Visual attention and academic performance in children with developmental disabilities and behavioural attention deficits

Research Highlights

- The current findings indicate that children with autism spectrum disorder, Down syndrome and non-specific intellectual disability who share homogenous behavioural attention deficits experience unique visual attention difficulties.
- Visual attention was shown to be particularly impaired in children with Down syndrome.
- Visual attention difficulties were concurrently associated with poorer academic skills.
- Examining underlying cognitive attention skills may facilitate the development of tailored interventions that meet the unique needs of individuals with intellectual and developmental disabilities.

Abstract

Despite well documented attention deficits in children with intellectual and developmental disabilities (IDD), distinctions across types of attention problems and their association with academic attainment has not been fully explored. This study examines visual attention capacities and inattentive/hyperactive behaviours in seventy-seven children aged 4 to 11 years with IDD and elevated behavioural attention difficulties. Children with autism spectrum disorder (ASD; *n* = 23), Down syndrome (DS; *n* = 22), and non-specific intellectual disability (NSID; *n* = 32) completed computerised visual search and vigilance paradigms. In addition parents and teachers completed rating scales of inattention and hyperactivity. Concurrent associations between attention abilities and early literacy and numeracy skills were also examined. Children completed measures of receptive vocabulary, phonological abilities and cardinality skills. As expected, the results indicated that all groups had relatively comparable levels of inattentive/hyperactive behaviours as rated by parents and teachers. However, the extent of visual attention deficits varied as a result of group; namely children with DS had poorer visual search and vigilance abilities than children with ASD and NSID. Further, significant associations between visual attention difficulties and poorer literacy and numeracy skills were observed, regardless of group. Collectively the findings demonstrate that in children with IDD who present with homogenous behavioural attention difficulties, at the cognitive level, subtle profiles of attentional problems can be delineated.

Attention has been highlighted as a key facilitator in the development of complex cognitive skills (Posner & Rothbart, 2005); and a particularly salient predictor of academic outcomes (Dally, 2006; Grills-Taquechel, Fletcher, Vaughn, Denton, & Taylor, 2013; Spira & Fischel, 2005; McClelland, Acock, Piccinin, Rhea, & Stallings, 2013). In particular visual attention skills have been emphasised as integral to learning, with visual search and visual sustained attention being associated with core academic skills such as literacy (Prado, Dubois & Valdois, 2007; Bosse & Valdois, 2009) and numeracy (Steele, Karmiloff-Smith, Cornish, & Scerif, 2012). Visual search refers to the process of encoding and categorising relevant and irrelevant items within the environment (Treisman & Gelade, 1980), and as such plays an important role in directing attention within the classroom. Sustained attention involves the ability to detect periodically occuring events over a prolonged period of time (Robbins, 1998). This process includes vigilance, a state of alertness which is integral within educational settings (Stern & Shalev, 2013). In children with intellectual and developmental disabilities (IDD), attention difficulties are widespread, with rates of Attention Deficit Hyperactivity Disorder (ADHD) reported as more than 3 times higher than those observed in typically developing (TD) children (Neece, Baker, Blacher, & Crnic, 2011). Children with developmental disabilities and comorbid intellectual disability are particularly vulnerable to behavioural attention deficits, with rates of ADHD increasing four fold in children with a diagnosis of intellectual disability compared to those without (Voigt, Barbaresi, Colligan, Weaver, & Katusic, 2006). These behavioural attention difficulties, have been shown to amplify the already heightened vulnerability to learning impairments in children with IDD; with ADHD-like behaviours being a significant predictor of subsequent literacy skills (Cornish, Steele, Monteiro, Karmiloff-Smith, & Scerif, 2012a).

