD and LD in our groups, all ADHD children were required not to have scored 2 SDs below the mean on the lists of words (Sartori et al., 2007) or on the dictation of text (Tressoldi et al., 2000), and they were required not to have calculation and numerical standard scores below 70 (Biancardi et al., 2004). Moreover, children with LD were required to obtain a T-score less than 65 on the ADHD subscales of both the parents and teachers for the Conners' Rating Scales (Nobile et al., 2007).

Table 4.1 presents the means and SDs for age, IQ, ADHD symptoms according to parent and teacher ratings, reading, writing and computing performance. Reading and writing performance are reported as z-scores, so scores below zero reflect poor performance.

Table 4.1: Clinical characteristics of sample, IQ and reading, writing and computing performance

	TD (N=207)		**ADHD** (N=40)		**LD** (N=25)	
	Mean	SD	Mean	SD	Mean	SD
Age	10.21	1.69	10.02	1.69	9.96	1.69
Full Scale IQ	114.95	16.00	117.28	12.02	106.96	9.89
Symptoms						
Conners ADHD parents (T score)	51.30	4.20	73.95	6.79	52.30	5.82
Conners ADHD teachers (T score)	50.60	5.32	72.30	4.61	46.30	3.97
School Learning						
Reading words: Speed (z score)	0.45	0.38	-0.28	0.99	-2.05	3.73
Reading words: Accuracy (z score)	0.11	0.69	-0.14	0.88	-2.31	2.67
Dictation of text: Accuracy (z score)	0.52	0.25	0.00	0.78	-2.69	2.82
Numeric IQ (standard score)	92.15	6.25	83.42	32.12	85.28	31.76
Calculation IQ (standard score)	95.45	5.55	78.64	24.01	77.88	27.09

4.2.2 Materials

4.2.2.1 Intelligence measure

- <u>WISC-III</u>

Three subtests of the *WISC-III* were administered: Vocabulary, Block Design and Digit Span. Vocabulary and Block Design were used to estimate Verbal, Performance and Total IQ. Verbal IQ was obtained by multiplying the value of the weighted score on the Vocabulary subtest by a factor of 5. Performance IQ was obtained by multiplying the value of the weighted score on the Block Design subtest by a factor of 5. Total IQ was derived by converting the sum of Verbal and Performance IQ (Wechsler et al., 2006).

4.2.2.2 Symptoms measure

- <u>Conners' ratings scales</u>

The *Conners' Rating Scales* (Nobile et al., 2007) for parents and teachers were administered. The Conners' Rating Scales comprise a research and clinical tool for obtaining parental and teacher reports of childhood behavioral problems (age range: 3-17). The Conners' Rating Scales evaluate problem behaviors, ADHD and comorbid disorders (Oppositional Defiant Disorder, Conduct Disorder, Cognitive Disorder, depression and anxiety), as reported by teachers and parents. The parent version includes 80 items, and the teacher version includes 59 items.

4.2.2.3 School learning measure

- <u>Reading tasks</u> (Sartori et al., 2007)

All children were presented with four lists of 28 words of different lengths and frequencies. Children were asked to read as quickly and accurately as possible. The number of errors and the time to read the lists were recorded.

- Dictation (Tressoldi et al., 2000)

All children recorded dictated texts that differed according to age. The texts normally take a maximum of 20-25 minutes to write, according to age and length. The lengths of the texts were variable, ranging from 139 words to 250 words. Phonological errors and non-phonological errors were recorded.

- Calculation task (Biancardi et al, 2004)

Triplets: All children were presented with triplets of numbers. Children were asked to choose the greatest number as quickly and accurately as possible. The number of errors and the time of execution were recorded.

Mental calculation: Children were asked to mentally perform 16 multiplication operations. The number of errors was recorded.

Written calculation: Children were asked to perform four addition, four subtraction and four multiplication operations of increasing complexity. The number of errors was recorded.

4.2.2.4 Executive Function measure

We developed a comprehensive test battery that included performance-based measures that assess working memory, retrospective and prospective memory, cognitive flexibility, inhibition, planning and organisation of behaviour, affective decision making, and visuo-spatial reasoning. The battery includes the following tasks: the Battersea Multitasking Paradigm, the Daily Planning Task, the Visuo-spatial Reasoning Task, the Junior Iowa Gambling Task and the Honk Task.

For a detailed description of the tasks, see Chapter 2.

- Battersea Multitasking Paradigm (adapted from Mackinlay et al., 2006)

The Battersea Multitasking Paradigm makes demands upon three constructs: retrospective and prospective memory, planning, monitoring of behaviour.

The BMP consists of 3 interleaved but very simple tasks that children must perform in a time limit of 6 minutes. The performance is constrained by four rules: 1) children had to try all 3 games before the sand runs out, 2) yellow items get more points than blue, 3) full clusters get extra points, and 4) items must only be picked or coloured one-by-one. The goal of the task is to score a maximum of points without breaking any rules. The optimal way to perform the game is to fill up small clusters of yellow items in all three tasks. The BMP is administered in a 5-stage invariant behavioural sequence. Each stage generated a dependent variable: 1) *Learning*, 2) *Planning*, 3) *Execution*; 4) *Monitoring* and 5) *Memory*.

- Daily Planning Task (adapted from Schweiger and Marzocchi, 2008)

The Daily Planning Task (DPT) assesses retrospective and working memory, planning and temporal estimation.

The DPT is proposed in two versions, one for children aged 8-10 years and one for teens aged 11-14 years. The main task is to order ten activities following logical and chronological constraints. The DPT is administered according to a 3-stages invariant sequence. Each stage generated one dependent variable: *Learning, Temporal estimation and Activities*.

- Visuo-Spatial Reasoning Task (adapted from Burgess et al., 1997; Shallice et al., 2002)

The Visuo-Spatial Reasoning Task (VSRT) is a rule attainment task that gives information about visuo-spatial reasoning, working memory and cognitive flexibility.

Participants were presented with a 55-page stimulus booklet. Each page contained 10 circles, 9 blue circles and 1 red circle that changed in position from one page to the next following 7 rules. Participants were required to point to the position where they thought the red circle would be in the following page. Performance was described by two dependent variables: *Perseveration* (when children continue to use previous rule or responses) or *Non perseverative errors*.

- Junior Gambling Task (adapted from Bechara et al., 1994)

The Junior Gambling Task (JGT) is designed to assess affective decision making.

The subjects are instructed to maximize their gain by making 100 choices (selections of cards) from four different decks of cards. The subject received a starting amount of money (300 Euros) and receives a reward for each card that is pulled, with the expectation of some cards which penalize the subject. The four decks differ in the magnitude of the rewards and in the magnitude and frequency of the penalty. Unbeknownst of the participant the reward/penalty schedule of the cards is predefined. For each block (25 cards), the number of disadvantageous choices was subtracted from the number of advantageous choices. A mean score of the four blocks, *Total*, was calculated: a positive value means the predominance of advantageous choices.

- Honk Task (Marzocchi et al., 2006)

The Honk Task (HT) is a children's computerised task designed following the principles of the Stop Task paradigm (Logan, 1994) and the Change Task paradigm (Sergeant and Oosterlaan, 1998). The Honk Task is designed to assess vigilance, inhibition and cognitive flexibility.

The Honk Task consists of three sessions of 160 trials each: 1) *GO session* used to build up a prepotent motor response; 2) *STOP session* in which children were asked to initiate the same response as in the GO trials, but after hearing the stop signal, children were asked to inhibit their response; 3) *CHANGE session* in which a signal tone indicated that an alternative response should be executed. The Honk Task has six dependent variables: 1) *Median RTs* in GO, STOP and CHANGE sessions; 2) *Total Omissions* in GO, STOP and CHANGE sessions; 3) *STOP session errors*; 4) *CHANGE session errors*; 5) *GO session SD of RTs*; 6) *Mean SD of RTs* in STOP and CHANGE sessions.

4.2.3 Procedure

The cognitive and neuropsychological tests were administered in one session and took approximately 115 minutes (with a 10-minute break).

First, the subtests of the WISC-III, reading words, dictation of text, triplets, mental and written calculation were administered. On average, these tests took approximately 30 minutes.

Then, the neuropsychological battery was administered. On average, the battery of EF tests took approximately 75 minutes to administer. The tasks were administered in a fixed order to minimize any error due to a participant-by-order interaction.

Children were tested individually in a separate, quite room within the school environment.

4.2.4 Data analyses

First, we analyzed the performances of different groups on all tasks. The data were analyzed using multivariate analyses of variance (MANOVAs) using Group (3 levels) as the between-subject factor. The alpha level was set to 0.05. Significant differences were followed up with post hoc Tukey’s honest significant difference tests to determine if a group effect was significant for some variable. Exploratory discriminant analyses and logistic regression analyses were also performed to investigate the contributions of executive processes to possible differences between clinical groups and the control group.

Then, we compared the three groups using the EF latent factors—Vigilance, Strategic Behavior, Inhibition/Cognitive Flexibility and Memory—as dependent variables, as found in our previous study (Valagussa et al., submitted). The data were analyzed using multivariate analyses of variance (MANOVAs) with Group (3 levels) as the between-subject factor. The alpha level was set to 0.05. Significant differences were followed up with post hoc Tukey’s honest significant difference tests to determine if a group effect was significant for a factor.

4.3 RESULTS

4.3.1 Analysis of the Executive Function performance

4.3.1.1 Diagnosis differences

A univariate analysis did not find a significant difference in Age $F(5,267)=0.362$ $p=0.874$. A Chi-square test was then run to compare the distribution of Gender. The chi-square test revealed no difference in distribution of Gender $\chi^2(2)=0.573$, $p=0.751$.

We conducted analyses of variance to verify if executive impairments existed in children with ADHD and LD in comparison to control group and if the two disorders could be distinguished on the basis of their executive functioning features.

All 17 variables were submitted to a MANOVA with Group (three levels) as the between-subjects variable. The MANOVA showed that, for most of the variables, the Group effect was significant.

According to the post hoc test, we could describe the ADHD group and LD group in the following way.

The children with ADHD had lower scores on the following tasks.

1) Learning, Execution and Memory in the Battersea Multitasking Paradigm

The children in the ADHD group recalled fewer rules both immediately after their presentation and after completing the task and had less effective and efficient performance.

2) Learning in the Daily Planning Task

The children in the ADHD group recalled fewer items immediately after their presentation.

3) Non perseverative errors on the Visual-Spatial Reasoning Task

The children in the ADHD group committed a greater number of non-perseverative errors.

4) Total omissions, GO session SD of RTs and Mean SD of RTs in the Honk Task

The children in the ADHD group committed more omissions and had greater variability in reaction times across all tasks. The children with ADHD exhibited performance above the norm on Perseverations in the VSRT, insofar as the ADHD group committed a smaller number of perseverative errors.

The children with LD had lower scores on the following tasks.

1) Learning, Execution and Planning in the Battersea Multitasking Paradigm

The children in the LD group recalled fewer rules immediately after their presentation and had less effective and efficient performance and planning ability.

2) Non perseverative errors on the Visual-Spatial Reasoning Task

The children in the LD group committed a greater number of non-perseverative errors.

3) Total Omissions and Mean SD of RTs in the Honk Task

The children in the LD group committed more omissions and had greater variability in reaction times in the main task of Stop and Change sessions.

Three variables differentiated the two clinical groups (ADHD vs LD): “Planning” in the BMP, Learning in the Daily Planning Task and Perseverations in the Visuo-Spatial reasoning task. For Planning in the Battersea Multitasking Paradigm and Perseverations in the Visuo-Spatial Reasoning Task, the children with LD had the worst performance; conversely, for Learning in the Daily Planning Task, the ADHD group had the lowest scores.

The means and standard deviations of all measures for each group and Group effect are reported in *Table 4.2*.

