Executive functions in early childhood: interrelations and structural development of inhibition, set-shifting and working memory

Paolo Stievano [1] **- Giovanni Valeri** [2]

[1] *USL 12 Toscana, Viareggio (LU), Italy*

[2] *Ospedale Pediatrico Bambino Gesù, Rome, Italy*

doi: 10.7358/neur-2013-013-stie paolo.stievano@inwind.it

Abstract

The aim of the present study is to examine the interrelations of executive function (EF) tasks with general cognitive ability and linguistic level in preschool children. The analyses of the correlation between EF sub-domains, particularly inhibition and set-shifting, have been studied to comprehend the ontogenesis of EFs. Task analysis has allowed us to identify which EF sub-domains are prevalent in each task, with particular attention to inhibition and set-shifting definitions. The sample was composed of 40 typically developing children from 48 to 69 months old (M = 58 months, SD = 5.02); 28 boys and 12 girls. The results give some insight into the development of executive functions, their utility in clinical assessment and indication.

Keywords: Executive function; Inhibition; Set-shifting; Working memory; Preschoolers

1. Introduction

Executive functions (EF) include the storage of information in working memory, the inhibition of prepotent responding and the appropriate shifting and sustaining of attention for the purpose of goal-directed actions (Blair, Zelazo & Greenberg, 2005). In toddlers the assessment of EF is based on simple neuropsychological tasks of specific functions in conformity with child developmental level and interests.

In particular, recent years have seen a massive growth in the number of developmentally appropriate tasks available for assessing EF in children (Carlson, 2005; Diamond, Prevor, Callender & Druin, 1997; Espy, Kaufmann, McDiarmid & Glisky, 1999; Hughes, 1998; Zelazo & Muller, 2002). These child-friendly tasks have led to dramatic improvements in our understanding of the development of EF. For istance, it is now know that EF: (1) begins to emerge in the first few years of life (Diamond, 1991); (2) continues to develop through to adulthood (Huzinga, Dolan & van der Molen, 2006); (3) is a unitary construct with partially dissociable components (Garon, Bryson & Smith, 2008); (4) shows strong associations with family factors, such as socioeconomic status (Hughes & Ensor, 2005; Mezzacappa, 2004); (5) shows equally robust associations with cognitive characteristics, such as language ability and understanding of false-beliefs (Hughes, 1998); (6) predicts school readiness (Blair & Peters, 2003), success in numeracy and literacy and are more important for school readiness than is intelligence quotient (IQ) (Blair & Razza, 2007); (7) can be improved in at-risk samples through preschool intervention programs (Diamond, Barnett, Thomas & Munro, 2007).

According to brain anatomy EFs are linked to the prefrontal cortex, but a strict localizationist approach does not give enough importance to the fact that the brain is an integrated functioning unit that includes both cortical and sub-cortical networks. The prefrontal cortex is not a homogeneous zone of tissue but rather is differentiated on a both cytoarchitectonic and functional basis. In human beings, it comprises between a quarter and a third of the entire cortex and it is functionally and anatomically heterogeneous. It may be subdivided into three broad regions: the dorsolateral prefrontal cortex (DLPFC), the ventro-medial prefrontal cortex (VMPFC) and the orbitofrontal cortex (OFC).

The VMPFC is involved in drive and motivation, the DLPFC in working memory and set-shifting, and the OFC in inhibitory control of impulses and interference (Fuster, 2002). Both the VMPFC and the OFC are part of a frontostriatal circuit that has strong connections to the amygdala and other parts of the limbic system.

During the past decade, there have been various systematic studies of EF but only recently have we started to look at preschool children. The independence of EF from other aspects of cognitive development, both verbal and non-verbal, is still not clear for preschoolers.

A further topic of discussion is the extent to which various EF tasks provide evidence for a primarily unified construct or a diverse, moderately interrelated set of constructs in early childhood (Blair et al., 2005). Theoretically and practically, this discussion is central for developmental neuropsychology regarding the hypothesis on the modularity of mind: is it an early occurrence or a progressively structured function (Karmiloff-Smith, 1992; Fodor, 1983)?

