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Measuring Impulsivity in School-Aged Boys and Examining Its Relationship With ADHD and ODD Ratings

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Seven different laboratory measures of impulsivity were administered to a group of 165 school-aged boys. Parents' and teachers' ratings of Attention Deficit and Hyperactivity Disorder and Oppositional/Defiant Disorder were also obtained. Factor analyses of impulsivity measures revealed the existence of a strong Inhibitory Control Factor including measures derived from Stop Task, the Continuous Performance Test, the Matching Familiar Figures Test, and the Circle Tracing Task. Other forms of impulsivity like resistance to interference, the Wisconsin Card Sorting Test and efficiency in the DRL Task loaded on a second independent factor. The Inhibitory Control factor was correlated with ADHD ratings, whereas the second factor was slightly related to the presence of ODD symptoms. Discussion is focused on the relevance of inhibitory control in impulsivity and ADHD research.

KEY WORDS: impulsivity; inhibitory control; disinhibition; ADHD; ODD.

Impulsivity appears to be a common characteristic of children exhibiting a variety of behavior problems. The term *impulsive* has been applied to children with hyperactivity, learning disability, and conduct disorder (American Psychiatric Association [APA], 1994), but also to adults with other psychopathologies like psychopathy, alcoholism, or other substance abuse disorders. Although it is widely used to characterize these psychopathologies, research on impulsivity has traditionally encountered several problems (Milich & Kramer, 1984). First, impulsivity has been considered a multifactorial construct, especially when self-reported measures are used. Second, there are different measures of impulsivity that are poorly related to each other. This is especially relevant when comparing self-reported and behavioral measures of impulsivity (White et al., 1994). Third, Milich, Hartung, Martin, and Heigler (1994) highlighted the lack of theory-driven research. Overall, we may conclude that one of the problems that has beset the study of impulsivity is that different researchers have adopted different definitions and measures without precise knowledge of the relationships among them and what they are really measuring.

Multiple tasks have been used in laboratory evaluations of impulsivity or inhibitory control (see Zaparniuk & Taylor, 1997, for a review). The most used tasks have been the Matching Familiar Figures Test (MFFT), the stop signal task, the circle-tracing task, the Differential Reinforcement of low rate responding (DRL) Task, the Wisconsin Card Sorting Test (WCST), the Stroop test and the Trail Making Test. However, none of them may be actually considered the gold-standard measure of impulsivity, and more importantly, little knowledge exists as to whether these measures are tapping the same construct.

Several studies in adults and children have used and compared different measures of impulsivity. Generally, measures of impulsivity derived from laboratory tasks and rating scales have been independent of one another (Carrillo de la Peña, Otero, & Romero, 1993; Gerbing, Ahadi, & Patton, 1987; Luengo, Carrillo de la Peña, Otero, & Romero, 1991). One of the most relevant studies was conducted by White et al. (1994) with 404 boys, 12–13 years of age. They factor-analyzed 11 rating-scale and laboratory-derived measures of impulsivity, and obtained relatively low to moderate correlations between measures

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(maximum was 0.33). Factor analysis yielded two factors, labeled Cognitive Impulsivity and Behavioral Impulsivity. Cognitive impulsivity had high loadings on laboratory-derived measures including the Trail Making Test, the Stroop test, time perception tasks, number of cards played on the Newman card playing task, circle-tracing time, and immediate choices on the delay of gratification task. All rating scales loaded on the Behavioral Impulsivity factor including measures of parent-reported undercontrol, observer-rated motor restlessness and impatience-impersistence, and teacher- and self-reported impulsivity. Further analyses showed that scores on Cognitive Impulsivity were negatively related to IQ, whereas scores on Behavioral Impulsivity were positively associated with delinquency. However, as the factors obtained in this study differed primarily in terms of methods of assessment, we can not rule out the possibility that they were artifactual (Zaparniuk & Taylor, 1997).

