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Visual search and attention in five-year-old very preterm/very low birth weight children ☆

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ABSTRACT

Introduction: This study aimed to establish visual search performance and attention functioning in very preterm/very low birth weight (VP/VLBW) children using novel and well established measures, and to study their contribution to intellectual functioning.
Methods: Visual search and attention network efficiency were assessed in 108 VP/VLBW children and 72 age matched term controls at 5.5 years corrected age. Visual search performance was investigated with a newly developed paradigm manipulating stimulus density and stimulus organization. Attention functioning was studied using the Attention Network Test (ANT). Intellectual functioning was measured by a short form of the Wechsler Preschool and Primary Scale of Intelligence. Data were analyzed using ANOVAs and multiple regression analyses.
Results: Visual search was less efficient in VP/VLBW children as compared to term controls, as indicated by increased search time (0.31 SD, $p = .04$) and increased error rate (0.36 SD, $p = .02$). In addition, VP/VLBW children demonstrated poorer executive attention as indicated by lower accuracy for the executive attention measure of the ANT (0.61 SD, $p < .001$). No differences were found for the alerting (0.06 SD, $p = .68$) and orienting attention measures (0.13 SD, $p = .42$). Visual search time and error rate, and executive attention, collectively, accounted for 14% explained variance in full scale IQ ($R^2 = .14$, $p < .001$).
Discussion: VP/VLBW children were characterized by less efficient visual search ability and reduced executive attention. Visual attention dysfunctions contributed to intelligence, suggesting the opportunity to improve intellectual functioning by using interventions programs that may enhance attention capacities.

1. Introduction

Very preterm birth/very low birth weight (VP/VLBW) is associated with abnormalities in brain development, including diffuse white matter damage in periventricular and prefrontal brain regions [1]. As a result, VP/VLBW children are at risk for poor attention functioning [2]. Attention dysfunctions, in turn, crucially interfere with acquisition of new skills and hinder academic attainment [3]. Furthermore, lower IQ scores in VP/VLBW have consistently been found across studies and are reported as principal neurodevelopmental outcome measure, with IQ decreasing almost 1 point with each week of birth before term age [4]. Although attention dysfunctions may play an important role in the observed weaker intellectual development in VP/VLBW children, and both reduced IQ scores and attention dysfunctions are concurrently found in these children [2,5], their association is scarcely studied.

Attention is a core factor underlying the regulation of human behavior and neurocognitive functioning [6]. The most influential model has been developed by Posner et al. [7] and distinguishes between alerting, orienting and executive attention (i.e. between awareness for and orientation towards stimuli, and resolving conflict between stimuli, respectively) that can be differentiated from early childhood onwards[8]. Attention assessments in children comprise a wide range of methods [9]. Two recent systematic reviews have identified attention deficits in VP/VLBW children, including worse performance on visual search tasks [10] and a variety of methods that were classified according to alerting, orienting and executive attention functioning [11]. However, interpretation of results was limited. Firstly, comparability of study results was limited by differences in complexity of the visual search tasks used (i.e. spacing and positioning of items) [10] while complexity is known to impact on search performance [12,13]. In addition, visual search tasks are

Abbreviations: ANT, Attention Network Test; BW, birth weight; GA, gestational age; IQ, intelligence quotient; VLBW, very low birth weight; VP, very preterm; WPPSI-III, Wechsler Preschool and Primary Scale of Intelligence 3rd edition.

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typically paper-and-pencil tasks that require an additional visual-motor response to cross out the identified targets. Since visual-motor functioning has also been found compromised in VP/VLBW children [14], impaired task performance cannot be exclusively attributed to reduced attention abilities. Secondly, the review that classified studies according to Posner's attention network components, showed inconsistent evidence for adverse attention development across alerting, orienting, as well as executive attention components [11]. Interpretation of these findings is hindered by the varying characteristics of the samples studied, and by the wide range of tasks used that, besides attention resources, could also require additional neurocognitive processes [11]. Therefore, it remains unclear whether very preterm born children display a specific profile of attention dysfunctions. Interestingly, the Attention Network Test (ANT), a paradigm firmly grounded in neuroscience, systematically distinguishes between alerting, orienting and executive components of attention [15]. Thereby, the ANT opens the opportunity to study the specificity of attention dysfunctions in children.

This study investigates attention abilities in VP/VLBW children at 5.5 years corrected age using well established tasks and by minimizing additional fine motor demands. The aims are to 1) assess visual attention performance using an improved adaptation of visual search tasks and using an Attention Network Test, and 2) explore the association between attention dysfunctions and intellectual dysfunctions.