One prominent theoretical framework integrates these opposing perspectives by suggesting that the EF construct consists of interrelated, but distinct, components described as the "unity and diversity of EF" by Miyake et al. (2000). Miyake (2009) has questioned whether inhibition can be considered a distinct component. Senn, Espy and Kaufmann (2004), also with preschoolers, used path analysis, which forms each latent variable by drawing on only one task rather than multiple tasks (which makes it more susceptible to extraneous influences such as test order and task reliability that may affect relations among the measures). Although performance on the WM and inhibition tasks was correlated and predicted complex task performance, shifting performance was unrelated to the other measures. This provided evidence that the EF components are dissociable in early childhood but also that those components are interrelated to some degree.

Confirmatory factor analysis (CFA) with older children seems to provide stronger support for Miyake's "unity and diversity view". First, Lehto, Juujärvi, Kooistra and Pulkkinen (2003) found that Miyake's three factor model provided the best fit of data from children ages 8 to 13. Second, Huizinga, Dolan and van der Molen (2006) employed CFA in a more developmental fashion by comparing the model of 7, 11, 15 and 21 years olds. They found partial support for the Miyake model as only the WM and shifting measures loaded onto latent variables, whereas the inhibition measures did not load onto a common latent variable. Miyake (2009) reported similar results with adults.

Most of the research in this field of developmental neuropsychology is on the more cognitive aspects of EF operative in abstract reasoning and problem solving aspects associated mainly with the DLPFC region rather than affective, motivational aspects associated more with the OFC and related medial regions. Although the literature on adult neuropsychology has seen an emerging and growing interest in the study of the OFC and its contributions to EF, developmental research has lagged behind (Happaney, Zelazo & Stuss, 2004).

Assessments of EF in children have relied almost exclusively on the cool, cognitive aspects of EF associated with the DLPFC. Much less is known about the hot affective aspects associated with the VMPFC, but interest in the topic is growing (Blair et al., 2005).

1.1. Executive function

Inhibition

As in one of the existing EF models by Barkley (1997), we believe that inhibition is the basis of the other EFs and it is central for its influence on other neuropsychological domains such as language.

Inhibition is central to developmental research as it describes both suppression of prepotent motor response and attention control (Nigg, 2000). Inhibition is considered foundational for EF (Miyake et al., 2000), however most inhibition tasks are not pure measures of inhibition (Simpson & Riggs, 2005) nor do they tap into a single inhibitory process (Nigg, 2000). Garon, Bryson and Smith (2008) distinguished simple from complex response inhibition tasks based on whether WM also is needed. Simple response inhibition requires a small amount of WM, making it one of the purest forms of inhibition (Cragg & Nation, 2008). It shows its rudiments during infancy (Garon et al., 2008), as when a child can delay eating a treat. Complex response inhibition also requires substantial WM by requiring that an arbitrary rule be held in mind and/or by requiring that the child inhibit one response (prepotent or not) and produce an alternative response.

As other researchers have shown, emerging self-regulation integrates inputs from several developing systems, including cognitive functions such as memory, language, or the developing attention mechanism (Rueda, Posner & Rothabart, 2005). Parent-child interaction factors, including qualities of attachment and parental control have also been identified as contributors to the growth of inhibitory and impulse control processes (Kochanska, Murray, Jaques, Koenig & Vandegeest, 1996).

Inhibitory functioning is thought to contribute to individual differences or developmental changes, or both, in a wide array of cognitive abilities, including intelligence, attention and memory (Carlson & Moses, 2001).

Behavioral disinhibition is a general vulnerability factor hypothesized to underlie different types of so-called externalizing behavior problems, such as attention deficits, novelty seeking/risk taking, conduct disorder, and substance use. A latent variable for behavioral disinhibition was substantially correlated (-.63) genetically with the common EF variable (the phenotypic or non genetic correlation was -.35), indicating that better general EF ability is associated with fewer such behavioral problems (Miyake & Friedman, 2012).

