**Attentional abilities constrain language development:**

**A cross-syndrome infant/toddler study**

*[Running title: Attentional abilities: A cross-syndrome study]*

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Research Highlights

* Very little was known about visual orienting in infants/toddlers with neurodevelopmental disorders other than autism
* The study is the first to identify a visual disengagement impairment in infants/toddlers with Down syndrome
* Also, our results suggest that visual disengagement is related to language ability
* The impairment in Down syndrome may therefore contribute to their language delay

Abstract

Typically developing (TD) infants adapt to the social world in part by shifting the focus of their processing resources to the relevant aspects of a visual scene. Any impairment in visual orienting may therefore constrain learning and development in domains such as language. However, although something is known about visual orienting in infants at risk of autism, very little is known about it in infants/toddlers with other neurodevelopmental disorders. This is partly because previous studies focused on older children and rarely compared the children to *both* chronological- and mental-age matched TD controls. Yet, if visual orienting is important for learning and development, then it is imperative to investigate it *early in development* and ascertain whether it relates to higher-level cognitive functions such as language. We used eye tracking technology to directly compare visual orienting in infants/toddlers with one of three neurodevelopmental disorders—Down syndrome (DS), fragile X syndrome (FXS), and Williams syndrome (WS)—matched on chronological- or mental-age to TD controls (~15 months). We also measured language ability using the Mullen Scales of Early Learning. We found that the ability to *disengage* attention from a visual stimulus in order to shift it to another visual stimulus is related to language ability in infants/toddlers irrespective of group affiliation. We also found that, contrary to the literature, infants and toddlers with DS (but not WS) are slow at disengaging attention. Our data suggest that orienting attention constrains language development and is impaired in DS.

*Keywords:* visual orienting, visual disengagement, language acquisition, Down syndrome, fragile X syndrome, Williams syndrome

The ability to actively select and attend to relevant aspects of the ever-changing environment, by shifting one’s focus of visual attention, is crucial for learning and development (Stevens & Bavelier, 2012). For example, Slaughter and McConnell (2003) found that an infant’s ability to follow gaze is related to their language ability. It is therefore possible that infants use eye gaze to infer what object or event is being referred to and labelled by their caregiver; certainly infants are more likely to learn an object’s label if the object being labelled dominates their visual field (Pereira, Smith, & Yu, 2014). Also, the ability to match auditory and visual information positively correlates with language ability, which suggests that visual processing bootstraps word learning (Bahrick, Todd, & Soska, 2018). Consequently, any irregularity in shifting attention may constrain how one interacts with, and thus learns from, the environment, with deleterious effects. Irregularities in shifting attention have been observed in children with neurodevelopmental disorders. For example, infants who develop autism are slower than typically developing (TD) controls at *disengaging* attention from a central fixation stimulus in order to shift attention to the sudden appearance of a peripheral target (e.g., Elsabbagh et al., 2013; Zwaigenbaum et al., 2005). This visual attention impairment has been linked to language impairments – e.g., to spoken word recognition in 4-to 7-year-olds with autism (Venker, 2017). This fits with the hypothesis that shifting one’s focus of attention to objects being labelled strengthens correct word-object associations and prunes incorrect ones; while focusing on the wrong object during labelling builds competing incorrect word-object associations (Kucker, McMurray, & Samuelson, 2015). It fits with evidence that visual processing bootstraps word learning (Bahrick, Todd, & Soska, 2018). It also fits with data that support a broader hypothesis that the ability to disengage and shift attention facilitates the coordination of attention between child and caregiver (joint attention) (Hood, Willen, & Driver, 1998), which in turn feeds into the emergence of social skills, including language learning (Carpenter, Nagell, & Tomasello, 1998). It is therefore important to identify visual attention impairments in young children, before the impairments may constrain the emergence of higher codifficulties cascade nderstand the

However, evidence of atypical visual orienting in neurodevelopmental disorders other than autism is ambiguous. For example, although as many as one third of children with Williams syndrome (from 8 months to 5 years of age) were found to be relatively slow at disengaging attention from a central fixation stimulus that remained onscreen when a peripheral target appeared (Atkinson et al., 2003), it is difficult to interpret the data because the fixation stimulus used in the study was face-like – and individuals with WS are drawn to faces (Riby & Hancock, 2009; Riby et al., 2011). Therefore, it is possible that the long disengagement latencies reported in Atkinson et al. (2003) are specific to face stimuli. Also, the WS data were not directly compared with data from TD controls.

Another study tested attentional orienting in eight 3- to 41-month-old infants/toddlers with WS (Cornish, Scerif, & Karmiloff-Smith, 2007). These children were presented with peripheral targets on a computer screen that were either validly cued or invalidly cued. The researchers found that the participants with WS were slower at orienting towards invalidly cued targets than a group of nine toddlers with fragile X syndrome (FXS) and 20 mental age matched TD controls. Because the groups did not significantly differ in speed of orienting to validly cued targets, the authors concluded that the children with WS had difficulty with disengaging attention. However, it is difficult to draw firm conclusions from this experiment. For instance, at least one of the eight children with WS was 3 months of age (age range: 3-41 months; mean chronological age: 18 months). Yet, the ability to disengage attention only gradually emerges from 3- to 4-months of age in TD children (Johnson, Posner, & Rothbart, 1991). Furthermore, because the sample size was small, even that one infant could have distorted the effects (the data were not screened for outliers) and the youngest child in the FXS comparison group was much older at 14 months (age range: 14-55 months; mean chronological age: 35 months). Also, the groups were matched on mental age (MA), but mean MA was 12 months in WS, 19 months in FXS, and 22 months in the TD controls.

One study (Brown et al., 2003) did clearly demonstrate an attentional irregularity in WS, however. Thirteen toddlers with WS were presented with a fixation stimulus that was followed by the brief appearance of two targets (in different parts of the screen) that flashed sequentially with no period of overlap. The face of each child was videotaped and coded. Whereas the majority of TD controls made a first saccade to either the first or second flash, followed by a second saccade to the second flash, the majority of toddlers with WS made a first saccade to either the first flash *or* the second flash *or* somewhere in between, and made no second saccade. Interestingly, a well matched group of toddlers with DS also completed the task and performed similarly to the TD controls. This suggests that toddlers with WS cannot direct their saccadic eye movements as effectively as toddlers with DS or TD controls. However, it is difficult to know how poor target localisation in WS relates to real world visual exploration when the duration of the first target in the experiment was just 0.07 s long (i.e., it was a mere flash) and the second target, which was 0.1 s long, followed with no temporal gap. The paper is important because it identified a (possibly syndrome-specific) atypicality in visual attention, but relating the data to other data and contexts is not easy. Clearly, more research is required before we can draw firm conclusions about basic visual orienting in WS.