Table 4.2 Descriptive statistics for executive function measures and group differences

	TD (n =207)		ADHD (n=40)		LD (n=25)		Effect of group F (2, 270)		Contrast between groups
MEASURE	M	SD	M	SD	M	SD	F	P	Tukey post-hoc
Battersea Multitasking Paradigm Task									
Learning	11.98	1.09	11.30	1.34	11.20	1.89	8.60	0.000	ADHD, LD < TD
Planning	8.63	0.83	8.40	0.81	6.80	2.10	36.58	0.000	LD < TD, ADHD
Execution	43.40	16.46	31.15	16.63	29.96	13.41	15.19	0.000	ADHD, LD < TD
Monitoring	12.90	4.27	14.23	2.59	14.16	3.65	2.59	0.076	n.s.
Memory	3.04	0.84	2.38	0.95	2.64	0.10	10.96	0.000	ADHD < TD
Daily Planning Task									
Learning	7.97	1.54	6.87	2.36	8.20	1.47	7.77	0.001	ADHD < TD, LD
Temporal estimation	7.20	1.99	7.33	1.94	6.60	2.29	1.15	0.319	n.s.
Activities	9.06	1.88	9.38	1.15	8.88	1.83	0.71	0.495	n.s.
Visuo-spatial reasoning task									
Perseveration	3.05	2.11	0.83	1.378	2.68	3.17	18.23	0.000	TD, LD > ADHD
Non perseverative errors	12.48	8.61	16.70	8.53	20.28	7.13	12.14	0.000	ADHD, LD > TD
Junior Gambling Task Total	-1.15	5.40	-1.38	6.87	-2.84	7.10	0.95	0.389	n.s
Honk Task*									
GO session SD of RTs	154	71	217	85	190	90	12.88	0.000	ADHD > TD
STOP session errors	17.47	11.35	18.23	12.21	16.60	10.10	0.16	0.852	n.s.
CHANGE session errors	14.27	8.76	17.07	9.66	14.36	5.59	1.78	0.171	n.s.
Mean SD of RTs	285	78	318	78	341	99	7.31	0.001	ADHD,LD > TD
Median RTs	637	151	663	127	683	178	1.38	0.254	n.s.
Total omissions	9.06	10.52	18.48	19.38	15.96	17.93	10.81	0.000	ADHD, LD > TD

Legend: 1) Mean SD of RTs: mean of SD of RTs in main task of STOP and CHANGE sessions; 2) Median RTs: median RTs in main task of GO, STOP and CHANGE sessions; 3) Total omissions: total number of omissions committed in main task of GO, STOP and CHANGE sessions.

4.3.1.2 Exploratory discriminant analyses

Exploratory discriminant analyses were performed to investigate the contributions of EF domains to possible differences between the clinical groups and the typically developing group. In these analyses, the tasks in the neuropsychological battery were used to predict group membership. Specifically, we used all 17 variables: Learning, Planning, Execution, Monitoring and Memory in the Battersea Multitasking Paradigm; Learning, Temporal estimation and Activities in the Daily Planning Task; Non perseverative errors and Perseverations in the Visuo-Spatial Reasoning Task; Total in the Junior Gambling Task; SD of RTs in the GO session, STOP session errors, CHANGE session errors, Total omissions in the main task of the GO, STOP and CHANGE sessions, mean SDs of RTs in main task of the STOP and CHANGE sessions and Median RTs in the main task of the GO, STOP and CHANGE sessions of the Honk Task.

To investigate the capability of the neuropsychological battery to detect specific clinical group membership, the sample was divided into three groups: TD, ADHD and LD. Overall, 73.9% of cases were correctly classified: 75.8% of normative children, 70% of ADHD children, and 64% of LD children. The results of the group classification are reported in *Table 4.3.*

Table 4.3: Classification results

	TD	**ADHD**	**LD**
TD	**75.8%**	16.9%	7.2%
ADHD	22.5%	**70.0%**	7.5%
LD	24.0%	12.0%	**64.0%**

4.3.1.3 Logistic regression analyses

Logistic regression analyses were performed to examine the diagnostic utility of performance-based executive function measures. All variables that were used in the neuropsychological battery were simultaneously entered as predictors of ADHD and/or LD status. A separate regression analysis was performed for each clinical diagnosis.

As far as ADHD diagnosis was concerned, Nagelkerke's R^2=0.532 and Perseveration in the Visuo-Spatial Reasoning Task (Wald= 18.99; p= 0.000; Exp(B)= 0.424) and GO session SD of RTs in the Honk Task (Wald= 4.345; p= 0.037; Exp(B)= 1.101) were significant predictors of ADHD status.

With reference to the LD group, Nagelkerke's R^2=0.489 and Planning in the Battersea Multitasking Paradigm (Wald= 21.426; p= 0.000; Exp(B)= 0.447) and Non perseverative errors in the Visuo-Spatial Reasoning Task (Wald= 7.740; p= 0.005; Exp(B)= 1.105) were significant predictors of LD status.

4.3.2 Analyses of the Executive Function profile

The study presented in Valagussa and colleagues (submitted) suggested a four-factor executive structure with Vigilance, Strategic Behavior, Inhibition/Cognitive Flexibility and Memory as separate but partially interrelated dimensions that remain stable over the school-age period and across the genders. Vigilance refers to the capability to attend to specific stimuli and maintain attention for a prolonged period. Strategic Behavior represents the core of EF and reflects the ability to initiate, plan, organize, sustain future-oriented problem solving in working memory, self-manage tasks and monitor one's own performance. Inhibition/Cognitive Flexibility refers to the capability to control interference, to suppress prepotent responses and to make a fast and accurate choice between two or more competing responses. Finally, Memory refers to the capability to learn task parameters, generate strategy without external stimuli and maintain in mind the constraints to formerly used strategies.

We conducted analyses of variance to discriminate among ADHD, LD and typically developing children using the four executive dimensions described above.

The Group effect was significant for Vigilance, Strategic Behavior and Memory.

The results are reported in *Table 4.4.*

Table 4.4: Group effects (z score)

	ADHD (n=40)		LD (n=25)		Effect of group (2, 406)		Contrast between groups
	M	SD	M	SD	F	P	Post-hoc Tukey tests
Vigilance	-0.51	0.95	-0.41	1.21	13.24	0.000	ADHD, LD < Controls
Strategic Behavior	-0.42	0.89	-0.66	0.69	17.30	0.000	ADHD, LD < Controls
Inhibition/Cognitive flexibility	-0.20	1.21	0.07	0.80	0.92	0.401	n.s.
Memory	-0.38	0.90	-0.30	0.74	9.57	0.000	ADHD, LD < Controls

Significant findings were followed up with Tukey's honest significant difference post hoc tests. Post hoc testing showed that typically developing children had better performance than children with ADHD or LD with respect to Vigilance, Strategic Behavior and Memory skills. No executive domains differentiated the two clinical groups from one other. Children with ADHD performed worst in Vigilance and Memory. Children with LD performed worst in Strategic Behavior.

4.4 DISCUSSION

Executive functioning deficits have been well-established as part of the neuropsychological profiles of ADHD and LD.

This study sought to determine: 1) whether executive impairments exist in children with ADHD and LD in comparison with normally developing children and 2) whether the two disorders can be distinguished on the basis of their executive functioning features. To achieve these aims, we administered a neuropsychological battery of tasks assessing both hot and cool EF (Zelazo, 2004). The Junior Gambling requires the flexible appraisal of motivationally significant stimuli and, therefore, was chosen to investigate hot EF. In contrast, the Battersea Multitask Paradigm, the Daily Planning Task, the Visuo-Spatial Reasoning Task and the Honk Task were chosen to measure cool EF.

Our data suggested, in line with our predictions and the literature, that both clinical groups exhibit significant executive functioning impairments but that there are different patterns of executive performance in the two disorders.

As far as the executive profile of children with ADHD is concerned, consistent with the literature, our data suggest impairments in different tasks used to evaluate cool EF, but these data did not support the hypothesis of generalized executive deficit (Barkley, 1997). The children with ADHD performed more poorly than the controls in tasks related to Memory (Learning and Memory in the BMP and Learning in the DPT), Strategic behavior (Execution in the BMP and Non perseverative errors in the VSRT) and Vigilance (Total omissions, GO session SD of RTs and Median RTs in the HT).

As far as Memory is concerned, the ADHD group had low scores on variables related to incidental memory (Learning in the BMP and Learning in the DPT). The children with ADHD recalled fewer items and rules immediately after their presentation. In contrast, they did not exhibit difficulties recalling their own performance (Monitoring in the BMP) in the same testing condition. The findings also suggest difficulties with verbal WM: the children with ADHD recalled fewer rules after completing the task. These findings are consistent with part of the literature: Roodenrys and colleagues (2001) and Martinussen and colleagues (2005) supported the hypothesis of a deficit in the verbal component of WM in the ADHD population. With regard to Strategic Behavior, the children with ADHD had difficulties with the implementation of strategically oriented behavior and behavior consistent with the rules. The ADHD group had difficulty efficiently and effectively organizing their behavior in both the BMP and the VSRT. In the BMP, the ADHD group attempted fewer tasks, switched between subtasks less efficiently (these children engaged in the game as enthusiastically as others but often failed to attempt all three tasks) and used rules in a less strategic manner. Similar findings have been found in studies that have used other multitasking paradigm tasks, such as the Six Elements Task (SET). For instance, Clark and colleagues (2000) found that an

ADHD group attempted significantly fewer tasks than controls but did not commit more rule violations. In the VSRT, the children with ADHD committed a significant number of non-perseverative errors: they basically provided random answers. A similar finding was reported by Shallice and colleagues (2002): in their study resulted in an ADHD effect on Guessing responses, a kind of error that a child committed when he or she did not try to figure out a plausible spatial rule but when he or she did not make a error. Finally, the group with ADHD had a Vigilance deficit. The ADHD children had problems attending to specific stimuli, maintaining attention for a prolonged period and maintaining a steady rhythm of action. These data were in line with other studies (Oosterlaan et al.,1998, Schachar et al., 1995, Scheres et al., 2001, Sergeant et al., 1999), wherein children with ADHD had slower and more variable executive processes and committed more errors compared to control groups. Deficits in this executive dimension and, in particular, in the variability of RTs in GO session seemed to be a good predictor of ADHD status.

Our study ruled out problems with planning, cognitive flexibility, inhibition and affective decision making in children with ADHD. As far as planning skill is concerned, these findings are not surprising, because findings in the literature are inconsistent and because numerous studies have not found deficits in this executive domain. With regard to cognitive flexibility, our ADHD group did not show perseverative errors: the children performed well on the VSRT. This result was in line with the study by Bayliss and colleagues (2001) that found that children with ADHD may have difficulty on this task but that the number of errors they make fails to discriminate an ADHD sample from normally developing children. The authors suggested that ADHD children were no more impulsive or perseverative in their responding compared to control children. Others studies have documented the opposite results: for example, Shallice and colleagues (2002) found that their ADHD group produced an excess of perseverative responses on a similar task. It is interesting to note that our results are in line with the findings obtained by the administration of another executive task used to measure cognitive flexibility: the Wisconsin Card Sorting Test (WCST). The majority of the studies analyzed by Willcutt and colleagues in their meta-analysis (2005) did not detect a significant difference between children with and without ADHD with regard to perseverative errors on this task. These inconsistent results may suggest that weaknesses in cognitive flexibility are poor candidates for primary neuropsychological deficits in ADHD. In contrast with the literature (Castel et al., 2011, Nigg et al., 2001, Pennington et al., 1996, Willcutt et al., 2005), we did not find problems in performance on variables used to tap inhibitory processes namely, errors in Stop and Change sessions of the HT. The children with ADHD committed more errors than the controls, but the difference was not statically significant. Our data are in line with the results obtained by Marzocchi and colleagues (2008). In their study, errors in the Change task failed to differentiate normally developing children from children with ADHD. Finally, in the JGT that provides information about affective decision making, the ADHD group performed similarly to the normally developing children. Different studies have investigated the performance of children/adolescents with ADHD on similar tasks (Garon et al., 2006; Geurts et al., 2006; Hobson et al., 2011; Luman et al., 2008; Masunami et al., 2009; Toplack et al., 2005). In contrast to our results, two studies have reported that children with ADHD clearly exhibit more risky behavior than controls (Garon et al., 2006, Hobson et al., 2011). Children with ADHD less often chose the advantageous decks than controls, and they did not make more advantageous decisions during the task. On the other hand, other studies (Luman et al., 2008, Geurts et al., 2006, Masunami et al., 2009, Toplack et al., 2005), in line with our results, have found no abnormalities in the degree of risk-taking on the JGT by children and adolescents with ADHD.

