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# Orbitofrontal cortex-related executive functions in children and adolescents: their assessment and its ecological validity

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## Abstract

*This paper discusses the ecological validity of recently proposed tasks for the assessment of executive functions related to the Orbitofrontal Cortex, in children and adolescents. This topic is discussed considering two conceptually distinct approaches to ecological validity, verisimilitude and veridicality. The issue of ecological validity has been increasingly recognized in child neuropsychology, but an attention to this topic seems to lack in studies that assessed the development of Orbitofrontal cortex-related executive functions in children and adolescents with gambling tasks or delay of gratification tasks. An exception is represented by ADHD population, where specially delay aversion tasks seem to have a good veridicality-oriented ecological validity. The weakness of literature about the ecological validity of these executive measures must encourage to keep in mind ecological validity during the development of new tasks.*

*Keywords:* Orbitofrontal Cortex; Executive functions; Ecological validity; Verisimilitude approach; Veridicality approach; Delay aversion; Decision making; ADHD

## 1. Introduction

In recent years, psychologists demonstrated an increasing interest about the development of Executive Functions (EF). This interest raised in order to find cognitive correlates of the protracted maturation that characterizes Prefrontal Cortex (PFC) since childhood to young adulthood (Almli, Rivkin & McKinstry, 2007; Lenroot & Giedd, 2006; Segalowitz & Davies, 2004). If the assessment of EF related to the Dorsolateral portion of the PFC (DLPFC) in children and adults has a longer empirical history (see Romine & Reynols, 2005), the assessment of EF related to the Orbital portion of the PFC (OFC) has begun only in recent years: as a matter of fact, an increasing number of tasks have been recently developed for the assessment of OFC-related EF in children and adolescents. The aim of this paper is to discuss the ecological validity of these tasks, that is the degree to which behaviors elicited by these tasks reflect behaviors that actually occur in natural settings: in other words the extent to which findings from a study can be generalized to the "real world".

Ecological validity is an important topic when developing a new task for the assessment of a specific cognitive function (Silver, 2000): as a matter of fact, psychologists are typically asked to identify dysfunctions and the everyday implications of this dysfunction, once identified. The ability of child psychologists to predict how a child adaptively functions in his naturalistic environment, using standardized tasks, is actually variable and moderate at best (Bennet, 2001; Ready, Stierman & Paulsen, 2001; Sbordone, 2001).

Two conceptually different approaches to ecological validity have been proposed: verisimilitude and veridicality. Verisimilitude is the degree to which the cognitive demands of a test theoretically resemble the cognitive demands in the everyday environment (Franzen & Wilhelm, 1996). This approach typically requires the attempt to create new tasks with ecological goals in mind: these tasks tend to be more face valid than traditional tests, trying to simulate critical everyday cognitive tasks. The primary purpose of these tasks is to identify subjects who have difficulty performing real-world tasks, regardless of the aetiology of the problem (Chaytor & Schmitter-Edgecombe, 2003).

Veridicality refers to the degree to which existing tests are empirically related to measures of everyday functioning (Franzen & Wilhelm, 1996). Typically, these studies use statistical techniques to relate performances on neuropsychological tasks to measures of real-world functioning, such as questionnaires or clinician ratings. Thus, even though traditional tasks were not designed with ecological validity in mind, they may still be predictive of everyday cognitive skills. Therefore, attempting to establish the ecological validity of existing tasks, veridicality may prove to have a broader impact on the actual practice of child neuropsychology (Chaytor & Schmitter-Edgecombe, 2003). Regardless of the approach to ecological validity, neuropsychologists have to decide which everyday behaviors should be related to the task, selecting from among many possible types of everyday behavior. Once the behaviors of interest are selected, it must be determined how to measure these behaviors. This could include self or informant questionnaires, clinician ratings, or interviews.

For the purpose of this paper will be subsequently discussed: (1) OFC-related functions and their assessment (2) the assessment of OFC-related in childhood and adolescence and its ecological validity. Studies reviewed in this paper were identified in electronic database MedLine and PsychInfo; the final search was carried in January 2010.

## 2. A framework for Executive Functions

PFC is one of the latest cortical region to mature and to reach its definitive thickness during adolescence (Lenroot & Giedd, 2006). PFC is involved in several cognitive functions, like language, movement and high level perception, but plays also a fundamental role in functions usually defined as EF (Stuss, 1992). EF are usually considered a variety of high level cognitive processes as attention, set-shifting, planning, working memory, cognitive flexibility, decision-making, feedback use, error detection, response inhibition and self regulation, that are necessary for an appropriate affective and contextual goal-directed behavior (Alvarez & Emory, 2006; Miyake et al., 2000).

