Assessment of the global intelligence and selective cognitive capacities in preterm 8-year-old children

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The aim of this study was to assess various cognitive abilities such as attention, IQ, reasoning, and memory related to academic achievement in 8- and 9-year-old preterm children. A total of 141 children were assessed. The preterm group (= 37 weeks) comprised 63 children and was compared to 78 full-term children. Attention was evaluated using the d2 Selective Attention test, and the IQ by the L-M form of the Stanford-Binet Intelligence Scale, establishing a profile of abilities: perception, memory, comprehension, reasoning, and verbal fluency. Significant differences in IQ were found between the preterm and full-term children. Of the cognitive abilities assessed, the only significant differences were found in verbal fluency, with preterm boys showing lower verbal fluency scores than full-term children. In conclusion, all preterm groups have attention ability similar to that of full-term children. However, preterm children obtain lower scores in intelligence measures. In addition, preterm boys have verbal fluency difficulties. Taking into account the increase in preterm births, suitable intervention programs must be planned to attend the difficulties found.

Evaluación de la inteligencia y capacidades cognitivas específicas en niños prematuros de 8 años de edad. El objetivo de este estudio fue evaluar diferentes habilidades cognitivas tales como la atención, cociente intelectual, razonamiento y memoria relacionadas con el rendimiento académico en niños prematuros de 8 y 9 años de edad. Se evaluaron un total de 141 niños. El grupo de prematuros (= 37 semanas) estaba compuesto por 63 sujetos y se comparó con 78 niños nacidos a término. La atención fue evaluada con la prueba D2 de atención selectiva, y el cociente de inteligencia con la forma de LM de la escala de inteligencia del Stanford-Binet, estableciendo un perfil de habilidades: percepción, memoria, comprensión, razonamiento y fluidez verbal. Se encontraron diferencias en el cociente intelectual entre los niños prematuros y los nacidos a término. De las habilidades cognitivas evaluadas, se encontraron diferencias en la fluidez verbal, donde los niños prematuros mostraron puntuaciones más bajas. En conclusión, los prematuros tienen una capacidad de atención similar a los niños a término pero obtienen puntuaciones menores en las medidas de inteligencia. Además, los niños prematuros tienen dificultades en la fluidez verbal. Considerando el aumento en los nacimientos prematuros, deberían organizarse programas de intervención adecuados para asistir a las dificultades encontradas en esta población.

In the last few decades, the high prevalence of preterm children in western countries has increased considerably. According to the National Vital Statistics Reports, the rate of preterm births (<37 weeks gestation) in the USA increased to 12.7% in 2007 (Hamilton, Martin, & Ventura, 2009). Likewise, in Spain, the preterm birth rate has doubled in the last ten years with a quantity 9% of the total of births in that same year (Consejería de Vivienda y Bienestar Social, 2005). As a consequence of the premature birth, cerebral development is impaired. These preterm children have an increased risk of disabilities such as moderate mental retardation, cerebral

palsy, accompanied in most cases by respiratory problems, apnea, intraventricular hemorrhages, anemia, motor retardation, and visual problems (Aylward, 2005; Kumar & Suresh, 2008; Ricci et al., 2008; Skrablin, Maurac, Banovic, & Bosnjak-Nadj, 2009). In addition, school problems are frequently reported in these children. These problems are associated with neuromotor problems, delayed cognitive process, speech/ language delay or behavioral problems. Likewise, it has been shown that these difficulties are especially noticeable in the so-called very low birth weight (VLBW; weight ≤1500 g) and extremely low birth weight (ELBW; weight ≤1000 g) preterm children, and is more pronounced when the preterm children start school (Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Böhm, Smedler, & Forssberg, 2004). But we still do not know whether prematurity affects general cognitive functioning or specific abilities. Hoff, Hansen, Gresien, & Mortensen (2006) have found that 5-year-old ELBW children and extremely preterm children display cognitive difficulties related to global intellectual