Other studies, however, have obtained different results. Kindlon, Mezzacappa, and Earls (1995) administered a set of laboratory tasks to a mixed sample of 48 normal and 88 behaviorally disturbed children between the ages of 6 and 16 years (nearly all boys). Factor analysis suggested two factors, labeled Executive Inhibitory Control and Motivational Inhibitory Control. Measures loading on the first factor were number of correct responses in the word and color conditions of the Stroop test, number of examiner redirections to task, mean probability of inhibition on the stop task and number of errors in part B of the Trail-Making Test. The Motivational Inhibitory Control Factor had high loadings on the number of correct nonresponses and responses on the passive avoidance task, and number of cards played on the Newman card-playing task. Almost all these variables were able to discriminate between normal and disturbed groups of children with cognitive ability and age controlled.

Studies with normal toddler- and preschool-aged children have focused on identifying subdimensions of impulsivity able to predict functioning in broader social contexts such as home or school (Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996; Olson, 1989; Olson, Schilling, & Bates, 1999). Using interactive laboratory tasks, these studies have consistently identified a subdimension, labeled inhibitory control, that refers to the "child's ability to respond to task situations in a planful manner and inhibiting inappropriate responses according to situational demands"; Olson et al., 1999, p. 152). Inhibitory control can be reliably distinguished from other forms of impulsivity such as speed of response initiation (Kochanska et al., 1996; Rothbart, Ahadi, & Hershey, 1994), resistance to temptation (Kochanska et al., 1996), and ability to delay gratification (Olson, 1989). In a recent report of the Bloomington Longitudinal Study, Olson et al. (1999) administered several measures of impulsivity when children were 6 and 8 years of age. As in previous studies, a robust and stable inhibitory control factor was obtained at both ages, and this was different from delay of gratification at age 6 and fast motor control at age 8. Importantly, inhibitory control was associated with hyperactivity ratings of teachers and mothers at both ages 6 and 8, but not at ages 14–17. However, and contrary to White et al. (1994), an aggregated measure of impulsivity at ages 6 and 8 predicted maternal and self-ratings of externalizing behavior at ages 14–17.

In sum, we agree with Zaparniuk and Taylor (1997) when they concluded that "There have been too few studies to determine the nature of the underlying factors [of impulsivity]" (p. 174). The studies reviewed above have used different rating measures and experimental approaches to assess impulsivity. As the results from factor-analytic studies mainly depend on the measures selected, a few conclusions can be derived from them. The first is the advisability of not mixing self-reported and observer rated measures with behavioral tasks in the same analysis. The second conclusion is that measures related to the concept of inhibitory control are associated with later externalizing behavior. The third conclusion is that even though impulsivity is a relevant factor in normal development, we have not found any research focused on the multidimensionality of impulsivity in normal school-aged boys.

In the light of these issues, this study aimed to assess impulsivity in normal nonselected school-aged boys using different laboratory tasks and relating them to parent and teacher ratings of hyperactivity and oppositional/defiant disorder. Laboratory tasks were selected from Zaparniuk and Taylor (1997)[4] and measure diverse facets of impulsivity such as inhibitory control (Stop Task), reflectivity (MFFT), delay of gratification (DRL Task), motor impulsivity (circle-drawing task), ability to inhibit prepotent responses (Stroop test), set-shifting (WCST), and impulse control during a sustained attention task (CPT). Even though there exist other possible tasks, we considered these tasks to represent a wide sample of cognitive processes related to impulsivity. A second characteristic is that all these measures have shown good test–retest

[4]From the list of laboratory tasks made by Zaparniuk and Taylor (1997) we have not included the Card Playing Task because a previous study of Kindlon et al. (1995) showed stability problems, and the Time Perception Tests because pilot studies showed some problems in boys in age from 6 to 8.

reliability in previous studies (Halperin, Sharma, Greenblatt, & Schwartz, 1991; Heaton, Chelune, Talley, Kay, & Curtis, 1993; Kindlon et al., 1995; Servera & Llabrés, 2000). A third characteristic of all these tasks is that they have been widely used in impulsivity and ADHD research (Nigg, 2000, 2001; Sergeant et al., 2002; Zaparniuk & Taylor, 1997). Finally, a single measure of impulsivity is derived from each task.