Strengthening the less developed EF sub-domains, in rehabilitation of children with developmental disorders, could improve the efficacy of the whole learning process. The early identification of children with lower self-regulation capabilities, influenced by genetics and environment, could reduce disadvantages linked to this condition. Applying specific therapy and more structured learning situations with gradual self-regulation requests should improve their behavioral internal locus of control.

Set-shifting

Set-shifting ability allows the modification of behaviors that require continuous adjustments especially when external conditions change.

Another important purpose of EF assessment in preschool age is to understand complex developmental disorders by identifying the specific EF deficit involved in each disorder. It is important here to refer to the "discriminant validity" definition (Pennington & Ozonoff, 1996) which outlines the possibility that specific EF deficits are at least correlate with and possibly a cause of the atypical developmental profiles seen in various disorders.

2. Objectives and hypotheses of this study

The current study has these goals:

1. Evaluation of the possible independence of EF sub-domains from both verbal and non-verbal cognitive capabilities in 4-6 year-old children. Clinical assessment should have all independent information from the test necessary to obtain a complete neurodevelopmental profile. This is crucial to understand whether EF tasks yield unique informations not present in other test/task.
2. To study inhibition in preschool age children. Inhibition is the basis of the other EFs processes and it is central for its influence on other neuropsychological domains such as language. The early identification of children with lower self-regulation capabilities could be possible by inhibition tasks like the ones proposed in this study. An analysis of the tasks has been made on the basis of the definitions of inhibition and set-shifting by assessing the role of inhibition in the EF tasks administered. The task analysis has allowed us to identify which EF sub-domains are prevalent in each task.

3. Method

3.1. Participants

The sample was composed of 40 typically developing children ranging from 48 to 69 months old (M = 58 months, SD = 5.02); 28 boys and 12 girls.

To study the relation between EF tasks from general cognitive and linguistic level a non-verbal cognitive task (Leiter-R) and a receptive vocabulary test (Peabody Picture Verbal Test – PPVT), Italian version (Stella, Pizzoli & Tressoldi, 2000) were administered.

Assessments were conducted individually in a quiet room in their school.

3.2. Measurer of EF

Specific EF tasks have been used according to a functional perspective of cognitive domains related to different area of prefrontal cortex. EF tasks are linked to specific subdomain according to the unitary construct of EF with partially dissociable components (Garon, Bryson & Smith, 2008). The EF subdomains considered are: inhibition, set-shifting and working memory.

Inhibition tasks

Whisper [Kochanska et al., 1996 in Carlson, 2005]

The experimenter asked children if they could whisper their names and then presented a series of 10 cards depicting cartoon characters (6 familiar, 4 unfamiliar to most preschoolers). Children were told to whisper the names of each character and that it was okay if they did not know all of them. On each trial they received a score of 0 if they loudly blurted out the name or used a normal voice and a score of 1 if they whispered. Unfamiliar characters were included so that children would be more excited upon seeing a familiar one (and more likely to shout out the name). "Don't know" trials were unscored.

Night and Day – "Stroop-like day-night task" [Gerstadt, Hong & Diamond, 1994 in Carlson, 2005]

The experimenter engaged children in a conversation about when the sun comes up (in the day) and when the moon and stars come out (at night). He then presented a white card with a yellow sun drawing on it and a black card with a white moon and stars on it. Children were instructed that in this game they were to say night for the sun card and day for the moon/stars card. After a brief warm-up, there were 16 test trials with each card presented (from beneath the table) in a fixed, pseudorandom order. There were no breaks or rule reminders. Accuracy (number correct out of 16) was recorded.

Less is more [Carlson, Davis & Leach, 2005 in Carlson, 2005]

"Less is more" is a reverse reward contingency task in which children were asked to select between a larger and smaller array of candy placed in shallow trays (e.g. five vs. two jelly beans). All children indicated that they preferred the larger amount. They were told that whichever tray they chose, those treats would go to a naughty puppet and they would get the threats in the other, non-selected tray. Children therefore need to infer that they should point to the smaller amount to get the larger amount of treats. The candies accumulated in clear plastic cups (one for the child and one for the puppet) across trials. After a brief practice and verbal rule check, 16 test trials followed with a rule reminder halfway through but without explicit feedback. In this last inhibition task, we also measured aspects linked to reward contingency.