deterioration instead of specific cognitive alterations. But executive functions and memory process can also be affected by prematurity. Bayless & Stevenson (2007) found poorer performance in executive functioning in children between 6-12 years of age. Their capacity to switch or shift and their response inhibition were also affected, in addition to having a lower Intelligence Quotient (IQ). Also, some studies have shown that preterm children are more vulnerable to difficulties in attention process. It has been shown that these children display a lower IQ, excessive distraction, and difficulties to maintain the tone of attention (Bayless, Pit-ten Cate, & Stevenson, 2008; Pritchard, Clark, Liberty, Champion, Wilson, & Woodward, 2009; Shum, Neulinger, O'Callaghan, & Mohay, 2008). Studies like those of Wocadlo & Rieger show that 8-year-old children with antecedents of prematurity have difficulties in academic abilities such as reading, phonological processing, orthography, and mathematics even when their intelligence is within the normal values (Wocadlo & Rieger, 2007). These reading difficulties could be related to the alteration of complex cognitive abilities such as phoneme and word recognition, together with the impairment of attention and memory. These difficulties could persist in adolescence and adult life (Narberhaus et al., 2007; Saavalainen et al., 2006; Tideman, 2000). Narberhaus et al., (2007) administered the Weschler Intelligence Test for Children (WISC-R) and for Adults (WAIS-III) to adolescents between 11 and 18 years of age. In this study, although preterm children attained appropriate IQ scores, a lower total IQ in preterm children was found compared to children born at full-term, and also a lower verbal and manipulative IQ in the case of the preterm children.

We currently do not yet know whether prematurity affects global cognitive functioning or exclusively the attention process. Moreover, most of the studies about the effects of prematurity have focused on so-called very preterm children (<1500 g) compared to full term children. However, the inclusion in these studies of late preterm or moderately low birth weight children has recently been recommended. Stein, Siegel & Bauman (2006) indicate that these moderately low-weight children (1500-2499 g) can also have learning alterations and attention disorders. In addition, significant clinical behavioral problems and learning difficulties were found in these children at school age (Huddy, Johnson, & Hope, 2001; Morse, Zheng, Tang, & Roth, 2009).

Other studies have shown that preterm children have problems in linguistic abilities. It has been observed that full-term children show linguistic difficulties at school age, but these problems are even more pronounced in low birth weight (LBW) and VLBW children (Ortiz-Mantilla, Choudhury, Leevers, & Benasich, 2008). VLBW and LBW children obtain lower scores than full-term children in linguistic tasks. Also, VLBW girls obtain higher scores than VLBW boys in SB-4 verbal reasoning (Ortiz-Mantilla et al., 2008). In studies like that of Hindmarsh, Callaghan, Mohay & Rogers (2000), in which the Griffiths scale was administered to 2-year-olds, it was observed that the girls presented a higher score in the general quotient on this scale than the boys. Moreover, the girls scored higher in language-related skills (hearing and speech).

The primary goal of this study was to assess the effect of prematurity on basic cognitive abilities such as intelligence and attention in 8- to 9-year-old children. For this purpose, we employed for the first time the d2 Selective Attention test, a cancellation task of attention, in preterm children. The secondary goal was to determine whether preterm children present a global cognitive delay or an alteration of certain skills such as verbal fluency, reasoning, perception, memory, and comprehension that would affect academic achievement. We also examined possible gender differences in global cognitive functioning and the above-mentioned basic skills.

Method

Participants

A total of 141 children born between November 1994 and November 1997 participated in this study. They were divided into two groups: 63 preterm children and 78 full-term children. The preterm children (≤37weeks) were selected from the Hospital of Cabueñes in Gijón and the Central University Hospital of Asturias in Oviedo (Spain). Mean gestation age of the preterm children was 33 weeks, distributed as follows: 11 children between 26-29 weeks, 10 children between 30-33 weeks, and 42 children between 34-36 weeks (Table 1).

The full-term children (>37 weeks) were selected from three educational centers of the city of Oviedo. The participants were children who are not at obvious risk for the development severe disorders. Therefore, during the selection process, the following criteria had to be met for exclusion from this study: Children with a diagnosis of attention deficit with hyperactivity disorder (ADHD), neuropathy, cerebral palsy, periventricular leukomalacia, bronchopulmomary dysplasia, and mental deficiency (IQ<85). In the Apgar test, the risk level was considered zero when the score

Table 1
Characteristics of the participants. The table shows the size and/or percentage of the sample in relation to the age, gender, gestational age, birth weight, educational level and special needs.

