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The role of motor impulsivity in socioemotional adjustment in high-risk seven year old children and healthy controls: A follow-up study

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Título: El papel de la impulsividad motora en el ajuste socioemocional de niños de alto riesgo y de controles sanos de 7 años de edad: Un estudio de seguimiento.
Resumen: El presente estudio persigue dos objetivos: primero evaluar la presencia de alteraciones conductuales e intelectuales en niños de 7 años caracterizados como de alto riego al nacer – comparados con un grupo de controles sanos – y, segundo, y lo que es más importante, evaluar el valor discriminativo de una tarea neuropsicológica de impulsividad motora (Go/No-go) como indicador del ajuste emocional en la vida cotidiana. Se administró la Escala de Evaluación de Conducta para Niños (BASC), la Escala de Inteligencia de Weschler (WISC) y la Go/No-go a 14 niños de 7 años de alto riesgo y a 20 controles sanos. Los niños de alto riego habían sido clasificados como tales al poco tiempo de nacer, a causa de la presencia de factores de riesgo perinatal, y posteriormente dados de alta de la unidad de atención temprana. Actualmente están escolarizados conforme a su edad. Esperábamos que la ejecución en la tarea Go/No-go fuera un indicador de problemas conductuales en los niños de alto riesgo y, específicamente, de aquellos más relacionados con el ajuste socioemocional. Los niños de alto riego mostraron peores puntuaciones en la mayor parte de las subescalas del BASC y el WISC, y cometieron más errores de omisión y de comisión en la Go/No-go. Los análisis de regresión para toda la muestra mostraron que la ejecución en la Go/No-go es un predictor (independientemente del CI) de los problemas de ajuste socioemocional. Este resultado concuerda con la idea de que la impulsividad motora es un mediador importante entre el desarrollo de la función ejecutiva y el ajuste emocional.
Palabras clave: impulsividad; función ejecutiva; tarea Go/No-go; BASC; niños de alto riesgo; neuropsicología experimental.

Abstract: The main aim of the present study was two-wise: first, to assess the presence of behavioral and intellectual disturbances in high-risk 7-year-old children, compared to healthy controls; and, second, and most importantly, to evaluate the discriminative validity of a motor impulsivity neuropsychological task (Go/No-go) as an indicator of daily-life socioemotional adjustment. We administered the Behavior Assessment Scale for Children (BASC), the Weschler Intelligence Scale for Children (WISC-IV), and the Go/No-go task to 14 high-risk 7 year-olds and 20 matched healthy controls. High-risk children had been classified as so shortly after birth, due to the presence of perinatal risk factors, and later released from the early care unit. They are currently schooled according to their age. We expected performance in the Go/No-go task to be a good indicator of behavioral disturbances in high-risk children, and more specifically of those related to socioemotional adjustment. Accordingly to such a hypothesis, high-risk children showed significantly worse scores in most BASC and WISC subscales, and committed more commission and omission errors on the Go/No-go task. Most importantly, regression analyses showed that performance on the Go/No-go task (but not WISC scores) was an independent indicator of socioemotional adjustment problems. This result is in accordance with proposals that motor impulsivity is an important mediator between altered executive function development and socioemotional adjustment.
Key words: Impulsivity; executive function; go/no-go task; BASC; high-risk children; experimental neuropsychology.

Introduction

High-risk children are customarily defined as those who, due to pre-, peri- or post-natal factors, are exposed to an elevated probability of suffering difficulties or abnormalities during their psychological development. These factors include social and organic ones, as impoverished early environmental/social stimulation, drug use during pregnancy, intrauterine or postnatal infections, perinatal trauma, low weight at birth, prematurity, and hypoxia. More specifically, a risk factor would be any cause or any circumstance increasing the likelihood for a child to present subsequent abnormal communication, motor, sensory, cognitive, emotional, or behavioral skills, or a combination of them (Robles, Poo, & Poch, 2008; Pérez-López & Brito de la Nuez, 2004). These children normally receive early care but, fortunately, and despite the initial risk factors, many of them are later released without obvious symptoms of malfunctioning or disability. Still, some stay at risk of a range of subtle neurocognitive impairments (see Aylward, 2005, for a review). For example, it has been observed that preterm children, with white matter described as structurally normal by conventional MRI diagnosis, may show abnormal signal intensity later in life (Counsell et al., 2008).

Executive functions seem to be particularly sensitive to this kind of subtle neurological damage (Aaarnoudse-Moens, Duivenvoorden, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2011; Aaarnoudse-Moens, Weisglas-Kuperus, Duivenvoorden, Oosterlaan, & van Goudoever, 2013). This core set of cognitive functions are involved in flexible planning, goal pursuing, and self-regulation, and have been proven to critically depend on certain parts of the prefrontal cortices and their connections with more posterior and subcortical areas – where some functional sub-specialization has been described – (see, for example, Garavan, Ross, Murphy, Roche, & Stein, 2002; Roberts, Robbins, & Weiskrantz, 1998; Stuss & Knight, 2002).