## 3. Anatomical distinction

In order to describe the different cognitive and behavioural deficits after injuries to its different portions (Stuss & Levine, 2002), neuroscience actually distinguishes between DLPFC-related EF (DLPFC-EF) and OFC-related EF (OFC-EF) (Ardila, 2008). DLPFC comprises the lateral portions of Brodmann's areas 9, 10, 11, and 12; areas 45 and 46 and the superior part of area 47 (Damasio, 1996; Gazzaniga et al., 1998). In addition to its connections with OFC, DLPFC is connected to a variety of brain areas that allow it to play an important role in the integration of sensory and mnemonic information and in the regulation of intellectual function and action. These areas include thalamus, basal ganglia (the dorsal caudate nucleus), hippocampus, and primary and secondary associative areas of neocortex, including posterior temporal, parietal, and occipital areas (Fuster, 1989). OFC consists of both orbital (ventral) and medial regions of PFC, including the medial portions of Brodmann's areas 9, 10, 11, and 12; areas 13 and 25; and the inferior portion of area 47 (Damasio, 1996; Gazzaniga et al., 1998). OFC is part of a frontostriatal circuit that has strong connections to the amygdala and other parts of the limbic system (Chudasama & Robbins, 2006). Hence, OFC is well suited for the integration of affective and cognitive information, and for the regulation of motivated and goal-oriented behavior (Rolls, 2004).

## 4. Functional distinction

DLPFC-EF have been differently labelled; some authors used the term "Cool EF", because they provide a cognitive and controlled elaboration of information (Zelazo & Mueller, 2002), while other authors used the term "Metacognitive EF" (Ardila, 2008). DLPFC-EF permit an attentional control on behavior and include working memory, planning, task or set-switching, problem solving and strategy development: they are assessed by classic executive tasks like the Trail Making Test, the Wisconsin Card Sorting Test, the Tower of London and the Stroop Test.

Also OFC-EF have been differently labelled: some authors used the term "Hot EF", considering that these functions provide an emotional and automatic processing of information (Zelazo & Mueller, 2002), while other authors used the term "Emotional/Motivational EF" (Ardila, 2008). OFC-EF guide a reward-based control of behavior and the management of risk; they include reward processing, reversal learning and decision making. Converging evidence from nonhuman primate neurophysiology and functional imaging studies in normal human subjects supports the general hypothesis that OFC represents the current value of choices. Single-unit recordings showed that macaque OFC neurons respond to the expectation of reward and to reward delivery; these responses discriminate between different kinds of reward, responding selectively to the most preferred reward, among those available in a given session (Padoa-Schioppa & Assad, 2006; Tremblay & Schultz, 1999). Patterns of activity in human OFC consistent with this hypothesis have been observed also in fMRI studies (Schnider, Treyer & Buck, 2005; Sugrue, Corrado & Newsome, 2005; for review Kringelbach, 2005). More specifically, medial and lateral areas of the OFC represent positive and negative outcomes, respectively (Frank & Claus, 2006). Resuming, OFC is involved in representing the current relative value of a stimulus: what a potential choice is "worth" to the chooser at that moment, compared with other available choices (Wallis, 2007). This value information guides decision making determining the goals toward the behavior is directed and providing a context from which to judge decision outcomes.