The specific objective of this study was to investigate the relationships among different laboratory measures of impulsivity to determine if these measures are tapping a unitary factor. Consistent with the previous data reviewed above in normal toddlers and preschool children (Kochanska et al., 1996; Olson, 1989; Olson et al., 1989), we expected to find a reliable factor of impulsivity or inhibitory control on which other forms of impulsivity would load poorly. Our second objective was to investigate the link between laboratory measures of impulsivity and parent and teacher ratings of ADHD and Oppositional Defiant Disorder (ODD).

METHOD

Participants

Boys were selected from six primary schools. A total of 194 boys were initially invited to participate in the study, but only those who had written informed parental consent and those whose teachers wanted to participate were included. Because all the boys were recruited in state and regular schools, none of them had mental retardation or severe intellectual deficits. A total of 165 boys were finally included and assessed. The age distribution was as follows: 23 boys were 6 years old, 27 were 7 years old, 24 were 8 years old, 29 were 9 years old, 34 were 10 years old, 21 were 11 years old, and 8 were 12 years old. Descriptive data on the sample appear in Table I.

Table I. Means and Standard Deviations of Age, IQ, ADHD, and ODD Ratings

	M	*SD*
Age in months	109.84	20.95
Vocabulary	10.81	3.32
Block design	10.77	3.37
Hyperactivity ratings		
Inattention	7.65	5.67
Hyperactivity-impulsivity	6.55	5.59
Total score	14.2	10.11
IOWA: oppositional defiant disorder	2.19	2.73

Tasks[5]

Stop Signal Paradigm

The task was a children's version of that employed by Avila and Parcet (2001). The experimental task contained two components: the go task and the stop task. The stimuli for the go task were letters X and O presented in the center of the screen for 1000 ms. These stimuli were uppercase letters of approximately 3.4° high × 2.1° wide. These letters were preceded by a 500-ms fixation point, also presented in the centre of the screen. Participants were required to make speeded responses to the targets in the go task by pressing the "1" key on the keyboard number pad whenever the target letter was X, and to press the "2" key on the same keyboard whenever the letter was O. They had to respond with the index and middle fingers of their preferred hand.

The stop task required participants to inhibit responses to the stimulus in the go task when a stop-signal appeared. The stop-signal was a 150-ms. green circle with a diameter of 3.4° located 3.2° above the go stimulus for 150-ms. This stimulus always appeared with a delay after the go stimulus. Following the tracking procedure used by Logan, Schachar, and Tannock (1997), the stop-signal delay was set at 250 ms initially and then adjusted dynamically depending on the participant's behavior. The delay increased by 50 ms if the participant inhibited the response successfully (making it harder to inhibit on the next stop-signal trial) and decreased by 50 ms if the participant failed to inhibit (making it easier to inhibit on the next stop-signal trial). Participants were instructed to try to inhibit their response in the go task, but they were also told that this response inhibition was harder, and that they should not worry if they were not able to do it. They were told that the stop signal would occur at different times, so sometimes they would be able to stop and sometimes they would not. They were specifically instructed not to let the stop task interfere with the go task, and not to wait for the stop signal.

The experimental task involved 280 trials administered in two identical blocks separated by a 2-min rest pause. The first 40 trials were used as practice trials and also served to adjust stop-signal delay to each participant. These 40 trials were removed from statistical analysis. Each different letter in the go task appeared the same number of times. Stop signals were presented in 25% of the trials, a quarter of time with each letter of the go task.

[5]Instructions given for each task and other details may be obtained from the authors.

The impulsivity measure was the Stop Signal Reaction Time (SSRT), that is, the time needed to inhibit the go response approximately 50% of the time.

Wisconsin Card Sorting Test (WCST)

This test had 64 cards on which appeared one of four symbols—triangle, square, cross, or circle—in red, green, yellow, or blue. No two cards were identical. The participants' task was to associate each card with one of the four target stimuli presented above (one red triangle, two green squares, three yellow crosses, or four blue circles) according to a principle that participants should induce from feedback (right or wrong). For instance, if the principle was color, participants had to associate each blue card with a target of four blue circles independently of the number and the form. After 10 consecutive correct responses, the principle shifted to a different one without any warning. The task finished when participants had completed six different rules ("color," "form," "number," "color," "form," and "number") or 128 responses.