Executive functions and their brain substrate change dramatically with age (Posner, Rothbart, Sheese, & Voelker, 2012), and are critical for social and academic adjustment

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(Rueda, Checa, & Rothbart, 2011; Sastre-Riba, Merino-Montero, & Poch-Olivé, 2007; Sastre-Riba, 2006). In addition, although executive functions do not fully develop until late adolescence or early adulthood, some of their components are operating by the end of the first year of life (Diamond, 1998). Unfortunately, research efforts on the relationship between executive functioning and abnormal development are incomplete in at least two aspects. First, although there exist many studies showing executive impairments in children with ADHD (e.g. Semrud-Clikeman, Pliszka, & Liotti, 2008), clinically significant aggressive behavior (e.g. Kockler, & Stanford, 2008), obsessive-compulsive disorder (e.g. Shin, Choi, Kim, Hwang, Kim, & Cho, 2008), autism (e.g. Happé, Booth, Charlton, & Hughes, 2006), Down syndrome (Sastre-Riba et al., 2007), and other clinical diagnoses, only a few of them focus on executive functioning development in high risk children (e.g. Aarnoudse-Moens et al., 2011, 2013; Calderon, Bonnet, Courtin, Concordet, Plumet, & Angeard, 2010; Roussotte et al., 2012) According to Johnson (2000), executive functions are particularly fragile, and their alteration – even a subtle one – in high-risk children can have an impact on the acquisition of basic skills and knowledge during the preschool age. From a practical point of view this is especially important, as the difficulties shown by some of these children are often subtle but generalized to many cognitive and behavioral domains, are not easily classifiable, and their causal connection with the original risk factors can remain obscure.

And second, when considering the impact of executive dysfunction on development, purely intellectual skills have received much more attention than socioemotional ones (see, for example, Bunge & Zelazo, 2006; Crone, Wendelken, Donohue, van Leijenhorst, & Bunge, 2006; although there are some relevant exceptions; Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Levin & Hanten, 2005; see Rueda & Paz-Alonso, 2013; Eisenberg, Smith, & Spinrad, 2011, for recent reviews), despite the fact that the latter probably have a much larger impact on children's adjustment to their social environment and their quality of life.

In the present work, we will focus on one specific aspect of executive functioning, motor control and inhibition (as measured by a lab paradigm known as Go/No-go task) and its value as discriminative indicator of socioemotional adjustment in high-risk children, as reported by their parents. The Go/No-go task is a simple reaction time task in which individuals must make a single motor response (i.e. press a key) when a certain stimulus is presented on screen and to restrain from making any response when a second, similar one, is presented, normally under time pressure conditions. In previous works with adults, we have found distinctive response patterns in this task in drug users (Verdejo-García, Perales, & Pérez-García, 2007), and high trait-impulsivity individuals from non-clinical samples (Perales, Verdejo-García, Moya, Lozano, & Pérez-García, 2009), and, in general, a number of works have found associations between performance in this task and behavioral patterns with elements of impulsiveness (e.g. Dougherty et al., 2003; Berlin & Bohlin, 2002; Fernández-Serrano, Perales, Moreno-López, Pérez-García, & Verdejo-García, 2012; see Perales et al., 2009; Spinella, 2004, for reviews). Trait impulsivity is, in turn, related to inappropriate or disruptive behavior (Muñoz, Carreras, & Braza, 2004; Pihet, Suter, Halfon, & Stephan, 2012; Romer et al., 2009).

The term *motor impulsivity* (Bechara, 2002) has been coined to differentiate impulsivity as reflected by tasks with a primary motor component (Go/No-go, Flanker task, Stop-signal, Stroop; see Spinella, 2004) from cognitive impulsivity, understood as lack of deliberation either about the presence of the conditions necessary to make a response, or about the immediate and delayed consequences of making a decision. In this sense, motor impulsivity has often been equated to 'disinhibition', referring to the idea that top-down control mechanisms ordinarily suppress automatic or prepotent responses that are not appropriate for the current demands (Aron, 2007; Simmonds, Pekar, & Mostofsky, 2008). The common view, with regard to the Go/No-go task, is that the no-go stimulus triggers some inhibitory signal that allows the individual to restrain from responding. Weakness of that signal (disinhibition) should then be associated to high rates of commission errors in lab tasks, and by extension, to impulsive behavior in daily life.

Although, according to our previous results, this account the Go/No-go task is probably too simplistic, the relationship between Go/No-go performance and impulsive-like behavior in daily life, both in clinical and non-clinical populations, stands undeniable. Multiple versions of the Go/No-go task have been used in a variety of populations and environments (see Perales et al., 2009; Chamberlain & Sahakian, 2007, for reviews), and, most interestingly, the Go/No-go task is a marker of the development of inhibitory control in children (Simpson & Riggs, 2006). In accordance with the predominant interpretation of the task, it is suggested that younger children often do respond in the no-go trials because their weak inhibitory control is insufficient to stop the prepotent response. In addition, similarly to what happens with adults, motor impulsivity in children has been linked to learning problems (Donfrancesco, Mugnaini, & Dell'uomo, 2005; Arce & Santiesteban, 2006), ADHD (Wodka et al., 2007; Rubia, Smith, & Taylor, 2007), and personality disorders (Reynolds, Ortengren, Richards, & De Wit, 2006; Chapman, Leung, Lynch, & Lynch, 2008).

In summary, there are good reasons to think that the Go/No-go task is a sensitive indicator of prefrontal/executive alterations related to behavioral control and impulsivity. Most importantly, we expect performance in the Go/No-go task to be a good indicator of behavioral disturbances in high-risk children, and more specifically of those related to socioemotional adjustment (via the connection between impulsivity and problematic behaviors).

This hypothesis is relevant in two ways. First, from a practical point of view, it is important to take into account that the children participating in the study (7 year-olds) had been long ago released from any kind of special treatment program. Although they had been monitored in a special care unit shortly after birth, due to the presence of one or more risk factors (as defined above), since then they have been considered normal, and are currently schooled in accordance with their age. The identification of executive functioning abnormalities, even if they are slight, and the corroboration that these abnormalities have detectable behavioral consequences, is crucially important to decide how high-risk children should be monitored and treated during early development.