Set-shifting tasks

Bear and Dragon [Reed, Pien & Rothbart, 1984 in Carlson, 2005]

The experimenter introduced children to a "nice" bear puppet (using a soft, high-pitched voice) and a "naughty" dragon puppet (using a gruff, low-pitched voice). He explained that in this game they are to do what the bear asks them to do (e.g. "Touch your nose") but not to do what the dragon asks. After practicing, there were 10 trials with the bear and dragon commands in alternating order. Children were seated at a table throughout the task, and all actions involved hand movements. Performance on dragon trials was taken as an index of self-control (0 = movement, 1 = no movement, scored individually for each trial). This task is essentially based on verbal material. In this task there is also an inhibitory component present.

Card Sort [Frye, Zelazo & Palfay, 1995; Zelazo et al., 2003 in Carlson & Moses, 2001]

In this task children were instructed to sort cards according to one criterion (shape) and then by a different criterion (color), thus requiring then to inhibit the old sorting rule. Children were shown two black containers with slots cut out of the lids. A drawing of a red bear was attached to one container and a drawing of a blue house to the other. Then, the experimenter produced a stack of cards depicting a red bear and a blue bear, and a red house and a blue house, explaining that in the shape game all the bears should be placed in the bear container and all the houses in the house container. After demonstrating with a blue bear and a red house card, the experimenter asked children to sort five cards in the following order: blue bear, red house, blue house, red bear and blue bear. The rule was repeated before each trial and children were praised when they sorted correctly. No child made errors in this pre-switch phase. The experimenter, then announced that they were going to switch to the color game and told the children that they should place all the blue cards in the blue container and all the red cards in the red container. Five post-switch trials followed in which the experimenter repeated the rule before handing children a card, but did not give feedback. Two of the post-switch trials were compatible with the rules of the prior shape game (trial 2, red bear; trial 3, blue house) and three were incompatible (trial 1, red house; trial red house and trial 5, blue bear). The critical score was the number correct on the incompatible trials. This task is essentially based on visual material.

Working memory tasks

Count and Label [Gordon & Olson, 1998 in Carlson, 2005]

Children were shown three objects (e.g. a key, a shoe, and a toy dog) and asked to label them. Then the experimenter suggested they count the objects. He demonstrated how to count the objects and label them each in turn (e.g. "one is a key, two is a shoe, three is a dog"). There were two test trials using different objects. Children were scored as incorrect if (a) they labeled the objects and then counted them or vice versa, or (b) (more commonly) if they said "one is a key, one is a shoe, one is a dog" or similar.

4. Results

A correlation analysis was conducted to examine the relation of EF tasks to chronological age (*maturation effect*) and with verbal and non-verbal cognitive processes (*relation between EF and measures of general intellectual function*). Inter-correlations among EF tasks (*relations among measures of EF*) were also examined.

4.1. Age effects

Table 1. Correlation between tasks and age

	Age in months
Less is more	0.15
Whisper	0.19
Bear and Dragon	0.32
Night and Day	0.42
Count and Label	*0.47***
Card Sort	*0.60***

Less is more and Whisper have the lowest correlation with chronological age.

Bear and Dragon and Night and Day have high but not significant correlation with age. It remains possible that significant age effects might be found in a broader sample.

Card Sort and Count and Label are the only tasks significantly related to age ($p < 0.05$).

The sample has been divided by age into two groups to examine in more detail the evolutive trajectories of each EF sub-domain. The percentage of correct answers has been considered to assess the level of mastery in the skill related to the task.