This task yielded several relevant measures. The most widely used are categories, perseverative errors, and nonperseverative errors. Categories refer to the number of principles learned as indicated by 10 consecutive correct responses. Perseverative errors occur either when participants continue to sort according to a previously successful principle, or in the first series, when participants persist in sorting on the basis of an initial erroneous guess. Nonperseverative errors include other types of errors. The measure which most related impulsivity and executive inhibition is the number of perseverative errors.

Circle Tracing Task

This task was adapted from that employed by Bachorowski and Newman (1990). Participants were instructed to trace with their preferred hand over three-fourth of a predrawn circle of 24.3 cm of diameter as slowly as possible. The circle had a clearly marked start and end points, and the impulsivity measure used in the analyses was the total time to complete the tracing. A practice trial without time constraints was given before the test trial.

Stroop Color-Word Interference Test

The Spanish version adapted from a standardized version of Golden (1978) was employed. This version consisted of three sets of stimuli, presented separately. These were (1) word-words ROJO (red), VERDE (green) or AZUL (blue), written in black, (2) color-patches of red, green, or blue, and (3) color-word—the words ROJO, VERDE, or AZUL written in conflicting colors. In each of the three conditions, participants were asked to make as many correct identifications as possible within a 45-s time period. In the color-word or interference condition, participants were required to name the color and ignore the word. The impulsivity-related measure in this task was the interference score that we calculated following recommendations included in the manual: Interference $= (C \times W/(C + W)) - CW$, where W is the number of responses in the word condition, C is the number of responses in the color condition, and CW is the number of responses in the color-word condition.

Differential Reinforcement of Low Rate Responding (DRL) Task

This task was a computerized implementation of the principle of differential reinforcement of low rate responding (DRL). To attain the highest number of points, participants were instructed to press the button, wait a while and then press it again. If participants waited for 10-s without responding, then they won a point after the first response. Responses before this delay reset the timer for another 10-s. The overall duration of the task was 8 minutes.

The impulsivity measure obtained in this task was the Efficiency Ratio (ER) or number of correct responses divided by the total number of responses.

Matching Familiar Figures Test (MFFT)

A new computerized and revised version of the MFFT was administered (Servera & Llabrés, 2000). It consists of 16 match-to-sample trials plus four practice trials. Each trial consists of one superior figure and two rows of three figures located below. Participants were required to match the figure above with one of the six located below by clicking on it with the mouse. A trial did not finish until the correct response was given. Performance was assessed by the time taken to give the first response (latency) and the total number of errors. These scores were standarized according to Spanish samples and transformed to obtain the impulsivity score (errors minus latency) and efficiency (errors plus latency).

Continous Performance Test (AX Version)

The AX version of the CPT consisted of the letters A, B, F, G, H, J, K, N, T, V, and X. The letters were white on a black background. The letters were 2.3×3.1 cm and remained on the screen for 400 ms, with a fixed interstimulus of 600 ms. Two sets of 250 letters were presented, lasting 8 min and 20-s in total. Participants were instructed to press the space bar upon the presentation of the X after the appearance of the letter A. Target letter X and letter X without the A each appeared with a frequency of 10%. Letter A appeared with a probability of 20%. The child received two practice blocks of 1-min to ensure comprehension of the task. Omission and commission errors were calculated as measures of inattention and impulsivity, respectively.

Intelligence: Vocabulary and Block Design of the WISC

Intelligence was controlled by including Vocabulary and Block Design subtests of the Wechsler Intelligence Scale for Children (WISC). Age-graded scaled scores were obtained for each participant.