And second, given the vast array of socioemotional adjustment and intellectual variables assessed in this study (those include in the BASC scale and the WISC-IV scale, see Method section) the identification of which of these are consistently correlated with motor impulsivity will provide a much clearer picture of what motor impulsivity is, and the role it plays in daily children's psychological functioning. Previewing the results, according to regression analyses, Go/No-go performance (at difference with purely intellectual variables as measured by the WISC scale) strongly and consistently correlated with problems in several behavioral domains related to impulse control, self-regulation, and social interaction. This finding is of special theoretical importance, as it demonstrates that the Go/No-go task is not capturing altered psychological development molarly, but a subset of aspects especially relevant for socioemotional adjustment.

Method

Participants

14 high-risk children and 20 healthy controls, matched in age and sociodemographic variables, took part in this study. The high-risk (HR) group was composed of 8 males and 6 females, with a mean age of 97 months (SD = 4.64). All of them were in primary school during the assessment period (1 in 1st grade, 10 in 2nd grade, and 3 in 3rd grade), and had been classified as high-risk children by a team including a psychologist, a pediatrician, and a neuropediatrician shorly after birth (Early Monitoring and Stimulation Unit, San Cecilio University Hospital, Granada, Spain). The reasons for being classified as high-risk were diverse: 6 of them had been given birth prematurely, 2 showed slowed psychomotor development, 1 of them showed slowed fetal growth, 1 of them showed neuroimaging abnormalilties, 1 had recovered from an episode of cot death, 1 suffered convulsions, 1 suffered a metabolic disorder, and 1 suffered respiratory distress. The clinical characteristics of the sample are described in Table 1.

On the other hand, the group of healthy controls (HC) was composed of 8 males and 12 females with a mean age of 94 months (SD = 4.08), recruited from the second grade at a primary school in Albolote, Granada (Spain).

Instruments

Go/No-go task. As noted above, the Go/No-go task is considered a marker of inhibitory control and motor impulsivity. The task consisted of 100 trials. During the first 50 trials, the child was instructed to press any key in a keyboard whenever a distinctive stimulus (a duck or a mouse in the identity version of the task, or a circle of one of two different colors, in the color version) appeared on screen, and to refrain from responding when the other stimulus of the pair (the other animal or the other color) was presented. After the 50th trial, a distinctive sound warned the child that the criterion had changed, in such a way that the 'go' stimulus became the 'no-go' one, and vice versa. In both phases (pre- and post-shift) half of the trials were 'go' and the other half 'no-go' ones. The inter-stimulus interval (ISI) was set at 900 ms, and each stimulus was presented during 1000 ms. Auditory feedback (one of two distinctive sounds) was provided after each response to indicate whether that response had been right or wrong. Half of the children received the identity version of the task, and the other half the color version. The assignation of stimuli to the go and no-go conditions was balanced.

Table 1. Clinical data for the High-risk children group.

Variable	*Mean*	*SD*	*n*
Gestational age	36.07	4.14	
Weight at birth (g)	2537.50	922.15	
Height at birth (cm)	46.12	5.36	
Head diameter at birth (cm)	32.33	4.32	
Apgar test (1 min.)	6.40	2.12	
Apgar test (5 min.)	7.90	1.90	
Duration of stay in the unit (days)	13.88	8.29	
Birth type			
Normal			5
Cesarean			9
Neurological problems (severity)			
None			2
Low			8
Moderate			1
High			0
Highest			0
Unknown			3
Admission diagnosis			
Preterm birth			6
Neuroimaging abnormalities			1
Slow intrauterine growth			1
Psychomotor retardation			2
Cot death incident			1
Metabolic disorder			1
Respiratory distress			1
Convulsions			1
Release diagnosis			
Preterm birth			6
Neuroimaging abnormalities			1
Slow intrauterine growth			2
Abnormal muscular tone			2
Cot death incident			1
Congenital metabolopathy			1
Convulsions			1

BASC (Behavior Assessment System for Children). This toolkit (Reynolds & Kamphaus, 1992 [2004]) assesses a number of behavioral dimensions in children and adolescents, by means of several multi-item Likert-type scales. Although the instrument includes scales for parents (P), teachers (T) and other tools for observation and self-report, all of them can be administered separately. Only the P scale (for parents) was used in the present work. This allows to assess Adaptability (e.g. *the child adjusts well to family plans*, *recovers quickly after a setback*), Agression (*hits other children*, *seeks revenge*), Anxiety (*is nervous*, *worries about making mistakes*), Attention problems (*listens to directions*, *pays attention*), Atypicality (*acts strangely*, *sees things that are not there*), Conduct problems (*lies out of troubles*, *deceives others*), Depression (*is sad*, *seems lonely*), Hyperactivity (*cannot wait to take turn*, *acts out of control*), Leadership (*gives good suggestions for solving problems*, *is good at getting people to work together*), Social skills (*compliments others*, *offers help to other children*), Somatization (*has stomach problems*, *complains of being sick when nothing is wrong*), and Withdrawal (*avoids other children*, *does not join group activities*). Several composite measures were computed from these sub-scales: Internalizing problems (Anxiety, Depression, Somatization), Externalizing problems (Hyperactivity, Aggression, Conduct problems), and Adaptive skills (Adaptability, Social Skills, Leadership). So, 15 measures (3 of them composite) were obtained for each child.

WISC-IV (Weschler Intelligence Scale for Children, version IV). This is most recently updated version of the Wechsler scales for children (WISC, WISC-R and WISC-III, Weschler, 2005). It provides information on the child's overall intellectual capacity (Total IQ) and on his performance on four major factors of intelligence (Verbal comprehension, Perceptual reasoning, Working memory, and Processing speed). The scale contains 15 subtests, 10 compulsory and 5 optional. In the last version, 5 new tests have been included (Animals, Riddles, Matrices, Concepts, and Letters and Numbers) and 3 have been removed (Mazes, Puzzle, and Comics). All materials have also been renovated, and contents of the subtests have been reviewed and updated in accordance with social changes and recent research advances. The Spanish version has been validated with a sample of 1590 children, which allows 33 age groups for referencing (in 4-month intervals).