Given the pivotal role of visual attention in the acquisition of academic skills in TD children, an assessment of whether an analogous relationship exists in children who experience elevated behavioural attention difficulties as a result of IDD is warranted. In the current study both visual and behavioural attention capabilities are assessed in the context of two IDD; Down syndrome (DS) and autism spectrum disorder (ASD). These disorders represent some of the most common causes of developmental delay, with DS occurring in 1 in 690 live births (Parker et al., 2010) and ASD occurring in 1 in 150 (Fombonne, 2009). Despite significant differences in their aetiology these disorders are both characterised by elevated inattentive/hyperactive behaviours and an increased risk of ADHD (Ekstein, Glick, Weill, Kay, & Berger, 2011; Leyfer et al., 2006). Of the 41 children with DS included in Ekstein and colleagues (2011) study, 43.9% of the children fulfilled a diagnosis for ADHD. Similar prevalence rates of ADHD have been reported in children with ASD (50%; Leyfer et al., 2006). Most studies have focused on the extent to which attention difficulties are present in these populations, however the nature of these deficits may be qualitatively different. Therefore, assessing types of attention difficulties across both behavioural and cognitive domains in a cross syndrome manner will add value to our understanding of IDD and facilitate the delineation of disorder specific attention deficits.

In contrast to the commonalities observed in behavioural attention difficulties, unique and dynamic profiles of visual attention have begun to be identified in children with DS and ASD. A widely reported feature of children with ASD is superior performance on visual search tasks compared to TD children (Joseph, Keehn, Connolly, Wolfe, & Horowitz, 2009; Vaidya et al., 2011). In typical visual search tasks children are required to locate a pre-specified target amongst a series of simultaneously presented distractors. Two types of visual search are commonly contrasted: feature search, where the target is uniquely defined by one feature, and conjunction search, where the target shares each of its feature with the distractors (O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Treisman & Gelade, 1980). Children with ASD have shown proficiencies in both feature and conjunction visual search tasks (Kaldy, Kraper, Carter, & Blaser, 2011; Kemner, Van Ewijk, Van Engeland, & Hooge, 2008; O'Riordan & Plaisted, 2001; O'Riordan et al., 2001). These superior visual search abilities in ASD have been attributed to enhanced visual discrimination abilities (O'Riordan et al., 2001) and faster-paced visual processing (Kaldy, Kraper, Carter, & Blaser, 2011). In contrast children with DS have shown particular weaknesses in visual search compared to TD children (Breckenridge, Braddick, Anker, Woodhouse, & Atkinson, 2013) and children with other genetic based developmental disabilities, such as fragile X syndrome (Cornish, Scerif & Karmiloff-Smith, 2007; Munir, Cornish, & Wilding, 2000). Interestingly fragile X syndrome (FXS) is strongly associated with ASD, with 50% of FXS males also meeting DSM-IV criteria for a diagnosis of ASD (Hall, Lightbody, & Reiss, 2008). Taken together these findings suggest that visual search abilities which encompass selective attention and visual perception skills, are impaired in children with DS, but intact in children with ASD. However, it is important to note that the outlined studies have only included children with ASD who function within or above the average cognitive range. Therefore, whether or not these competencies in visual search are present in the two thirds of children with ASD who have an intellectual disability (Dykens & Lense, 2011), is unknown.

Sustained attention is commonly assessed using vigilance tasks, which involve participants monitoring an array of non-target distractors over a prolonged period of time, and identifying when infrequently occurring targets appear. In children with ASD who also have an intellectual disability, little data exist regarding sustained attention abilities and for those with ASD without intellectual disabilities investigations have largely been inconclusive. Some studies suggest equivalent sustained attention abilities to TD children (Johnson et al., 2007;

May, Rinehart, Wilding, & Cornish, 2013, 2015), whilst others show significant impairments in sustained attention that have been attributed to underlying abnormal maturation of neural regions (Murphy et al., 2014). Of the limited studies that have examined sustained attention in DS, an interesting developmental trajectory has been noted. In infancy shorter and fewer periods of sustained attention have been observed compared to TD peers and children with other developmental disabilities (Brown et al., 2003). However, by mid-late childhood sustained attention is actually a relative strength in DS (Cornish et al., 2007); particulary during visual sustained attention tasks (Costanzo et al., 2013; Trezise, Gray, & Sheppard., 2008). Collectively, these findings indicate that despite global behavioural attention deficits, children with developmental disabilities are likely to have disparate visual attention capabilities. However the extent of difficulties in visual attention in children with ASD and DS needs to be further elucidated, particularly in those who also have reduced cognitive capacities.

