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Visual attention control differences in 12-month-old preterm infants

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ABSTRACT

There have been few previous attempts to assess the development of early markers of executive function in infants born preterm despite well-established deficits reported for older preterm children that have been closely linked to poorer academic functioning. The present study investigates early attention control development in healthy 12-month-old age-corrected pre-term infants who were born less than 30 weeks and compares their performance to full-term infants. Eye-tracking methodology was used to measure attention control. Preterm Infants spent less time focused on the target and were slower to fixate attention, with lower gestational age associated with poorer target fixation and slower processing speed. There were no significant group differences observed for inhibition of return or interference control. These findings suggest that specific emerging deficits in attention control may be observed using eye tracking methodology in very preterm infants at this early stage of development, despite scores within the average range on the Bayley Scales of Infant Development.

1. Introduction

Deficits in executive skills such as attention, inhibition, and processing speed have been widely reported in preterm children at school age (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009; Mulder, Pitchford, Hagger, & Marlow, 2009). The extent of these deficits has been linked to factors such as gestational age, birth weight, and gender (Atkinson & Braddick, 2012b; McGrath et al., 2005). Children who are born at less than 32 weeks of gestation are at greatest risk of developing deficits in executive functioning (Anderson & Doyle, 2004; Bayless & Stevenson, 2007; Clark, Woodward, Horwood, & Moor, 2008; Lindström, Lindblad, & Hjern, 2011; Luu, Ment, Allan, Schneider, & Vohr, 2011) and the prevalence may be related to increasing immaturity (Mulder et al., 2009). Despite the accumulating evidence for differences in executive function by school age, there is little known about how these skills emerge in preterm infants (van de Weijer-Bergsma, Wijnroks, & Jongmans, 2008). The identification of early markers of altered or delayed developmental trajectories is important because of the potential for early intervention to promote school readiness and the robust evidence for associations between foundational executive skills and later cognitive and academic ability (Garon, Bryson, & Smith, 2008; Lawson & Ruff, 2004; Rose, Feldman, Jankowski, & Van Rossem, 2008). The utility of eye-tracking methodology in the early detection of markers of potential executive problems warrants further investigation, particularly as widely administered behavioural scales, such as the Bayley Scales of Infant and Toddler Development (BSID) alone, may not pick up on these deficits

Abbreviations: ADHD, attention deficit hyperactivity disorder; ASD, autism spectrum disorder; BSID, Bayley Scales of Infant Development; IOR, inhibition of return

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(Spencer-Smith, Spittle, Lee, Doyle, & Anderson, 2015).

Most studies have relied on behavioural coding measures to investigate early executive development in infants born preterm (Rose, Feldman, & Jankowski, 2001; Ross-Sheehy, Perone, Macek, & Eschman, 2017; Sun, Mohay, & O'Callaghan, 2009). Eye-tracking methodology complements behavioural findings as it is less prone to human error and has higher spatial and temporal resolution than traditional behavioural looking methods (Wass, Smith, & Johnson, 2012). Eye-tracking methodology is particularly relevant to infant populations as it offers a direct and unbiased means of assessing early markers of executive skills (Amso & Scerif, 2015; Roderer, Krebs, Schmid, & Roebers, 2012).

Anderson's developmental model of executive function suggests that a more basic attentional control domain emerges first and lays down the foundation for later emerging higher-order skills such as goal setting, cognitive flexibility, and information processing (Anderson, 2002). Foundational executive skills such as selective attention and inhibition are thought to be intact by 12 months of age in typically developing infants (Atkinson & Braddick, 2012a). Early executive skills have been described as integral components of later cognitive development (Diamond, 1990). Lawson and Ruff (2004) found that focused attention at seven months was predictive of both behavioural and parental reports of attention in the toddler and preschool years. Similarly, Cuevas and Bell (2014), reported that attention at 5-months-old was related to executive performance on behavioural tasks at 23-,36-, and 48-months old. Previous research has indicated less optimal development of executive subsystems in preterm infants when compared with full-term controls in the first few years of life, and that these deficits become more evident with time (van de Weijer-Bergsma et al., 2008). However, despite evidence for early attentional delays predicting later executive outcomes, there has been a lack of focus on early emerging markers of executive domains in preterm infants and there have been no eye-tracking studies that have attempted to address this. This is in contrast to the investigation of social attention in preterm infants, which has been more widely investigated using eye-tracking methodology (Imafuku et al., 2017; Peña, Arias, & Dehaene-Lambertz, 2014).