The importance of executive deficits in children with LD is becoming more appreciated in recent years. Signs of executive dysfunction have not yet been well documented in children with LD. Our data revealed difficulties in tasks used to assess Memory (Learning in the BMP), Strategic Behavior (Execution in the BMP and Non perseverative errors in the VSRT), Vigilance (Total omissions and Mean SD of RTs in the HT) and Planning (Planning in the BMP). In part, our results are in line with part of the literature in that we found mnemonic and attentive deficits. According to Roodenry and colleagues (2001), Semrud-Clikeman and colleagues (2005), and Willcutt and colleagues (2001), children with LD have a weakness in verbal WM: they have difficulties actively holding multiple pieces of transitory information in their minds in a way that facilitates manipulation of that information. Children with LD also had problems with tasks that tapped incidental memory (Learning in the BMP): they recalled fewer items immediately after their presentation. As reported by Lyon and colleagues (1996), Semrud-Clikeman and colleagues (2005) and Willcutt and colleagues (2001), our children with LD had lower scores on variables used to measure attention, vigilance and speed-related processes (Total omissions and Mean SD of RTs in the HT). Their condition was characterized by problems attending to specific stimuli and maintaining attention for a prolonged period. One interesting finding of our study was the identification of significant problems on measures used to provide information about planning and strategic behavior. With regard to planning skills, the children with LD had difficulties in imagining, developing and reaching a goal: this feature was a good predictor of LD status. In the BMP, their plans were simpler and less detailed. The literature has not typically found deficits in planning being associated with LD status. Using the Tower of London, Reiter and colleagues (2005) merely found longer planning times, whereas Marzocchi and colleagues (2008) did not find significant problems in total score, planning time, or execution time for children with LD.

As far as strategic behavior is concerned, children with LD had difficulties strategically determining the most effective methods or steps needed to attain a goal. The children with LD used rules with fewer strategic behaviors in the BMP. In the VSRT, the children with LD committed more non-perseverative errors. These children tried to figure out a spatial rule: they reused rules and usually pointed to a stimulus close to target. Otherwise, in the literature, problems with the Junior Brixton task have not been reported (Bayliss et al., 2000; Shallice et al., 2002). The LD group did not show problems with inhibition, cognitive flexibility or affective decision making. Their scores on variables that reflect inhibition and cognitive flexibility (STOP session errors and CHANGE session errors in the HT and Perseverations in the VSRT) and affective decision making (Total in the JGT) were in line with the performance of normally developing children.

Comparing the two clinical groups, our data suggest that the children with ADHD and LD in our sample had similar strategic behavioral deficits and performance on tasks used to evaluate inhibition, cognitive flexibility and affective decision making. Both groups were characterized by deficits in memory and vigilance, but impairments were higher in children with ADHD. Finally, only children with LD exhibited problems in the planning domain.

Our findings supported the utility of the neuropsychological battery to detect membership in either of the specific clinical groups. The variables of the neuropsychological battery had good specificity and were able to distinguish between the typically developing and clinical groups. The neuropsychological battery was less successful at predicting the presence of ADHD or LD individually.

4.5 CONCLUSIONS

The current study confirmed the presence of executive deficits in our samples of children with ADHD or LD. Neither clinical groups exhibited a generalized executive deficit, nor was any hot EF deficit present. The children with ADHD and LD were characterized by weaknesses in the same executive domains: Vigilance, Strategic Behavior and Memory. Decreased performance on Vigilance tasks was a good predictor of ADHD status; in contrast, decrease performance in Planning was a good predictor of LD status.

4.6 LIMITATIONS OF THE STUDY

The current study has some caveats. First, there were measurement problems with all tasks: the tasks applied in the current study cannot be considered “pure measures” of any one EF domain.

Second, there was a caveat in the sampling procedure: the control group was composed of children recruited from schools, whereas children with ADHD or LD were recruited from clinics. This different procedure may have emphasized the differences between the clinical and the control children. Finally, a group with comorbidity (i.e., ADHD and LD) was absent from this study.

CHAPTER 5: RELATIONSHIP BETWEEN PARENT AND TEACHER REPORTS AND PERFORMANCE-BASED MEASURES OF EXECUTIVE FUNCTION

5.1 INTRODUCTION

The procedures used to operationalize EF in clinical and research settings employ either performance-based or behavior rating measures. In theory, they are intended to index the same underlying mental construct of EF. However, the extent to which these two types of measures actually reflect the same underlying mental construct is far from certain. The evidence for such convergence is somewhat mixed. Studies are heterogeneous and include different periods of development (child, adolescent and adult) and different populations (various clinical groups). We focused our attention on studies that used Behavior Rating Inventory of Executive Function (BRIEF) as the questionnaire.

The BRIEF includes a total of 86 items that describe difficulties in everyday activities. The questionnaire is composed of 8 individual scales: Inhibition, Shift, Emotional Control, Working Memory, Plan/Organize, Organization of Materials, and Initiation and Monitoring. The BRIEF also provides 3 summary indices: the Behavioral regulation index (BRI), the Metacognitive index (MI) and the Global score (the GEC). The Inhibition, Shift, Emotional control and Self-monitoring scales compose the Behavioral Regulation Index (BRI). The Initiation, Working memory, Plan/organize, organization of materials and Task monitoring scales compose the Metacognitive Index (MI). The BRI and the MI can be combined to form an overall the Global Executive Index (GEC). We considered the most cited executive processes: Working Memory (WM), cognitive flexibility, vigilance, planning, inhibition and affective decision making.

Most studies have investigated the verbal component of Working Memory using various performance-based tests: 1) tests that assess the short memory using a distraction task such as the Consonant Trigram (Paniak et al., 1997), where children were orally presented with three letters and asked to perform a distractor task and children stop the distractor task and recall the three consonants after a delay; 2) tests that measure verbal WM, such as the digit span task; and 3) tests that require a manipulation and active maintenance of verbal materials in WM such as the N-back, where children were asked to press the key only if the numeral presented after the tone was identical to the one presented two trials before the tone. Findings were mixed but supported the hypothesis of a convergence between performance based and behavioral measures. In particular, 1) the Consonant Trigram was a consistent predictor that accounted for unique variance of MI and GEC in BRIEF (Mangeot et al., 2002), and 2) there were mixed data about verbal WM (Digit span). Two studies reported significant correlations between performance in digit span and BRIEF global indices such as Metacognitive Index (Hummer et al., 2010) or BRIEF individual indices such as the WM, Inhibition, Planning and Shifting subscales (Toplack et al., 2008). There were small correlations between BRIEF indices and the N-back task that requires manipulation of verbal information (McAuley et al., 2010).

Cognitive flexibility was mainly tested using two types of tasks: 1) tasks that require flexible shifting between a set of responses or a set of answer criteria, such as the Contingency naming test, the Color Trail Test and the Trial making test; and 2) tasks that require inference of rules or criteria, such as the Wisconsin Card Sorting Test and the Children Category Test. Data confirmed the presence of convergence between the two types of assessment procedures. In particular, 1) there were significant correlations between tasks that required flexible movement between responses or response criteria (with the exception of the Trial Making Test) and global indices of BRIEF such as MI and GEC (Anderson et al., 2002; Garrison et al., 2014; Niendan et al., 2007; Oberg et al., 2014; Vriezen et al., 2002), and 2) there was a significant relationship between performance in a test that requires the identification of grouping criteria and indices of BRIEF (Bishop et al., 2011; Brown et al., 2008; Oberg et al., 2014).

Regarding vigilance, the findings suggested a significant relationship between cognitive and behavioral measures. Vigilance was mainly investigated using Continuous Performance Test and Test of Variables of Attention. Performance in both tests was significantly correlated with BRIEF global indices such as MI and BRI (Hummer et al., 2010) and specific subscales such as WM and Inhibition (Bishop et al., 2011; Bodnar et al., 2007; Brown et al., 2008).

Regarding planning, the findings suggested that performance-based and behavioral measures did not reflect the same underlying mental construct. Planning was assessed using different tasks: the Rey-Osterrieth Complex Figure, the Tower of London, the Stocking of Cambridge and the Tower of D-KEFS. Only one study reported a significant finding: Toplack and colleagues (2008) reported convergence between performance in the Stocking of Cambridge and the Inhibit index of the teacher form of BRIEF.

Various studies have focused on inhibition. Authors have mainly used the Stop and Stroop task. The hypothesis of convergence between tests and questionnaires used to tap this executive domain was supported by data. In particular, 1) performance in both Stop and Stroop tasks was significantly correlated with the Inhibition subscale of BRIEF and 2) performance in the Stroop task was significantly related to Shift and WM subscales of BRIEF.

Finally, Shuster and colleagues (2009) focused on affective decision making and investigated this skill using Card Playing and the Iowa Gambling Task. The authors reported that the Inhibitory problem reported on a rating scale was negatively correlated with the quantity of money won on a card playing task.

The studies presented above indicate that there were associations between ratings on various EF questionnaires and performance-based measures of EF; however, data were mixed, and relationships were weak in intensity. Currently, the reasons for the apparent dissociation between ratings and scores on performance-based tasks of EF are not well understood. Various interpretations have been proposed. A set of interpretations is based on the premise that these measures assess different aspects of the same underlying construct (Andreson et al., 2002). These authors suggested that the EF construct can be fractionated into a behavioral component that is assessed using the questionnaires and a cognitive component that is assessed using performance-based tasks (Anderson et al., 2002). Toplak and colleagues (2013) also proposed this point of view and suggested that performance-based measures provide an indication of processing efficiency and that rating measures provide an indication of individual goal pursuits. An alternative explanation is that performance-based tasks assess underlying skills, whereas the questionnaire assesses the application of those skills at home and at school. Environmental variables may mediate this relationship, which would explain why scores on performance-based tasks do not correspond with parent and teacher ratings on the BRIEF (Burgess, 1997). Finally, another interpretation is that performance-based tasks of EF lack ecological validity due to the manner in which they are typically administered. Because these conditions bear little resemblance to the environments in which we typically function, it has been suggested that performance-based tasks do not engage the same set of skills that are required in naturalistic settings (McAuley et al., 2010).

5.1.1 Aims of the study

The purpose of the current study is to examine the relationship between parents' and teachers' ratings on the Questionnaire for the assessment of EF and children's scores on performance-based tests of EF. For this purpose, we conducted a correlational analysis.

In particular, it is predicted that the QuFE Metacognition and Initiation subscales, which are purported to tap cognitive dimensions of EF, will correlate with performance on tasks used to obtain information about cool EF (variables of Battersea Multitasking Paradigm Task, Daily Planning Task, Visuo-spatial reasoning task, Honk Task). In contrast, the QuFE Emotional and behavioral regulation and Shift subscales, which are purported to measure behavioral and emotional dimensions of EF, will correlate with performance on tasks that provide information about hot EF (variable of Iowa Gambling Task).

5.2 METHOD

5.2.1 Participants

A total of 408 children with Attention Deficit Hyperactivity Disorder (ADHD), Learning Disabilities (LD) or Typically Developing (TD) participated in this study (342 TD children, 41 children with ADHD and 25 children with LD).

The eligibility criteria for both the typical and clinical children were as follows: 1) children aged between 8 and 13 years old; 2) children with IQ equal or higher than 85; 3) children spoke Italian as their first language; and 4) children did not show any other neurological or psychiatric disease.

Typically developing children

A total of 342 children (156 boys, 186 girls) with a mean age of 10.47 years (SD=1.71; range 8-13) and mean full scale IQ of 114.95 (SD=16.00) participated in this research. The children were recruited in public schools of Lombardy, Piedmont, Veneto and Sardinia.

The eligibility criteria specific for the TD children included the following: no diagnosis of any neurological, psychiatric or developmental disorders and no history of brain damage or sensory deficit.

Both teachers and parents were informed about the aims of the study. Written parental consent was obtained for all participating children.

Children with ADHD or LD

A total of 66 children (51 boys, 15 girls) with a mean age of 10.03 years (SD=1.68; range 8-13) participated in this research (41 children with ADHD and 25 children with LD). The children in the clinical groups met the International Classification of Diseases (ICD-10) criteria for Attentional Deficit/Hyperactivity Disorder (ADHD) and Learning Disabilities (LD).

The clinical participants were recruited from specialized assessment and diagnostic services for children and adolescents with neurodevelopmental disorders in Bergamo, Milan (Fatebenefratelli Hospital, Niguarda Hospital and San Paolo Hospital) and Venice (San Donà di Piave Hospital).