The present study therefore has two core aims: first to comprehensively assess the types of attention difficulties present in children with Down syndrome (DS) and autism spectrum disorder (ASD) who have similar behavioural attention deficits. Given the contrast in cognitive abilities of children with IDD and TD children, past studies have suggested children with non-specific intellectual disability (NSID) as a more appropriate comparison group (Trezise et al., 2008). Thus we compared visual attention capabilities (visual search and vigilance performance) as well as inattentive/hyperactive behaviours at home and in the classroom across these three groups. As this sample consisted of individuals with heightened behavioural attention difficulties it was hypothesised that across groups, children would have similar levels of inattentive/hyperactive behaviours, but would differ in visual search and vigilance capabilities. In particular, children with ASD were predicted to have fewer visual search difficulties than children with NSID and DS, but similar vigilance difficulties to children with NSID and DS. The second aim was to assess the association between distinct types of attentional difficulties (i.e. visual attention, inattention and hyperactivity) and core academic skills (literacy and numeracy) in this sample of children with IDD. The inclusion of a cross syndrome approach allowed us to further establish whether this relationship between attentional deficits and academic skills differed across groups. We hypothesised that difficulties within both visual and behavioural attention domains would be associated with literacy and numeracy weaknesses as in TD populations; but that these relationships may differ as a result of group.

Methods

Participants

Participants were 77 children with intellectual and developmental disabilities (IDD), aged 4 to 11 years (M_{age}= 8 years, 3 months, SD = 1.83). This sample was recruited through mainstream schools, special schools, special developmental schools and organisations within the state of Victoria, Australia. Standardised assessments of intelligence from psychologists using either the Wechsler Preschool and Primary School Intelligence (WPPSI-III; Wechsler, 2002) or the Wechsler Intelligence Scales for Children (WISC-IV; Wechsler, 2003) were used to confirm diagnosis of intellectual disability (ID). As some children were unable to complete standardised assessment measures due to task demands, the Vineland Adaptive Behaviour Scales - II parent/caregiver rating form (VABS-II; Sparrow, Cicchetti, & Balla, 2005) was also used as a secondary confirmation tool of ID. In rare cases where parent/caregivers were unable to complete this rating form ($n = 6$), children's class teachers completed the equivalent Vineland teacher rating form; good agreement between parent and teacher ratings has been shown (Szatmari, Archer, Fisman, & Streiner, 1994). Given that this study aimed to assess the types of attention deficits present in children with IDD, children were deemed eligible to participate if they had elevated behavioural attention difficulties on the Conners 3 parent rating scale (Conners, 2008). Consequently four children were excluded from the study. In addition, children were excluded if they had any visual, auditory or motor impairments that would prevent them from understanding or executing the requirements of the assessment measures ($n = 1$).

All eligible children were classified into three groups (DS, ASD and NSID) based on clinical assessment reports (paediatrician, geneticist). In addition, children were only included in the ASD group if they had a score above the specified clinical ASD cut off on the parent rated Social Responsiveness Scale (SRS; Constantino & Gruber, 2005). Consequently one child was excluded from the study. Table 1 outlines the demographic information for children included in each of the three groups.