Irregularities in visual orienting have also been found in fragile X syndrome. Roberts and colleagues (2012) found that a group of twelve 12-month-olds with fragile X syndrome (FXS) spent more time looking at a toy before switching attention than TD controls matched on chronological age. However, this difference was not statistically significant after an outlier had been removed. We must therefore draw conclusions with caution. Moreover, some studies have found no evidence of visual orienting impairments in neurodevelopmental disorders. For example, Landry and Bryson (2004) administered a visual orienting task to 3-to 8-year-old children with Down syndrome (DS) and 2- to 6-year-old TD controls matched on mental age (3-4 years). In each trial, a visual fixation stimulus appeared at the centre of a monitor. After a 0.25 s delay, a visual target stimulus appeared at the periphery (left or right of centre). In 10 of 20 trials, the fixation stimulus disappeared when the target appeared (the *baseline* condition). In the other 10 trials, the fixation stimulus remained onscreen even after the target had appeared (the *overlap* condition). Landry and Bryson (2004) found that whereas the TD controls were slower at orienting in the overlap condition than the baseline condition, the children with DS were not. Moreover, the children with DS produced significantly faster response times in the overlap condition than the TD controls. Furthermore, whereas the TD children completely failed to disengage attention from the fixation stimulus on 7.7% of the trials, the children with DS completely failed to disengage attention on only 0.8% of the trials. The authors concluded that children with DS can disengage attention with “remarkable ease” (Landry & Bryson, 2004, p. 1120). However, it is important to note that saccadic eye movements become faster over developmental time (Irving, Steinbach, Lillakas, Babu, & Hutchings, 2006), and the children with DS were on average two years older than the TD controls. *It would therefore be useful to compare DS on both chronological- and mental-age matched controls.* It may also be important to study visual orienting in DS *earlier in development*, especially because differences in visual attention (hand-eye coordination) predict differences in joint attention (toddlers’ and parents’ coordinated attention to each other and to an object; Yu & Smith, 2008, 2013, 2015, 2017), which in turn predicts word learning in toddlers (Yu & Smith, 2012). So, visual attention appears to be associated with early language development.

In sum, evidence for visual orienting impairments in neurodevelopmental disorders other than autism is ambiguous. Moreover, the studies have focused on older children. Yet, if visual orienting is critical for learning and development in naturalistic contexts (see D’Souza, D’Souza, & Karmiloff-Smith, 2017, for discussion), then it is important to investigate it *early in development* (in infants and toddlers) and ascertain whether it relates to higher-level cognitive functions such as language. Also, for data interpretation, it is imperative to compare atypically developing groups with both chronological- *and* mental-age matched controls. We seek to directly compare visual orienting across three neurodevelopmental disorders (DS, FXS, WS) matched on chronological- and mental-age to TD controls, early in development, and relate attention (a basic-level function) to a higher-level function and index of real-world learning: language. DS, FXS, and WS were chosen for comparison because they are often reported as having a core impairment in different attentional domains: sustained attention in DS, attentional control in FXS, and orienting in WS (e.g., Brown et al., 2003).

**Methods**

**Participants**

One hundred infants/toddlers with a neurodevelopmental disorder participated in this experiment, including 22 infants with DS, 26 toddlers with DS, 13 toddlers with FXS, 14 infants with WS, and 25 toddlers with WS. The participants had been clinically diagnosed and genetically tested for full trisomy 21 (DS), mutation of the FMR1 gene (FXS), or deletion of the ELN gene (WS). The participants in this study had no uncorrected visual or hearing impairment. Data collected from these children were compared with data from 24 typically developing (TD) controls. See Table 1.

Because children with DS, FXS, or WS have a mental age (MA) of approximately half their chronological age (CA), the participants were matched on either CA or MA to the TD controls. Participants’ mental ages were obtained using the Mullen Scales of Infant Learning (MSEL; Mullen, 1995). The MSEL was selected because children are not required to understand speech in order to complete items (except for the items that were designed to directly measure language ability). This makes it an ideal tool for measuring MA in young children with language delay. Unfortunately, we were unable to recruit a large enough sample of infants with FXS who could be matched to TD controls as young as 15 months. This is due to FXS not being usually diagnosed until late childhood. Table 1 shows mean CA/MA for each of the remaining CA-/MA-matched groups. Crucially, the CA-matched groups (TD controls, DS infants, WS infants) did not significantly differ on CA, *F*(2,57) = 1.21, *p* = .306. Nor did the CA-matched DS and WS groups significantly differ on MA, *t*(30) = 0.32, *p* = .751. Furthermore, the MA-matched groups (TD controls, DS toddlers, FXS toddlers, WS toddlers) did not significantly differ on MA, *F*3,80 = 0.98, *p* = .408. Age equivalent scores in the MSEL were analysed instead of standardised scores, because MSEL norms were generated using TD data and scores from children with neurodevelopmental disorders often fall below the 2nd percentile.

**Design**

The gap-overlap task—adapted from Hood & Atkinson (1993) and Elsabbagh et al. (2013)—measures efficiency of visual orienting. In this gaze-contingent paradigm, participants were presented with three trial conditions: baseline, gap, and overlap. Each trial started with the appearance of an attention-grabbing central fixation stimulus. In the baseline trial condition, this central fixation stimulus vanished and was immediately followed by a peripheral target. In the gap condition, the central fixation stimulus was followed by the peripheral target after a 0.2 s delay. In the overlap condition, the central fixation stimulus was still present when the target appeared, with both stimuli remaining onscreen for the duration of the trial. The time it took for the participant to shift their gaze to the peripheral target from the onset of the peripheral target was measured for each trial.

In a review of the literature, Hayhoe and Ballard (2005) concluded that saccadic movements are driven by prospects of reward (see also Takikawa, Kawage, Itoh, Nakahara, & Hikosaka, 2002). Therefore, successful shifts of attention (i.e., any shift of attention from the central fixation stimulus to the peripheral target within 1.2 s) were “rewarded” with an interesting dynamic stimulus and sound.

**Materials**

Three stimuli types were used: central fixation, peripheral target, and “reward”. The central fixation stimulus was a colourful 4.5° x 4.5° animated cartoon of a clock. The peripheral target was an 3.0° x 3.0° animated cartoon of a cloud. The reward was one of six 3.0° x 3.0° animated cartoons (e.g., a balloon, car, butterfly). All visual stimuli flickered and were accompanied by a nonverbal sound (beep! or yip!) to attract the infant’s attention.