## 5. OFC Function-assessment

The potential devastating effects of damages to OFC (aneurysm ruptures, traumatic brain injuries, tumours or neurodegenerative diseases) on behavior have been clinically recognized since long time, reporting everyday decision making impairments, described as blindness to the future, that is the inability to evaluate and avoid possible negative consequences of their own behaviors (Bechara, Damasio, Damasio & Anderson, 1994). There has long been a gap between the clinical descriptions of the effects of OFC damages in real life and the ability to successfully measure these changes in a laboratory setting. A recent progress in closing this gap was triggered by the development of experimental tasks able to detect decision making difficulties, evaluating the ability to alter choice behavior in response to fluctuations in reward contingencies. Of these task, the Iowa Gambling Task (IGT: Bechara et al., 1994) is that most used in experimental studies (Dunn, Dalgleish & Lawrence, 2006). The original risk-taking version of this task requires 100 card selections from four decks of cards identical in appearance; subjects are asked to maximize their profit starting from a 2000 $ loan of play money. The goal of the game is defined as to win as much money as possible, otherwise, to avoid losing money as far as possible; to obtain this goal subjects must find out the most advantageous decks and prevalently pick up cards from that decks. After turning over some cards, subjects are both given money and sometimes asked to pay a penalty according to a pre-programmed schedule of reward and punishment. Gain and losses are different for each card selected from the four decks: decks A and B are "disadvantageous" as whilst they pay 100 $, the penalty amounts are higher in these high-paying decks, so they cost more in the long run; decks C and D are "advantageous" because they pay only 50 $, but the penalty amounts are lower in these low-paying decks, resulting in an overall gain in the long run. In summary, decks A and B are equivalent in terms of overall net loss over the trials, as are decks C and D; the difference is that in decks A and C punishment is more frequent, but of smaller magnitude, while in decks B and D punishment is less frequent but of larger magnitude.

When performing the IGT, healthy subjects progressively choose cards from more advantageous decks along the tasks, while several clinical populations show impaired performances, continuing to chose from more disadvantageous decks: as a matter of fact IGT performances have been shown to be a highly sensitive measure of impaired OFC functioning in a variety of neurological and psychiatric conditions known to be characterised by real world decision-making impairments. Neurological conditions include OFC damages (Bechara et al., 1994), Frontotemporal Dementia (Torralva et al., 2007), Parkinson's Disease (Pagonabarraga et al., 2007), and Alzheimer's Disease (Sinz, Zamarian, Benke, Wenning & Delazer, 2008). Psychiatric conditions include Pathological Gambling (Cavedini, Riboldi, Keller, D'Annucci & Bellodi, 2002; Goudriaan, Oosterlaan, de Beurs & van den Brink, 2005), Obsessive Compulsive Disorder (Cavedini, Gorini & Bellodi, 2006), eating disorders (Brand, Kranke-Sievert, Jacoby, Markowitsch & Tuschen-Caffier, 2007; Cavedini et al., 2004) and personality disorders (Jollant et al., 2007). Considering that ecological validity is defined as the degree to which behaviors elicited by a task reflect behaviors that actually occur in natural settings, in the "real world" (Sbordone, 1996), IGT is deemed to be ecologically valid in adult assessment, within a veridicality approach, being able to reveal and detect real-world decision making impairments.

### *5.1. OFC Functions in pre-schoolers*

OFC functions are actually a topic at the centre of the scientific debate because they are at the intersection between emotion and cognition and rely on emotion-cognition brain hubs (Pessoa, 2008). The focus on OFC functions stimulated the interest on the their development and their relationship with social and emotional development in early childhood (Boyer, 2006), also considering that early postnatal years are associated with a rapid maturation of the brain (Amli, Rivkin & McKinstry, 2007). How to assess the development of OFC functions in early years? Researchers have taken advantage of experimental tasks that have been successfully used in studies on adults, proposing developmental analogues of these tasks, subsequently reviewed.

## 6. The Children Gambling Task

On each of 40 trials of the Children Gambling Task (CGT: Kerr & Zelazo, 2004), children choose from one of two decks of cards, a striped deck and a dotted deck. When turned, cards display a number of happy and sad faces, corresponding to the number of rewards (candies) won and lost, respectively. Cards in one deck (striped) offer more rewards per trial but are disadvantageous across trials due to occasional large losses; cards in the other deck (dotted) offer fewer rewards per trial but are advantageous overall. Cards in the disadvantageous deck always offer two rewards together with losses of nothing, four, five, or six candies (with a net average of five candies lost per

10 cards). At the start of the task, children are instructed that they should try to win as many candies as possible and that they could select from whichever deck they wish. During demonstration, children are told that the happy faces on the cards indicate the number of candies won, whereas sad faces indicate the number of candies lost. When a card is turned over, only the happy faces are visible initially, because the sad faces are covered with a sticky note. After the number of candies won is revealed to the child and the candies distributed, the sticky note is removed, and the number of candies lost is revealed (to ensure that children attend to both wins and losses). In keeping with evidence that data from the second half of the IGT provides a more reliable index of performance (Monterosso, Ehrman, Napier, O'Brien & Childress, 2001), the dependent variable was the net score on these trials (i.e., the number of advantageous choices minus number of disadvantageous choices made during last 20 trials). Thus, higher scores indicated better performance. In this study (Kerr & Zelazo, 2004), on later trials, 4-year-olds made more advantageous choices than would be expected by chance, whereas 3-year-olds made fewer. Moreover, there was a tendency for boys to outperform girls in some of the late blocks of cards.