	Participants (N= 141)	
	Full-term group (n= 78)	**Preterm group (n= 63)**
Mean age (years)	8.3	8.6
Gender (%)	Boys: 57 Girls: 43	Boys: 61 Girls: 39
Gestational age in weeks (n)	39-40 (78)	26-29 (11) 30-33 (10) 34-36 (42)
Mean birth weight (g.)	3,102	2,041
Number (%) attending second grade (Total %= 7)	7 (8.97)	2 (3.17)
Number (%) attending third grade (Total %= 72)	70 (89.74)	30 (47.62)
Number (%) attending fourth grade (Total %= 21)	1 (1.28)	31 (49.20)
Special needs (%):		
Early intervention service		18
Learning aid		8
Speech therapy		18
Psychological aid		3

was 8-9-10 five minutes after birth, risk level 1 with a score of 6-7, and risk level 2 with scores below 6. The preterm children were assessed with the following risk levels: risk zero (n= 36, 57%); risk 1, (n= 9, 14%); risk 2, (n= 13, 21%). In the case of the full-term children, those who presented low weight for the gestational age (LWGA), were also excluded from the study.

Mean age of the sample of preterm children was 8 years and 3 months, and in the case of the full-term children, 8 years and 6 months.

At the start of this study, the following parameters were analyzed: birth weight/weeks of gestation, finding a Pearson correlation between them of 0.84; therefore, the variable birth weight was taken into account to establish groups. To investigate the effect of extent prematurity on performance, the following groups were formed: group 1, normal birth weight NBW (≥2500 g, n= 78); group 2: moderately low birth weight (MLBW) preterm children (≥1500 <2500 g, n= 48); group 3: very low birth weight (VLBW) preterm children (<1500 g, n= 15). Thus, as the participants are not randomly selected but instead their membership in the groups was determined by certain characteristics, we used an *ex post facto* design.

Instruments

The L-M form of the Stanford-Binet Scale 1960, (Spanish version Espasa Calpe, 1975) (Terman & Merrill, 1960) was employed to measure general IQ. Its subtests provide a profile of abilities: memory, perception, comprehension, reasoning, and verbal fluency. This type of L-M test places more emphasis on verbal material. This test is considered very adequate and reliable for students with specific educational needs because it indicates the abilities that may be related to low academic achievement. Upon completing the test, a direct global score is obtained for each area assessed.

Attention ability was measured with the spanish version of the d2 Selective Attention Test (Seisdedos, 2002), a cancellation test that provides a measurement of selective attention and mental concentration. This test is composed of 14 lines, each containing 47 characters, and 658 total items. The subject's task consists of reviewing the content of each line of letters and marking all the "ds "with two dashes, which can be either above or below the letter. Twenty seconds per line are allowed. Total administration time for the d2 is 6 minutes.

In the d2 Attention Test, the following scores were analyzed: total responses (TR), number of elements attempted, as a measure of processing speed and amount of effort put out for the task or motivation; total hits (TH), number of relevant elements correctly marked, as a measure of attentional allocation; omissions (O), number of relevant unmarked elements, as a measure of vigilance; commissions (C), number of irrelevant marked elements, as a measure of focus; total effectiveness of the test (TOT), consisting of TR- (O + C), an indicator of the relation between speed and precision, indicating good inhibitory control of the response; concentration (CON), consisting of total hits minus commissions (TH-C), as a measure of impulsivity; variation index (VAR), as an indicator of the stability and consistency in the performance across trials that is, it takes into account the fluctuations of sustained attention during the task (see d2 manual; Seisdedos, 2002). E% refers to the percentage of errors committed and the quantity of elements processed. The higher E%, the lower the precision and thoroughness of the work performed.