Insert Table 1 here

Measures

Screening

Prior to enrolment in the study, parents completed the Social Responsiveness Scale (SRS; Constantino & Gruber, 2005). This scale has 65 items measuring indices of social awareness, social cognition, social communication, social motivation and autistic mannerisms. A total *t* score was calculated from these subscales, and children with a diagnosis of ASD who scored above 60 (mild to severe range of deficiencies in social reciprocity) were included in the ASD sample. The Vineland Adaptive Behaviour Scale - II parent/caregiver rating form (VABS-II; Sparrow et al., 2005) was used to assess personal and social skills needed for everyday living. Parents rated their child's behaviour on a scale of 0 'never performed' to 2 'usually performs'. This scale was used to give an overview of adaptive functioning for use as a covariate in analyses and to confirm diagnosis of ID. In addition parents, completed the Conner's 3 Parent Rating Scale - Long Form (Conners, 2008) to screen for behavioural attention difficulties. This scale consists of 108 items measuring indices of inattention, hyperactivity, executive functioning, learning problems, aggression, peer relations and family relations. Parents respond to each item on a 4 point scale of never, occasionally, often and very often. Children who scored above the recommended cut of score of 42 for screening ADHD symptoms in children with ID (Deb, Dhaliwal & Roy, 2008) as well as above 60 (elevated range) on the subscale relating to inattentive behaviour were deemed eligible for inclusion in the study.

Visual Search

The Wilding Attention battery (Wilding, Munir, & Cornish, 2001) was used to assess visual attention. This battery involves computerised visual search 'Visearch' and vigilance 'Vigilan' tasks, and has consistently demonstrated sensitivity to capture attention profiles in typically and atypically developing children regardless of intellectual level (Cornish, Wilding, & Hollis, 2008; Scerif, Cornish, Wilding, Driver & Karmiloff-Smith, 2004). Children completed this battery on a 12 inch portable touch screen computer. The experimenter introduced the Visearch task, explaining that a number of monsters were hiding under large black circles displayed on the screen. Children were instructed to locate these monsters as quickly as they could by touching the large black circles with their index finger. Children completed a total of 5 trials, each containing 10 large black target circles (4cm diameter) which were randomly placed on a green background. Trial 1 was a practice condition and included no distractors. Trials 2 and 3 were both feature search trials and contained 6 and 24 distractors respectively; medium black circles (3cm diameter). Trials 4 and 5 were both conjunction search trials and contained a total of 24 distractors; 12 medium black distractor circles and either 12 large red distractor circles or 12 large distractor ovals. The time taken to complete each trial (seconds) and the number of errors made was recorded.

Vigilance

The experimenter introduced the Vigilan task, explaining that children had to monitor the screen which contained a variety of different coloured shapes (black or brown, ovals or circles). The experimenter explained that in this task monsters were hiding under black ovals, and that a yellow border would appear around one of these ovals to indicate the location of the monster. Children were required to press this shape as quickly as they could. After a practice trial, children viewed a total of 16 targets that randomly appeared one by one at irregular intervals between 6 to 14 seconds. The yellow border only remained around the targets for a maximum of 7 seconds. The number of targets detected over the duration of the task (4 minutes) was recorded.

Inattention and Hyperactivity

Both teachers and parents completed the Strengths and Weaknesses of ADHD symptoms and Normal behaviour scale (SWAN; Swanson et al., 2005). The SWAN employs 18 items which map onto the symptoms of ADHD outlined in the DSM-IV (American Psychiatric Association, 2000). Items are rated on a seven point scale, ranging from +3 being 'far below average' to -3 being 'far above average'. The first nine items correspond to inattentive behaviour and the last nine items to hyperactive behaviour. Total subscale scores were derived by totalling responses on the corresponding nine items; higher scores indicate greater problems. This measure has been shown to capture variability at both negative and positive ends of ADHD symptomology (Arnett et al., 2013), and as such offers to potential to capture variation in behavioural attention problems.

Early Literacy Skills

As vocabulary and phonological abilities have been shown to be strong preschool predictors of reading and comprehension (e.g. Muter, Hulme, Snowling, & Stevenson, 2004), tasks that measured these skills were included in the assessment battery. Phonological abilities were assessed using two subtests from the Phonological Abilities Test; 'Letter Knowledge' and 'Rhyme Detection' (PAT; Muter, Hulme, & Snowling, 1997). The rhyme detection subtest involved presenting the child with four images, reading the names of the images aloud and then asking the child which of the pictures rhymed. A total of ten trials were completed and children scored one point for each correct answer. For the letter knowledge subtest participants were randomly presented with all 26 lowercase letters from the alphabet and asked to verbally identify them. One point was scored for each correct letter. A total Phonological Ability score was derived by totalling scores across the two subtests. The Peabody Picture Vocabulary Test 4 (PPVT- 4; Dunn & Dunn, 2007) was used to assess receptive vocabulary.