Another study (Garon & Moore, 2004) used a four deck CGT version to compare 3, 4, and 6 year old children and included a questionnaire that measured how well children understood what happened in the task, following the procedure adopted to investigate declarative knowledge in adults performing the IGT (Maia & McClelland, 2004). The four deck version of the CGT may be more sensitive to individual differences in decision making because it includes also two additional decks with infrequent loss (Garon & Moore, 2006). The results of this study indicated that girls chose from the advantageous decks more than boys, but age (i.e. 6 year olds compared to 3 and 4 year old) only influenced awareness of the task. Other studies with a two deck version of the CGT replicated age-related differences in CGT performance, while findings about sex-related differences in CGT performance remain still controversial (Heilman, Miu & Benga, 2009; Hongwanishkul et al., 2005).

A recent study (Garon & Moore, 2007a) manipulated the timing of loss and the pattern of regularity of deck consequences in the CGT administered to younger (i.e., mean age of 50.8 months) and older (i.e., mean age of 56.5 months) 4-year old children. Older children chose significantly more from the good decks compared to the younger ones. In addition, girls and boys improved their performance in opposing conditions, depending on the timing of loss; older 4-year olds showed better awareness of task. There were also sex-related differences on decision-making strategies, with girls shifting more than boys following a loss, and girls together with older boys staying more on the same deck after wins from the advantageous decks. Another study used a two-deck version of the CGT and found that 4-year old children indeed performed better than 3-year olds; performance was significantly associated with delay of gratification in 3, but not 4-year old children; and 4-year olds' performance benefited of online labelling of decks as good or bad, whereas 3-year olds' performance had limited benefit of the same procedure only in conditions that loaded less their working memory (Garon & Moore, 2007b).

## 7. Delay Discounting Tasks

Another possible measure of OFC functioning is offered by tasks that assess delay discounting (Green, Myerson & Ostaszewski, 1999). In these tasks individuals are asked to choose between smaller, immediate rewards and larger, delayed rewards (e.g., € 8 immediately vs. € 10 in 1 week). By varying the delay and the amount immediately offered, it is possible to calculate the rate at which a reward is discounted overtime. This approach is deemed to have a good verisimilitude approach, resembling the cognitive demands in the everyday environment. Recent evidence suggested that OFC sustains delay discounting (e.g., Rahman, Sahakian, Cardinal, Rogers & Robbins, 2001). Versions of this delay paradigm (referred to as Delay of Gratification) have been used extensively with children (Mischel, Shoda & Rodriguez, 1989, for review). A study (Thompson, Barresi & Moore, 1997) used a modified choice paradigm and found a significant increase between 3 and 4 years of age in children's tendency to choose delayed rewards. Prencipe and Zelazo (2005) adapted this procedure including additional trials. The Delay of Gratification task consists in nine test trial types, created by crossing three types of reward (stickers, pennies, candies) and three types of choice (one now vs. two later, one now vs. four later, one now vs. six later). There are also two demonstration trials, one in which the option was one candy now versus one candy later and one option for one candy now versus eight candies later. The two demonstration trials are presented first. On both trials, the experimenter read the decision aloud and made a choice herself. For each trial, the choice is explained verbally and visually by placing the two reward options in separate piles (i.e., immediate pile vs. delay pile). For the one candy now versus one candy later option, the experimenter choose the immediate reward. For the one candy now versus eight candies later option, he choose the delayed reward. Nine test trials are then presented, involving all nine trial types presented in a random order. Test trials are presented in the same fashion as demonstration trials. However, on each trial, the experimenter ask, “What do you want to do?”. The experimenter provides no feedback regarding the wisdom of children’s choices, apart from administering the consequences (i.e., dispensing the rewards). When children choose the immediate option, they are allowed to eat the candy, stick their stickers on a special piece of paper, or put their pennies in a penny box. Delayed rewards are placed in an envelope and set aside. Scores are the number of times that children chose to delay. Prencipe & Zelazo (2005) found that 4-year-olds were more likely to choose delayed rewards than were 3-year-olds. In addition, whereas 3-year-olds were less likely to choose delayed rewards than would be expected based on chance responding, 4-year-oldsweremore likely to do so. These results were robust across all three types of reward. Similar findings are reported elsewhere (Hongwanishkul et al., 2005). Summarizing, these results suggested that the developmental period between 3 and 4 years of age marks a leap in OFC functioning.