Rating Scales for Parents and Teachers (see Table I)

Two different rating scales were completed by parents and teachers:

(1) A rating scale including *DSM-IV* criteria for Attention Deficit and Hyperactivity Disorder. Each of the 18 items has four possible answers corresponding to the frequency of the behavior in question scoring between 0 and 3. Three different scores were obtained averaging, when possible, ratings of parents and teachers: subscales of Inattention (scores ranging from 0 to 27), Hyperactivity–Impulsivity (scores ranging from 0 to 27) and Total Hyperactivity Score (scores from 0 to 54).
(2) The Hyperactivity and Aggression (Oppositional/Defiant) subscale of the IOWA Conners Teacher Rating Scale (adapted and translated from Loney & Milich, 1982). This subscale is composed of five items with the same method of scoring as previous scales. The scores range between 0 and 15. This measure has been especially important in this study because it was used as a criterion to differentiate aggressive-hyperactive children from non-aggressive-hyperactive children as has been done in other research (Johnston & Patenaude, 1994; Oosterlaan & Sergeant, 1996).

Procedure

Boys were tested individually or in pairs in a quiet room in the school setting. The measures already described and three other measures not relevant to this study were administered on two different days in 1-h sessions. Each of the two sessions included the same tests, but the order of sessions was counterbalanced within participants of the same age. There were six different orders of administration of tasks within a session. Each of these orders was designed so that each of the tasks was administered in a different position in the sequence. These orders were also counterbalanced among boys of the same age. Participants received small presents for acceptable performance on tasks. Almost all participants received these presents. Once finished, participants received an envelope with rating scales for parents, who were invited to complete it voluntarily. Teachers were given all rating scales from their pupils together and who were invited to complete them. A total of 148 parents and all the teachers completed the rating scales.

RESULTS

Descriptive Data

Table II shows means, range, and Pearson correlations for each measure derived from tasks with age in months, and Vocabulary and Block Design scores. Most impulsivity measures were correlated with age and intelligence measures as expected. These variables are clearly modulating performance in our sample. However, efficiency of the DRL task was not correlated with age, and interference of the Stroop task was correlated positively with age and not related to any intelligence test.

Preliminary Analyses

Prior to analyses we examined variables for univariate outliers and normality. Variables were standardized for inspection, and those with univariate outlying cases at $\alpha < .001$ were transformed to the next most extreme score (Tabachnick & Fidell, 2001). Normality was assessed by examining the Kolmogorov–Smirnov test (criterion $\alpha <$ .001). Logarithmic transformations were taken to normalize distributions for perseverative errors in the WCST, commission errors in the CPT, and time to trace the circle.

Partial correlations

Table III shows partial correlations between different impulsivity measures derived from each task controlling for age, Vocabulary, and Block Design. Most variables yielded low to moderate correlations in the expected direction with other impulsivity measures.

Table II. Means, Range and Pearson Correlations With Age in Months, and scores on Vocabulary and Block Design Subtests of the WISC

	M	*SD*	Range	Age	Vocabulary	Block design
Stop task						
TR	692.66	107	457–986	−23**	.04	.02
Correct	92.20	8.65	69–100	38**	.12	.35**
SSRT[a]	255.01	147	58–495	−37**	−.21**	−.24**
WCST						
Correct	73	18.54	29–103	33**	.25**	.21*
Perseverative errors[a]	30.70	11.87	10–89	−26**	−.13	−.25**
Nonperseverative errors	23.09	18.10	2–86	−20**	−.26**	−.12
Categories	3.04	1.77	0–6	29**	.29**	.24**
Stroop test						
Color	49.37	12.84	16–90	68**	.05	−.16*
Color-word	27.01	7.51	13–54	42**	.00	−.17*
Interference[a]	1.89	7.37	−17.9–39.3	24**	.02	−.09
CPT						
Omissions	5.08	6.08	0–27	−33**	−.24**	−.29**
Commissions[a]	13.53	14.12	0–80	−21**	−.19*	−.31**
MFFT						
Errors	21.25	11.62	0–55	−63**	−.14	−.28**
Latency	11.84	6.34	2.67–43.48	46**	.09	.06
Impulsivity[a]	0	1.81	−6.51–4.51	−60**	−.12	−.18*
Efficiency	0	0.84	−1.72–3.40	−22**	−.03	−.26**
DRL task						
Rewards	19.89	6.11	4–34	19*	.08	.37**
Responses	51.68	26.03	10–173	−06	−.10	−.40**
Efficiency ratio	0.48	0.24	.03–1	08	.18*	.39**
Circle trace task						
Time[a]	83.92	76.27	5–352	36**	.05	.19*

[a] Impulsivity measures considered in further analyses.
*$p < .05$. **$p < .01$.