Procedure

Selection of HR children from the special care unit was made incidentally, among children born between September 1, 1998 and the end of 1999. The parents of all the children were first contacted by mail, and then telephonically, to be informed about the aims of the study. Finally, a date was arranged with each of the families to discuss the issue personally, and informed consent was obtained.

Individual assessments were carried out on the Special Care Unit facilities, by one Psychologist with an MD in Clinical Psychology. WISC and Go/No-go tasks took between 2 and 3 hours per child, breaks included (these were arranged individually). While the child was being assessed, and after being instructed, the parents filled the BASC-P scale in another room.

Recruiting for the healthy controls' group was made with the informed consent of the school board of the *Tinar* Infant and Primary School (Albolote, Spain). For assessment, children were called to the school's counselor one by one during regular class activities. Assessment was carried out by the same evaluator, and following the same protocol as in the HR group. The parents of these children were contacted and instructed to fill the BASC-P scale at home, which was later collected by the teachers and handed to the evaluator. An individual report on the results of the assessment was made for each child, for the teachers' and school's records.

Analysis rationale

First, in order to properly characterize the differences between the two groups of participants, from the behavioral and intellectual point of view, T-scores from HR and controls in the 15 (previously described) sub-scales of the BASC were submitted to a MANOVA with Group (high risk children, HR; age-matched controls) as the independent factor and the 15 BASC typical scores as dependent variables. Independent one-way ANOVAs, with Group as the independent variable, were also carried out over each of the 15 BASC typical scores. The same analysis procedure (global MANOVA plus independent ANOVAs) was also followed with the 5 WISC scores (Total IQ, Verbal comprehension, Perceptual reasoning, Working memory and Processing speed).

Secondly, performance measures from the Go/No-go tasks were included in a series of ANOVAs with Group (HR; controls) as the main independent variable. False alarm rates (f), hit rates (h), and hit latencies were calculated for each 10 trial block in the Go/No-go task. Hit rate, h, was computed as the ratio between the number of hits (correctly responded Go trials) and the number of Go trials (hits + misses) in a block. False alarm rate, f, on the other hand, was computed as the ratio between the number of false alarms (incorrectly responded No-go trials), and the total number of No-go trials (false alarms + correct rejections) in a block. Corresponding Group x Block ANCOVAs on the three measures were also carried out with the total WISC score (IQ) as the only covariate.

And third, and most importantly, scores in the different sub-scales of the behavioral problems questionnaire (BASC) were regressed over Go/No-go pre-shift false alarm and hit rates, Go/No-go post-shift false alarm and hit rates, and WISC total IQ score, for the two groups together. Pre-shift hit and false alarm rates were computed over the 50 trials in the first five blocks of the Go/No-go task (preceding the response assignation shift), whereas post-shift hit and false rates were computed over the 50 trials posterior to the response assignation shift (blocks 6 to 10). Separate linear regression analyses were carried out for pre-shift and post-shift rates, in order to avoid correlations among variables beyond the colinearity tolerance level. The aim of this series of analyses was to corroborate whether the Go/No-go task can signal behavioral problems, independently of general cognitive deficits detected by the WISC scale.

Results and interpretation

BASC and WISC scores in HR children and controls

T-scores were obtained for each child in each of the following BASC-P (parents) sub-scales: Aggression, Hyperactivity, Conduct problems, Attention problems, Atypicality, Depression, Anxiety, Withdrawal, Somatization, Adaptability, Social Skills, Leadership, Externalizing problems (Externalization), Internalizing problems (Internalization), and Adaption skills. A MANOVA was carried out over all of them, with Group (HR, controls) as the independent variable. Mean scores for each group and each dependent variable are displayed in Table 2 (top panel).

Such a MANOVA yielded a main significant effect, Wilks' *lambda* < .001, $F(15, 18) = 3.511$, $p < .001$, of the grouping factor. Results of independent ANOVAs on each dependent measure are displayed in Table 2 (top panel). As can be readily seen, the effect of group was significant on all measures except Anxiety, Withdrawal, and Somatization. The difference was marginally significant for Internalizing problems as a whole. For all significant differences, scores were worse (higher for negative traits, lower for positive traits) for HR children than for controls.

An equivalent MANOVA was carried out on the five scores of the WISC test. As expected, this yielded a significant main effect of Group, Wilks' *lambda* < .428, F(5, 28) = 7.473, $p < .001$. Results of independent ANOVAs on each dependent measure are displayed in Table 2 (bottom panel). The effect of group was significant on the 4 sub-scales, and IQ, with HR children showing worse scores than controls.

Go/no-go performance in HR children and controls

Hit rates. The Group (HR, controls) x Block (1-10) ANOVA on hit rates, *h*, yielded significant effects of Block, $F(9, 270) = 4.50$, $MSE = .025$, $p < .001$, Group, $F(1, 30) = 4.30$, $MSE = .063$, $p = .047$, and the Group x Block interaction, $F(9, 270) = 1.97$, $MSE = .025$, $p = .044$. As displayed on Table 3, *h* grew across blocks for the two groups, and was globally higher for controls (although the response assignation shift in Block 6 produced an abrupt decay in the control group that was not evident in the HR group). Partial tests (LSD) showed that the group effect was significant only in the first block, and marginally significant in the second one ($p = .063$), which means that the performance improvement for the control group was faster than for the HR group.

