Classroom displays - Attraction or Distraction? Evidence of impact on attention and learning from children with and without autism.

Mary Hanley, Mariam Khairat, Korey Taylor, Rachel Wilson, Rachel Cole-Fletcher, Debbie Riby.

Department of Psychology, Durham University, UK

Correspondence to: Dr Mary Hanley, Department of Psychology, Durham University, Science Site, South Road, Durham DH1 4JJ, UK. Telephone: 00441913343239. Email:mary.hanley@durham.ac.uk

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Abstract

Paying attention is a critical first step towards learning. For children in primary school classrooms there can be many things to attend to other than the focus of a lesson, such as visual displays on classroom walls. The aim of this study was to use eye-tracking techniques to explore the impact of visual displays on attention and learning for children. Critically, we explored these issues for children developing typically and for children with autism spectrum disorder (ASD). Both groups of children watched videos of a teacher delivering classroom activities – two of 'story-time' and 2 mini-lessons. Half of the videos each child saw contained high levels of classroom visual displays in the background (high visual display; HVD) and half had none (no visual display; NVD). Children completed worksheets after the mini-lessons to measure learning. During viewing of all videos children's eye movements were recorded. The presence of visual displays had a significant impact on attention for all children, but to a greater extent for children with ASD. Visual displays also had an impact on learning from the mini-lessons, whereby children had poorer learning scores in the HVD compared to the NVD lesson. Individual differences in age, verbal, non-verbal and attention abilities were important predictors of learning, but time spent attending the visual displays in HVD was the most important predictor. This novel and timely investigation has implications for the use of classroom visual displays for all children, but particularly for children with ASD.

Keywords

Attention, learning, eye-tracking, visual distraction, autism

The primary school provides a crucial environment for children in terms of their academic and social outcome. In the United Kingdom (UK), children typically start attending primary school between the ages of 4 to 5 years, spending the majority of their school days in their classroom (Barrett, Davies, Zhang & Barrett, 2015). Classrooms are usually colourfully decorated with displays of children's work along with educational posters which can act as learning aids (e.g. multiplication tables, grammar rules). These displays are intended to create a positive and stimulating visual environment and research has shown that personalising classrooms with a student's own work can increase their level of self-esteem (Maxwell & Chmielewski, 2008). Although there may be a positive impact from classroom displays in terms of self-esteem, it is also possible that such displays could impact upon paying attention and learning in the classroom. Recent evidence suggests this is the case for typically developing (TD) children, although the impact on children developing atypically is less clear.

Barrett et al. (2015) surveyed the physical characteristics of 153 classrooms in the UK for evidence of naturalness (e.g. light), individualisation (e.g. ownership) and stimulation (e.g. complexity and colour) and their effect on academic progress for primary school children. These physical aspects of the classroom accounted for 16% of the variance in academic progression over the course of 1 year, measured by National Curriculum Level (NCL) tests. Complexity of the classroom– that is, how aspects of the classroom ”combine to create a visually coherent and structured, or random and chaotic environment” (p.120) was found to have a curvilinear relationship with academic progress. Too much or too little complexity was predictive of poorer academic progress from NCL tests of reading, writing and maths at the start or the year, compared to NCL tests at the end of the year. Barrett et al. (2015) suggested that complexity of classroom displays could interact with a child's ability to focus attention in the classroom which may then impact upon their potential learning.

The ability to focus and sustain attention to relevant information is crucial for learning in the classroom and subsequently for academic achievement (e.g., Erickson, Thiessen, Godwin, Dickerson, & Fisher, 2015; McKinney, Mason, Perkerson, & Clifford, 1975; Oakes, Kannass, & Shaddy, 2002). Attention is the gateway to learning from instruction across domains (e.g. language, visuo-spatial; Steele, Karmiloff-Smith, Cornish & Scerif, 2012) and the more time we spend focused on a task, the better the learning outcome (Carroll's 'time-on-task hypothesis', 1963). Attentional abilities follow a developmental trajectory – as children get older they get better at sustaining attention for longer periods and become less susceptible to interference from irrelevant distractors (Gaspelin, Margett-Jordan,& Ruthruff, 2015; Matusz et al., 2015), although attentional abilities vary between children of the same age. Erickson et al. (2015) showed that an experimental measure of attentional control (the Track-It Task) was associated with performance on a classroom-type learning task in TD 5-6 year olds. Those children who performed better on a task requiring high levels of attentional control (lack of interference from distractors) had higher scores on the learning task.