Analyzing the percentage of correct answers in tasks, we can see, in some of the tasks, almost the same values in two age groups (Table 1). It can be stated therefore that the skills measured are already developed in the following tasks where the percentage of correct answers (between 72% and 88.75%) remains similar in both age groups (see Table 2): Whisper, Bear and Dragon, Night and Day and Less is more.

Both Card Sort and Count and Label, however, are significantly correlated with age (Table 1). In these tasks the second age group (5-6 years old) reach almost the top score (90% and 87.5% of correct answers). Bear and Dragon in the second age group also produces a very high performance (84% correct answers) but with less advantage on the younger group (78%) compared to Card Sort (63%). In Bear and Dragon an important inhibitory component is also present together with set-shifting skill, and inhibition has already developed, earlier than set-shifting.

From the results emerges a frame of EF structure in which inhibition results as the less age-dependent function compared to working memory and set-shifting probably because it matures earlier. Inhibition is probably the first EF sub-domain that matures.

Table 2. Percentage of correct answers, mean, standard deviation and top score in relation to age groups

1st Age group (M = 53.8, SD = 3.12)

	Whisper	Bear and Dragon	Count and Label	Night and Day	Less is more	Card Sort
Mean	21.6	11.7	2.6	13.1	11.1	1.9
Standard Deviation	8.3	6.2	0.8	3.5	3.5	0.8
Max	30	15	4	16	15	3
% of correct anwers	*72*	*78*	*65*	*81.8*	*74*	*63.3*

2nd Age group (M = 61.5, SD = 3.24)

	Whisper	Bear and Dragon	Count and Label	Night and Day	Less is more	Card Sort
Mean	22.9	12.7	3.5	14.2	12.1	2.7
Standard Deviation	4.8	4.6	1.08	1.6	4.6	0.4
Max	30	15	4	16	16	3
% of correct anwers	*76.3*	*84.6*	*87.5*	*88.75*	*75.6*	*90*

4.2. Relation between EF and measures of general intellectual functions

No task was significantly related to verbal and non-verbal cognitive processes at this age (Table 3).

Count and Label and Less is more show relatively high correlations with PPVT (respectively 0.44 and 0.30), and a similar relation emerges between Card Sort and Leiter-R (0.31). The lack of significance is probably due to the small size of the sample.

Table 3. Correlations between tasks and language (PPVT) and non-verbal cognitive performances (Leiter-R)

	PPVT	Leiter-R
Wispher	0.26	-0.25
Bear and Dragon	0.01	0.20
Count and Label	*0.44*	0.19
Night and Day	0.04	-0.17
Less is more	*0.30*	0.11
Card Sort	0.18	*0.31*

4.3. Relations among measures of EF

Table 4 shows the correlations among all different sub-domain tasks and their relations to working memory assessed with the Count and Label task.

Whisper is correlated exclusively with Night and Day and not with Less is more even if they are both inhibition tasks.

Night and Day is related to Bear and Dragon and Card Sort which are set-shifting tasks. The correlation between Bear and Dragon and Card Sort is not significant.

Less is more and Bear and Dragon are correlated with Count and Label (which measures working memory).

Table 4. Correlations between tasks

	Whisper	Night and Day	Bear and Dragon	Card Sort	Less is more	Count and Label
Whisper						
Night and Day	*0.75***					
Bear and Dragon	0.29	*0.55***				
Card Sort	0.43	*0.56***	0.22			
Less is more	-0.16	-0.08	0.17	0.04		
Count and Label	0.29	0.38	*0.51***	0.29	*0.63***	

5. Discussion

5.1. Maturation level

Tasks significantly age related are Count and Label (working memory) and Card Sort (set-shifting). Inhibition has the least correlation with age. We believe that this result is not linked with the simplicity of the tasks administered, but derives from the early development of inhibition.

The Less is more task is the least correlated with age, probably because it is associated with basic functions that develop early in ontogeny. It is also linked with reward contingency, an important phylogenetic ability.

Also Whisper is independent from age. In accord with Barkley's (1997) study, we suppose that inhibition is an early skill, the basis of the development of the other EFs and self-regulation. Furthermore, this result provides support that the task is more sensible to individual differences than to age modifications.