Early Numeracy Skills

In the context of early numeracy skills, understanding the principles of cardinality has been shown to predict numerical abilities in early school years (e.g. Muldoon, Lewis, & Fracis, 2007). Cardinality understanding was therefore assessed using a version of the 'give-a-number' (GAN) protocol originally designed by Wynn (1990) and extended by Steele et al. (2012). Children were given an empty bowl and 15 small fish. The experimenter held up a penguin puppet and explained to the child that they needed to feed the penguin by placing fish in the empty bowl. Children were asked to place small (1, 2 and 3) and large (7, 8 and 9) numbers of fish in the bowl. Each numerosity was asked three times and one point was awarded for each correct response.

Procedure

The study was approved by the Human Research Ethics Committee of Monash University and the Victorian Government Department of Education and Early Childhood, Australia. Parents received an explanatory statement and provided written informed consent, before completing the screening measures. Participants were assessed at the Monash University campus or at their school. All participants were assessed in a quiet room, in a single session which lasted between 60 to 90 minutes, including regular breaks. Task presentation was consistent for all participants with children completing the attention, literacy and numeracy measures in the order described above. Parents completed the questionnaires as per their standard instructions whilst their children were being assessed. Questionnaires were posted out to participants schools, and were completed by class teachers or aides. Standardised scores were utilised for screening purposes and total raw scores were used in all subsequent analyses.

Data Analysis

Data were analysed using Stata Statistical Software (StataCorp, 2015). Two sets of analyses were conducted; in both cases multiple linear regressions were used to model the dependent variables as functions of the independent variables. First to determine group differences in attention difficulties, the variables of visual search time, visual search errors, vigilance targets, inattention and hyperactivity, were modelled as linear functions of group (DS, ASD and NSID). Adaptive behaviour, gender and chronological age were included as covariates (autism symptomology was not significantly associated with visual attention or teacher rated inattention/hyperactivity ($p > .05$), and as such was not included as a covariate). Second, to assess the relationship between attention difficulties and academic skills; the dependent variables of receptive vocabulary, phonological abilities, and cardinality, were modelled as linear functions of attention difficulties (visual search time, visual search errors, vigilance targets, inattention and hyperactivity), group (DS, ASD and NSID), adaptive behaviour, gender and chronological age. Given the high association between difficulties on the attention measures, each attention variable was separately entered into the regression model to avoid issues of multicollinearity. Children with DS were expected to show the greatest contrast in attentional abilities and as such were used as the reference group for all regressions.

Results

Table 2 presents the mean scores, standard deviations and ranges for each group on the attention measures of visual search, vigilance, inattention and hyperactivity.

Insert Table 2 here

Visual Attention Difficulties

Table 3 presents the results of the investigations of group differences in attention difficulties, accounting also for age, gender and level of adaptive behaviour. Significant group differences were present in visual search abilities. On the Feature Search task children with ASD were 12.3 seconds faster and made 3.4 fewer errors, on average, than children with DS. On the Conjunction Search task children with ASD were 16.4 seconds faster and made 11.5 fewer errors, on average, than children with DS. Those with NSID made 2.6 (Feature Search) and 9.4 (Conjunction Search) fewer errors than children with DS, but were not significantly faster on either search. Further significant group differences were present in Vigilance performance. Both children with ASD and NSID located more targets (4.2 and 5.2 respectively) than children with DS on the Vigilance performance measure. In addition, older children were faster and more accurate on both Feature and Conjunction Search tasks and located more targets on the Vigilance task than younger children. Higher levels of adaptive behaviour were also associated with better speed and accuracy on the search tasks (see Table 3). Visual search time was not normally distributed, however transformation to normalise the data made marginal differences to the reported results, therefore transformation was not justified.