A Tobii T120 remote eye tracker (Tobii Technology AB) subtending 24° was used to capture moment-to-moment point of gaze at a sampling rate of 120 Hz, with measurement accuracy of about 0.5°. The visual stimuli were presented on a 34 x 27 cm TFT liquid crystal display monitor, with a resolution of 1280 x 1024 pixels and a response rate of 4 ms. The tracking equipment and stimulus presentation were controlled using customised scripts in MATLAB R2010a. A camera mounted directly above the horizontal midpoint of the screen was used to monitor and record infant behaviour. Auditory stimuli were delivered via two speakers positioned behind the display monitor and facing the participant.

**Procedure**

Infants sat on their parent’s lap, in a dimly lit featureless room, facing the stimulus-presentation screen with their eyes at approximately 65 cm from the screen. The experimenter sat behind a curtain and observed the infant via a camera that was positioned centrally and above the screen. Caregivers were asked to close their eyes during the experiment. Trials were pseudorandomised and presented consecutively. Each trial began with a centrally presented cartoon (the central fixation stimulus) that expanded and contracted for 0.8 s in order to attract the infant’s attention. In the baseline and gap trials, once the child fixated on the central stimulus for 0.15 s, the central stimulus would disappear and a peripheral target would be presented. The target was immediately presented in the baseline trials and after a 0.2 s delay in the gap trials. In the overlap trials, the central stimulus would not disappear; instead it would cease expanding and contracting but remain onscreen and overlap with the appearance of the target. It ceased expanding/contracting so the dynamic peripheral target would be more interesting to the infant. The target was presented to either the left or the right of the central fixation stimulus at an eccentricity of 6°. It remained on screen until either the child looked at it, or until 3 s had elapsed. If the child looked at it within 1.2 s, s/he was “rewarded” with one of six animated “reward” stimuli.

Trials were presented pseudo-randomly in blocks of 12 until at least 14 usable (‘valid’) trials were acquired for each condition or a maximum of 74 trials were presented (D’Souza, 2014). Trials were considered to be valid if the infant fixated on the target after 0.2 s and before 1.2 s of its appearance (Matsuzawa & Shimojo, 1997). If the participant did not fixate on the peripheral target within this time window, then the trial was recorded as a “failure to disengage”. In addition, trials were considered invalid if the participant failed to look at the central stimulus prior to the presentation of the target or if the child blinked or looked away during the presentation of the stimulus. The whole procedure lasted around 5 minutes.

**Data Processing and Analysis**

Reaction time (RT) was calculated as the time it took for the participant to land a fixation at the location (a 9˚ square) of the peripheral target from the moment that the peripheral target appeared onscreen. Trials were excluded from analysis if (1) there was a period of more than 0.06 s of continuous data loss between the onset of the peripheral target and fixation of the peripheral target, (2) the eyes were not fixating the central stimulus at the onset of the peripheral target, and/or (3) the participant did not make a saccade to the peripheral target within 2 s of target onset. RTs less than 0.1 s (i.e., less than the minimum latency required to program a saccade in response to the appearance of a visual stimulus) and RTs greater than 1.2 s (which are unlikely to represent an exogenously driven reaction to the sudden appearance of a stimulus) were also excluded from analysis (Elsabbagh et al., 2013; Matsuzawa & Shimojo, 1997). Finally, for each condition, only data from participants who provided at least nine valid trials (see above) were included in the analysis (Table 2).

For each condition (baseline, gap, overlap), mean RT was calculated. Because we were interested in group-level effects, data that fall ±2 standard deviations from the group mean were excluded from analysis. The time it took the participants to disengage attention from the central fixation stimulus (the *Disengagement effect*) was calculated by subtracting RTs in the baseline condition from RTs in the overlap condition. (A facilitation effect was also calculated by subtracting RTs in the gap condition from RTs in the baseline condition; see Supplementary Information.) Whenever the spread of scores significantly differed across the groups, the degrees of freedom were adjusted using the Welch-Satterthwaite method.

**Results**

**CA-matched Comparisons**

**Main analyses*.*** A one-way ANOVA was used to investigate group differences in visual disengagement (overlap RTs minus baseline RTs). There was a significant main effect of Group, *F*(2,40) = 8.80, *p* < .001, *r* = .55. Post hoc tests revealed a significantly larger disengagement effect in DS than in TD controls and WS (*t*(26) = 3.21, *p* = .003, *d* = 1.04, *t*(27) = 3.33, *p* = .003, *d* = 1.42, respectively; α-level = .017 [Bonferroni]; Figure 1). The infants with WS did not significantly differ from the TD controls, *t*(21) = 1.93, *p* = .068.

**Relationship to language ability*.*** The infants with WS did not provide enough attention and language data (*n* = 9) for the following analysis and were thus excluded. To investigate whether the individuals’ ability to disengage attention was associated with language development, we took the median of each group and coded participants as either ‘fast’ or ‘slow’ depending on whether they scored higher or lower than their group’s median score (a classic median split; Iacobucci et al., 2015). If a participant’s score was the same as their group’s median, then that participant was coded as ‘slow’. Two 2 (Group: TD controls, DS infants) x 2 (Disengagement: fast, slow) ANOVAs were then carried out, with either receptive or expressive language as the dependent variable. For receptive language, the ANOVA revealed no interaction effect, *F*(1,27) = 0.55, *p* = .463, a significant effect of Group, *F*(1,27) = 44.66, *p* < .001, *η*2 = .62, and a marginal effect of Disengagement, *F*(1,27) = 4.15, *p* = .052, *η*2 = .13 (Figure 2). For expressive language, the ANOVA revealed no interaction effect, *F*(1,27) = 0.69, *p* = .414, a significant effect of Group, *F*(1,27) = 57.46, *p* < .001, *η*2 = .68, and a significant effect of Disengagement, *F*(1,27) = 4.90, *p* = .035, *η*2 = .15 (Figure 3). This hints at a relationship between the ability to disengage attention and receptive/expressive language irrespective of group affiliation.[[1]](#endnote-1)

To check that (basic-level) visual orienting ability is related to higher-level cognitive functions like language, *rather than “developmental age” per se*, two similar 2 x 2 ANOVAs were carried out but with fine motor ability and gross motor ability (measured using the Mullen) as the dependent variables. We selected motor ability because although by definition all measures of the Mullen relate to general development, there is probably more overlap between cognitive and language measures than between motor and language measures. There were significant effects of Group, both *F* > 59.80, *p* < .001, *η*2 > .68. However, there were no main effects of Disengagement on fine or gross motor ability, nor were there any interaction effects, all *F* < 0.48, *p* > .499. This suggests that visual orienting is not merely related to “developmental age”.