An equivalent ANCOVA with the same design, and global WISC IQ as covariate made all effects but the one of Block [$F(9, 161) = 1.99$, $MSE = .025$, $p = .041$] disappear ($F \leq 1$ for the two previously significant effects). This an strong association between general cognitive functioning and motor impulsivity (as measured by hit rates in the Go/No-go task) in this sample of children that makes the effect of group on one measure non-differentiable from the effect on the other one.

Table 2. Mean, *SD* for the two groups of children (HR, Controls) in each of the 15 BASC sub-scales (typical scores), and each of the 5 WISC scores. *MSE*, *F*, and *p* are reported for each ANOVA involving the independent factor Group and each of the dependent variables.

	Sub-scale	Group	*Mean*	*SD*	*MSE*	*F*	*p*
	Agression	HR	57.21	16.72	181.23	5.77	.022
		Controls	45.95	10.67			
	Hyperactivity	HR	60.14	17.39	155.72	13.44	.001
		Controls	44.20	7.45			
	Conduct problems	HR	67.07	14.58	13.19	18.87	.000
		Controls	49.80	8.59			
	Attention problems	HR	64.57	12.33	14.18	23.20	.000
		Controls	44.70	11.49			
	Atypicality	HR	54.36	10.47	65.58	12.96	.001
		Controls	44.20	5.95			
	Depression	HR	56.50	13.05	106.58	8.44	.007
		Controls	46.05	7.93			
BASC	*Anxiety*	HR	50.93	8.25	53.60	.02	.885
		Controls	51.30	6.61			
	Withdrawal	HR	49.93	13.53	93.15	3.38	.075
		Controls	43.75	5.62			
	Somatization	HR	47.29	13.26	96.48	1.83	.185
		Controls	42.65	6.49			
	Adaptability	HR	47.71	1.90	78.96	7.33	.011
		Controls	56.10	7.19			
	Social skills	HR	45.07	9.79	93.55	11.20	.002
		Controls	56.35	9.59			
	Leadership	HR	44.57	6.98	58.79	15.23	.000
		Controls	55.00	8.10			
	Externalization	HR	63.57	17.03	165.91	15.76	.000
		Controls	45.75	9.00			
	Internalization	HR	53.21	13.26	91.79	4.04	.053
		Controls	46.50	5.85			
	Adaption skills	HR	45.29	7.56	61.71	19.10	.000
		Controls	57.25	8.05			
	Verbal comprehension	HR	75.86	13.59	235.26	3.04	.000
		Controls	105.15	16.43			
	Perceptual reasoning	HR	83.21	18.84	27.00	14.15	.001
		Controls	104.75	14.55			
WISC	*Working memory*	HR	82.50	19.54	319.10	17.11	.000
		Controls	108.25	16.62			
	Processing speed	HR	86.93	18.66	20.06	15.85	.000
		Controls	106.55	9.94			
	IQ	HR	75.57	18.22	275.19	29.28	.000
		Controls	106.85	15.37			

False alarm rates. The same Group x Block ANOVA on false alarm rates, *f*, yielded a significant effect for Group only, $F(1, 30) = 13.28$, $MSE = .34$, $p = .001$. Partial tests (LSD) showed this difference to be significant for blocks 2, 3, 4, 5, 7, 8, 9, and 10. Seemingly, the response assignation shift just before Block 6 produced a local increase in *f* in the control group, which made the difference between the two groups temporarily disappear. Jointly, then, the two analyses reveal that controls were more sensitive to the response criterion shift that HR children (probably because controls were faster to transfer performance to an automatic, non-controlled mode).

Table 3. Mean and Standard Deviation (*SD*) for hit rates (h), false alarm rates (f), and hit latencies for each Block (1-10) x Group (HR, Controls) condition.

		h		f		hit latency	
		mean	*SD*	*mean*	*SD*	*mean*	*SD*
Block 1	HR	.67	.32	.26	.32	930	379
	Control	.87	.20	.18	.17	832	230
Block 2	HR	.79	.26	.35	.24	1170	546
	Control	.93	.15	.14	.18	813	310
Block 3	HR	.90	.17	.38	.37	1031	398
	Control	.96	.12	.12	.17	817	265
Block 4	HR	.93	.16	.49	.41	801	310
	Control	.97	.09	.10	.18	723	192
Block 5	HR	.86	.29	.34	.30	615	256
	Control	.96	.09	.10	.13	784	286
Block 6	HR	.92	.14	.39	.38	820	341
	Control	.84	.25	.23	.22	816	229
Block 7	HR	.90	.20	.33	.36	780	266
	Control	.98	.06	.04	.08	751	226
Block 8	HR	.97	.10	.33	.38	801	386
	Control	.99	.06	.06	.13	825	260
Block 9	HR	.95	.18	.33	.39	814	443
	Control	.95	.14	.09	.15	759	166
Block 10	HR	.93	.11	.35	.36	770	342
	Control	.97	.09	.11	.19	802	256

As in the previous analysis, the equivalent ANCOVA, with WISC global IQ score as covariate made the effect of Group vanish, $F(1, 29) = 2.89$, $MSE = .331$, $p = .091$. Our interpretation is similar to the one given for hit rates.

Hit latencies. Response latencies are reported for hits, but not for false alarms, as there were no false alarms in a number of blocks, which produces a significant impoverishment of data. The Block x Group ANOVA on hit latencies yielded significant effects of Block, $F(9, 270) = 3.76$, $MSE = 62423.389$, $p < .001$, and, more interestingly, Block x Group, $F(9, 270)=2.61$, $MSE = 62423.389$, $p = .007$. Non-corrected partial tests (LSD) showed a significant difference between groups for block 2 ($p = .027$), and a marginally significant one for block 3 ($p = .078$). In other words, controls were faster than HR children in the beginning of the task, and reaction times became more similar as the task progressed.