All considerations on correlations are limited to the age range considered. Different age samples could produce different results.

5.2. Relation between EF and measures of general intellectual functions

Most EF tasks are relatively independent from language: no significant correlation has been found with PPVT. Only Count and Label has a higher but not significant correlation with language. Probably in a larger sample it would have been significant because it demands the use of both working memory and verbal skills (naming).

Leiter-R (a non-verbal cognitive measure) has no relation to EF tasks. This evidence is important because it confirms the independence between IQ and EF in preschool age, as in adult neuropsychology, suggested by the earliest theoretical models (Pennington & Ozonoff, 1996) and in specific work on children (Blair et al., 2005).

Card Sort has a higher, but not significant correlation, with cognitive level, probably because it is a more complex task.

5.3. Relations among measures of EF

Our data confirm that the distinction between different EF sub-domains is present not only in adults, but also in early childhood. From the analysis of the task performances, inhibition proves to be independent from set-shifting and working memory.

Less is more is different from the other tasks, as it measures inhibition, but it is also the only task linked to reward contingency (hot executive function). Hot executive functions are linked to affective aspects associated with the VMPFC. Instead cool cognitive aspects of EF are associated with the DLPFC (Hongwanishkul, Happaney, Lee & Zelazo, 2005). Therefore cool EF is more likely to be elicited by abstract, decontextualized problems (Card Sort, Night and Day), whereas hot EF is more likely to be elicited by problems that involve the regulation of affect and motivation. There are some indications that the VMPFC develops earlier than the DLPFC (Gogtay et al., 2004; Orzhekhovskaya, 1981 in Hongwanishkul et al., 2005). The Less is more task is probably linked with decision making about events that have emotionally significant consequences (i.e. meaningful rewards and/or losses).

Between the different set-shifting tasks there is no correlation. They probably measure different aspects of set-shifting. Bear and Dragon is a set-shifting task with a higher demand of working memory. This is confirmed by both the task analysis and the correlation with Count and Label (working memory task). Card Sort is probably more linked to perceptual and cognitive aspects dependent on set-shifting.

Inhibition can be differentiated in tasks which require attention shifting and others that demand suppression of behavioral responses. For instance Night and Day is an inhibition task which features attentional set-shifting aspects, while Whisper requires the suppression of behavioral responses.

The Night/Day task asseses complex response inhibition by requiring the child to inhibit a prepotent verbal response (i.e., upon viewing a sun).

Our data supports the hypothesis that the role of inhibitory control in EF tasks which demand attention shifting is different from its role in other tasks which require inhibition or suppression of a given response. This would confirm Nigg's (2000) and Garon et al. (2008) hypothesis on the different forms of inhibition.

Espy and Bull's (2005) results suggest that response suppression is distinct from and developmentally in advance of attention control. In addition, their finding provides evidence in preschool children for distinctions between response suppression and attention shifting that have been observed previously in older children and adults in both neuropsychological and brain imaging research (Blair et al., 2005).

Structural and functional changes in the prefrontal cortex in childhood suggest that inhibition is the earliest EF sub-domain that matures. These changes seem to be connected with myelination, interhemispheric connectivity, synaptic density and metabolic and electrical activity. There is some suggestion that, within the prefrontal cortex, the prefrontal orbital cortex develops earlier than the dorsolateral prefrontal cortex (Happanney, Zelazo & Stuss, 2004).

From a developmental neuropsychological perspective it is important to analyze the interaction between the specific processes and their evolutive trajectories. This method allows us to determine a specific skill profile of every child.

The relative independence of EF tasks from general cognitive level and language is not only a confirmation of theoretical work, but it is also an important operative clinical indication. Developmental neuropsychological assessment should include EF tasks to obtain a complete profile.

Another clinical indication that could derive from our data is relative to the use of the Night and Day task as a screening tool. This could shorten assessment procedure because it measures both inhibition and set-shifting.

6. Conclusion

In accord with the objectives of the present study we can draw the following conclusions.