Factor Analysis

We selected the impulsivity measure obtained from each task. A principal-component analysis was conducted with the seven selected impulsivity measures. As similar factor solutions were obtained if we split the sample into two age groups of 6–8 years and 9–12 years, we decided to present a single factor solution with the overall sample. Screen test revealed the existence of two principal components with eigenvalues greater than 1, accounting for 50% of variance. Table IV shows loadings of the pattern matrix greater than 0.40 after rotation after Oblimin rotation. Factor 1, called Inhibitory Control, explained 33% of variance and contained variables related to the inhibitory control. Factor 2, called Other Forms of Impulsivity, explained 17% of variance and contained three variables:

Table III. Partial Correlations Between Impulsivity Measures Controlling for Age, and Scores on Vocabulary and Block Design

	1	2	3	4	5	6
1. SSRT Stop task						
2. Perseverative errors WCST	.00					
3. Interference Stroop test	−.11	−.14				
4. Commissions CPT	.39**	−.02	−.08			
5. Impulsivity MFFT	.22**	.02	.08	.18*		
6. Efficiency ratio DRL task	−.21**	−.09	.06	.02	−.12	
7. Circle trace time	.01	.07	−.18	−.13	−.17*	−.12

*$P < .05$. **$P < .01$.

Table IV. Pattern Matrix After Oblimin Rotation (Loadings Greater Than 0.40)

	1 Inhibitory control	2 Other types of impulsivity
Impulsivity MFFT	.75	
Commissions CPT	.70	
SSRT stop task	.70	
Circle trace time	−68	
Interference Stroop test		.65
Perseverative errors WCST		.58
Efficiency DRL task		−.50

Table V. Partial Correlations Between Impulsivity Measures and Parents' and Teachers' Ratings Controlling for Age, and Scores on Vocabulary and Block Design

Variable	*DSM-IV* Inat	Hip- Imp	Total	ODD
SSRT stop task	32**	27**	34**	12
Perseverative errors WCST	−07	05	−01	−05
Interference Stroop test	−04	01	−02	20**
Commissions CPT	27**	40**	38**	33**
Impulsivity MFFT	31**	20**	30**	06
Efficiency ratio DRL task	.07	03	04	02
Circle trace time	05	14	11	19*
Factor 1: Inhibitory control	28**	22*	29**	03
Factor 2: Other types of impulsivity	08	14	14	22**

$^{*}p < .05$. $^{**}p < .01$.

interference in the Stroop test, perseverative errors in the WCST, and efficiency in the DRL task.

Factor scores on Inhibitory Control were significantly correlated with age ($r(165) = -0.51$, $p < .001$), Vocabulary ($r(165) = -0.20$, $p < .01$), and Block Design ($r(165) = -0.33$, $p < .001$). Scores on Factor 2 related to other forms of impulsivity were significantly correlated with age ($r(165) = -0.27$, $p < .01$), and Block Design ($r(165) = -0.23$, $p > .01$), but not to Vocabulary ($r(165) = -0.15$, $p > .05$),

Relationship Between Impulsivity Measures and Scores on Rating Scales of ADHD and ODD

Table V shows partial correlations between impulsivity measures and factors, and scores on ratings of ADHD and ODD controlling for age in months and Vocabulary and Block Design scores. Basically, measures of inhibitory control (Factor 1), but not other forms of impulsivity were significantly correlated with ADHD ratings. However, scores on Factor 2 were correlated with the presence of ODD symptoms.