As in previous analyses, when WISC global IQ was introduced as a covariate in the Group x Block design, the effect of Group and the Group x Block interaction disappeared (all Fs < 1).

Relationship between Go/No-go performance and BASC scores

In this section we go a step beyond in the exploration of common neuropsychological factors to the behavioral problems observed in the sample of HR children. As mentioned above, the Go/No-go task is interpreted as a neuropsychological marker of prefrontal functioning, and more specifically, of the integrity of the neural mechanisms necessary to inhibit inappropriate prepotent behaviors. Our prediction is thus that Go/No-go performance will be a factor significantly contributing to socioemotional adjustment, independently of its association with intellectual deficits in the sample selected for this study.

In order to test that hypothesis, we carried out two regression analyses for each BASC sub-scale. In the first of them, the corresponding BASC *T*-score was regressed over the rates of hits and false alarms in the 50 trials prior to the response criterion shift in the Go/No-go task, and the Total IQ score from WISC[1]. In the second one, the pre-shift Go/No-go scores were replaced by post-shift scores.

Results of the described series of regression analyses are reported in Tables 4.1., 4.2., and 4.3. When Go/No-go pre-shift scores were used as predictors (left panel in Tables 4.1.-4.3.), hit rate (*h*) was independently predictive of Aggression, Hyperactivity, Adaptability, and the composite measure Externalizing problems. Note however, that in all of these cases a larger hit rate predicts worse BASC scores (larger scores in negative traits, and smaller ones in positive traits). This can seem paradoxical, unless the hit rate is considered along with the false alarm rate. *f* is independently predictive of Aggression, Atypicality, Withdrawal, Adaptability, and the composite measure Adaption skills. In all cases, a larger false alarm rate predicts worse BASC scores (larger scores for negative traits and smaller scores for positive ones). This pattern indicates that children with worse BASC scores, and particularly those with higher scores in aggression and lower adaptability, tend to respond more often in the Go/No-go task. In other words, more aggressive and less adapted children are more likely to press the key (make the response) both in go and no-go trials, which lead them to make less omissions, but also more commissions than controls.

As described in a previous section, in the second half of the task (and despite a local decrement due to the response shift), controls tend to reach a certain level of proficiency, with maintained low false alarm rates (f) and high hit rates (h). HR children, on the other hand, come neck to neck with controls (and close to ceiling) in terms of hit rates, but keep on committing a large number of false alarms. In consonance with that, we expected hit rates to become unrelated to BASC measures in the second part of the task (as most children show rather high hit rates), whereas false alarm rates should keep on being highly predictive of an array of

1 We carried out equivalent analyses introducing the 4 WISC sub-scores (Verbal comprehension, Perceptive reasoning, Working memory, and Processing speed) instead of Total IQ score. The results observed were mostly equivalent to the ones reported here. We kept the three-independent-variable (*h*, *f*, *IQ*) for two reasons. First, for the sake of simplicity; and second, because splitting IQ in its several component measures weakens its predictive value with regard to socioemotional adjustment, which would give the non-realistic impression that intellectual functioning is completely unrelated to socioemotional adjustment.

Table 4.1. Results of regression analyses of the first 5 BASC subscales' scores. The left panel displays regression of BASC scores over the total IQ as measured by WISC, and pre-shift measures of the Go/No-go task. The right panel displays regression of BASC scores over the total IQ as measured by WISC and post-shift measures of the Go/No-go task. Non-standardized (*B*) and standardized (*β*) regression coefficient, *t* value, and significance level (*p*) are reported for each linear regression analysis.

	regressed over	*B*	*β*	*t*	*p*	*regressed over*	*B*	*β*	*t*	*p*
Agression	IQ	-.22	-.36	-1.84	.077	IQ	-.02	-.03	-.14	.890
	h (pre-shift)	77.66	.67	3.25	**.003**	h (post-shift)	29.48	.15	.82	.418
	f (pre-shift)	35.57	.55	2.72	**.011**	f (post-shift)	27.67	.50	2.42	**.022**
Hyperactivity	IQ	-.48	-.74	-4.17	**.000**	IQ	-.24	-.37	-1.86	.073
	h (pre-shift)	71.73	.63	3.34	**.002**	h (post-shift)	21.22	.10	.60	.555
	f (pre-shift)	14.80	.22	1.19	.243	f (post-shift)	15.70	.34	1.49	.178
Conduct Problems	IQ	-.36	-.58	-3.15	**.004**	IQ	-.31	-.50	-2.78	**.010**
	h (pre-shift)	18.39	.17	.86	.399	h (post-shift)	25.20	.12	.83	.415
	f (pre-shift)	16.44	.25	1.33	.195	f (post-shift)	15.93	.29	1.64	.113
Attention problems	IQ	-.410	-.62	-3.20	**.003**	IQ	-.22	-.33	-.1.76	.088
	h (pre-shift)	36.15	.31	1.50	.145	h (post-shift)	-35.03	-.16	-1.03	.313
	f (pre-shift)	13.86	.20	1.00	.327	f (post-shift)	16.58	.28	1.52	.140
Atypicality	IQ	-.21	-.50	-2.70	**.012**	IQ	-.12	-.30	-.82	.079
	h (pre-shift)	21.77	.30	1.51	.142	h (post-shift)	30.49	.23	1.67	.108
	f (pre-shift)	13.37	.40	2.09	**.046**	f (post-shift)	21.05	.57	3.59	**.001**

Table 4.2. Results of regression analyses of the second 5 BASC subscales' scores. All other parameters are equivalent to the ones in Table 4.1.