Processing speed, which can be measured by investigating eye movement reaction times to target stimuli, develops rapidly in the first year of life and continues to develop with age, playing an important role in the processing of information and learning (Canfield et al., 1997; Luna, Garver, Urban, Lazar, & Sweeney, 2004). Specific deficits in processing speed have been previously reported for infants and children born preterm (Mulder et al., 2009; Rose, Feldman, & Jankowski, 2002; Rose, Feldman, Jankowski, & Caro, 2002). Aarnoudse-Moens and colleagues reported poorer processing speed in their population of schoolage preterm children. They also showed that deficits in executive function were independent of poor processing speed (Aarnoudse-Moens, Duivenvoorden, Weisglas-Kuperus, Van Goudoever, & Oosterlaan, 2012).

Selective attention involves attending to relevant information while simultaneously inhibiting distracting or irrelevant information (Desimone & Duncan, 1995). Studies using behavioural tasks of executive functioning, such as habituation, A not B, object examination, and object permanence paradigms, with infants born preterm, have reported evidence for poorer attention when compared to their full-term counterparts (Ross, Tesman, Auld, & Nass, 1992; Sun et al., 2009). Interestingly, Anderson and colleagues administered a battery of executive measures to a cohort of preterm children and matched controls at eight years of age and found poorer performance across all attention domains, including selective attention and shifting attention, in their preterm group, except for inhibition (Anderson et al., 2011).

Inhibition of distracting, or irrelevant, information is an important aspect of attention control (Fuchs & Ansorge, 2012). IOR is the natural bias of reducing the likelihood of returning attention to previously attended locations (Johnson & Tucker, 1996). This results in a slowed response towards a location that previously contained an ignored distractor and reflects the ability to inhibit interfering information in the visual scene so that the most relevant information can be processed. It is an important process in the ability to inhibit interfering visual information, so that the most relevant information can be processed. IOR can be observed from infancy and becomes more efficient with increasing age (MacPherson, Klein, & Moore, 2003). Previous research with typically developing nine-month-old infants found longer saccade latencies in the Ignored Repetition (IR) condition, where the target appears in a location that previously held a distractor (Amso & Johnson, 2008). IOR is disrupted in children with cerebral palsy who have anterior and diffuse lesions, and children with neurodevelopmental disorders such as attention deficit hyperactivity disorder (ADHD) and Tourette's syndrome, in which there is co-morbid attention deficit hyperactivity disorder or obsessive-compulsive disorder (Schatz, Craft, White, Park, & Figiel Gary, 2001; Yuen, Bradshaw, Sheppard, Lee, & Georgiou-Karistianis, 2005). However, IOR has been found to be intact or even enhanced in children with autism spectrum disorder (ASD) (Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2008). IOR has not yet been explored in children born preterm using eye-tracking methodology. Children born preterm are at a greater risk for both ADHD and ASD (Johnson et al., 2010), therefore it is of interest to establish which patient group their performance will more closely reflect. A recent study found that interference control was intact in school-age children from four to 12 years born preterm but that there was a significant delay in response inhibition, a group difference that showed gradual catch up with developmental progression (Aarnoudse-Moens et al., 2012).

Early executive markers such as processing speed, attention fixation, distractor suppression, and IOR, have not been previously investigated in healthy infants born preterm with the exception of two studies which looked at visual orienting and attention in preterm infants using behavioural coding measures (Rose et al., 2001; Ross-Sheehy et al., 2017). Evaluating the development of specific executive skills in very preterm infants with eye-tracking methodology will establish the sensitivity of this research tool with this patient population and demonstrate the potential utility of this tool in future clinical assessment in terms of developing targeted interventions. Attention control is a multifactorial process. It is difficult to determine where the breakdown in an infant's task performance occurs on a behavioural level. Poor performance on a task at a behavioural level may be due to a deficit or delay in one specific cognitive control process and identifying this process is important in terms of early targeted intervention. Eye-tracking paradigms can separate individual processes of interest, such as processing speed, attention fixation, distractor suppression, and IOR in the case of this study, providing more detailed information on group differences and similarities in markers of emergent executive