Although focussing or sustaining attention on a task is clearly important for learning, so too is modulating or changing the overt focus of visual attention. Studies of looking behaviour during cognitive tasks have shown that children look at the experimenter/teacher when listening (e.g. when being given information), but look away when thinking (formulating an answer), and that gaze aversion (looking away) increases with task difficulty and is associated with greater accuracy (Riby, Dorothy-Sneddon & Whittle, 2012). Therefore, modulating overt attention plays a functional role in thinking. Gaze aversion studies have shown that children functioning on the autism spectrum also modulate their gaze to look away when thinking. However, these children show atypicalities of gaze when required to listen, i.e. more gaze aversion during listening (Dorothy-Sneddon et al., 2012). Thus, while sustaining attention on task promotes better learning, there are reasons why children need to modulate the focus of overt attention. A pertinent question is whether being in a classroom containing lots of visual displays increases the likelihood of attention being directed and maintained 'off-task', and whether this has an impact on learning.

Fisher, Godwin and Seltman (2014) provided the first systematic exploration of the impact of visual displays on behaviour and learning in young typically developing children (mean age 5.5. years). They systematically manipulated the amount of visual displays in a lab classroom over the course of six brief science mini lessons, such that half the lessons were delivered when the lab classroom was heavily decorated with visual displays and half when there were no visual displays. Children visited the lab classroom for the 6 lessons over the course of a two week period, and completed an assessment workbook at the end of each lesson containing multiple choice pictorial answers. They were video-recorded during the lessons and their behaviour was coded in terms of their visual engagement as either being on-task (e.g. looking at the teacher, looking at their books) or off-task (e.g. looking at peers, looking at the walls). In the sparse condition (visual displays removed), children did engage in off-task behaviour (28.42 % of instructional time), mostly with their peers (approx. 20% attributable to peer distraction). In the presence of lots of visual displays (decorated condition), children spent more time overall engaging in off-task behaviour than in the sparse condition (38.58% of instructional time). This was directly attributable to more time looking at the displays on the walls (3.21% in sparse compared to 20.56 % in decorated conditions). Importantly, children performed significantly worse in terms of their learning scores in the decorated condition than the sparse condition. More time spent off-task was related to poorer learning, and mediation analysis confirmed that time off-task mediated the relationship between classroom condition (sparse vs decorated) and learning.

Emerging evidence therefore highlights that visual features of primary school classrooms, specifically wall displays, have implications for attention and learning (Barrett et al., 2015; Fisher et al., 2014). These studies provide the first empirical evidence for the possible detrimental impact of classroom visual displays on learning, and yet several important questions remain. For example, the study by Barrett and colleagues (2015) was observational in design and did not systematically manipulate the level of classroom visual distraction, thus providing an indirect measure of the impact of visual displays on learning. While Fisher et al.'s (2014) study of young TD children did involve a systematic manipulation of visual distraction, their measure of eye gaze was less precise than other measures, such as eye-tracking techniques. Critically, neither Barrett et al. (2015) nor Fisher et al. (2014) explored the relationship between individual differences in cognition and behaviour and the impact of distraction from the environment. It is only by taking such an approach that we can begin to understand how and why visual displays might impact attention and learning. This has implications for all children, especially for children with developmental conditions that impact upon attention. Here we explore these issues in relation to Autism Spectrum Disorder (ASD).

Attention, Distraction and Autism Spectrum Disorder

Autism Spectrum Disorder is a neurodevelopmental condition defined by impairments in socio-communication and the presence of repetitive and restricted patterns of behaviour (American Psychiatric Association, 2013). Alongside the diagnostic dyad of impairments, a range of attentional atypicalities have been documented (Ames &Fletcher-Watson, 2010; Mottron, Dawson, Soulieres, Hubert & Burack., 2005). One feature of atypical attention in ASD involves priority for social versus non-social information. Whereas TD individuals selectively prioritise social information such as people and faces over non-social information (e.g. objects, background scene information) (Birmingham, Bishof & Kingstone, 2008; Smilek, Birmingham, Cameron, Bishcof, & Kingstone, 2006), attention in autism is characterised by a lack of social priority, and increased interest in non-social stimuli (Hanley, McPhillips, Mulhern & Riby, 2013; Klin, Jones, Schulz, Volkmar & Cohen, 2002; Riby & Hancock, 2008; Sasson, Turner-Brown, Holtzclaw, Lam, Bodfish, 2008). Individuals with autism show atypically reduced looking at others' faces, particularly the eyes (Hanley et al., 2014; Klin et al., 2002; Riby & Hancock, 2008) although there have been some inconsistencies in the literature (Falck-Ytter & von Hofsten, 2011; for a discussion / meta-analysis see Papagiannopoulou, Chitty, Hermens, Hickie, & Lagopoulos, 2014). Considering the tendency for children with autism spectrum disorders (ASD) to prioritise non-social over social information for attention, in the context of a classroom scenario it may mean that non-social information such as classroom displays captures attention more readily than a teacher.