Lastly, we estimated the discriminant validity of the d2 compared to the Stanford-Binet L-M (IQ score). For this purpose, we calculated the Pearson correlation matrix among the different measures of the d2 and the global intelligence score obtained in the L-M. The correlations obtained were nonsignificant, so the scores obtained in the d2 and the IQ score can be considered independent.

Procedure

All procedures and measures were approved by the Ethics Committee of the Faculty of Psychology (University of Oviedo) and written informed consent was obtained from all parents/guardians. The psychologists who administered the tests were blind to the group status.

Data analysis

The statistical program SPSS, version 15.0 (SPSS Inc., Chicago, USA), was used to analyze the scores obtained in the tests, applying a multivariate analysis of variance (MANOVA) (Wilks's Lambda). Bonferroni test was used as post-hoc test.

Results

The first step was to verify the MANOVA assumptions of homogeneity of the variance-covariance matrixes and of normality. In the analyses of the intelligence variables, we accepted the assumption of homogeneity of the variance-covariance matrixes [Box's M (84, 6755)= 90.089, p= .637], and likewise, after applying Levene's test to the six dependent variables, we accepted the assumption of variance homogeneity. Regarding the attention variables, the assumption of variance homogeneity was verified but not the assumption of the homogeneity of the variance-covariance matrixes [Box's M= (60, 7009)= 167.76, p= .000]. Regarding multivariate normality, we used Mardia's (1970) test for multivariate skewness and kurtosis. We used the program FACTOR (Lorenzo-Seva & Ferrando, 2006) to calculate it. For the intelligence variables, the results were: λ_1 (skewness)= 4.407, df = 56, p= .999 and λ_2 (kurtosis)= 46.621, p= .202, so we conclude that the distribution is symmetric and mesokurtic. In the attention variables, the results for skewness were: λ_1= 22.467, df= 35, p= 1.0; and for kurtosis: λ_2= 72.812, p= .000, which implies a symmetric, albeit slightly leptokurtic, distribution. In view of these results, although we should be cautious about the attention variables, it does not seem unrealistic to use the initially foreseen tests.

There were statistically significant differences between the groups in the measures obtained from the L-M Form of the Stanford-Binet Scale [$F(12,260)$= 2.187, p= .013, η^2= .092]. There were also statistically significant differences as a function of gender, [$F(6,130)$= 2.47, p= .027, η^2= .102], but there were no statistically significant differences in the Group × Gender interaction [$F(12,260)$= 1.06, p= .395]. The univariate tests yield statistically significant differences in the IQ [$F(2, 260)$= 10.476, p= .001, η^2= .134]. Post-hoc tests reveals significant differences between the IQ obtained by the full term group and each preterm group, although the IQ values obtained by the preterm children were within the levels of normality (Table 2). In addition, when the ability defined as verbal fluency was considered the Group × Gender interaction was also statistically significant [$F(2,260)$= 3.252, p= .042, η^2= .046]. Therefore, the VLBW group of boys displayed statistically significant differences in comparison to

the full- term children in verbal fluency, whereas the rest of the groups showed no differences (Table 2). However, there were no significant differences in the subtest of memory, perception, comprehension and reasoning (Table 3).

In the measures of attention, no statistically significant differences were found in groups [$F(10,262)= 0.345$, $p= .98$] and gender [$F(5,131)= 0.354$, $p= .87$]. The Group × Gender interactions were not statistically different [$F(10,262)= 0.811$, $p= .61$] (Table 4).

Table 2
Form L-M of the Stanford-Binet Scale. Mean ± SEM of the studied groups in intelligence quotient (IQ) scores and Verbal Fluency (VF).

		Full-Term	Preterm >1,500g #	Preterm <1,500g *
Boys	IQ	107±7,8	104±8.3	96±4
	VF	2,37±0,57	2,21±0,78	1,7±0,48*
Girls	IQ	105±7,56	99±8,2	99±8,9
	VF	2,6±0,6	2,3±0,58	2,8±0.44

Note. = Diff.= differences, Gend.= gender, F= F-value ANOVA, p= p-value from F statistic. The full-term group showed a higher IQ score than the preterm >1,500 g group (#p= 0.005) and preterm <1,500g group (*p= 0.001). Differences between Full-Term and <1,500g group of boys in VF score, *p= 0.043.