Behavioural Attention Difficulties

As expected no significant group differences were present on parent rated inattention or hyperactivity (see Table 3). However, children with ASD scored 5.3 lower than children with DS on teacher rated inattention. No group differences were evident on teacher rated hyperactivity.[1] Neither parent nor teacher rated inattentive/hyperactive behaviours were significantly associated with chronological age. However, girls were lower than boys on parent-rated hyperactivity and higher levels of adaptive behaviour were associated with lower parent- and teacher-rated hyperactivity.

Insert Table 3 here

Concurrent Associations between Academic Skills and Attention Difficulties

[1] Changing the reference group from DS to NSID revealed that only on teacher rated inattention was there any evidence that ASD differed from NSID (ASD lower inattention scores than NSID, B = -4.74, *p* = .049).

The mean scores, standard deviations and ranges for each group on the academic measures of phonological ability, vocabulary and cardinality are presented in Table 2. Given the high number of attention variables, performance on the visual search tasks (feature and conjunction search) were collapsed, for the purpose of the regression analyses, to give an overall measure of visual search time and visual search errors. Feature search errors and conjunction search errors were strongly correlated, r (71) = .80, p<.001, as were feature search time and conjunction search time, r (71) = .89, p<.001. In addition, only parent ratings of inattention and hyperactivity were used in the regression analyses, as parent reports have shown greater sensitivity to attention difficulties in children with developmental disabilities than teacher reports (Deb et al., 2008).

Insert Table 4 here

Table 4 presents the results of investigations of the associations of three academic skills (phonological ability, receptive vocabulary and cardinality) with five attention measures (search time, search errors, vigilance, inattention and hyperactivity) separately, accounting also for group differences, age, gender and level of adaptive behaviour. Performance on all academic measures were significantly associated with visual search time and vigilance performance. Phonological abilities[2], receptive vocabulary and cardinality skills were better among those who were quicker on the search tasks, and better among those with greater vigilance performance. In addition, receptive vocabulary and cardinality skills, were also better among those making fewer errors on the search tasks. Better receptive vocabulary was also associated with lower parent-rated inattention scores. None of the academic measures were associated with parent-rated hyperactivity (see Table 4).

The results presented in Table 4 also indicate that group was a significant contributor to performance on the academic measures. Children with ASD performed significantly better than those with DS on each academic skill, while those with NSID were better than children with DS on receptive vocabulary and cardinality, but not on phonological abilities (see Table 4).[3] In addition, older children performed better than younger children, and those with higher levels of adaptive behaviour than those with lower levels, on each of the academic skills. Gender was not associated with any of the academic skills (see Table 4).

Discussion

[2] The observed relationships between phonological abilities and measures of attention were consistent across the phonological ability subtests (rhyme detection; letter knowledge), with the exception of rhyme detection not being associated with visual search time.

[3] Analysis not shown included interactions to assess whether the relationship between the academic outcome measures and attention abilities was dependent on disorder, but no evidence to support this was found.

The present study had two core aims, the first was to compare the types of attention deficits present in children with intellectual and developmental disabilities (IDD) who had behavioural attention difficulties. The second aim was to establish whether visual attention deficits alongside inattentive/hyperactive behaviours were associated with literacy and numeracy skills in children with IDD; and to further ascertain if these associations differed across groups (i.e. Down syndrome, autism spectrum disorder and non-specific intellectual disability).

As anticipated our findings predominately revealed comparable behavioural attention deficits in relation to the severity of inattention and hyperactivity in children with Down syndrome (DS), autism spectrum disorder (ASD) and non-specific intellectual disability (NSID). The lack of group differences in parent rated attentional strengths and weaknesses was expected given the sample was restricted to children with elevated behavioural attention difficulties. However, group differences in teacher rated inattentive behaviours were observed, with lower levels on inattention being reported in children with ASD than children with DS or NSID. These findings indicate that the pattern of behavioural attention difficulties may vary across home and school environments. Indeed although children with ASD had the lowest teacher reported levels of inattention compared to children with DS and NSID, they had the highest reported parent levels of inattention. These findings indicate the importance of assessing attention deficits across a range of environments, to obtain a comprehensive picture of how behavioural attention deficits manifest in everyday life.