It may also be the case that the type of classroom activity the child is engaged in plays a role in how attention is prioritised. Falck-Ytter, Carlmström and Johansson (2015) and Falck-Ytter (2015) compared the attentional allocation of children with ASD to TD children during a one-on-one interaction with an experimenter in a situation designed to be comparable to a classroom. There were two parts to the interaction, a passive story-telling part where children simply listened to the experimenter and a cognitively demanding part where the children did the digit span test. Eye-tracking techniques were used to measure children's visual attention during both parts. When listening to a story being told, children with ASD looked less at the experimenter's face than TD children and more at the background which contained two posters (one on either side of the experimenter's head; Falck-Ytter, 2015). However, during the listening phase of the cognitively demanding task, there were no differences between the groups in time spent looking at the experimenter's face (Falck-Ytter et al., 2015). This reflects the eye-tracking literature on ASD in that it appears that children with ASD can and do look at faces when necessary or when there is very little competition from non-social information, but lack the typical spontaneous priority for looking at faces (Chawarska, Macari & Shic, 2012; Hanley et al., 2013; Riby et al., 2013; Speer et al., 2007). It is important therefore to explore the impact of classroom displays on attention during different types of classroom activities.

Linked to atypicalities of attention in ASD are atypicalties of sensory processing. Atypical responses to sensory input have been well documented in ASD, and have recently been added to the DSM 5 criteria (American Psychiatric Association, 2013). They can include atypical under- and over-responding to a wide variety of sensory inputs (sounds, tastes, touch, vision etc.; Tomchek & Dunn, 2007). Importantly, atypical sensory processing in children with ASD has been linked with poorer academic performance (Ashburner, Ziviani & Rodger, 2008). Ashburner et al. (2008) suggest that maladaptive responses to classroom sensory environments can contribute to poorer academic achievement in these children (see also Howe & Stagg, 2016). It may be that a classroom heavily decorated with displays is particularly stimulating for children with ASD, more so than the focus of lessons. Of the studies that exist which look at predictors of academic achievement in ASD, large focus has been placed on factors internal to the child (IQ, autism severity, sensory processing; for a review, see Keen, Webster & Ridley, 2015). However, as Keen et al. (2015) highlight, it is important to understand how factors external to the child, such as physical features of the classroom, may impact upon learning as these are amenable to intervention.

Thinking about the atypicalities of attention and sensory processing in ASD, it is clearly important to understand how classroom visual displays may impact upon attention and learning for these children. A heavily decorated classroom may make children with ASD more susceptible to distraction from learning tasks than TD children. Therefore we aimed to compare the impact of classroom displays on attention and learning for children with and without autism.

Using eye-tracking to explore the impact of classroom visual distraction

Fisher et al. (2014) relied on codings of where children were looking from video recordings to measure the focus of their participants' attention. Eye-tracking offers a rigorous and precise method of measuring visual attention allocation during a task and gives an excellent measure of 'online' processing. Although it is possible to be looking at something and attending to something else (e.g. auditory input), overt visual attention provides a good proxy for attention. The assumption that underlies the majority of eye tracking research is that what we look at closely corresponds to what we are thinking about (eye-mind assumption; Yarbus, 1967). In other words, by tracking a participant's eye movements it is possible to measure precisely what information is available for processing (and conversely, what information might be missed). Eye-tracking has been used to provide significant insights into attention abilities in children with and without developmental disorders (Hanley et al., 2014), and therefore offers an ideal method to probe attention to classroom displays during a learning task.

In the current study, we created videos of a teacher delivering two different classroom activities – story time and lessons. As the videos were made using green-screen technology, we were able to manipulate visual distraction after recording, meaning that the teacher's behaviour could not have been influenced by the presence of visual displays. While a structured lab task approach has obvious limitations with respect to ecological validity, it has many advantages which were crucial in terms of understanding the impact of visual displays (high visual display vs. no visual display). It controlled for classroom-specific and teacher-specific factors, allowing us to test a range of children (TD & ASD).