Table 3
Form L-M of the Stanford-Binet Scale. Mean ± SEM of the studied groups in the following subtest (standard scores): memory (M), perception (P), comprehension (C) and reasoning (R)

	Boys			Girls			Group Diff.	Gend. Diff.
	Full-Term	Preterm >1,500g	Preterm <1,500g	Full-Term	Preterm >1,500g	Preterm <1,500g	F p	F p
M	6.77±1.16	6.60±1.16	6.00±0.81	6.69±1.01	6.55±1.19	6.40±1.34	1.38 0.25	0.12 0.72
P	11.37±1.11	11.35±1.56	10.70±1.41	10.96±1.40	11.40±1.14	11.40±1.81	0.48 0.62	1.44 0.70
C	13.75±2.12	14.25±1.81	13.10±2.07	14.15±1.85	14.30±1.83	14.80±2.16	0.41 0.66	2.73 0.10
R	12.71±0.84	12.82±1.02	12.40±0.96	12.57±1.03	12.60±0.94	12.80±1.30	0.10 0.90	.005 0.94

Note: Diff.= differences, Gend.= gender, F= F-value ANOVA, p= p-value from F statistic

Table 4
Performance on d2 test. Means ± SD of the groups of boys and girls in the d2 test scores are shown

d2	Full- term	Preterm ≥1500 g	Preterm ≤1500 g
Total Responses (TR)	347.95±69.97	334.35±68.39	343.33±47.16
Total Effectiveness (TOT)	331.73±68.99	317.35±68.26	324.53±53.05
Concentration (CON)	129.50±32.875	123.58±31.19	125.40±31.89
Variation index (VAR)	14.96±4.97	15.40±6.83	16.60±3.15
Percentage of Errors (E%)	4.62±5.91	5.16±4.89	5.59±6.26

Note: No statistically significant differences were found between groups

Discussion

Our results show that preterm children, in general, display great heterogeneity in the impairment of the cognitive abilities assessed. In our case, the group of VLBW boys had a lower IQ than the rest of the groups. In most of the studies of prematurity, the VLBW group displays more retardation in their neurocognitive development and has lower IQs than full-term children (Bayless, et al., 2008; Bhutta et al., 2002; Wocadlo & Rieger, 2007). In our case, the IQ values were within normality but the group of boys with birth weight <1500 g. had an IQ of 85. Therefore, our work supports the presence of difficulties in the MLBW group, as mentioned by Huddy et al., (2001) and Stein et al., (2006). These measures of general intelligence have been used as an indicator of subsequent difficulties when starting school and these difficulties persist in adolescence.

However, in our study, some methodological considerations must be taken into account: the sample of VLBW preterm children was very small and the within-group variability was high; it is therefore difficult to determine statistically significant differences. The sample of preterm children should be larger but not many children who belong to this group have no neurological sequelae.

Academic difficulties amongst preterm participants that are associated with lower cognitive or IQ scores may be related to the impact of preterm birth on corpus callosum growth (Nosarti, Rushe, Woodruff, Stewart, Rifkin, & Murray, 2004). Narberhaus et al., (2007) found a relation between the level of reduction of the corpus callosum and IQ measured in adolescents. Thus, the group of less than 27 weeks of gestation displays a reduction both of the posterior and the anterior part of the corpus callosum and a lower IQ, whereas the group of 34-36 weeks of gestation does not show a significant reduction in the size of the corpus callosum or in the IQ score.

In our case, the ability of verbal fluency seems to be affected in the case of the preterm boys VLBW in comparison to the group of preterm girls. These language-related difficulties of preterm children have been found in other investigations (Ortiz-Mantilla et al., 2008; Saavalainen et al., 2006).