The children with ADHD were diagnosed using a diagnostic interview (K-SADs-PL; Kaufman et al., 2004), a neurological exam, and clinical observation. To confirm impairment in several contexts, Conners Rating Scales for Parents and Teachers were completed (Nobile et al., 2007). The children with ADHD were required to obtain a T-score greater than 65 on the ADHD subscales of both the parents and teachers. None of the children had received a diagnosis of any chronic neurological illness, and none were taking medication during the testing. Three children were treated with methylphenidate; however, it was mandatory for medication to be discontinued for 24 hours before testing was performed to allow a complete wash-out.

Learning disabilities included Dyslexia, Spelling disorder and Dyscalculia. Dyslexia was diagnosed using an Italian standardized test, *reading words* (subtest 2 of Battery for the Assessment of Developmental Dyslexia and Dysortography, Sartori et al., 2007). To be classified as Dyslexic, children had to obtain a score at least 2 SDs below the mean (Speed and Accuracy). Spelling disorder was diagnosed using an Italian standardized test, *dictation of text* (Battery for the Evaluation of Writing and Spelling skills, Tressoldi et al., 2000). To be classified as spelling impaired, children had to obtain a score of at least 2 SDs below the mean (Accuracy). Dyscalculia was diagnosed using an Italian standardized battery, *Battery for Developmental Dyscalculia* (Biancardi et al., 2004). Triplets, mental math and written calculations were administered. To be classified as having Dyscalculia, children were required to obtain calculation standard scores and numerical standard scores less than 70.

None of the children had received a diagnosis of any chronic neurological illness.

To ensure that there was no comorbidity of ADHD and LD in our groups, all ADHD children were required have scored better than 2 SDs below the mean on the lists of words (Sartori et al., 2007) or on the dictation of text (Tressoldi et al., 2000) and they were required to have calculation and numerical standard scores of 70 or higher (Biancardi et al., 2004). Moreover, the children with LD were required to obtain a T-score less than 65 on the ADHD subscales of both the parents and teachers for the Conners Rating Scales (Nobile et al., 2007).

Table 5.1 presents the means and SDs for age IQ, ADHD symptoms according to parent and teacher ratings, reading, writing and computing performance. Reading and writing performance is reported as a z-score, so scores below zero mean poor performance.

Table 5.1: Clinical characteristics of sample, IQ and reading, writing and computing performance

	TD (N=342)		**ADHD** (N=41)		**LD** (N=25)	
	Mean	SD	Mean	SD	Mean	SD
Age	10.47	1.71	10.07	1.69	10.03	1.68
Full Scale IQ	114.95	16.00	113.28	13.02	106.96	9.89
Symptoms						
Conners ADHD parents (T score)	51.30	4.20	73.95	6.79	52.30	5.82
Conners ADHD teachers (T score)	50.60	5.32	72.30	4.61	46.30	3.97
School Learning						
Reading words: Speed (z score)	0.45	0.38	-0.28	0.99	-2.05	3.73
Reading words: Accuracy (z score)	0.11	0.69	-0.14	0.88	-2.31	2.67
Dictation of text: Accuracy (z score)	0.52	0.25	0.00	0.78	-2.69	2.82
Numeric IQ (standard score)	92.15	6.25	83.42	32.12	85.28	31.76
Calculation IQ (standard score)	95.45	5.55	78.64	24.01	77.88	27.09

5.2.2 Materials

5.2.2.1 Intelligence measure

- WISC-III

Three subtests of the *WISC-III* were administered: Vocabulary, Block Design and Digit Span. Vocabulary and Block Design were used to estimate Verbal, Performance and Total IQ. Verbal IQ was obtained by multiplying the value of the weighted score on the Vocabulary subtest by a factor of 5. Performance IQ was obtained by multiplying the value of the weighted score on the Block Design subtest by a factor of 5. Total IQ was derived by converting the sum of Verbal and Performance IQ (Wechsler et al., 2006).

5.2.2.2 Symptoms measure

- Conners' ratings scales

The *Conners' Rating Scales* (Nobile et al., 2007) for parents and teachers were administered. The Conners' Rating Scales comprise a research and clinical tool for obtaining parental and teacher reports of childhood behavioral problems (age range: 3-17). The Conners' Rating Scales evaluate problem behaviors, ADHD and comorbid disorders (Oppositional Defiant Disorder, Conduct Disorder, Cognitive Disorder, depression and anxiety), as reported by teachers and parents. The parent version includes 80 items, and the teacher version includes 59 items.

5.2.2.3 School learning measure

- Reading tasks (Sartori et al., 2007)

All children were presented with four lists of 28 words of different lengths and frequencies. Children were asked to read as quickly and accurately as possible. The number of errors and the time to read the lists were recorded.

- Dictation (Tressoldi et al., 2000)

All children recorded dictated texts that differed according to age. The texts normally take a maximum of 20-25 minutes to write, according to age and length. The lengths of the texts were variable, ranging from 139 words to 250 words. Phonological errors and non-phonological errors were recorded.

- Calculation task (Biancardi et al, 2004)

Triplets: All children were presented with triplets of numbers. Children were asked to choose the greatest number as quickly and accurately as possible. The number of errors and the time of execution were recorded.

Mental calculation: Children were asked to mentally perform 16 multiplication operations. The number of errors was recorded.

Written calculation: Children were asked to perform four addition, four subtraction and four multiplication operations of increasing complexity. The number of errors was recorded.

5.2.2.4 Executive Function measures

We developed a comprehensive test battery that included performance-based measures that assess working memory, retrospective and prospective memory, cognitive flexibility, inhibition, planning and organisation of behaviour, affective decision making, and visuo-spatial reasoning. The battery includes the following tasks: the Battersea Multitasking Paradigm, the Daily Planning Task, the Visuo-spatial Reasoning Task, the Junior Iowa Gambling Task and the Honk Task.

For a detailed description of the tasks, see Chapter 2.

- Battersea Multitasking Paradigm (adapted from Mackinlay et al., 2006)

The Battersea Multitasking Paradigm makes demands upon three constructs: retrospective and prospective memory, planning, monitoring of behaviour.

The BMP consists of 3 interleaved but very simple tasks that children must perform in a time limit of 6 minutes. The performance is constrained by four rules: 1) children had to try all 3 games before the sand runs out, 2) yellow items get more points than blue, 3) full clusters get extra points, and 4) items must only be picked or coloured one-by-one. The goal of the task is to score a maximum of points without breaking any rules. The optimal way to perform the game is to fill up small clusters of yellow items in all three tasks. The BMP is administered in a 5-stage invariant behavioural sequence. Each stage generated a dependent variable: 1) *Learning*, 2) *Planning*, 3) *Execution*; 4) *Monitoring* and 5) *Memory*.

- Daily Planning Task (adapted from Schweiger and Marzocchi, 2008)

The Daily Planning Task (DPT) assesses retrospective and working memory, planning and temporal estimation.

The DPT is proposed in two versions, one for children aged 8-10 years and one for teens aged 11-14 years. The main task is to order ten activities following logical and chronological constraints. The DPT is administered according to a 3-stages invariant sequence. Each stage generated one dependent variable: *Learning, Temporal estimation and Activities*.

- Visuo-spatial Reasoning Task (adapted from Burgess et al., 1997; Shallice et al., 2002)

The Visuo-Spatial Reasoning Task (VSRT) is a rule attainment task that gives information about visuo-spatial reasoning, working memory and cognitive flexibility.

Participants were presented with a 55-page stimulus booklet. Each page contained 10 circles, 9 blue circles and 1 red circle that changed in position from one page to the next following 7 rules. Participants were required to point to the position where they thought the red circle would be in the following page. Performance was described by two dependent variables: *Perseveration* (when children continue to use previous rule or responses) or *Non perseverative errors*.

- Junior Gambling Task (adapted from Bechara et al., 1994)

The Junior Gambling Task (JGT) is designed to assess affective decision making.

The subjects are instructed to maximize their gain by making 100 choices (selections of cards) from four different decks of cards. The subject received a starting amount of money (300 Euros) and receives a reward for each card that is pulled, with the expectation of some cards which penalize the subject. The four decks differ in the magnitude of the rewards and in the magnitude and frequency of the penalty. Unbeknownst of the participant the reward/penalty schedule of the cards is predefined. For each block (25 cards), the number of disadvantageous choices was subtracted from the number of advantageous choices. A mean score of the four blocks, *Total*, was calculated: a positive value means the predominance of advantageous choices.

- Honk Task (Marzocchi et al., 2006)

The Honk Task (HT) is a children's computerised task designed following the principles of the Stop Task paradigm (Logan, 1994) and the Change Task paradigm (Sergeant and Oosterlaan, 1998). The Honk Task is designed to assess vigilance, inhibition and cognitive flexibility.

The Honk Task consists of three sessions of 160 trials each: 1) *GO session* used to build up a prepotent motor response; 2) *STOP session* in which children were asked to initiate the same response as in the GO trials, but after hearing the stop signal, children were asked to inhibit their response; 3) *CHANGE session* in which a signal tone indicated that an alternative response should be executed. The Honk Task has six dependent variables: 1) *Median RTs* in GO, STOP and CHANGE sessions; 2) *Total Omissions* in GO, STOP and CHANGE sessions; 3) *STOP session errors*; 4) *CHANGE session errors*; 5) *GO session SD of RTs*; 6) *Mean SD of RTs* in STOP and CHANGE sessions.

- Questionnaire for the assessment of Executive Function (Valagussa et al., submitted)

The Questionnaire for the assessment of Executive Function (QuFE) is a questionnaire that concerns specific behaviors relating to executive functioning in children. The QuFE enables professionals to assess Executive Function behaviors in the home and school environments.

The questionnaire is completed by raters (parent and/or teacher) who indicate how often a given behavior has occurred in the previous 6 months on a five-point Likert scale (1 = never; 5 = usually). High scores in individual subscales correspond to better functioning in that domain. The Parent and the Teacher Forms of the QuFE each contain 32 items. Some of the items included in the two versions are different and specific for home and school environments. The instructions to the parent and the teacher should emphasize the importance of responding to all items on the form. The QuFE takes approximately 10 minutes to complete.

The two versions give information about various executive domains (Valagussa et al., submitted).

The Parent version investigates the following:

1. *Metacognition* refers to the ability to begin a task or activity; to generate ideas, responses or problem solving strategies; to manage current and future-oriented task demands; to anticipate future events; to set goals and develop appropriate steps ahead of time to perform a task or activity; to organize information and appreciate ideas or key concepts; and to maintain concentration and attention for a prolonged period of time.

2. *Emotional and behavioral regulation* refers to the ability to stop one's own behavior at an appropriate time and modulate emotional responses.

3. *Organization of materials* assesses the orderliness of work and play storage spaces and the manner in which children order and organize their world and belongings.

4. *Shift* refers to the ability to move freely from one situation, activity or aspect of a problem to another as the circumstances demand.

5. *Initiation* measures the capabilities to begin a task or activity and independently generate ideas, responses or problem solving strategies.

The Teacher version investigates the following:

1. *Metacognition* refers to the ability to begin a task or activity; to generate ideas, responses or problem solving strategies; to manage current and future-oriented task demands; to anticipate future events; to set goals and develop appropriate steps ahead of time to perform a task or activity; to organize information and appreciate ideas or key concepts; and to maintain concentration and attention for a prolonged period of time.

2. *Emotional and behavioral regulation* refers to the ability to stop one's own behavior at an appropriate time; to modulate emotional responses; to move freely from one situation, activity or aspect of a problem to another as the circumstances demand; and to monitor personal behavioral activities.

3. *Organization of materials* assesses the orderliness of work and play storage spaces and the manner in which children order and organize their world and belongings

5.2.3 Procedure

Cognitive and neuropsychological tests were administered in one session and took approximately 115 minutes (there was a 10 minute break).

First, subtests of WISC-III, reading words, dictation of text, triplets, mental and written calculation were administered. On average, these tests took approximately 30 minutes.

Then, a neuropsychological battery was administered. On average, the battery of EF tests took approximately 75 minutes to administer. The tasks were administered in a fixed order to minimize any error due to order interaction. The children were tested individually in a separate and quiet room within the school environment.

Parents and teachers individually completed the questionnaire.

5.2.4 Data analyses

To assess the relationship between ratings on the QuFE and scores on performance-based tests, Pearson correlation coefficients were calculated with statistical significance set at $p<0.05$. We conducted two correlational analyses: in the first subscale, scores of QuFE and the variables used to describe the profile in performance-based measures were entered into the analysis, and in the second subscale, we used the subscale scores of QuFE and the 4 factors in which the variables of battery are organized.