**MA-matched Comparisons**

**Main analyses*.*** A one-way ANOVA was used to investigate group differences in visual disengagement (overlap RTs minus baseline RTs). There was a significant main effect of Group, *F*(3,62) = 4.74, *p* = .005, *r* = .43. Post hoc *t*-tests showed that the disengagement effect in toddlers with DS was significantly larger than in TD controls, *t*(36) = 3.18, *p* = .003, *d* = 0.97 and toddlers with WS, *t*(39) = 3.26, *p* = .002, *d* = 1.06 (α-level = .008, Bonferroni) (Figure 4). This is a similar finding to the one found in the above CA-matched comparisons. No other significant differences were found.

**Relationship to language ability*.*** For receptive language, the 4 (Group: TD controls, DS toddlers, FXS toddlers, WS toddlers) x 2 (Disengagement: fast, slow) ANOVA revealed neither an interaction effect, *F*(3,56) = 0.13, *p* = .941, nor a main effect of Group, *F*(3,56) = 1.95, *p* = .131. There was, however, a main effect of Disengagement, *F*(1,56) = 4.39, *p* = .041, *η*2 = .07 (Figure 5). This suggests that there is a relationship between the ability to disengage attention and receptive language irrespective of group affiliation.

For expressive language, the 4 x 2 ANOVA revealed no interaction effect, *F*(3,56) = 0.15, *p* = .927, and a main effect of Group, *F*(3,56) = 4.80, *p* = .005, *η*2 = .21 – but no main effect of Disengagement, *F*(1,56) = 0.73, *p* = .398. This could be because expressive language is so variable in toddlers with neurodevelopmental (Table 1).To confirm that the ability to disengage attention is related to receptive language, *rather than “developmental age” per se*, two 2 x 2 ANOVAs were carried out with fine motor ability and gross motor ability (measured using the Mullen) as the dependent variables. There was no interaction effect, *F*(3,56) = 1.17, *p* = .330; nor was there a main effect of Group or Disengagement on fine motor ability, both *F* < 0.56, *p* > .476. For gross motor ability, the effect of Group was trending, *F*(3,52) = 2.68, *p* = .056. However, there was no interaction effect, *F*(3,52) = 2.24, *p* = .095; nor was there an effect of Disengagement, *F*(1,52) = 0.06, *p* = .807. These data suggest that visual orienting is not merely related to “developmental age”.

**Failure to Disengage**

In some trials, at least some of the participants completely failed to disengage attention from the central fixation stimulus. This raises the possibility that our strict exclusion criteria (e.g., saccadic response times of under 1.2 s) led to the exclusion of infants/toddlers with severe disengagement problems. To address this concern, we analysed “sticky fixation” (proportion of “stuck” trials to total number of overlap trials[[2]](#endnote-2)). However, we found no significant effect of Group, *F*(2,57) = 1.81, *p* = .174 (CA-matched), *F*(3,84) = 1.65, *p* = .183 (MA-matched).

**Discussion**

We found that the ability to disengage attention is associated with language development in typically and atypically developing infants/toddlers. It’s unlikely that this relationship merely indexes “developmental age”, because disengaging attention was not associated with fine or gross motor skills. At first blush, this is somewhat paradoxical because motor development should correlate with cognitive and language development, and it may even bootstrap the development of social and communication abilities – including word learning (see Leonard & Hill, 2014, for review). However, although language abilities emerge from interactions between many diverse factors (see D’Souza, D’Souza, & Karmiloff-Smith, 2017, for discussion), the effect of motor ability is likely to lessen over developmental time (for evidence, see Wang, Lekhal, Aaro, Holte, & Schjolberg, 2014). Also, it is possible that only some aspects of motor development relate to language development. For example, the relationship between manual gestures or rhythmical arm movements and language development appears to be stronger and more robust than the relationship between gross/fine motor abilities and language development (e.g., Bates, 1979; Bonvillian et al., 1983). This would explain why, for example, Alcock and Krawczyk (2010) found concurrent relationships between motor and language abilities using two parent report questionnaires, but when using lab-based measures found that language development was linked to oral motor control rather than fine/gross motor ability more generally. Motor development is therefore a useful proxy for general (non-linguistic) infant development – even if it is not completely isolated from cognitive/language development. Because the ability to orient attention develops very early in life (Johnson, Posner, & Rothbart, 1991) and does not seem to index “developmental age”, we suggest it constrains the emergence of higher-level cognitive functions including language.

We also found that, contrary to claims in the literature (e.g., Landry & Bryson, 2004), the ability to disengage attention is impaired in young children with DS. Our results may differ because previous studies focused on older children. For example, Landry and Bryson (2004) studied thirteen 5-year-olds with DS, while Cornish, Scerif, and Karmiloff-Smith (2007) studied eight 4.7- to 6-year-olds with DS. We studied children matched chronologically and mentally to 15 months. In TD children, the ability to disengage attention increases over developmental time (e.g., Kulke, Atkinson, & Braddick, 2015) and then is likely to plateau due to its relationship with the development of the splenium of the corpus callosum (Elison et al., 2013) which has a decreasing rate of expansion (Ansado et al., 2015). It is therefore possible that the ability to disengage attention is impaired relative to TD only during infancy and toddlerhood in DS. Interestingly, children with WS (who did not demonstrate such an impairment) often go on to develop relatively strong language skills. We found no significant difference in language ability between infants/toddlers with DS and WS, but plan to follow up the children at 7-10 years to ascertain whether early visual attention is more predictive of later language outcomes in DS than WS.