2. Methods

2.1. Participants

A sample of 108 VP/VLBW children and 72 term controls participated in this study. All VP/VLBW children were born between 2003 and 2006 and originally participated in a multicentre randomized controlled trial on post discharge intervention in Amsterdam, the Netherlands [16]. Initially, 176 children born at a gestational age (GA) <32 weeks and/or with birth weight (BW) <1500 g were included. Exclusion criteria at study entry were severe congenital abnormalities, severe maternal physical or mental illness/problems, not mastering the Dutch language and unavailability of an interpreter, and participation in other trials on post discharge management [16]. Of the 176 infants, 160 were available for follow-up at 5.5 years corrected age, of whom 136 (77% of the initial sample) agreed to participate. Not all data was collected successfully in 28 children (excluded from analyses), due to developmental delay or behavioral problems that crucially interfered with task execution (n = 8), declined participation in the second assessment day (n = 3), time constraints (n = 11), and technical problems (n = 6). Participating children (n = 108) were born more often at <28 weeks of gestation than non-participants (n = 68) (25 [23%] and 7 [10%], respectively, $p = .03$), and non-participating children more often had low-level educated parents (31 [30%] and 12 [52%], respectively, $p = .03$) and single parent families (9 [8%] and 15 [22%], respectively, $p = .01$). No other differences were present between participating and non-participating children on the variables listed in Table 1 (p-values > .05). The final VP/VLBW sample comprised 57 and 51 children that initially participated in the intervention and control group, respectively, of the trial on post-discharge intervention [16].

Age matched, term controls, were recruited from regular schools attended by the VP/VLBW children (n = 29) and additional schools located in the same geographical area (n = 43), to enhance feasibility. Controls were included if they had a GA > 37 weeks and BW > 2500 g. Exclusion criteria were parent reported severe perinatal complications or illnesses that might interfere with normal brain development, and learning difficulties.

Perinatal and socio-demographic characteristics are depicted in Table 1. Perinatal risk factors were taken from the medical records at discharge for VP/VLBW children and reported by parents for term controls. Socio-demographic data were obtained by parent questionnaire at the 5.5-year assessment. The measure of parental education was derived from the number of years post elementary education of both parents and classified as high (either parent > 8 years), middle (both parents 6 to 8 years) or low (either parent < 6 years).

Table 1
Group characteristics.

	VP/VLBW (n = 108)	Term controls (n = 72)	p-value
Perinatal characteristics			
Gestational age, weeks	30.1 (2.3)	39.9 (1.3)	<.001
Gestational age ≤28 weeks	25 (23%)		
Birth weight, gram	1264 (355)	3600 (539)	<.001
Small for gestational age[a]	25 (23%)		
Antenatal steroid use	79 (73%)		
Oxygen at 36 weeks PMA	21 (19%)		
Postnatal steroid use	6 (6%)		
Intraventricular haemorrhage[b]			
Grade I–II	17 (16%)		
Grade III–IV	5 (5%)		
Periventricular leucomalacia[c]			
Grade I–II	11 (10%)		
Grade III	1 (1%)		
Ventricular dilatation	3 (3%)		
Socio-demographic characteristics			
Family status, 2 parents	82 (77%)		
Parents born in the Netherlands	62 (57%)		
First language, non-Dutch	12 (11%)		
Follow-up characteristics			
Corrected age, years	5.5 (0.1)	5.6 (0.3)	.39
Gender, male	55 (51%)	40 (56%)	.54
Parental education			
High	55 (52%)	32 (44%)	.46
Middle	19 (18%)	18 (25%)	
Low	31 (30%)	22 (31%)	

Note. Data are presented as n (%) or as M (SD). PMA = post menstrual age.
[a] Defined as <−1 SD for Dutch reference norms.
[b] Defined according to Papile et al.
[c] Defined according to de Vries et al.

2.2. Materials

2.2.1. Visual search task

Visual search was assessed using a newly developed, child friendly adaptation of widely used search tasks [9,10]. Children were asked to point as fast as possible to all target images that were identical to a presented sample image and to indicate when they had found all targets. Images were presented on a touch screen monitor to minimize fine motor demands. In order to pinpoint potential effects of differences in stimulus presentation in previous studies [10], stimulus density and stimulus organization were manipulated in four conditions (Fig. 1). Low density conditions contained a total of 40 images (8 targets) and high density conditions included 80 images (16 targets). In structured conditions, images were equidistantly spaced in rows and columns, whereas in random conditions, images were presented in a randomly scattered array. Images were contours of eight different animals familiar to young children and were displayed in black on a white background. All animals had identical size and were displayed in fixed positions. To minimize possible effects of stimulus differences on search performance, the target for each condition was randomly selected from four predefined target images (cat, dog, goat and horse). For each condition, search time, the number of correctly identified targets, and erroneous responses were recorded. Search time per target (total search time divided by the number of correctly identified targets) and search errors (summed percentage of incorrectly identified images and missed targets) were used as measures of search efficiency and included as dependent variables in the analyses.

2.2.2. Attention network efficiency

Alerting, orienting and executive network efficiencies were assessed using a modified version of the computerized Attention Network Test