Although all children shared relatively comparable behavioural attention difficulties; at the cognitive level group differences in visual attention deficits were found that suggest unique/disorder-specific pathways might lead to these common behavioural deficits. With regards to visual search abilities, children with ASD and NSID were shown to make fewer errors on both feature and conjunction search tasks than children with DS. In addition, children with ASD were quicker on these tasks than children with DS. The heightened difficulties observed in children with DS are consistent with past findings that outline similar deficits in visual search abilities in children with DS (Breckenridge et al., 2013; Cornish et al., 2007; Costanzo et al., 2013; Munir et al., 2000). Comparisons of visual search across children with ASD and NSID revealed no differences in performance, indicating a common influence of reduced intellectual abilities across both groups. These findings provide the first indication that visual search is not necessarily a universal strength in ASD as previously noted (Kaldy et al., 2011; Kemner et al., 2008; O'Riordan et al., 2001); but rather specific to those with ASD who have intellectual abilities within or above the average range. Recent studies have suggested that enhanced visual search in infancy predicts emerging autism symptoms in early childhood (Gliga, Bedford, Charman & Johnson, 2015), and have suggested that assessments of visual search performance may be a useful component in the identification of ASD.

The findings of the current study are therefore particularly salient in highlighting that these reported associations need to be interpreted with caution, as they are not necessarily applicable to all individuals with ASD.

In terms of visual sustained attention, a similar pattern of results occurred; namely children with ASD and NSID presented with fewer difficulties on the vigilance task than children with DS. These findings are partially in line with evidence from the existing literature, which highlights that infants with DS have greater difficulties in visual sustained attention than TD infants (Brown et al., 2003). In contrast, additional studies have indicated that children with DS have relative proficiencies in visual sustained attention (Cornish et al., 2007; Costanzo et al., 2013; Trezise et al., 2008). These inconsistencies may be attributable to the age related changes observed in sustained attention in children with DS (Cornish et al., 2007). Cornish and colleagues (2007) indicate that the relative strengths in sustained attention in DS are only apparent around mid to late childhood. Unlike previous investigations that have included older children, adolescents and adults (Costanzo et al., 2013; Trezise et al., 2008), the current study involved young children (4 to 11 years) and as such disparate sample characteristics may explain the seemingly conflicting findings. In conjunction with these past studies, the current findings provide support for a potential developmental deficit in sustained attention in children with DS that is more pronounced in early childhood. However, studies that include a wider age range of participants, extending in to late childhood and adolescents are needed to comprehensively map developmental changes in sustained attention, and indeed further attentional processes in children with DS, as well as other IDD.

Consistent with the developmental trajectories of attention in TD children (Steele et al., 2012; Zhan et al., 2011) and toddlers with developmental disabilities (Scerif et al., 2004), younger children in our sample had poorer performance on the visual search and vigilance tasks than older children. These findings are important in suggesting that visual attention skills may be dynamic in children with IDD. In contrast, inattentive and hyperactive behaviours were not associated with age, suggesting that behavioural attention difficulties may be comparatively stable across the age range of our sample, 4 to 11 years. Past studies have highlighted that inattentive and hyperactive behaviours in children with developmental disabilities, such as fragile X syndrome remained constant over a period of 3 years (Cornish, Cole, Longhi, Karmiloff-Smith & Scerif, 2012). Although these findings may indicate that behavioural attention deficits are relatively stable in children with IDD, the concurrent nature of the present study impedes any firm conclusions being made regarding changes over time in children with ASD, DS or NSID. In addition, it is also possible that in children with IDD who have known behavioural attention difficulties, rating scales may have reduced sensitivity in detecting differences in attention profiles across time and disorders. Collectively, these finding underscore the need to dissect difficulties within cognitive attentional components, to fully understand what on the surface appear to be universal attention deficits in children with IDD. Such assessments may help to establish unique cognitive strengths that can be enhanced and cognitive weaknesses that require intervention.