**Why is the ability to disengage attention associated with language development?**

One explanation is that attentional disengagement and language development interact through reflexive joint attention (Bruner, 1983) and gaze-following (Scaife & Bruner, 1975). Infants learn their first words by matching what they hear to what they *see*. But because visual scenes are often cluttered, it seems impossible for children to work out what a spoken word could be referring to (Quine, 1960). How can an infant infer the meaning of a word they hear when their everyday visual experience contains so much referential ambiguity? One possible solution is that they follow their caregiver’s gaze (attention) to objects that the caregiver subsequently labels. These moments of joint attention—when the infant and caregiver share attention to an object—reduce referential ambiguity and make word learning possible. Infants are more likely to learn the label for a novel object when only that object fills their view (Pereira, Smith, & Yu, 2014; Yu & Smith, 2012). The initial step—gaze following—requires the infant to flexibly *disengage* and shift attention. Difficulty in disengaging attention may thus have deleterious consequences for the coordination of visual attention to objects – which in turn may reduce moments of joint attention and impair language acquisition. However, gaze direction is not a spatially precise cue and infants tend to focus more on hands and objects being handled than on caregivers’ eyes (Yu & Smith, 2013). The extent to which variation in attentional disengagement impacts this process (if at all) is not clear. Furthermore, joint attention does not appear to be a particular weakness in DS (Hahn, Loveall, Savoy, Neumann, & Ikuta, 2018). Future work using head-mounted eye tracking to study attention allocation during naturalistic parent-child interaction is therefore crucial in order to elucidate the sensorimotor mechanisms that link different aspects of visual attention to language acquisition.

Another possibility is that one or more factors early in development underpin the correlation between attentional disengagement and language ability later in development. For example, mutual gaze during dyadic interaction at 5 months of age predicts attentional disengagement at 11 months (Niedźwiecka, Ramotowska, & Tomalski, 2017), while dyadic re-engagement at 6 months predicts gaze following at 12 months (Yazbek & D’Entremont, 2006), which is associated with language development (Brooks & Meltzoff, 2008). It is therefore possible that mutual gaze tunes neural systems involved in arousal, motivation, and/or attention, which over developmental time, facilitate attention and social development, including language development. This explanation complements the former one. However, frequency of joint attention was negatively correlated with language development in one study of children with DS (Harris et al., 1996) and not at all correlated with language development in another (Mundy et al., 1998). Furthermore, one study found a dissociation between joint attention and language development in WS (Laing et al., 2002). So, variability in mutual gaze may account for variability in attention/language in TD but not atypical development.

An alternative explanation is that visual disengagement is an index of early inhibitory control, selective attention, and/or the tendency to explore the external world (impaired in DS; D’Souza, D’Souza, & Karmiloff-Smith, 2017), which in turn constrains the emergence of higher-level cognitive functions critical for language development. Furthermore, visual attention enhances not only visual information but also multimodal information. For example, foveating on a location enhances sound clarity as well as visual acuity in the foveated area (Driver, Eimer, Macaluso, & van Velzen, 2004). Functional MRI studies suggest that brain areas involved in orienting to visual stimuli are also involved in orienting to stimuli in other modalities (Driver et al., 2004). Moreover, visual orienting seems to encompass higher-level (non-sensory) cognitive processes, such as working memory (Desimone, 1998; Griffin & Nobre, 2003) and long-term memory (Summerfield, Lepsien, Gitelman, Mesulam, & Nobre, 2006), which are all impaired in DS (Fidler, 2005), as well as necessary for (word) learning. Future work will relate basic-level attentional processes to a wide range of higher-level cognitive processes.

**Why is visual *disengagement* atypical in DS but not WS?**

Orienting attention involves two (dorsal and ventral) frontoparietal brain networks (Corbetta & Shulman, 2002). The dorsal network is impaired in WS (Atkinson & Braddick, 2011; Brown et al., 2003; Jackowski et al., 2009; see also Supplementary Information). However, breaking attention involves the ventral network. This ventral system, which includes the temporoparietal junction (TPJ), appears to function as a ‘circuit breaker’ for the dorsal system, redirecting attention to unexpected or salient events – such as the appearance of the peripheral target in the gap-overlap task. It is possible that this system is more impaired in DS than WS. Interestingly, a functional parcellation of the brain (using data from fMRI scans) revealed a vastly simplified network structure in adults with DS, with no sign of the TPJ in the default mode network (Anderson et al., 2013). We hope to confirm this simplified structure using EEG data we collected from our DS sample.

It is important to note, however, that our data do not suggest that visual orienting is typical in WS. On the contrary, the infants/toddlers with WS did not allocate their attentional resources in the same way as TD controls (Supplementary Information; see also Brown et al., 2003, for evidence that toddlers with WS have difficulty redirecting attention when visual stimuli are presented in rapid succession). We draw a distinction between attentional disengagement and attentional engagement. While the former is delayed in DS, the latter may be delayed in WS. According to Petersen and Posner (2012), selecting and attending to the relevant aspects of one’s visual environment involves (1) *disengaging* one’s attention from the current focus, (2) *shifting* it to a new target, and finally (3) re-*engaging* it on the new focus of attention. The disengagement effect (overlap RTs minus baseline RTs) measures the ability to *disengage* attention and was atypical in DS. RTs in the gap condition reflect the ability to *shift* attention and appears to be similar across groups. The gap-overlap task cannot directly measure the ability to *engage* and process stimuli, but RTs were similar across experimental conditions in the CA-matched WS group. This is highly unusual and suggests that visual orienting is atypical in infants with WS. Our only explanation is that the children with WS did not have sufficient time to fully engage with the central fixation stimulus (perhaps because it only appeared on screen for a short amount of time before the target appeared). Because the children with WS did not have sufficient time to deeply engage the central fixation stimulus, they were able to quickly shift away from it. In other words, they did not have to disengage their attention to the same degree as the other children. They were not quicker at disengaging attention (overlap minus baseline). But they seemed to produce similar RTs irrespective of the experimental manipulation, and this suggests that they had not fully engaged with the central fixation stimulus in the first place, to the continued presence of the central fixation stimulus or the temporal gap had less effect on their ability to shift attention to the target (see SI). Also, the data do not suggest that the infants with WS were less engaged with the task itself – because trials were valid only when infants looked at the central fixation stimulus and then shifted attention to the target within 1.2 s, indicating engagement with the experimental stimuli. We can therefore infer that the infants with WS were *engaging* the central fixation stimulus less deeply than the other children. We can test our hypothesis in future by varying the length of duration of the central fixation stimulus and calculating the effect that this manipulation would have on RTs across conditions in WS.

Therefore, while we do not exclude the possibility that at least one aspect of attention—*attentional engagement*—is delayed in WS, our data suggest that in addition to sustained attention (Brown et al., 2003) and executive attention (Breckenridge, Braddick, Anker, Woodhouse, & Atkinson, 2012), attentional orienting—specifically, the ability to *disengage attention*—is also impaired in DS. Our data also challenge the traditional view that attentional deficits in DS are confined to the auditory modality (Fidler, 2005). We argue that all components of attention—including visual attention—develop atypically in DS, and thus children with DS should no longer be used as MA-matched controls in cross-syndrome studies of visual orienting (e.g., Flanagan et al., 2007).