	regressed over	*B*	*β*	*t*	*p*	*regressed over*	*B*	*β*	*t*	*p*
Depression	IQ	-.17	-.34	-1.55	.131	IQ	-.08	-.16	-.84	.410
	h (pre-shift)	17.12	.20	.85	.404	h (post-shift)	34.29	.21	1.28	.211
	f (pre-shift)	14.27	.28	1.22	.231	f(post-shift)	21.52	.49	2.51	**.018**
Anxiety	IQ	-.03	-.09	-.36	.720	IQ	.02	.08	.34	.739
	h (pre-shift)	-1.66	-.03	-.12	.908	h (post-shift)	2.21	.02	.11	.913
	f (pre-shift)	-1.61	-.05	-.20	.846	f(post-shift)	7.83	.28	1.22	.233
Withdrawal	IQ	-.08	-.18	-.88	.39	IQ	.04	.10	.61	.546
	h (pre-shift)	11.12	.14	.67	.508	h (post-shift)	1.27	.01	.07	.947
	f (pre-shift)	23.03	.51	2.41	**.023**	f(post-shift)	31.23	.81	5.18	**.000**
Somatization	IQ	-.12	-.28	-1.20	.239	IQ	.00	.00	.02	.980
	h (pre-shift)	23.38	.30	1.23	.230	h (post-shift)	-1.63	-.01	-.06	.952
	f (pre-shift)	8.15	.18	.74	.464	f(post-shift)	13.56	.35	1.56	.129
Adaptability	IQ	.19	.46	2.34	**.027**	IQ	.06	.14	.79	.434
	h (pre-shift)	-37.25	-.51	-2.44	**.021**	h (post-shift)	-39.00	-.29	-1.94	.062
	f (pre-shift)	-18.27	-.43	-2.07	**.047**	f(post-shift)	-22.60	-.61	-3.53	**.001**

Table 4.3. Results of regression analyses of the third 5 BASC subscales' scores. All other parameters are equivalent to the ones in Table 4.1.

	regressed over	*B*	*β*	*t*	*p*	*regressed over*	*B*	*β*	*t*	*p*
Social skills	IQ	.25	.53	2.88	**.008**	IQ	.24	.51	2.80	**.009**
	h (pre-shift)	-17.48	-.21	-1.07	.293	h (post-shift)	-30.68	-.20	-1.30	.203
	f (pre-shift)	-16.70	-.340	-1.78	.087	f(post-shift)	-11.16	-.26	-1.49	.149
Leadership	IQ	.15	.38	1.98	.057	IQ	.17	.44	2.29	**.030**
	h (pre-shift)	9.16	.13	.65	.519	h (post-shift)	-3.42	-.03	-.17	.869
	f (pre-shift)	-7.37	-.18	-.81	.370	f(post-shift)	-7.36	-.21	-1.12	.274
Externalization	IQ	-.42	-.62	-3.41	**.002**	IQ	-.23	-.34	-1.78	.086
	h (pre-shift)	64.65	.54	2.78	**.010**	h (post-shift)	31.05	.14	.87	.390
	f (pre-shift)	26.92	.38	2.00	.055	f(post-shift)	23.82	.39	2.10	**.045**
Internalization	IQ	-.15	-.33	-1.47	.152	IQ	-.03	-.06	-.30	.768
	h (pre-shift)	18.86	.24	1.00	.324	h (post-shift)	15.45	.11	.61	.547
	f (pre-shift)	9.53	.21	.88	.386	f(post-shift)	18.96	.48	2.34	**.027**
Adaption skills	IQ	.23	.56	3.24	**.003**	IQ	.18	.44	2.75	**.010**
	h (pre-shift)	-17.89	-.25	-1.34	.190	h (post-shift)	-27.74	-.21	-1.54	.135
	f (pre-shift)	-16.81	-.39	-2.19	**.037**	f(post-shift)	-16.52	-.45	-2.87	**.008**

behavioral deficits. Actually, when post-shift Go/No-go scores were introduced in the regression analyses (instead of pre-shift ones), *f* resulted to be independently predictive of Aggression, Atypicality, Depression, Withdrawal, Adaptability, Externalizing and Internalizing problems, and Adaption skills. With the exception of depression and internalizing problems, these measures are the same observed to be predicted by pre-shift Go/No-go performance. Again, in all cases, a higher false alarm rate predicted worse BASC scores. The hit rate, on the other hand, became (as expected) non-predictive of any BASC score.

In relation to this, it is important to note that these effects are independent of purely intellectual measures. Obviously, Total IQ predicted some dimensions of socioemotional adjustment. Hyperactivity, Conduct and Attention problems, Atypicality, Adaptability, Leadership, Social skills, and Adaption skills independently correlated with IQ in at least one of the two regression analyses. However, the match between these dimensions and the ones predicted by Go/No-go performance was quite loose. Externalization, aggression, withdrawal and, to a lesser degree, depression and internalization problems, were predicted by Go/No-go performance, but not by IQ. And the other way round, Conduct problems, attention problems, social skills and leadership were predicted by IQ, but not by Go/No-go performance. As we will discuss later, *Go/No-go seems to specifically predict those dimensions most directly related to impulse control and emotion regulation*.

On the other hand, although controlling for WISC measures (by using ANCOVA) eliminated all differences between HR children and controls (see previous section), including the same scores do not hamper predictive validity of Go/No-go measures in regression analyses when all children are considered together. Moreover, whereas hit rate is lower for HR children than for controls in one-factor ANOVAs, once WISC factors are controlled for, hit rate – in the same direction as false alarm rate –, is positively correlated with behavioral disturbances. In other words, the predictive value of Go/No-go measures is mostly independent of the differences found between groups.

General Discussion

The HR children in our study keep on showing emotional and cognitive disturbances long after being released from any kind of special treatment or monitoring unit. All WISC scores are consistently lower in these children, and the prevalence of socioemotional adjustment problems is higher in most of the variables assessed. Poorer scores are also evident in a so-called motor impulsivity task (Go/No-go).