To test the unique contribution of impulsivity to the variance in ADHD and ODD ratings, hierarchical and stepwise multiple regression analyses were conducted to determine the relationships of the different impulsivity variables to the development of ADHD and ODD symptoms. Age in months and scores on Vocabulary and Block Design were entered in the first step of the analyses. Stepwise multiple regression analyses were then used to determine the importance of the different impulsivity-related measures. Different models were obtained for each variable (Table VI). Overall, three measures included in the inhibitory control factor were related to the dependent variables: SSRT and Commission errors of the CPT were relevant on ADHD ratings, whereas Interference on the Stroop test and Commission Errors on the CPT were relevant associated with ODD symptoms.

DISCUSSION

The construct of impulsivity has far-reaching importance for understanding children's normal and abnormal development. To date, however, there have been few studies designed to investigate the multidimensional nature of impulsivity. The main finding of this study is that several impulsivity measures seem to be related to a single construct like inhibitory control or behavioral inhibition (Barkley, 1997; Nigg, 2000). The measures related to this concept were those derived from the stop task, the MFFT, the CPT, and circle-drawing task. A close inspection of these tasks shows that all of them require inhibiting dominant responses in different circumstances. Importantly, this factor was independent of other types of impulsivity like resistance to automatic interference (Stroop task), modifying responses proving ineffective (WCST) and delay of gratification (DRL task), which seem to measure a different construct of inhibitory control.

This broad dimension of inhibitory control has been identified in prior studies of normal toddlers- and preschool-aged children (Kochanska et al., 1996; Olson, 1989; Olson et al., 1999) and in studies of clinically referred children with ADHD (Avila et al., 2001; Tannock & Schachar, 1996). Overall, there is a growing body of research showing that inhibitory control is an important subdimension of impulsivity in young children that underlies several classical and new measures of this construct, and which is related to children's externalizing problems. In this sense, this factor resembles the concept of behavioral inhibition based on the suppression of prepotent responses to an event so as to create a delay in responding (Barkley, 1997; Nigg, 2000). As explained previously, all the tasks with high loadings on this factor seem to measure the ability to inhibit a dominant response to evaluate the possible consequences of responses.

Three different variables loaded on the second factor, which was independent of inhibitory control. Previous theoretical reports have proposed that the process of resistance to interference measured by the Stroop test is independent from behavioral (Barkley, 1997) or executive (Nigg, 2000) inhibition. This result was not consistent with previous results of Kindlon et al. (1995), who found that measures derived from the stop task and the Stroop test loaded on the same factor. Differences in the measures

Table VI. Hierchachical Multiple Regression Analyses

Dependent	Step	Variable	β	R^2	F
Inattention	1	Age	.04		
		Vocabulary	−.23		
		Block design	−.23	.16	$F(3, 147) = 8.59 p < .001$
	2	SSRT	.23	.05	$F(1, 149) = 6.67 p < .01$
Hyperactivity-impulsivity	1	Age	−.09		
		Vocabulary	−.16		
		Block design	−.22	.10	$F(3, 147) = 5.17 p < .001$
	2	Commission	.26	.07	$F(1, 148) = 8.37 p < .01$
ADHD total	1	Age	−.02		
		Vocabulary	−.21		
		Block design	−.25	.15	$F(3, 147) = 8.38 p < .001$
	2	Commission	.23	.05	$F(1, 148) = 6.62 p < .01$
ODD	1	Age	−.06		
		Vocabulary	−.26		
		Block design	−.16	.12	$F(3, 147) = 6.44 p < .001$
	2	Interference Stroop test	.22		
		Commission	.21	.10	$F(2, 148) = 6.59, p < .01$

Note. Inat = Inattention; Hip-Imp = Hyperactivity-Impulsivity; ODD = Opositional Defiant Disorder.
$^{*}p < .05$. $^{**}p < .01$.

included in the factor analysis (they included measures related to motivational inhibition) and the fact that they included raw scores instead of the interference score, may explain this conflicting result. In sum, our results were consistent with the idea that, when cognitive tests are included, the Stroop test measures a different process than the stop task. A second variable independent from inhibitory control was the perseverative errors in the WCST. Consistent with Barkley's classification, inhibitory control should be distinguished from inhibition caused by the need to interrupt an ongoing response that is proving ineffective (sensitivity to error). According to our results, perseverative errors in the WCST should not be considered measures of inhibitory control. Finally, delay of gratification measured by the DRL task was also independent from the inhibitory control measures as previously obtained in studies with preschool and school-aged children (Olson, 1989; Olson et al., 1999). This result is also consistent with the independence between inhibitory control and delay aversion proposed by Sonuga-Barke (2002).