### *7.1. OFC Functions in older children and adolescents*

The development of OFC-related EF in late childhood and adolescence is a hot topic of neuroscience. This interest increased because longitudinal studies with structural neuroimaging (for review see Blakemore & Choudhury, 2006; Lenroot & Giedd, 2006; Thompson et al., 2005) shed new light on brain development, reporting that adolescent brains undergo great changes, specially marked in PFC, due to two fundamental phenomena: (1) linear increase of white matter, due to a process of myelination of cortico-cortical and cortico-subcortical neural connections, that increase the efficiency of conduction and communication by up to a hundred-fold (Durston et al., 2006); (2) an inverse U-curve shaped development of grey matter, due to the process of synaptic pruning, that cuts down less used and wired synapses.

How do these brain changes impact on the development of OFC functions? Findings from developmental studies reported that performances in decision tasks are worse than those of adults until 11-12 years of age, because of a bias for immediate wins, despite possible greater future gains (Crone, Bunge, Latenstein & van der Molen, 2005). These authors, using an adapted child version of the IGT in a sample of subjects from 7 to 15 years of age and varying the frequency and the temporal discount of wins and punishments, reported an age-related increase of the sensitivity towards possible future punishments, also in uncertain situations. But until 12 years of age, only when the punishment was very probable and heavy it received attention by subjects, while it was ignored in other cases.

Only few studies directly examined the maturation of decision making with the standard version of the IGT. A study found a linear increase of IGT performances from early adolescence (about 11 years of age) to young adulthood (Overman et al., 2004). A study conducted with four age groups (6-9 year-olds, 10-12 year-olds, 13-15 year-olds and 18-25 year-olds) reported that the youngest subjects drew equally from the good and bad decks (Crone & van der Molen, 2004). The two middle groups showed modest improvement over time; by the final trial block, they were drawing from the good decks about 55% and 60% of the time, respectively. By the final block, however, the young adults were drawing from the good deck nearly 75% of the time, and they began shifting towards the good decks much earlier than the younger groups.

Another study, of 9 to 17-year-olds, also found significant improvement in performance on this task with age (Hooper, Luciana, Conklin & Yarger, 2004). 14-17 year-olds drew from the good decks more often than 9-10 year-olds (although not more often than 11-13 year olds) and began shifting to the good decks earlier than did either of the younger groups.

Finally, a recent study administered a modified version of the IGT to a wide sample of 901 individuals between the ages of 10 and 30 (Caufmann et al., 2010). Results indicate that approach behaviors (operationalized as the tendency to play increasingly from the advantageous decks over the course of the task) display an inverted U-shape relation to age, peaking in mid- to late adolescence. In contrast, avoidance behaviors (operationalized as the tendency to refrain from playing from the disadvantageous decks) increase linearly with age, with adults avoiding disadvantageous decks at higher rates than both preadolescents and adolescents. These findings suggested that adolescents, compared to adults, are relatively more approach oriented in response to positive feedback and less avoidant in response to negative feedback.

Successful IGT performances require participants to pay attention to the outcomes of their decisions, and then to incorporate that information in their future decisions. Thus, deficiencies in performance may results from an insensitivity to loss, or an inability to use outcome information in anticipation of future risk. A recent physiological study demonstrated that the ability to anticipate future outcomes of decisions continues to develop until late adolescence (Crone & van der Molen, 2007), supporting the hypothesis that 8-10-year-old and 12-14-year-old children perform like OFC damaged patients (Bechara et al., 1994), because they fail to anticipate outcomes prior to making a decision. These data rejected the hypothesis that 8-10-year-old children and 12-14-year-old children perform disadvantageously because they'd fail to process the outcomes of their decisions.

### *7.2. Ecological validity of OFC Function assessment*

In previous paragraphs, studies that assessed OFC functions in childhood and adolescents were reviewed. Which is the degree of ecological validity of tasks adopted in these studies? As reported above, IGT performances of adult patients seem able to reveal and mimic real-world decision making impairments, suggesting a good ecological validity from a verisimilitude-oriented approach. The discussion on developmental versions of IGT or similar decision tasks may be done considering both verisimilitude and veridicality approaches to ecological validity and considering three samples of subjects: early childhood (3-6 years of age), childhood (7-10/11years of age) and adolescence (12-18 years of age).