These results have important and straightforward practical implications. Given the clear statistical (although not necessarily clinical) significance of the differences between the two groups, and their permanence as late as after 7 years after birth, our results call the need to monitor HR children's development even when symptoms of abnormal neurological development are not evident during the first months or years after birth. Rather likely, subtle abnormalities gain importance as the brain develops, and higher functions are assembled and coordinated with the critical participation of the most complex and richly connected areas of the brain (Aarnoudse-Moens et al., 2011; Beauchamp et al., 2011; Crove, Catroppa, Babl, & Anderson, 2013). However, given the variety of etiologies that define high-risk, it is difficult to go beyond this conclusion by looking into between-groups differences only.

Analyzing the pattern of correlations among the measures under study is crucial to understand the mechanisms by means of which socioemotional disturbances are linked to brain development. According to regression analyses, *purely intellectual variables, as measured by the WISC scale are insufficient to account for the variability seen in socioemotional adjustment*. The present work clearly identifies a neurocognitive marker than could be directly related to socioemotional adjustment. Previous works have administrated the Go/No-go task to measure impulsivity or lack of self-control both in older and younger individuals (e.g. Dougherty et al., 2003; Berlin & Bohlin, 2002; see Duckworth & Kern, 2011, for a review), and have shown that motor impulsivity tasks are more reliable indicators of impulsivity in daily life than other cognitive tasks (Spinella, 2004). However, the present study is the first to include healthy controls and HR children in a single sample, which has the advantage of introducing enough variability in the sample to boost the predictive value of the variables under study.

The main conclusion to be drawn from our results is that the Go/No-go task (once the variability accounted by global intellectual functioning is disregarded) is independently predictive of a subset of variables related to socioemotional problems, all of them directly related to impulse control, and emotional self-regulation. Only conduct problems, attention problems, somatization, anxiety, social skills, and leadership appear as independent of all pre- and post-shift Go/No-go measures. The absence of a linkage between the Go/No-go task and anxiety contrasts with previous reports (Arce & Santisteban, 2006; López-Villalobos, Serrano-Pintado, & Delgado-Sánchez-Mateos, 2004), although, very probably, anxiety and depression are only secondarily linked to other regulation problems evaluated here. Adaptability, Aggresion, Atypicality, Withdrawal, Externalizing problems, and Adaption skills, on the other hand, are strongly linked to, at least, two of the four Go/No-go indices (pre-shift *h* and *f*, and post-shift *h* and *f*).

With regard to the validity of the BASC scale, it is important to note that the predictive value of Go/No-go performance is not equally high for all sub-scales. Crucially, false alarms and, in a lesser degree, hits, are predictive of externalizing problems and adaption skills (two of the composite scores) and the subscores related to them, but more weakly predictive of internalizing problems. In other words, in accordance with common idea of motor impulsivity, Go/No-go performance is neuropsychologically linked to positive signs of lack of behavioral control and emotion regulation, and, probably only in a deferred way, to mood and anxiety problems.

In general, false alarms (*f*) are more predictive of socioemotional problems than hits (*h*). However, taking hits into account is crucial to understand the meaning of Go/No-go performance. The customary interpretation of the failure to perform at a normal level in the Go/No-go task is that some inhibitory process triggered by the No-go stimulus is absent or weak, which leads to disinhibition. In accordance with this, children have more difficulties to inhibit responses in the no-go stimulus, show higher levels of activation in posterior areas of the brain than adults, and show larger and more variable reaction times in false alarms (Ciesielski, Harris, & Cofer, 2004; Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002). Our results, however, show a more complex picture: HR children not only show a higher false alarm rate, but also a lower hit rate, and longer latencies for hits, not only for false alarms. This between-groups difference is however explained away by covariates, which probably means that can be mostly accounted by a lack of discrimination due general cognitive development deficits. When the value of Go/No-go indices is however analyzed independently of group, these remain predicitive, but in a sense not completely compatible with the customary account. Not only false alarms (*f*) but also hit rates (*h*) are directly correlated with socioemotional disturbances, and, most importantly, both correlations are in the same direction. To put it in simple words, *socioemotional disturbances seem to be associated to a 'worse' performance in terms of false alarms, but to a 'better' performance in terms of hits* (see Perales et al., 2009; and Torres et al., 2013, for similar patterns of results in adults).

Our results are thus compatible with the existence of a double mechanism for motor inhibition (see De Jong, Coles, and Logan, 1995; although see also Band & Van Boxtel, 1999). One is selective and stimulus-dependent, and mostly corresponds to the one customarily hypothetized one; the second, however, is exerted both in Go and No-go trials and is responsible for retaining *any* response until the necessary conditions for releasing it are present. Disinhibition at this level would be equivalent to lower the level of activation generated by the decision mechanism necessary to respond.

Although our explanation is still tentative, our data in children and adults are highly compatible. The difficulties of people with impulsive or inappropriate behavior probably originate at the level of decision-making and affect all decisions, not only those to be made in the presence of No-go stimuli, which explain why impulsive people actually show slower decisions than controls (Torres et al., 2013). Disinhibition then results from an attempt by the individual to reach an acceptable level of hits and shorter latencies, by lowering the level of non-selective control over response releasing. In fact, this non-specific disinhibition is more compatible with the vast array of socioemotional disturbances seen than specific stimulus-dependent disinhibition.

Obviously, the results of our single study must be taken cautiously. The recruiting procedure and the long follow-up necessarily impose a limit on the size of the available sample. This is especially important for regression analyses, and the possibility exists that new significant factors could emerge if larger samples were used. Further research is probably required.

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