**Implications**

Although our sample size is comparable with similar studies, it is nevertheless small and our study should be replicated. Nevertheless, some tentative conclusions can be drawn. Because visual disengagement is related to language ability, our findings hint at the possibility that language abilities could be improved by targeting attentional impairments early in development. To confirm this, future work will need to elucidate the mechanisms through which visual attention and language interact – and establish cause and effect (which our study does not). The possible clinical implications should not be overlooked, because parent-mediated intervention has been reported to improve attentional disengagement (measured using the gap-overlap task) in infants at high risk of autism (Green et al., 2015). This suggests that attentional disengagement is amenable to attentional training in at least one group of atypically developing children (see Goodwin et al., 2016, for details of a randomised controlled trial involving another group: infants at risk of ADHD). It is important to know whether ameliorating the visual attention impairment in infants/toddlers with DS will result in better language outcomes.

**Conclusion**

We found that disengaging attention from a visual stimulus is associated with language ability—but not fine/gross motor ability—in typically- and atypically-developing infants and toddlers. Contrary to previous reports, this ability to disengage attention is impaired in DS. We suggest that attentional disengagement is slow to develop in DS – with relative long latencies in infancy and toddlerhood. Future research should aim to replicate these findings, elucidate the mechanisms through which visual orienting and language may interact, and ascertain whether attentional training can improve language development in DS.

**References**

Anderson, J. S., Nielsen, J. A., Ferguson, M. A., Burback, M. C., Cox, E. T., Dai, L., … & Korenberg, J. R. (2013). Abnormal brain synchrony in Down Syndrome. *NeuroImage: Clinical*, *2*, 703-715.

Ansado, J., Collins, L., Fonov, V., Garon, M., Alexandrov, L., Karama, S., ... & Brain Development Cooperative Group. (2015). A new template to study callosal growth shows specific growth in anterior and posterior regions of the corpus callosum in early childhood. *European Journal of Neuroscience*, *42*(1), 1675-1684.

Atkinson, J., & Braddick, O. J. (2011). From genes to brain development to phenotypic behavior: "dorsal-stream vulnerability" in relation to spatial cognition, attention, and planning of actions in Williams syndrome (WS) and other developmental disorders. *Progress in Brain Research*, *189*, 261-283.

Atkinson, J., Braddick, O. J., Anker, S., Curran, W., Andrew, R., Wattam-Bell, J., & Braddick, F. (2003). Neurobiological models of visuospatial cognition in children with Williams syndrome: Measures of dorsal-stream and frontal function. *Developmental Neuropsychology*, *23*(1-2), 139-172.

Bahrick, L. E., Todd, J. T., & Soska, K. C. (2018). The Multisensory Attention Assessment Protocol (MAAP): Characterizing individual differences in multisensory attention skills in infants and children and relations with language and cognition. *Developmental Psychology*, *54*(12), 2207.

Breckenridge, K., Braddick, O., Anker, S., Woodhouse, M., & Atkinson, J. (2012). Attention in Williams syndrome and Down’s syndrome: Performance on the new early childhood attention battery. *British Journal of Developmental Psychology*, *31*, 257-269.

Brown, J. H., Johnson, M. H., Paterson, S. J., Gilmore, R., Longhi, E., & Karmiloff-Smith, A. (2003). Spatial representation and attention in toddlers with Williams syndrome and Down syndrome. *Neuropsychologia*, *41*(8), 1037-1046.

Bruner, J. (1983). *Child’s talk: Learning to use language*. New York: W. W. Norton.

Carpenter, M., Nagell, K., Tomasello, M., Butterworth, G., & Moore, C. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development*, *63*(4), 1-174.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, *3*(3), 201.

Cornish, K. M., Scerif, G., & Karmiloff-Smith, A. (2007). Tracing syndrome-specific trajectories of attention across the lifespan. *Cortex*, *43*(6), 672-685.

Cousijn, J., Hessels, R. S., Van der Stigchel, S., & Kemner, C. (2017). Evaluation of the Psychometric Properties of the Gap‐Overlap Task in 10‐Month‐Old Infants. *Infancy*, *22*(4), 571-579.

Desimone, R. (1998). Visual attention mediated by biased competition in extrastriate visual cortex. *Philosophical Transactions of the Royal Society of London – Series B Biological Sciences*, *353*(1373), 1245-1255.

Driver, J., Eimer, M., Macaluso, E., & van Velzen, J. (2004). Neurobiology of human spatial attention: Modulation, generation, and integration. In N. Kanwisher & Duncan J. (Eds.), *Attention and Performance XX: Functional Brain Imaging of Visual Cognition* (pp. 267-300). Oxford, UK: Oxford University Press.

D’Souza, D. (2014). *Are early cognitive and neurophysiological markers of autism syndrome-specific? A cross-syndrome comparison* (Unpublished doctoral thesis). University of London, London, UK.

D’Souza, D., D’Souza, H., & Karmiloff-Smith, A. (2017). Precursors to language development in typically and atypically developing infants and toddlers: the importance of embracing complexity. *Journal of Child Language*, *44*(3), 591-627.

Elsabbagh, M., Fernandes, J., Jane Webb, S., Dawson, G., Charman, T., & Johnson, M. H. (2013). Disengagement of visual attention in infancy is associated with emerging autism in toddlerhood. *Biological Psychiatry*, *74*(3), 189-194.

Fidler, D. J. (2005). The emerging Down syndrome behavioral phenotype in early childhood. *Infants & Young Children*, *18*(2), 86-103.

Flanagan, T., Enns, J. T., Murphy, M. M., Russo, N., Abbeduto, L., Randolph, B., & Burack, J. A. (2007). Differences in visual orienting between persons with Down or fragile X syndrome. *Brain and Cognition*, *65*(1), 128-34.

Goodwin, A., Salomone, S., Bolton, P., Charman, T., Jones, E. J., Pickles, A., ... & Johnson, M. H. (2016). Attention training for infants at familial risk of ADHD (INTERSTAARS): study protocol for a randomised controlled trial. *Trials*, *17*(1), 608.

Green, J., Charman, T., Pickles, A., Wan, M. W., Elsabbagh, M., Slonims, V., ... & Johnson, M. H. (2015). Parent-mediated intervention versus no intervention for infants at high risk of autism: a parallel, single-blind, randomised trial. *The Lancet Psychiatry*, *2*(2), 133-140.