Individual differences in visual search and vigilance performance were significantly associated with concurrent phonological abilities, receptive vocabulary and cardinality skills, over and above age and adaptive behaviour skills. Importantly, the observed associations were not dependent on group, suggesting that difficulties within these attentional subcomponents were associated with problems in literacy and numeracy across children with DS, ASD and NSID. Of the attentional subcomponents, difficulties in sustained attention had the strongest relationship with performance across the academic skills assessed. These findings are supported by literature with TD children and children with elevated behavioural attention difficulties (e.g. ADHD), which also pinpoint sustained attention as a prominent indicator of mathematical competence (Steele et al., 2012) and reading attainment (Mayes & Calhoun, 2007; Stern & Shalev, 2013). In contrast to converging findings from research in TD children, suggesting that inattentive behaviour is a strong longitudinal predictor of both literacy and numeracy deficits (Grills-Taquechel et al., 2013; McClelland et al., 2013; Spira & Fischel, 2005), our study provided limited evidence for a similar cross sectional association in children with IDD. Our findings indicated that hyperactivity was not significantly associated with any of the academic skills assessed, and that inattention was only weakly associated with receptive vocabulary. These findings are partially supported by research that has investigated the concurrent relationship between behavioural attention and academic skills in two groups of children with developmental disabilities of genetic origin; DS and Williams syndrome (Cornish et al., 2012a). The authors revealed that hyperactivity was not associated with receptive vocabulary or phonological abilities in either group, thus supporting the findings from the current study. In contrast, inattention was associated with both of the literacy measures for children with DS, but not children with Williams syndrome. Although a similar link between inattention and vocabulary was observed in the current study, no association between inattention and phonological abilities was found. These limited associations are likely to be the result of range restriction, given that all children were characterised by similar elevated levels of inattention. The inclusion of children with heightened inattention may have produced a threshold effect; whereby once children exceeded a certain amount of behavioural attention difficulties, a clear interrelation between the degree of these problems and literacy or numeracy skills was no longer present.

The current study has some limitations that require acknowledgement. First, the focus of the study was primarily on visual attentional processes. Therefore, further investigations are needed to assess whether similar deficits are present across other attentional modalities, e.g. auditory domains. Second, this study was cross-sectional and therefore questions regarding the persistence of attention deficits and the directionality of the association between attentional difficulties and academic skills remain unanswered. As such future studies should endeavour to employ longitudinal designs to establish the nature and impact of attention deficits in children with IDD. Finally, it is important to acknowledge that other factors may also influence academic outcomes. Indeed, even after the influence of attention capacities, age, gender and adaptive behaviour had been controlled for, group differences in academic skills persisted. Namely children with DS performed worse than children with ASD on all academic measures, and worse than NSID on measures of receptive vocabulary and cardinality. Therefore, greater research is needed to establish the precise cognitive mechanisms that may drive early literacy and numeracy development in children with IDD.

In conclusion, the current results demonstrate that in children with IDD who have heightened behavioural attention difficulties, unique cognitive attention profiles can be delineated once attention is studied in depth. In particular, these findings indicate that children with DS have greater difficulties of visual attention than children with ASD and NSID. These findings have implications for researchers of children with and without intellectual disability as they draw attention to the differential sensitivity of gross behavioural indices and cognitively informed indices, with the latter offering more comprehensive assessments. In addition, this study provides evidence that superior visual search is not necessarily a universal feature of ASD; but rather restricted to those who have ASD without intellectual disability. Furthermore, this study extends our understanding of the concurrent association between attention difficulties and domain specific skills, such as literacy and numeracy in children with IDD. Given the correlational design of the current study, we cannot assert a causal role of visual attention on literacy and numeracy skills. Therefore, further research is needed to establish if the acquisition of early literacy and numeracy skills is indeed dependent on the successful development of visual attentional systems. If this directionality is confirmed, then difficulties in visual attention may be useful early indicators of learning impairments, as well as potential targets of early intervention for children with and without intellectual and developmental disabilities.

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