## 8. Early childhood

Of the studies previously presented, none suggested that performances in the CGT and in the Delay of Gratification task mimic real-world behaviors of 3-6 year aged children; moreover, no studies tried to relate behavioral performance of young children in these tasks with rating scales or questionnaires on everyday behaviors. For example, some studies reported sex-related differences (girls outperformed boys) in CGT performances in 3 years-old children (Heilman et al., 2009) and 4 year-old children (Garon & Moore, 2004) and 4 year-old children outperformed 3 year-old children in this task (Crone & van der Molen, 2004; Heilman et al., 2009; Hongwanishkul et al., 2005): which real-world differences in behavior are related to these deemed differences in decision making abilities between (1) boys and girls and (2) 4 year-old and 3 year-old children? Are these differences in OFC-functioning in preschoolers detectable in everyday behaviors? No studies in literature may actually permit to give an answer to these questions. This suggests that tasks deemed able to assess OFC functions in early childhood lack of ecological validity, considering both verisimilitude and veridicality approaches.

## 9. Childhood

No studies conducted with healthy children, ranging from 7 to 10-11 years of age, reported attempts to verify the ecological validity of tasks for the assessment of OFC functions. An exception is provided by studies that assessed OFC functions in subjects with Attention Deficit/Hyperactivity Disorder

(ADHD). Neurocognitive approaches first focused on a poor inhibitory control on internal and external interferences as the core deficit of ADHD. A recent meta-analysis raised doubts on the efficacy of the inhibitory control deficit to describe cognitive deficits of all ADHD subjects, highlighting the phenotypical heterogeneity of this clinical population (Lijffjt, Kenemans, Verbaten & van Engeland, 2005): as a matter of fact, another meta-analysis, taking in exam results from 83 studies on executive functions in ADHD, for a total amount of 6700 subjects, reported that the only robust finding across studies is a spatial working memory deficit (Wilcutt, Doyle, Nigg, Faraone & Pennington, 2005). To better describe the heterogeneity of performance of ADHD subjects has been proposed that this executive dysfunction is related to the attention deficit but not to the hyperactivity/impulsivity trait (Diamond, 2005; Nigg, 2005; Stefanatos & Baron, 2007). A better description of different ADHD phenotypes involves an inhibitory control deficit and a delay aversion (Luman, Oosterlan & Sergeant, 2005; Solanto et al., 2001). As previously reported, delay aversion is measured by tasks in which subjects choose between small immediate and large delayed rewards: varying the delay and the amount offered immediately, it is possible to calculate the rate at which a reward is discounted overtime (Green et al., 1999; Hongwanishkul et al., 2005). Choices of small immediate rewards (that is delay aversion) are uncorrelated with inhibitory difficulties, suggesting that inhibitory deficits and Delay Aversion in ADHD are dissociable processes. Then, performances on either tasks are only moderately associated with ADHD but together correctly classified nearly 90% of children and adolescents with ADHD (Sonuga-Barke, Dalen & Remington, 2003). In order to explain the presence of these dissociable behavioural characteristics in ADHD subjects, has been recently proposed that inattention reflects a deficit of DLPFC functions (inhibitory control and spatial working memory) (Martel, Nikolas & Nigg, 2007), while hyperactivity/impulsivity symptoms reflect a deficit of OFC functions (delay aversion): this approach hypothesizes that some subjects with ADHD manifest primarily deficits of OFC functions, whereas others show mainly deficits of DLPFC functions and others show both types (Castellanos, Sonuga-Barke, Milham & Tannock, 2006).

The deficit of OFC functions in subjects with ADHD, associated with hyperactivity/impulsivity symptoms but not symptoms of inattention, has been recently demonstrated in many studies adopting either delay (ore temporal) discounting tasks (Olson, Hooper, Collins & Luciana, 2007; Scheres et al., 2006; Scheres, Tontsch, Thoeny & Kaczkurkin, 2009) and decision making tasks (Bubier & Drabick, 2008; Drechlser, Rizzo & Steinhausen, 2009; Masunami, Okazaki & Maekawa, 2009; Olson et al., 2007; Toplak, Jain & Tannock, 2005)

Summarizing, decision making tasks and specially delay aversion tasks seem to have a good verisimilitude-oriented ecological validity within ADHD samples, being able (1) to detect their altered reinforcement sensitivity (Luman, Tripp & Scheres, 2009), that, at a behavioral level, results in impulsive and hyperactive tendencies; (2) to discriminate between children with inattentive subtype and children with impulsive/hyperactive subtype. In order to test the veridicality-oriented ecological validity of these tasks in ADHD, performances in these tasks should be related to rating scales of impulsive and hyperactive behaviors (e.g. the Conner's Parent Rating Scale: Conners, Sitarenios, Parker & Epstein, 1998).