Griffin, I. C., & Nobre, A. C. (2003). Orienting attention to locations in internal representations. *Journal of Cognitive Neuroscience*, *15*(8), 1176-1194.

Hayhoe, M., & Ballard, D. (2005). Eye movements in natural behavior. *Trends in Cognitive Sciences*, *9*(4), 188-194.

Hood, B. M., & Atkinson, J. (1993). Disengaging visual attention in the infant and adult. *Infant Behavior and Development*, *16*(4), 405-422.

Hood, B. M., Willen, J. D., & Driver, J. (1998). Adult's eyes trigger shifts of visual attention in human infants. *Psychological Science*, *9*(2), 131-134.

Iacobucci, D., Posavac, S. S., Kardes, F. R., Schneider, M. J., & Popovich, D. L. (2015). The median split: Robust, refined, and revived. *Journal of Consumer Psychology*, *25*(4), 690-704.

Irving, E. L., Steinbach, M. J., Lillakas, L., Babu, R. J., & Hutchings, N. (2006). Horizontal saccade dynamics across the human life span. *Investigative Ophthalmology & Visual Science*, *47*(6), 2478-2484.

Jackowski, A. P., Rando, K., de Araújo, C. M., Del Cole, C. G., Silva, I., & de Lacerda, A. L. T. (2009). Brain abnormalities in Williams syndrome: a review of structural and functional magnetic resonance imaging findings. *European Journal of Paediatric Neurology*, *13*(4), 305-316.

Johnson, M. H., Posner, M. I., & Rothbart, M. K. (1991). Components of visual orienting in early infancy: Contingency learning, anticipatory looking, and disengaging. *Journal of Cognitive Neuroscience*, *3*(4), 335-344.

Kucker, S. C., McMurray, B., & Samuelson, L. K. (2015). Slowing down fast mapping: Redefining the dynamics of word learning. *Child Development Perspectives*, *9*(2), 74-78.

Landry, R., & Bryson, S. E. (2004). Impaired disengagement of attention in young children with autism. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *45*(6), 1115-1122.

Leonard, H. C., & Hill, E. L. (2014). The impact of motor development on typical and atypical social cognition and language: A systematic review. *Child and Adolescent Mental Health*, *19*(3), 163-170.

Matsuzawa, M., & Shimojo, S. (1997). Infants' fast saccades in the gap paradigm and development of visual attention. *Infant Behavior & Development*, *20*(4), 449-455.

Mullen, E. (1995). *Mullen Scales of Early Learning* (AGS ed.).  Circle Pines, MN: American Guidance Service.

Niedźwiecka, A., Ramotowska, S., & Tomalski, P. (2018). Mutual gaze during early mother–infant interactions promotes attention control development. *Child Development*, *89*(6), 2230-2244.

Pereira, A. F., Smith, L. B., & Yu, C. (2014). A bottom-up view of toddler word learning. *Psychonomic Bulletin & Review*, *21*(1), 178-185.

Quine, W. V. (1960). *Word and object*. Cambridge, MA: MIT Press.

Riby, D. M., & Hancock, P. J. B. (2009). Do faces capture the attention of individuals with Williams syndrome or Autism? Evidence from tracking eye movements. *Journal of Autism and Developmental Disorders*, *39*, 421-431.

Riby, D. M., Jones, N., Brown, P. H., Robinson, L. J., Langton, S. R., Bruce, V., & Riby, L. M. (2011). Attention to faces in Williams syndrome. *Journal of Autism and Developmental Disorders*, *41*(9), 1228-1239.

Roberts, J. E., Hatton, D. D., Long, A. C., Anello, V., & Colombo, J. (2012). Visual attention and autistic behavior in infants with fragile X syndrome. *Journal of Autism and Developmental Disorders*, *42*(6), 937-946.

Scaife, M., & Bruner, J. S. (1975). The capacity for joint visual attention in the infant. *Nature*, *253*, 265-266.

Stevens, C., & Bavelier, D. (2012). The role of selective attention on academic foundations: A cognitive neuroscience perspective. *Developmental Cognitive Neuroscience*, *15*(2), Suppl 1:S30-S48. doi: 10.1016/j.dcn.2011.11.001

Summerfield, J. J., Lepsien, J., Gitelman, D. R., Mesulam, M., & Nobre, A. C. (2006). Orienting attention based on long-term memory experience. *Neuron*, *49*(6), 905-916.

Takikawa, Y., Kawagoe, R., Itoh, H., Nakahara, H., & Hikosaka, O. (2002). Modulation of saccadic eye movements by predicted reward outcome. *Experimental Brain Research*, *142*(2), 284-291.

Venker, C. E. (2017). Spoken word recognition in children with autism spectrum disorder: The role of visual disengagement. *Autism*, *21*(7), 821-829.

Yu, C., & Smith, L. B. (2012). Embodied attention and word learning by toddlers. *Cognition*, *125*(2), 244-262.

Yu, C., & Smith, L. B. (2013). Joint attention without gaze following: Human infants and their parents coordinate visual attention to objects through eye-hand coordination. *PLoS ONE*, *8*(11), e79659.

Zwaigenbaum, L., Bryson, S., Rogers, T., Roberts, W., Brian, J., & Szatmari, P. (2005). Behavioral manifestations of autism in the first year of life. *International Journal of Developmental Neuroscience*, *23*(2-3), 143-152.

**Table**

Table 1

*Mean chronological age (CA), mental age (MA), Mullen subscale score, and saccadic RT for each CA-matched group (TD controls, DS infants, WS infants) and MA-matched group (TD controls, DS toddlers, FXS toddlers, WS toddlers). Standard deviations are in parentheses.*