A linear regression analyses were also performed to investigate the contributions of neuropsychological tasks and executive domains (Vigilance, Strategic behavior, Inhibition/Cognitive flexibility and Memory) to the evaluation provided by teachers and parents.

5.3 RESULTS

5.3.1 Correlational analyses

Preliminary correlational analyses were conducted to exclude and age and gender effect on the relationships between performance-based measures and questionnaires.

To evaluate convergence across methods for studying EF, we conducted three correlational studies and we separately analyzed correlations in the typically developing children, ADHD and LD groups. The behavioral measures were the subscale scores in both versions of the QuFE. There were 17 cognitive measures, and they were organized as follows:

1) Vigilance: GO session SD of RTs, Mean SD of RTs, Total omissions and Median RTs in the Honk task;

2) Strategic behavior: Learning, Execution in the Battersea Multitasking Paradigm, Non perseverative errors in the Visuo-Spatial Reasoning Task, Total in the Iowa Gambling Task;

3) Inhibition/Cognitive flexibility: STOP session errors and CHANGE session errors in the Honk Task;

4) Memory: Planning, Monitoring, Memory in the Battersea Multitasking Paradigm, Perseverations in the Visuo-Spatial Reasoning Task, Learning, Temporal estimation and Activities in the Daily Planning Task.

Table 5.2 shows the results of the correlational analysis in the TD group.

In the TD group, the correlation coefficients of the behavioral and cognitive measures were low.

The findings in the Vigilance domain were interesting: 1) correlations mainly involved the subscales of the Teacher version; 2) GO session SD of RTs in the Honk Task was the measure with the highest number of correlations with the EF questionnaires; and 3) GO session SD of RTs in the Honk Task was significantly correlated with Metacognition in both versions.

The data on the Strategic abilities were as follows: 1) correlations between tests and questionnaires were similar in the two versions of the rating scale; and 2) Non perseverative errors in the Visuo-Spatial Reasoning Task were correlated with many questionnaire subscales.

The most significant results regarding the Inhibition skills were as follows: 1) the Teacher version of the QUFE showed more significant correlations than the Parent version; and 2) errors in the CHANGE session of the Honk Task correlated with all subscales of the Teacher form.

The results in the Memory domain were as follows: 1) significant correlations mainly involved the subscales of the Teacher version of the QUFE; 2) Perseverations in the Visuo-Spatial Reasoning Task correlated with Metacognition in both versions; and 3) monitoring in the Battersea Multitasking Paradigm and Learning in the Daily Planning Task correlated with all subscales of the Teacher form of the QUFE.

Table 5.2: Correlation coefficients between behavioral and cognitive measures in typically developing children

	Parent form of QuFE					Teacher form of QuFE		
	Metacognition	**Emotional and behavioral regulation**	**Organization of materials**	**Shift**	**Initiation**	**Metacognition**	**Emotional and behavioral regulation**	**Organization of materials**
VIGILANCE	-0.093	-0.041	0.031	0.073	0.023	-0.086	-0.080	**-0.121***
HT Go session SD of RTs	**-0.122***	-0.044	0.036	0.079	-0.005	**-0.122***	-0.089	**-0.154***
HT Mean SD of RTs	-0.048	-0.004	0.018	-0.005	0.058	-0.080	-0.038	-0.053
HT Total omissions	-0.063	-0.052	0.010	0.058	0.037	-0.049	-0.101	**-0.139***
HT Mean RTs	-0.012	-0.013	0.022	0.078	0.000	0.032	0.010	0.030
STRATEGIC BEHAVIOR	0.089	0.055	-0.014	-0.095	-0.045	-0.064	-0.058	-0.007
BMP Learning	0.099	0.012	-0.048	-0.032	0.013	0.070	0.027	0.023
BMP Execution	**0.136***	0.085	0.014	-0.045	0.003	-0.026	-0.012	0.049
VSRT Non perseverative errors	0.020	0.020	0.018	**0.124***	0.098	**0.139***	**0.144****	0.076
JGT Total	0.057	0.099	-0.041	-0.081	-0.042	-0.012	0.033	-0.026
INHIBITION	**-0.119**	0.010	-0.035	0.020	-0.024	**-0.137**	**-0.125***	**-0.177****
HT STOP session errors	**-0.122***	0.019	-0.037	0.029	-0.029	-0.117	-0.067	**-0.125***
HT CHANGE session errors	-0.081	-0.001	-0.024	0.005	-0.013	**-0.117***	**-0.145****	**0.176****
MEMORY	0.098	0.018	-0.044	-0.067	-0.006	**0.236****	**0.163****	**0.151****
BMP Planning	-0.044	-0.078	-0.015	**-0.154****	-0.071	-0.033	-0.086	-0.034
BMP Monitoring	0.041	0.008	-0.008	0.024	-0.012	**0.172****	**0.129***	**0.145****
BMP Memory	0.094	-0.007	-0.045	-0.064	-0.039	**0.128***	0.091	0.072
DPT Learning	0.026	0.051	-0.047	0.008	0.000	**0.186****	**0.146****	**0.161****
DPT Temporal estimation	0.096	0.030	-0.017	0.030	-0.022	**0.133***	0.086	0.044
DPT Activities	0.061	0.005	0.010	-0.084	0.088	**0.129***	0.093	0.058
VSRT Perseverations	**-0.112***	-0.070	-0.069	-0.012	**-0.131***	**-0.124***	**-0.129***	-0.095

Legend: - * p<0,05; **p<0,01

-1) Mean SD of RTs: mean of SD of RTs in main task of STOP and CHANGE sessions; 2) Median RTs: median RTs in main task of GO, STOP and CHANGE sessions;

3) Total omissions: total number of omissions committed in main task of GO, STOP and CHANGE sessions.

Table 5.3 shows the results of the correlational analysis of the neuropsychological tests and factors with QUFE subscales in the ADHD group.

In the ADHD group, the correlation coefficients of the behavioral and cognitive measures were low. The findings in the Vigilance domain were as follows: 1) no significant correlations in the subscales of the Parent version were found; and 2) GO session SD of RTs in the Honk Task significantly correlated with Metacognition of the Teacher version of the QUFE.

The data regarding the Strategic abilities were as follows: 1) correlations existed in both versions of the QuFE; 2) variables of the Battersea Multitasking Paradigm correlated with Metacognition; and 3) variables of the Visuo-Spatial Reasoning Task and the Iowa Gambling Task correlated with Behavioral and emotional regulation.

The results on Inhibition skills were as follows: 1) correlations were uniformly distributed in the two versions; 2) both variables correlated with Organization of materials in both forms of the QuFE; and 3) CHANGE session errors correlated mainly with the subscales of the Parent version.

The data regarding the Memory domain were as follows: 1) no correlations existed in the subscales of the Parent version; and 2) Temporal estimation was the only variable with significant correlation.

Table 5.4 shows the results of the correlational analysis of the neuropsychological tests and factors with QUFE subscales in the ADHD group.

Finally, in the LD group, the correlation coefficients of the behavioral and cognitive measures were low.

Table 5.3: Correlation coefficients between behavioral and cognitive measures in ADHD children

	Parent form of QuFE					Teacher form of QuFE		
	Metacognition	**Emotional and behavioral regulation**	**Organization of materials**	**Shift**	**Initiation**	**Metacognition**	**Emotional and behavioral regulation**	**Organization of materials**
VIGILANCE	-0.145	-0.078	-0.123	0.125	0.050	-0.166	-0.094	0.049
HT GO session SD of RTs	-0.296	-0.095	-0.224	0.054	-0.065	**-0.339***	-0.217	-0.093
HT Mean SD of RTs	0.060	0.008	-0.074	0.222	0.157	0.025	0.016	0.151
HT Total omissions	-0.036	-0.118	-0.085	0.041	0.072	0.012	-0.058	0.079
HT Median RTs	0.067	0.141	0.274	0.205	0.111	-0.020	0.242	0.185
STRATEGIC BEHAVIOR	**0.352***	0.294	0.150	0.066	-0.015	0.213	0.113	0.159
BMP Learning	**0.336***	0.143	0.113	-0.052	0.085	**0.312***	-0.128	-0.005
BMP Execution	**0.329***	0.116	0.116	-0.015	-0.116	0.132	0.019	0.208
VSRT Non perseverative errors	-0.237	**-0.312***	-0.130	-0.024	-0.062	-0.181	-0.176	-0.182
JGT Total	0.152	**0.449****	0.101	**0.374***	0.020	0.087	0.307	-0.075
INHIBITION/COGNITIVE FLEXIBILITY	-0.299	-0.307	**-0.31***	-0.151	-0.203	**-0.313***	**-0.391***	-0.165
HT STOP session errors	-0.212	-0.270	**-0.322***	-0.115	-0.179	**-0.340***	**-0.421****	-0.143
HT CHANGE session errors	**-0.362***	**-0.317***	**-0.367***	-0.175	-0.209	-0.255	**-0.323***	-0.174
MEMORY	0.215	0.072	0.004	-0.239	-0.039	0.155	0.047	0.081
BMP Planning	0.226	0.288	0.138	0.048	0.128	0.041	-0.021	-0.028
BMP Monitoring	0.085	-0.084	0.180	0.037	-0.212	0.011	0.035	-0.154
BMP Memory	0.205	0.138	0.011	-0.231	0.134	0.292	0.186	0.202
DPT Learning	0.124	-0.040	-0.052	-0.251	-0.124	-0.008	-0.074	-0.051
DPT Temporal estimation	0.206	0.169	-0.059	-0.117	0.091	**0.374***	0.172	**0.406****
DPT Activities	-0.001	-0.097	0.068	-0.029	-0.223	-0.124	-0.065	-0.151
VSRT Perseverations	0.054	0.072	0.104	-0.257	0.000	0.226	0.172	0.058

Legend: - * p<0,05; **p<0,01

- 1) Mean SD of RTs: mean of SD of RTs in main task of STOP and CHANGE sessions; 2) Median RTs: median RTs in main task of GO, STOP and CHANGE sessions; 3) Total omissions: total number of omissions committed in main task of GO, STOP and CHANGE sessions.

Table 5.4: Correlation coefficients between behavioral and cognitive measures in LD children

	Parent form of QuFE					Teacher form of QuFE		
	Metacognition	**Emotional and behavioral regulation**	**Organization of materials**	**Shift**	**Initiation**	**Metacognition**	**Emotional and behavioral regulation**	**Organization of materials**
VIGILANCE	0.071	-0.073	0.195	0.044	-0.126	0.210	0.379	0.124
HT GO session SD of RTs	-0.001	-0.058	0.095	0.005	-0.178	0.156	0.400	0.135
HT Mean SD of RTs	-0.007	-0.083	0.144	0.055	-0.009	0.075	0.271	0.143
HT Total omissions	0.176	-0.065	0.242	0.069	-0.074	0.285	0.332	0.061
HT Median RTs	0.084	-0.060	0.255	0.043	-0.149	0.200	0.269	0.102
STRATEGIC BEHAVIOR	-0.173	-0.045	**-0.463***	0.065	0.092	-0.171	-0.320	-0.177
BMP Learning	-0.156	-0.164	-0.344	0.365	-0.068	-0.129	-0.055	0.077
BMP Execution	0.023	-0.012	-0.322	0.126	0.250	0.141	0.017	0.152
VSRT Non perseverative errors	0.299	0.008	0.205	0.149	-0.003	**0.407***	**0.565****	**0.538****
JGT Total	0.057	0.111	-0.296	-0.274	-0.013	-0.127	-0.178	-0.132
INHIBITION/COGNITIVE FLEXIBILITY	-0.007	0.086	0.000	-0.257	0.053	-0.146	-0.133	-0.136
HT STOP session errors	-0.171	-0.021	-0.057	-0.233	0.011	-0.254	-0.191	-0.176
HT CHANGE session errors	0.205	0.211	0.073	-0.249	0.100	0.018	-0.038	-0.063
MEMORY	0.101	-0.085	0.073	-0.091	-0.089	0.193	0.063	0.042
BMP Planning	0.308	0.276	0.282	0.003	0.263	0.365	0.220	0.187
BMP Monitoring	0.257	0.037	0.389	-0.052	0.134	**0.441***	0.118	0.079
BMP Memory	-0.045	-0.188	-0.152	-0.036	-0.121	-0.050	0.083	0.046
DPT Learning	-0.163	-0.149	0.016	-0.338	-0.280	-0.099	-0.187	0.237
DPT Temporal estimation	0.021	-0.141	0.118	0.057	-0.063	-0.003	-0.089	0.044
DPT Activities	0.086	-0.027	-0.161	0.141	-0.067	0.238	0.057	0.038
VSRT Perseverations	-0.342	-0.222	-0.097	-0.305	-0.162	-0.078	-0.209	-0.310

Legend: - * p<0,05; **p<0,01

- 1) Mean SD of RTs: mean of SD of RTs in main task of STOP and CHANGE sessions; 2) Median RTs: median RTs in main task of GO, STOP and CHANGE sessions; 3) Total omissions: total number of omissions committed in main task of GO, STOP and CHANGE sessions.