Our results are similar to those obtained by Ortiz-Montilla et al., (2008). They found that VLBW preterm children have lower global IQ scores and also lower scores in each subscale of the Stanford-Binet 4. In addition, differences between VLBW and NBW children were found in expressive and receptive language abilities at 1-7 years (Ortiz-Mantilla et al., 2008). In our study, verbal fluency was also affected in VLBW children. Similar results were found in preterm children, assessed at 8 years, who obtained lower scores in the verbal intelligence scale (Isaacs, Edmonds, Chong, Lucas, Morley, & Gadian, 2004).

Adolescents with antecedents of prematurity perform more poorly in various tasks related to phonetic and categorical verbal fluency. Naberhaus et al., (2007) observed poorer performance in preterm adolescents, compared with full-term adolescents in the verbal and manipulative IQ scales, and the Vocabulary, Coding, and Stories subtests of the Wechsler scales discriminated these two groups of adolescents the best. Recent investigations have related these difficulties to alteration in the corpus callosum and to problems in the lateralization of language, which persist at even later ages. Nosarti et al., (2004) assessing preterm adolescents between 14-15 years of age, found that, in these children, there is a 7.5% reduction of the corpus callosum in comparison to the

group of full-term adolescents, accompanied by difficulties in verbal skills.

It is noteworthy that Shum et al., (2008) mentions that there are few studies on attention (both focused and sustained) in which groups VLBW and ELBW children are compared with a full-term group. Adequate attentional process are essential for normal cognitive development and these processes influence the performance of other basic processes such as memory, linguistic processing, reading, and executive functions (Van de Weijer-Bergsma, Wijnroks, & Jongmans, 2008; Wassenberg et al., 2008). Our work assessed attention in MLBW and VLBW groups of preterm children, compared with a group of full-term children, and it also combined the assessment of sustained attention with assessment of other skills.

The d2 test has been used frequently for neuropsychological assessment of sustained attention in children with a diagnosis of ADHD, in schizophrenia in adolescents, in the neuropsychological effects of radiation on children with leukemia, and in children with epilepsy, but it has not been used with preterm children (Van de Weijer-Bergsma et al., 2008). In our work, we found that prematurity did not affect diverse measures of attention (concentration and sustained attention). This may be due to the fact that all the children attended school and had no important disorders that could interfere with their cerebral functioning.

Studies with low-weight children have found that preterm children progressively acquire the characteristics of flexibility and inhibition of action, although more slowly than full-term babies. Our data revealed no group differences in the ability of sustained attention. This could be due to the fact that the preterm children had achieved maturity and stability of the components of the attention process. Moreover, concentration and task precision were not affected by prematurity. This could be due to factors such as test duration (six minutes). Thus, the short duration of the test could decrease the phenomenon of fatigue and interference. A recent study of Wassenberg et al., (2008) analyzes the patterns of development of selective attention across normal childhood (7-13 years old) with three components of selective attention: inattention, impulsivity, and processing speed. Inattention and impulsivity are part of the so-called attentional control. This process develops rapidly and is mature at the age of 9 years in normal children (Van de Weijer-Bergsma et al., 2008).

Lastly, we assessed a possible gender effect on global cognitive functioning and basic skills. We found a lower verbal fluency score in VLBW group of boys compared to full-term boys, whereas the girls displayed no differences. Thus, difficulties in verbal processing were notable in boys. Hindmarsh et al., (2000) found gender differences in the hearing and speech subscales of the Griffiths Scales: ELBW girls obtained higher scores than ELBW boys. Reiss et al., (2004) found that preterm boys and girls differ in cerebral grey and white matter volume at 8 years of age. They observed that preterm boys showed a reduction of white matter development compared to full-term boys, whereas no differences were found between preterm and full-term girls. The reduction of white matter volume seems to affect the temporal lobe and peristriatal cerebral region in preterm boys. These affected regions are involved in language process, reading, and emotional behaviors.

Taking into account that the prevalence of VLBW children has increased as a result of technical improvements and health care, it is important to know about the difficulties and deficiencies in these children's cognitive functioning. Future research should take the impairment of language-related abilities into account in order to carry out early interventions with these children. These preterm children need extra-academic reinforcement to allow them to decrease these difficulties in linguistic and global processing, preventing these deficiencies from persisting until adolescence or even beyond.

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