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Group** | ***N*** | **CA**  **in months** | **MA**  **in months** | **Gross Motor**  **in months** | **Visual Reception**  **in months** | **Fine**  **Motor**  **in months** | **Receptive Language**  **in months** | **Expressive Language**  **in months** | **Gap**  **RT**  **in ms** | **Baseline RT**  **in ms** | **Overlap RT**  **in ms** | **Disengage-ment**  **in ms** |
| TD controls | 24 | **15.6 *(0.9)*** | **16.9 *(2.5)*** | 16.4 *(3.3)* | 17.2 *(2.2)* | 17.4 *(1.8)* | 15.9 *(4.7)* | 17.1 *(3.7)* | 285 *(43)* | 388 *(35)* | 571 *(80)* | 193 *(79)* |
| DS infants | 22 | **16.3 *(1.8)*** | 8.5 *(2.4)* | 7.9 *(1.2)* | 9.4 *(3.2)* | 10.0 *(2.8)* | 7.2 *(2.3)* | 7.2 *(3.1)* | 256 *(28)* | 334 *(53)* | 634 *(139)* | 300 *(131)* |
| WS infants | 14 | **16.4 *(2.3)*** | 8.7 *(1.9)* | 9.2 *(1.5)* | 10.3 *(2.3)* | 10.4 *(2.7)* | 6.4 *(2.1)* | 7.8 *(2.7)* | 336 *(104)* | 379 *(80)* | 489 *(125)* | 133 *(94)* |
| DS toddlers | 26 | 27.2 *(7.2)* | **15.9 (*4.7*)** | 13.6 *(4.2)* | 16.9 *(4.9)* | 16.9 *(4.3)* | 14.9 *(6.0)* | 15.1 *(6.0)* | 242 *(27)* | 305 *(38)* | 584 *(133)* | 279 *(120)* |
| FXS toddlers | 13 | 32.7 *(7.4)* | **14.5 (*4.1*)** | 16.5 *(3.2)* | 17.7 *(4.9)* | 16.0 *(2.9)* | 14.2 *(7.0)* | 10.2 *(4.9)* | 258 *(23)* | 356 *(49)* | 577 *(134)* | 228 *(129)* |
| WS toddlers | 25 | 30.1 *(8.2)* | **16.1 (*4.5*)** | 14.7 *(4.1)* | 17.4 *(5.6)* | 15.8 *(3.2)* | 16.3 *(6.3)* | 15.0 *(5.8)* | 336 *(83)* | 424 *(81)* | 559 *(120)* | 154 *(119)* |

Table 2

*Number of participants who completed the language scales of the Mullen and who provided valid eye tracking data for at least nine trials, by group (mean numbers of valid trials per participant are in parentheses).*

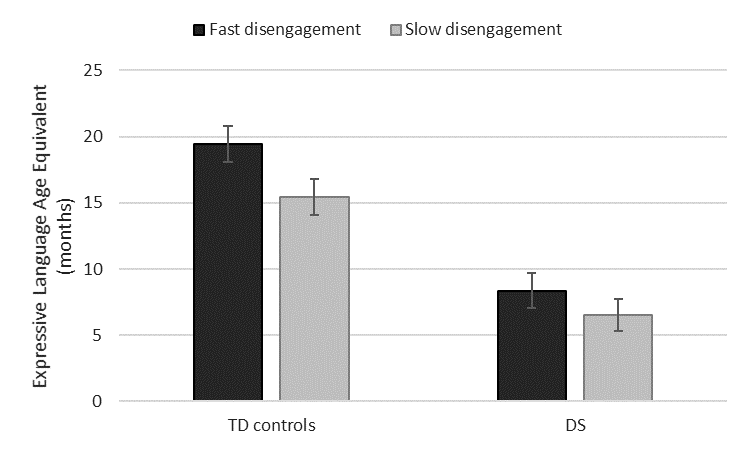
|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Group** | ***N*** | **Receptive Language** | **Expressive Language** | **Gap** | **Baseline** | **Overlap** | **Baseline + Overlap** |
| TD controls | 24 | 24 | 24 | 20 *(15)* | 17 *(14)* | 19 *(13)* | 16 *(27)* |
| DS infants | 22 | 18 | 18 | 21 *(16)* | 21 *(14)* | 21 *(14)* | 21 *(28)* |
| WS infants | 14 | 14 | 14 | 12 *(17)* | 11 *(14)* | 10 *(16)* | 9 *(30)* |
| DS toddlers | 26 | 23 | 23 | 24 *(16)* | 26 *(14)* | 26 *(16)* | 26 *(30)* |
| FXS toddlers | 13 | 13 | 13 | 13 *(14)* | 11 *(14)* | 11 *(14)* | 10 *(28)* |
| WS toddlers | 25 | 24 | 24 | 21 *(16)* | 20 *(14)* | 21 *(14)* | 19 *(28)* |

*Note*: For the experimental (gap-overlap) task, trials were presented pseudo-randomly until at least 14 valid trials *per condition* were acquired or a maximum of 74 trials were presented (D’Souza, 2014).

**Figures**

*Figure 1.* Infants with Down syndrome (DS) were slower at disengaging attention (overlap RTs minus baseline RTs = the Disengagement effect) than typically developing (TD) controls and infants with Williams syndrome (WS) (both, Cohen’s *d* > 1.03). Groups were matched on chronological age (~15 months). Error bars represent ±1 standard error of the mean.

*Figure 2.* Infants who were relatively quick at disengaging attention demonstrated marginally better receptive language ability than infants who were relatively slow at disengaging attention. Groups were matched on chronological age (~15 months). Error bars represent ±1 standard error of the mean.



*Figure 3.* Infants who were relatively quick at disengaging attention demonstrated better expressive language ability than infants who were relatively slow at disengaging attention. Groups were matched on chronological age (~15 months). Error bars represent ±1 standard error of the mean.

*Figure 4.* Toddlers with Down syndrome (DS) were slower at disengaging attention (overlap RTs minus baseline RTs = the Disengagement effect) than typically developing (TD) controls (Cohen’s *d* = 0.97) and toddlers with Williams syndrome (WS; Cohen’s *d* = 1.06). Groups were matched on mental age (~15 months). Error bars represent ±1 standard error of the mean.

*Figure 5.* Toddlers who were relatively quick at disengaging attention demonstrated better receptive language ability than toddlers who were relatively slow at disengaging attention. Groups were matched on mental age (~15 months). Error bars represent ±1 standard error of the mean.

1. If valid trials from every participant is included, then for receptive language, a 3 (Group: TD controls, DS infants, WS infants) x 2 (Disengagement: fast, slow) ANOVA reveals no interaction effect, *F*(2,50) = 0.94, *p* = .397, a main effect of Group, *F*(2,50) = 54.75, *p* < .001, *η*2 = .69, and a main effect of Disengagement, *F*(1,50) = 8.45, *p* = .005, *η*2 = .15. This larger—albeit less cautious—analysis supports our interpretation that there is a relationship between the ability to disengage attention and receptive language irrespective of group affiliation. [↑](#endnote-ref-1)
2. Only stuck and valid trials were included. Trials in which the child failed to engage with the central fixation stimulus or looked away from the experimental stimuli were excluded. [↑](#endnote-ref-2)