5.3.2 Regression analyses

Two sets of hierarchical regression analyses (Stepwise method) were conducted to establish the proportion of variance in Total Score in both versions of QuFE that was explained by variables of the neuropsychological battery and EF factors described in Chapter 1.

In each regression Total Score of the Parent and the Teacher versions of the QuFE were considered dependent variables.

Age, sex and diagnosis were entered as independent variable measures in the first step. In the first set of analyses the 17 variables of the neuropsychological battery entered as independent measures in the second step. In the second set of analyses the 4 EF factor, Vigilance, Strategic behavior, Inhibition and Memory, entered as independent measures in the second step.

In *Tables 5.5* significant predictors of Total Score in the Parent version of the QuFE were reported. As far as neuropsychological variables were concerned, only one variable, SD of RTs in Go session in Honk Task, was significant predictor of executive profile provided by parents. Considering the four EF factors, only Inhibition significantly predicted EF according to parents.

Table 5.5. EF performance predictors of Total score in the Parent version of the QuFE

	ΔR^2	ΔF	B	T
Variable				
Go session SD of RTs	0.217	37.138	-0.106	-2.336*
EF Factors				
Inhibition	0.215	36.789	-0.095	-2.150*

Legend: * p < .05;

In *Tables 5.6* significant predictors of Total Score in the Teacher version of the QuFE were reported. As far as neuropsychological variables were concerned, 6 variables were significant predictors of executive profile provided by teacher: errors in Change session of Honk Task, Learning in Daily Planning Task, SD of RTs in GO session of Honk Task, Non perseverative error in Visuo-Spatial Reasoning Task, Memory and Monitoring in Battersea Multitasking Paradigm. Considering the four EF factors, Inhibition and Memory significantly predicted EF according to parents.

Table 5.6 EF performance predictors of Total score in the Teacher version of the QUFE

	ΔR²	**ΔF**	**B**	**T**
Variables				
HT Change session Errors	0.235	41.060	-0.185	-4.234***
DPT Learning	0.250	33.482	0.129	2.909**
HT Go session SD of RTs	0.260	28.104	-0.105	-2.278*
VSRT Non perseverative error	0.272	24.863	0.115	2.582**
BMP Memory	0.281	22.170	0.103	2.155*
BMP Monitoring	0.288	20.121	0.091	2.106*
EF Factors				
Inhibition	0.234	40.834	-0.182	-4.169***
Memory	0.256	34.413	0.154	3.442**

Legend: * p < .05; ** p < .01 p < 0.001

5.4 DISCUSSION

The present study aimed to address the relationship between cognitive and behavioral aspects of Executive Function, by comparing parent and teacher ratings and children' test performances, in a typically developing (TD) children and in two clinical groups, namely ADHD and LD. Several significant associations were obtained between performance on the EF measures and the QuFE Parent and Teacher reports. This study provides support for some convergence between neuropsychological and behavioral ratings of Executive Function as evidenced by significant but low or modest correlations between the performance measures, and the Parent/Teacher ratings of the QuFE. Significant correlations were observed in particular between cognitive measures and the teacher ratings. The number of associations was higher in the TD than in the two clinical groups.

We hypothesized that the QuFE Metacognition and Initiation subscales, which are purported to tap more cognitive dimensions of EF, will correlate with performance on tasks used to obtain information about cool EF (variables of the Battersea Multitasking Paradigm, the Daily Planning Task, the Visuo-Spatial Reasoning Task and the Honk Task). In contrast, the QuFE Emotional and behavioral regulation and Shift subscales, which are purported to measure more behavioral and emotional dimensions of EF, will correlate with performance on tasks that give information about hot EF (variables of the Iowa Gambling Task).

In regards to the Parent version, our findings support the hypothesis of modest correlations between performance-based and behavioral measures of Cool EF. Few significant correlations between the two assessment procedures were principally observed in TD and ADHD groups. Metacognition was significantly related to measures of Strategic behavior, Memory and Vigilance. Metacognition refers to the ability to begin a task or activity, generate ideas, responses or problem solving strategies, manage current and future-oriented task demands, anticipate future events, set goals and develop appropriate steps ahead of time to carry out a task or activity, organize information and to appreciate ideas or key concepts, maintain concentration and attention for a prolonged period of time. Based on this definition, this subscale may capture components of performance in the domain of Cool EF. Our results were in line and strengthened findings reported by other research groups. Studies have indeed found significant correlations between mnestic (Brown et al., 2008; Hummer et al., 2010; Mangeot et al., 2002) and attentional (Bodnar et al., 2007; Hummer et al., 2010) measures and the Metacognitive Index (MI) of the BRIEF. In regards to performance-based measures of memory, Brown and colleagues (2008) analyzed memory in children with Spina Bifida Myelomeningocele using the Children Category Test in which children must recall rules. Relationships between MI and Total score on the Children's Category Test were found to be significant. In their study Mangeot and colleagues (2002) observed that the Consonant Trigrams was consistent predictor that accounted for a unique variance of scores in the BRIEF. Bodnar and colleagues (2007) instead focused on attentional control using the Test of Variables of Attention (TOVA). The results of experiments showed that there was a minimal relationship between score on the WM subscale of the BRIEF and the actual performance on computerized measures of attention. Finally, the study by Hummer and colleagues (2010) described both mnestic and attentional domains. The authors found significant results, including positive correlations between MI in the BRIEF and scores of the Digit Span task and of the Continuous Performance Task. In contrast, other researchers have not found significant results (Conklin et al., 2008; McAuley et al., 2010): Conklin and colleagues and McAuley and colleagues excluded significant relationships between digit span test and indices of the BRIEF. Findings regarding relationships between performance-based and behavioral measures of Hot EF were instead mixed. Only in ADHD group there was convergence between Total score on the JGT and Emotional and behavioral regulation in the QuFE. This is an interesting and new finding that, in future research, it will be interesting to deepen. In TD and LD groups there were no instead correlations between variables of performance-based test and the QuFE subscale in both versions. Data in TD children were consistent with the findings of Shuster and colleagues (2009). In their research the authors excluded association between the JGT and subscales of the BRIEF in a sample of college students. Finally, in our sample also convergence between performance based and behavioral measures of inhibition was excluded.

The majority of the studies focused their attention on the executive profile provided by parents. In our study we reported also the point of view of teachers. As far as the relation between performance-based and behavioral measures of Cool EF was concerned, the data were less robust.

Consistent with the Parents version, in the TD group, there were numerous significant correlations in particular between Metacognition and the performance-based measures of Memory. Similar data were presented by Toplack and colleagues (2009). In their study the authors found significant relationships between Planning and Working Memory subscales of the BRIEF and score on the variables of performance-based measures used to assess planning and Working Memory (Stockings of Cambridge and Digit Span task, respectively). With reference to clinical groups, in ADHD children the correlations were distributed in all executive domains, instead in LD children there were only two significant correlations with performance-based measures of Strategic behavior and Memory. Interesting data in our research was the convergence between the Initiation subscale of the QuFE and the Perseveration in the Visuo-Spatial Reasoning Task that suggested a new key of interpretation for perseverative errors: may be caused by a deficit of the capability to independently generate new problem solving strategies. With reference to convergence between performance-based and behavioral measures of Hot EF findings in the three studied groups were unequivocal: there were not significant correlations between the Total score in the JGT and Emotional and behavioral regulation in the QuFE. Interestingly, there were significant correlations between Emotional and behavioral regulation and the cognitive measures of Inhibition. These results were consistent with findings reported by Toplack and colleagues (2008): the authors found significant convergences between performance in the Stop Task and the Inhibition subscale in the BRIEF.

According to the current results it is necessary to make three considerations: 1) the convergence between performance-based and behavioral measures were greater in parent's report; 2) the convergence between test and rating scale were greater for the cognitive domain of EF; 3) the degree of convergence was different in the groups: the number of significant correlation was higher for the TD group, but the intensity of relations were greater in the ADHD and LD groups. It is interesting to note that, in our LD group, the convergence mainly concerned the cognitive variable that had proven to be good predictor of the clinical status (Non perseverative errors).

Findings of regression analyses confirmed the limited relationship between cognitive and behavioral assessment: the proportion of variance in Total Score in both versions of QuFE that was explained by variables of the neuropsychological battery and executive factors was limited. Differently from the correlational studies, the convergence was greater for teacher. Interestingly, parents and teachers only partially focused their attention on the same executive domains: attentional and inhibitory abilities. The executive profile provided by parents and teachers was predicted by variables tapping 1) the ability to deliberately inhibit dominant, automatic or prepotent responses when necessary, control interference and make a fast and accurate choice between two or more competing responses; 2) the capacity to maintain attention over time (sustained attention to a target, the organization of appropriate responses to signals, and the inhibition of inappropriate responses) and monitor a situation in which significant events may occur. This finding was consistent with other researches that suggested that questionnaires such as the QuFE and the BRIEF are sensitive to behavioral disruptive impairment (McAuley et al., 2010). Teachers seemed to pay attention on a wider range of skills: they defined the executive profile of students considering cognitive aspects such as memory and organizational skills. Memory skills referred to monitoring and coding incoming information for relevance to the task at hand and appropriately revising the items held in working memory by replacing old, no longer relevant information with newer, more relevant information. Organizational skills instead, in this case, referred to the ability to begin a task or activity independently and generate ideas, responses, or problem solving strategies and to access performance during or shortly after finishing a task to ensure the appropriate attainment of a goal.

5.5 CONCLUSION

In general, the current findings suggested that behavioral reports on Executive Function may capture some components of performance-based measures. The convergences are greater in the sample of children with typical development than in the ADHD and LD groups. However this study indicated that rating scales themselves are not a approximation for performance-based neuropsychological measures. It is important to integrate test and behavioral evaluation because both have the capacity to detect functional impairments. The current work highlights the need to continue to analyze the ecological validity of assessment techniques used to study EF in children.

5.6 LIMITATIONS OF THE STUDY

There were some limitations in this study. The current results were based on a relatively small number of parents and teachers reports about clinical samples. Further research with a larger groups of children with ADHD and LD would be necessary. Future studies should also involve different clinical groups in order to test specific convergence of EF measures.

CHAPTER 6: GENERAL CONCLUSIONS

In the introduction of this study it was underlined that Executive Function (EF) is one of the most widely invoked constructs in the cognitive science, neuropsychology, developmental and clinical research literature. This construct has become important in the assessment of typically developing children and special populations because of its relation to scholastic achievement and school readiness, social competence and theory of mind and behaviors associated with developmental disorders. EF is an umbrella term that includes different interrelated cognitive skills necessary in the conscious, goal-directed control of thought, action and emotion processes (Miyake et al., 2000). Two types of processes are included in executive domain: cognitive processes (Cool EF) and emotional, motivational processes (Hot EF). Studies and findings related to four major themes were presented: 1) assessment of EF, 2) structure of EF, 3) development of EF, 4) executive profile in children with developmental disorders.

6.1 ASSESSMENT OF EXECUTIVE FUNTION

To carry out a precise assessment of EF can be very challenging. Traditionally, efforts to operationalize assessment models of EF have largely focused on laboratory or clinical performance tests with their inherent construct and measurement problems. These tasks usually tap individual component of EF over a short time frame and do not integrate multidimensional, priority-based decision making that is often demanded in real-world situations (Shallice et al., 1991). Consequently this assessment procedure lacks in ecological validity: component tests may not be sufficient in capturing more complex, day-to-day, executive problem solving. It is necessary to build up ecologically valid tasks that give information about the broader aspects of complex, everyday, problem solving demands and consider the peculiarity of EF in childhood.

In line with this need we propose a neuropsychological battery that aspires to have characteristics similar to a naturally occurring behavior and can predict everyday functioning. This battery includes a questionnaire and a set of neuropsychological tasks.