The present results have shown a relationship between laboratory measures of impulsivity and parents' and teachers' ratings of hyperactivity. This is important because it is in contrast with several previous reports in this field that reported no correlation between rating scales and laboratory measures of impulsivity (Carrillo de la Peña et al., 1993; White et al., 1994). We attributed this difference to the selection of laboratory measures, and to the different variables included in the factor analyses in the study by White et al. and the present study. Tasks such as the stop task, the CPT or the new computerized version of the MFFT seem to be more sensitive to impulsivity and its disorders (Avila, 2001; Avila & Parcet, 2001, 2002; Sergeant et al., 2002), and were not used in these previous studies. It therefore seems necessary to include these variables in the behavioral assessment of impulsivity-related disorders.

This study also supports the proposal that a deficient inhibitory control is the main cognitive deficit in ADHD (Barkley, 1997; Nigg, 2001; Sergeant et al., 2002). In this sense, present results provide evidence for viewing the severity of ADHD symptoms as a continuum that is present throughout the population and that may be measured using the same cognitive measures of inhibitory control (see Billingsley, Jackson, & Moore, Schrimsher, 2002). This suggests that the study of the development of the executive functions in normal populations will serve to better understand the nature of the cognitive deficits of the ADHD. Thus, tasks such as the Stop Task, the MFFT, the CPT, and the circle-drawing task may form a 40-min battery to help to detect possible cases of ADHD in normal populations (Avila et al., 2001).

Finally, ODD symptoms reported by parents and teachers were moderately correlated with some impulsivity measures obtained from the CPT, the circle-trace task, and the Stroop test. Also, scores on Factor 2 but not on Factor 1 were correlated with teachers' ratings of ODD. Previous literature on ODD children has not clearly described a clear pattern of cognitive deficits. Different studies have shown performance difference in task such as the

Stop task and Stroop test, but the presence of comorbid ADHD symptoms may be responsible for these deficits (Sergeant et al., 2002). In fact, all the above-cited correlations between ODD symptoms and impulsivity measures (with the exception of the Stroop test) disappeared when controlled for the ADHD symptoms.

Limitations and Conclusion

This research sheds light on the multidimensional nature of impulsivity by confirming the importance of the subdimension of inhibitory control, which is independent from other forms of impulsivity. Inhibitory control is linked to a lower IQ, and to the presence of more ADHD symptoms reported by parents and teachers. More studies are needed to clarify the role of inhibitory control in ADHD and to correlate these impulsivity measures with ratings of delinquency and antisocial behavior. Furthermore, a psychobiological model of the areas of the brain controlling these functions would be of extreme relevance to enhancing knowledge of the psychopathology of disinhibition.

However, there are some limitations in this study. Although this study has used a broad set of laboratory tasks that constitute a good sample of the most important impulsivity tasks, there are some procedures such as the Card Playing Task, the Passive Avoidance Task or the Emotional Stroop that we decided not to include because of time limitations in assessment. Other cognitive tasks related to interference control (i.e. flanker task), cognitive inhibition (i.e. negative priming), and oculomotor performance (i.e. antisaccade task) recently proposed by Nigg (2000, 2001) were not included for the same reason. The relationship between these tasks and those used in the present study should be investigated in future.

Similarly, our study focused on the assessment of impulsivity in nonreferred school-aged children. Thus, care should be taken with the interpretation of ADHD and ODD ratings because higher scores on them do not necessarily indicate ADHD or ODD. In this sense, our findings are not directly generalizable to clinical samples, though a recent study in our lab has shown that children with ADHD performed more poorly than controls on tasks that loaded on the inhibitory control factor (Avila Cuenca, Félix, Parcet, Ribes, Miranda, 2001).

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