The present study has shown the relative independence of the EF tasks from general cognitive and linguistic level in preschool children. This suggests that it is recommendable to include EF assessments in the evaluation of children to obtain a more complete developmental profile.

The analyses of the correlation between EF sub-domains, particularly inhibition and set-shifting, support evidence that EFs are, even in early childhood, a construct of different sub-domains rather than a primarily unified construct.

From task analysis a further distinction has emerged between hot and cool EF. This has the potential to shed some light on the role of EF in clinical disorders with childhood onset. For instance, Zelazo and Muller (2002) have suggested that whereas autism may be primarily a disorder of hot EF with secondary impairments in cool EF, ADHD may be mainly a disorder of cool EF (although differences may exist among subtypes and as a function of comorbidity) (Hongwanishkul et al., 2005).

Our data, in agreement with previous research (Barkley, 1997), suggests that EFs develop following a hierarchic organization of which inhibition is the basis.

Perhaps inhibition itself has a constitutional basis which determines the individual's level of inhibitory self-control as well as a developmental component. A number of researchers have demonstrated individual differences in inhibition (Reed, Pien & Rothbart, 1984), although they disagree as to how inhibition should be conceptualized.

The hypothesis that inhibition is linked to individual differences and not to maturation could have implications in diagnosis and education. Identifying those children with low self-regulation, by an increased precision in the measurement of inhibition, could provide valuable diagnostic information in order to assist them with specific therapeutic plans.

Inhibitory control is likely to be one of the individual characteristics that make children actively control their impulses and comply with caregivers' standards of conduct. It also allows children to internalize family and societal principles.

Compliance with caregivers, prosocial or aggressive conduct, achievement and mastery, peer relations, coping, regulation of anger and general social competence have all been associated with the early development of inhibitory control and self-regulation (Kochanska et al., 1996). Children with worse self-control (less persistence, more impulsivity, and poorer attention regulation) at ages 3 to 11 tend to have worse health, earn less, and commit more crimes 30 years later than those with better self-control as children, controlling for IQ, gender, social class, and more (Moffitt et al., 2011). Individual differences in children's inhibitory control, that may, in part, have biological underpinnings, have also been shown to contribute to the development of conscience, above and beyond the contribution of parental influence. At the same time, children with poor inhibitory control pose special challenges for their caregivers.

Applying EF task assessments to clinical populations could create specific neuropsychological profiles among the different developmental disorders. Inhibition is susceptible to impairment in neurodevelopmental disorders such as ADHD, conduct disorder, antisocial personality disorder, obsessive compulsive disorder and Tourette's Syndrome (Rubia et al., 2001). However, correlations between the other EF sub-domains and developmental disorders are still to be studied in depth.

It is important to measure EF in children, not only to understand childhood disorders but also to further develop measurement tools that are based on the cognitive development of children, rather than relying exclusively on models of brain damage in adults. Clearly, more research integrating biological, socialization and developmental factors is needed.

It may be that EF deficits identified among otherwise typically developing cognitive abilities could prove to be an indicator of increased risk for early developing psychopathology or learning disorders in very young children. In the didactic field such indications could be used to create training tasks that specifically stimulate poor EF processes. Studies of curricula (Diamond et al., 2007; Lillard & Else Quest, 2006) and curricula-add-ons (Riggs, Greenberg, Kusché & Pentz, 2006) demonstrate that EF can be improved even at 4-5 years of age, by regular teachers (given training and support) in regular classrooms without expensive equipment.

Limitations of the current study

The current study has several limitations. First, the small size of the sample posed some limits both in the choice and in the power of the statistical analyses used. The correlations have begun to outline a framework which requires further future research with a sample large enough to conduct more meaningful analyses.

Second, there is a selection bias in the sample gender: males are prevalent. Further studies should examine this variable.

Third, in the comparison between the different EF sub-domains the general cognitive and linguistic level should have been measured with a more articulated set of intellectual and linguistic tests (e.g. for syntax and pragmatics).

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