The behavior rating scale is the Questionnaire for the assessment for Executive Function (QuFE). This questionnaire is inspired by the Behavior Rating Inventory for the Executive Function and it was developed for efficiently and systematically capture information about manifestations of EF difficulties in different environments. In *Chapter 3* evidence for internal factorial structure, reliability, and clinical use of the Parent and the Teacher forms of the QuFE were examined in a normative and clinical samples of children aged between 8 to 13 years. Different factor structures were found according to the raters, parents or teachers: confirmatory factorial analysis suggested five and three factors structure, respectively for the Parent and the Teacher forms. Five dimensions described executive profile according to parents: 1) *Metacognition* gave information about vigilance, planning, task and performance monitoring; 2) *Emotional and behavioral regulation* tapped the ability to control impulse, behavior and emotion; 3) *Organization of materials* measured the capability to organize time, space and materials; 4) *Shift* described the ability to manage changes in environment and programs; 5) *Initiation* referred to the capabilities to begin a task or activity, as well as independently generate ideas, responses or problem solving strategies. Instead, according to teachers EF could be described using three factors: *Metacognition, Emotional and behavioral regulation* and *Organization of materials*. Additionally our findings suggested that the QuFE was a reliable measure of EF: 1) the internal consistency of both versions of the QuFE was general high and 2) the correlations between scores that tapped the same executive domains in the Parent and the Teacher forms of the QuFE were statistically significant and greater than 0.3. Finally we tested the clinical usefulness of the QuFE. The QuFE correctly classified 70% of children, with 70.2% specificity and sensitivity between 61% and 70.8%. Almost all subscales in both forms were able to distinguish typically developing and clinical groups even if the discriminating power was greater for ADHD group. The scales were less successful at predicting the presence of ADHD or LD.

We selected empirical measures that give a globally overview on the executive domain. These tasks cover both aspects of EF: cognitive and emotional/motivational processes. The tests are: 1) the *Battersea Multitasking Paradigm* that assess the ability to prioritize, organize and carry out three tasks within six minutes; 2) the *Daily Planning Task* that emphasize planning and prospective memory; 3) the *Visuo-Spatial Reasoning Task* is a rule attainment task that give information about visuo-spatial reasoning; 4) the *Iowa Gambling Task* simulates real-life decision making under uncertainty; 5) the *Honk Task* requires vigilance, inhibition and cognitive flexibility.

In this work we analyzed clinical use and ecological validity of this battery.

We deepened the capability of the neuropsychological battery to detect the belonging to specific clinical groups in *Chapter 4*. Our findings supported its utility. The variables of the neuropsychological battery had good specificity and was able to distinguish typically developing and clinical groups. The neuropsychological battery was less successful at predicting the presence of ADHD or LD. In *Chapter 5* instead we investigated the ecological validity of this battery using correlational analysis. Correlations between variables of performance-based measures and factors of both versions of QuFE had been calculated. In general, the current findings suggested that performance-based measures of EF may partially capture metacognitive and adaptive aspects described by parents and teachers. The agreement principally interested the cognitive aspects of EF. According to the current data the relationship between different assessment procedures (tests and rating scales) may be significantly different in the clinical groups: 1) in the ADHD group the number of correlations were significantly lower, the correlations were uniformly distributed across Metacognitive, Emotional and behavioral regulation and Organization of materials in both versions of the QuFE; 2) in the LD group the correlations interested mainly the Strategic behavior domain. It is interesting to note that, in children with LD, the convergence mainly concerned the cognitive variable that has proven to be a good predictor of the status of LD: Non perseverative errors in the Visuo-Spatial Reasoning Task.

6.2 STRUCTURE OF EXECUTIVE FUNCTION

Another important unresolved issue is the structure of the EF domain. First models of EF adopted unitary and homogeneous frameworks, in which specific components of EF were not identified and the biological basis was simply allocated to the frontal lobes. Today, EF are acknowledged to represent a highly complex, interrelated set of cognitive abilities, which are critical for adapted function. Debate remains about which abilities should be included in this domain and which relationship should be present between them. In *Chapter 2* we investigated the structure of EF in typically developing children aged 8 to 13 years. We administered a set of neuropsychological tasks. Findings do not support antecedent EF models that included two (Working Memory and Cognitive flexibility) or three (Working Memory, Cognitive flexibility and Inhibition) separated factors in childhood. Joint Simultaneous Factor Analysis across several populations indeed suggested a four-factor structure which included Vigilance, Strategic Behavior, Inhibition/Cognitive Flexibility and Memory. Our findings are in line with contemporary views that EFs are simultaneously uniform and diverse (Miyake et al., 2000). Joint Simultaneous Factor Analysis across several populations indeed suggested that the Vigilance, Strategic Behaviour, Inhibition/Cognitive Flexibility and Memory are separate but interrelated dimensions. Consistent with Miyake and colleagues (2000) and Anderson and colleagues (2000), we found Memory, Inhibition, and Vigilance to be executive components. The main finding of our study was the discovery of a fourth factor: Strategic Behaviour. The factor Strategic Behaviour referred to skills that in other models were identified as distinct: initiative, planning, organization and self-regulation. Interestingly, the exploratory multi-group comparison in *Chapter 2* confirmed factorial invariance of the current model for two different age groups (8/10 years old versus 11/13 years old) and for two different gender groups. These results indicate that the executive components and the relationship between them do not alter in the age range and in both males and females. In future research, it will be interesting to verify the fitness of the present model in clinical populations.

6.3 DEVELOPMENT OF EXECUTIVE FUNCTION

In the literature there are evidence for developmental changes in all executive domains in the age range 8-13, and there are findings that suggest the presence of different developmental trends.

In *Chapter 2* we analyzed changes in different executive components across multiple ages to find similarities and differences in developmental trends.

As far as developmental changes in performance were concerned, analyses revealed that performance in all tasks improved with age and suggested multistage interpretation of EF development. The main differences were related to age extremes: children aged 12/13 outperformed children aged 8/9 in all tasks. Interestingly, for many variables, a slowdown was observed in the growth of performance between 10 and 11 years. This age-related dip has been documented in the literature (McGiven et al., 2002) and may represent functional markers of the phase shift between proliferation and onset of pruning that affect the neural substrate of EF in this period of life.

With reference to different developmental profiles we observed four different trajectories. Our data suggested that some skills growing continuously at early ages of 8 and 9 years old, possibly reaching a plateau at 12 to 13 years (vigilance and sustained attention). Other skills continue to growth during adolescence (strategic control of behavior). Notably, with reference to this population, our results were not consistent with the suggestion that Cool EF emerges earlier than Hot EF. The variable used to describe the performance on the tasks that tap Hot EF (the Junior Gambling Task) had a developmental trajectory similar to that of variables used to assess the other aspects of EF (memory, strategic behavior and attentional control).

The current study also added a developmental dimension to the EF model fitting and suggested that the structure of EF remained stable during the school-age years. The four-factor model, included Vigilance, Strategic behavior, Memory and Inhibition/cognitive flexibility, provided an adequate description of task performance in different age groups (children who attended primary school and children who attended middle school).

6.4 THE EXECUTIVE PROFILE IN CHILDREN WITH NEURODEVELOPMENTAL DISORDERS

EF deficits play an important role in several developmental and neurological disorders, and for this reason is important to clarify precisely which functions are impaired in each disorder. In *Chapter 3 and 4* we focused our attention on two common developmental disorders, Attention Deficit Hyperactivity Disorder (ADHD) and Learning Disabilities (LD). ADHD is a disorder characterized by a persistent pattern of inattention, hyperactivity, and impulsiveness that is not appropriate for the child developmental level. LD is a condition characterized by persistent difficulties in reading, writing, arithmetic, or mathematical reasoning skills during formal years of schooling. Both ADHD and LD are associated with EF deficit. The review of the literature suggests that: 1) EF weakness are significantly associated with ADHD but do not support the hypothesis that the EF deficits are the necessary and sufficient cause of ADHD in all individuals with the disorder. EF difficulties appear to be one of several important weakness that comprise the overall neuropsychological etiology of ADHD. The interested executive domains are: response inhibition, planning, vigilance and working memory (Willcutt et al., 2005); 2) EF weakness are associated with LD and mainly interested attention, response inhibition and verbal working memory.

We analyzed executive profile in ADHD and LD by behavioral and performance-based measures.

In *Chapter 3* we examined the diagnostic group differences in terms of parent and teacher ratings on the QuFE. Our data suggested that, while there were similarities in some executive domains between groups, there were also reasonable and consistent differences where they might be expected. ADHD children were characterized by more and general executive weakness than LD children, weakness that involved both cognitive and regulatory domains.

In *Chapter 4* we analyzed inhibition, cognitive flexibility, planning, memory, strategic behavior and affective decision making through a neuropsychological battery included the Battersea Multitasking Paradigm, the Daily Planning Task, the Visuo-spatial Reasoning Task, the Junior Iowa Gambling Task and the Honk Task. The current study confirmed the presence of executive deficits in our sample of children with ADHD and LD. Both clinical groups did not show a generalize executive deficit and there did not present Hot EF deficits but there are different pattern of executive performance in the two disorders.

6.4.1 EF in children with ADHD

As far as performance-based evaluation was concerned, consistent with the literature, our data suggested impairments in different tasks used to evaluate Cool EF, but they did not support the hypothesis of generalized executive deficit (Barkley, 1997). Children with ADHD performed more poorly than typically developing children in tasks that require 1) incidental memory and verbal WM: ADHD children recalled less items and rules; 2) strategic behavior: ADHD had difficulties in the implementation of strategically oriented and consistent with the rules behavior; 3) vigilance: ADHD children had problems in attending specific stimuli, in maintaining attention for a prolonged period and in maintaining a steady rhythm of action. Deficit in this last executive dimension seemed to be a good predictor of ADHD status. Our study excluded problems of planning, cognitive flexibility, inhibition and affective decision making in this clinical population.

With reference to executive characteristic in daily life, consistent with literature and with the expectation of pervasive and general executive dysfunction with ADHD, our sample exhibited general executive weakness in both home and school environments. Children with ADHD had difficulties in 1) beginning a task or activity and independently generating ideas (initiative); 2) holding information in mind for the purpose of completing a task (WM); 3) maintaining attention for a prolonged time (vigilance), 4) anticipating future events, setting goals and developing appropriate steps ahead of time to carry out an associated task or action (planning); 5) checking work and performance during or after finishing a task ensuring attainment of a goal (monitoring); 6) control impulse and stop own behavior at the proper time (inhibition); 7) moving freely between situation, activity or aspect of problem (shift), 8) modulate emotional responses appropriately (emotional control); 9) keeping workspace, play areas, and materials in orderly manner (organization of materials). The executive profile, that emerged at home and at school, was substantially overlapping even if the weakness was higher in school environment. The consistency between parent and teacher descriptions was higher for emotional, behavioral regulation and organization of materials.

Taking into account the results of the two types of evaluations (test and questionnaire) we have obtained a confirmation of the presence of a weakness in the cognitive domains of EF, in particular vigilance and sustained attention, WM, strategic organization and monitoring of behavior. Parents and teachers reported more generalized impairment: data suggest a weakness that also affect emotional and motivational processes.

6.4.2 EF in children with LD

With reference to performance-based measures, our data revealed difficulties in tasks used to assess different executive processes. In part, our results were in line with the literature because we found deficit in 1) incidental and verbal WM: LD children had difficulties in actively holding multiple transitory information in the mind and recalled less items immediately after their presentation; 2) attentional control: children with LD were characterized by problems in attending specific stimuli, in maintaining attention for a prolonged period. In addition we observed problems in: 1) strategic behavior: children with LD had difficulty in strategically determining the most effective method or steps to attain that goal and 2) planning: children with LD had difficulties in imaging, developing and reaching a goal (more simpler plan and less details). Deficit in memory and planning seemed to be a good predictor of LD status.

With respect to behavioral assessment there were convergences between parents and teachers in the description of the cognitive aspects of executive domain. Both parents and teachers reported difficulties in sustained attention, plan and organization, monitoring of activity and behavior, initiative. Instead there were differences in parent and teacher reports considering emotional/behavioral regulation and organization of materials. Our data suggested the presence of impairments in emotional and motivational aspects of EF at home, in particular in emotional control, behavior flexibility and inhibition. A similar weakness was not recognized in school setting. As far as organization of materials the opposite pattern emerged: only teachers observed difficulties in the management of material, time and space.