## 10. Adolescence

Studies on the development of OFC functions in adolescence encountered the interest of researchers of risk-taking behaviors of adolescents. As a matter of fact, crime, smoking, drug use, alcoholism, reckless driving, and many other unhealthy patterns of behaviors that play out over a lifetime often debut during adolescence (Centers for Disease Control and Prevention, 2004). A key question is to understand whether adolescents are developmentally competent to make decisions about risks (Reyna & Farley, 2006). Developmental neuroscience showed that risk-taking behaviors of adolescents may be understood and explained as the product of an interaction between socio-emotional and cognitive control networks (Yurgelun-Todd, 2007). The socio-emotional network is not in a state of constantly activation, even during early and middle adolescence, and when this network is not highly activated, the cognitive control network imposes regulatory control over impulsive and risky behaviors; in the presence of peers or under conditions of emotional arousal, however, the socio-emotional network becomes sufficiently activated to diminish the regulatory effectiveness of the cognitive control network (Steinberg, 2008).

Are decision of adolescents, for example during the IGT, able to reveal this risk-taking tendency? In other words, does the IGT has an ecological validity if used with samples of adolescents? At our knowledge, no studies tried to relate IGT performances with parent or teacher ratings of adolescent real-world risk taking behaviours or tendencies. Considering the developmental curve of IGT performance during adolescence (Crone & van der Molen, 2004; Hooper et al., 2004), IGT seems able to reveal that adolescent performances are worse than those of adults until 11-12 years of age, because of a bias for immediate wins, despite possible greater future gains: however, this finding is not sufficient to explain a complex phenomenon like adolescent risk-taking behaviors, that is also socially influenced (Steinberg, 2008). Summarizing, it's actually no possible to trace some conclusions about ecological validity of IGT in healthy adolescent population.

In order to improve the ecological validity of decision making assessment in adolescence, some points may be investigated in future studies. The first point involve the capacity of decision making tasks to discriminate between adolescent samples characterized by different degrees of risk-taking tendencies; this approach has been recently attempted in some studies that reported that performances in decision making tasks were able to discriminate between healthy adolescents and adolescents who deliberately self-harm (Oldershaw et al., 2009) adolescents with drinking behaviors (Xiao et al., 2009) and adolescents with externalizing behavior disorder (Ernst et al., 2003). The second point involves the effects of emotional activation and of social pressure (for example performing a decision making task alone or with peers) on risk taking during decision making tasks.

Future studies could permit to better understand those different variables impacting on decision making and risk taking in adolescence, a complex phenomenon whose adequate explanation is not completely offered only by performances in decision tasks.

## 11. Conclusions

This paper highlighted the importance to consider ecological validity when developing tasks for the assessment of OFC functions in childhood and adolescence. Few findings are available about the ecological validity of these tasks also in adults; however, if in adults decision making tasks are ecologically valid within a veridicality approach, no conclusions are actually possible regard their developmental versions.

After that a great amount of studies was published about OFC functions in healthly and clinical adult populations, the attention of developmental psychologists and neuroscientists focused on the possibility to assess these functions in developmental population with similar tasks. For what concerns children with typical development, this increasing trend of research was able to detect age-related leaps in performances in these tasks but was not able to offer clues about how these leaps are observable in everyday behavior. For what concerns children and adolescents with atypical development, tasks for the assessment of OFC-related EF have been shown to have a better ecological validity within a verisimilitude approach in some specific clinical population. In particular delay aversion (or delay of gratification) tasks seems able to show, in ADHD, samples those behavioral characteristics related to the impulsivity/hyperactivity trait.

The actual weakness of robust findings about the ecological validity of tasks for the assessment of OFC functions, specially in developmental age, should not debase the great advancement made in their comprehension, but should be seen as an encouragement to keep in mind ecological validity during the development of new tasks.

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