Taking into account the results of the two evaluations we found a confirmation of the presence of weakness in the cognitive domains of EF, in particular in vigilance, WM, strategic organization and monitoring of behavior, initiate and planning. Parents reported more generalized impairment: data suggest a weakness that also affect emotional and motivational processes.

6.4.3 Comparison between ADHD and LD in the EF domains

In order to compared children with ADHD or with LD, firstly we focused our attention on performance-based measures. As presented above, both ADHD and LD children had executive impairments. Comparing the two clinical groups, our data suggested that: 1) children with ADHD and LD had similar strategic behavior deficits; 2) children with ADHD and LD had deficits in memory and vigilance even if the impairment was higher in the ADHD group; 3) only children with LD had problems in planning domain; 4) children with ADHD and LD had performance in line with typically developing children in tasks used to evaluate inhibition, cognitive flexibility and affective decision making.

As far as behavioral procedure were concerned, children with ADHD and LD had similar impairment, from a qualitative point of view, but it is different in terms of severity: 1) ADHD children were characterized by more severe metacognitive and regulatory impairment both at home and at school; 2) at school children with ADHD had more difficulties in managing materials, space and time.

According to our results we suppose a generalized weakness in the executive domains in both developmental disorders, but it is more pronounced in the ADHD, in particular in the cognitive domains of EF.

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APPENDIX 1

This Appendix contains the original material in Italian.

PROTOCOLLO: BATTERIA PER LA VALUTAZIONE DELLE FUNZIONI ESECUTIVE

Nome:____________________ Cognome:____________________ Età:____________________

Data:____________________ Sperimentatore:____________________________

TEST BRUCHI-PALLINE-GETTONI

APPRENDIMENTO

	REGOLE/DOMANDE	PUNTEGGIO (1 punto per ogni regola rievocata, 0 se non risponde o fornisce una risposta errata)
1.	Provare tutti e 3 i giochi prima che il tempo finisca	
2.	I gialli valgono più punti dei blu	
3.	Avrai dei punti in più per ogni cosa completata	
4.	Solo una cosa per volta in mano	
TOTALE RIEVOCAZIONE LIBERA		**__/4**
1.	Quanti giochi ci sono? (Risposta: *3*)	
2.	Cos'hanno di speciale le cose gialle? (Risposta: V*algono di più dei blu*)	
3.	Quanti giochi devi provare? (Risposta: T*utti / 3*)	
4.	Quanto tempo hai per giocare (Risposta: *6 min./finché la sabbia non finisce*)	
5.	Pensi di riuscire a finire tutti i giochi prima che il tempo finisca? (Risposta: *No*)	
6.	Quando finisce il gioco? (Risposta: *Dopo 6 min./quando la sabbia o il tempo finisce*)	
7.	Puoi tenere più di una cosa in mano? (Risposta: *No*)	
8.	Perché devi fare più veloce che puoi? (Risposta: *Per avere più punti/perché il tempo termina/per completare le cose*)	
9.	Perché dovresti completare i bicchieri, i bruchi ed i quadrati? (Risposta: *Per avere più punti*)	
TOTALE RIEVOCAZIONE FACILITATA		**__/9**
TOTALE RIEVOCAZIONE LIBERA+TOTALE RIEVOCAZIONE FACILITATA		**__/13**

PIANIFICAZIONE, ESECUZIONE E RACCONTO

PALLINE				BRUCHI				GETTONI			
	P	**E**	**R**		**P**	**E**	**R**		**P**	**E**	**R**
Item piccoli				**Item piccoli**				**Item piccoli**			
Giallo alto				Giallo da 4				Giallo da 4			
Blu alto				Giallo da 4				Giallo da 4			
				Blu da 3				Giallo da 4			
				Blu da 3				Blu da 3			
								Blu da 3			
								Blu da 4			
Item medi				**Item medi**				**Item medi**			
Giallo quadrato				Giallo da 6				Giallo da 9			
Blu quadrato				Giallo da 8				Blu da 8			
Giallo Rettangolare				Giallo da 9							
Blu rettangolare				Blu da 6							
				Blu da 9							
				Blu da 9							
Item grandi				**Item grandi**				**Item grandi**			
Rotondo giallo				Giallo da 14				Giallo da 14			
Rotondo blu				Blu da 14				Giallo da 16			
VIOLAZIONI (*colonna E)*											

NOTE

1. **Colonna P (Pianificazione):** riportare l'ordine con cui vengono pianificati gli item;
2. **Colonna E (Esecuzione):** riportare l'ordine con cui vengono eseguiti gli item ed indicare se sono stati completati (C) o no (NC);
3. **Colonna R (Racconto):** riportare l'ordine con cui sono stati rievocati gli item eseguiti.
4. **Violazioni:** segnalare ogni volta che nell'esecuzione di un gioco il bambino prende più di un oggetto in mano alla volta

PIANIFICAZIONE

	GIOCHI	**PUNTEGGIO** (1 punto se pianificato, 0 se non viene pianificato)
PIANIFICAZIONE GIOCHI	Palline	
	Bruchi	
	Gettoni	
		---/3
PIANIFICAZIONE ITEM GIALLI	Palline	
	Bruchi	
	Gettoni	
		---/3
PIANIFICAZIONE COMPLETAMENTO ITEM	Palline	
	Bruchi	
	Gettoni	
TOTALE BATTERSEA PIANIFICAZIONE = PIANIFICAZIONE GIOCHI + ITEM GIALLI + COMPLETAMENTO ITEM		**---/9**

ESECUZIONE

	GIOCHI	PUNTEGGIO
PUNTEGGIO GIOCHI TENTATI (1 punto per ogni tipologia di gioco tentata)	Palline	
	Bruchi	
	Gettoni	
		---/3
PUNTEGGIO PRECEDENZA ITEM GIALLI (1 punto per ogni item giallo completato in ogni gioco)	Palline	
	Bruchi	
	Gettoni	
		---/3
PUNTEGGIO PRECEDENZA ITEM PICCOLI (2 punti per i piccoli gialli o blu 1 punto per i medi gialli o blu 0 punti per i grandi gialli o blu)•	Palline	
	Bruchi	
	Gettoni	
		---/36
PUNTEGGIO PRECEDENZA COMPLETAMENTO ITEM (1 punto se il primo item tentato viene completato prima di procedere)		
		---/30
PUNTEGGIO ITEM GIALLI PICCOLI COMPLETATI (1 punto per completamento palline alto giallo; max. 1 punto 1 punto per completamento bruchi giallo 4; max. 2 punti 1 punto per completamento gettoni giallo da 4; max. 3 punti)	Palline	
	Bruchi	
	Gettoni	
		---/6
SUBTOTALE BATTERSEA ESECUZIONE		**---/78**
PUNTEGGIO ERRORI (assegnare -1 per ogni volta in cui un item è messo nel contenitore sbagliato)	Palline	
	Bruchi	
	Gettoni	
PUNTEGGIO INFRAZIONE REGOLA (assegnare -1 per ogni volta in cui il bambino prende più di una cosa in mano alla volta)	Palline	
	Bruchi	
	Gettoni	
TOTALE ERRORI/INFRAZIONI		
TOTALE BATTERSEA ESECUZIONE= **SUBTOTALE BATTERSEA ESECUZIONE + TOTALE ERRORI/INFRAZIONI**		

RACCONTO

	DOMANDE	PUNTEGGIO (2 compito ricordato -2 compito non ricordato
PUNTEGGIO GIOCHI RICORDATI Da -6 a +6)	Palline	
	Bruchi	
	Gettoni	
		--/6
PUNTEGGIO		(1 posizione corretta -1 posizione errata)
PUNTEGGIO ORDINE GIOCHI	Palline	
	Bruchi	
	Gettoni	
		---/3
		PUNTEGGIO (1 risposta corretta -1 risposta errata)
PUNTEGGIO USO STRATEGICO DELLE REGOLE	N° palline gialle completate	
	N° palline blu completate	
	N° bruchi gialli completati	
	N° bruchi blu completati	
	N° gettoni gialli completati	
	N° gettoni blu completati	
	Infrazione delle regole	
	Uso della clessidra	
		---/8
TOTALE BATTERSEA RACCONTO= PUNTEGGIO GIOCHI + PUNTEGGIO ORDINE + PUNTEGGIO REGOLE		**--/17**

MEMORIA

REGOLE	**PUNTEGGIO** (1 punto per ogni regola rievocata)
Provare tutti e 3 i giochi prima che il tempo finisca	
I gialli valgono più punti dei blu	
Avrai dei punti in più per ogni cosa completata	
Solo una cosa per volta in mano	
TOTALE BATTERSEA MEMORIA	**---/4**

TEST DI PIANIFICAZIONE QUOTIDIANA

APPRENDIMENTO

COMMISSIONE DA RIEVOCARE	**PUNTEGGIO** (1 se la commissione viene rievocata 0 se la commissione viene omessa)
Andare in palestra con Marco per fare l'allenamento di basket	
Comprare il pane per la nonna	
Riaccompagnare a casa Marco dopo l'allenamento	
Svolgere i compiti di geometria	
Indossare la tuta da ginnastica per andare in palestra	
Passare a prendere Marco a casa sua per andare insieme in palestra	
Comprare il righello nuovo	
Andare a trovare la nonna	
Fare i compiti di italiano	
Comprare il quaderno nuovo di italiano	
TOTALE TPQ APPRENDIMENTO	**__/10**

STIMA TEMPORALE

ATTIVITÀ DA SVOLGERE	**VALORI ACCETTABILI**	**STIMA**	**PUNTEGGI** (1 punto per ogni stima corretta, 0 per ogni stima fuori dal range dei valori accettabili)
Andare in palestra per allenamento di basket	60'-120'		
Comprare il pane per la nonna	5'-15'		
Riaccompagnare a casa Marco dopo l'allenamento	1'-10'		
Fare compiti di geometria	15'-60'		
Indossare la tuta da ginnastica	1'-5'		
Prendere Marco per andare in palestra	1'-10'		
Comprare il righello	5'-15'		
Andare dalla nonna	1'-30'		
Fare compiti di italiano	15'-60'		
Comprare il quaderno	5'-15'		
TOTALE TPQ STIMA			**__/10**

ATTIVITÀ

	PUNTEGGIO
TPQ COMMISSIONI (1 punto per ogni attività disposta correttamente)	**__/10**

TEST DELLE SCOMMESSE

CARTA		*CARTA*		*CARTA*		*CARTA*	
1		26		51		76	
2		27		52		77	
3		28		53		78	
4		29		54		79	
5		30		55		80	
6		31		56		81	
7		32		57		82	
8		33		58		83	
9		34		59		84	
10		35		60		85	
11		36		61		86	
12		37		62		87	
13		38		63		88	
14		39		64		89	
15		40		65		90	
16		41		66		91	
17		42		67		92	
18		43		68		93	
19		44		69		94	
20		45		70		95	
21		46		71		96	
22		47		72		97	
23		48		73		98	
24		49		74		99	
25		50		75		100	

MAZZI	**Colonna 1**	**Colonna 2**	**Colonna 3**	**Colonna 4**	**TOTALE**
A					
B					
C					
D					
PUNTEGGIO TOTALE (C+D)-(A+B)/4					

<u>TEST DI RAGIONAMENTO VISUO-SPAZIALE</u>

	RISPOSTA CORRETTA	***RISPOSTA***	***TIPO DI ERRORI (Pl, Bi, P)***
1*	**5**	___________	***
2	1		
3	5		
4	1		
5	5		
6	1		
7*	**7**		***
8	3		
9	9		
10	5		
11	7		
12	3		
13	9		
14	5		
15*	**6**		***
16	7		
17	8		
18	9		
19	10		
20	1		
21	2		
22	3		
23	4		
24*	**2**		***
25	10		
26	8		
27	6		
28	4		
29	2		
30	10		
31	8		
32	6		

33*	**6**		***
34	6		
35	6		
36	6		
37*	**1**		***
38	5		
39	10		
40	6		
41	1		
42	5		
43	10		
44	6		
45	1		
46	5		
47*	**9**		***
48	3		
49	7		
50	1		
51	9		
52	3		
53	7		
54	1		
55	9		

	PUNTEGGIO
DISCO ROSSO ERRORI PLAUSIBILI	
DISCO ROSSO ERRORI BIZZARRI	
DISCO ROSSO PERSEVERAZIONI	
DISCO ROSSO ERRORI TOTALI	