Therefore, the aim of the current study was to explore the impact of classroom visual displays on attention and learning in children with and without autism using eye-tracking techniques. This is a timely investigation into how classroom visual displays may capture children's attention and impact on learning, focussing on the role of individual differences in cognitive abilities (verbal/non-verbal ability, attention ability). We compared children developing typically to children with ASD, as there is a clear basis upon which to hypothesise that children with ASD may be more susceptible to negative influences of classroom visual displays on attention and learning than TD children. We wanted to explore the effect of classroom visual displays in children across the primary school age range because we know that classroom displays are a feature of the visual environment throughout primary schools. We can hypothesise based on the literature, that attention to the background in the stimuli will be increased in the HVD condition compared to the no visual display condition (NVD), more so for children with ASD. It is important to emphasise that we do not suggest that looking at the teacher as opposed to the background is necessary for understanding of the content of the stories and lessons. Rather, that it is a typical response to look at people and faces, especially when someone is giving you information to aid interpretation; and that looking at the background when it contains lots of visual displays increases the chances of being distracted from the focus of what is being said. We therefore also hypothesise that learning scores for lessons will be poorer in the HVD condition compared to the NVD condition. Finally we hypothesise that better sustained and divided attention abilities will be associated with less background looking in HVD and better learning scores in HVD.

Methods

Participants

In total, we recruited 89 children through 8 schools (mainstream and special schools) in the North East of England and through local contacts. We recruited 37 children with ASD and 52 TD children. It was not possible to obtain complete data sets for all children for various reasons, including difficulties completing calibration, issues with the eye-tracking equipment (e.g. glasses with anti-glare coating) and school absences. Complete data sets were obtained for 26 children with ASD and 34 TD children. For analysis, children with ASD were matched to TD children on the basis of their verbal ability, measured by the British Picture Vocabulary Scale (BPVS III: Dunn & Dunn, 2009). It was possible to match 17 children with ASD to 17 TD children for the final sample. Children with autism had all been previously diagnosed by experienced clinicians according to the DSM-IV criteria (American Psychiatric Association, 1994), and they all had a full statement of special educational needs. Scores from the Social Responsiveness Scale (SRS; Constantino and Gruber, 2005) confirmed that all children in the ASD group fell above the cutoff which indicates difficulties with reciprocal social behaviour. Items on the SRS are based around the DSM diagnostic criteria for autism spectrum disorders. SRS T scores for the ASD ranged from 79 to 90, meaning that all children with ASD fell in the severe range. The group of children with ASD had a mean age of 10years 6months (ranging 7years 10months to 12years 9months) and a mean raw verbal ability score of 115 on the BPVS. The TD group had a mean age of 9years 0months (ranging 5years to 13years 3months), with a mean raw verbal ability score of 114 on the BPVS. The groups did not differ significantly on the basis of their raw verbal ability scores, $t(32) = .105$, $p > .05$, $d = .03$, but did on the basis of age, $t(32) = 2.662$, $p < .05$, $d = .91$, with the children with ASD being on average older. To match on verbal ability a difference in age was expected. Parental consent was provided for all participants prior to their involvement.

Cognitive & behavioural measures

As already indicated, children completed the BPVS III which gave a standardised measure of their receptive vocabulary. Children's non-verbal reasoning abilities were measured using the Ravens Coloured Progressive Matrices (RCPM: Raven, Court, & Raven, 1990). Children with autism had higher raw non-verbal ability scores than TD children, $t(32) = 2.362$, $p<.05$, $d = .81$. Furthermore, children completed several sub-tests from the Test of Everyday Attention for Children (TEA-Ch; Manly, Robertson, Anderson & Nimmo-Smith, 1998). The TEA-Ch provided a standardised measure of attention abilities (designed for use with children aged 6 to 16 years). Two sub-tests from the TEA-Ch were used, including a task measuring sustained attention (Score!) and a dual task measure of divided attention (SkySearch DT). The sustained attention task required the participant to listen and keep a count of a series of bleeps which occurred at different intervals. At the end of each round, the child has to state how many bleeps they heard. The Sky Search DT subtest from the TEA-Ch was used to assess divided attention. This assessment combines the Score! test with a second test, in which the child must find image pairs within a large grid of images. For the Sky Search DT subtest, children must complete the visual search task while keeping count of the bleeps. Children with autism performed similarly to TD children in terms of their performance on both sub-tests of the TEA-Ch, both for raw scores and for age scaled scores (sustained attention raw : $t(32) = -1.331$, $p= .193$, $d = .46$, age scaled: $t(32) = -1.854$, $p = .07$, $d = .65$; divided attention raw: $t(32) = -.244$, $p= .808$, $d = -.08$, age scaled: $t(31) = .857$, $p=.745$, $d = -.11$). Table 1 provides the descriptive information for performance on the cognitive tasks.

Finally, we administered the SRS (Constantino and Gruber, 2005) to teachers. This 65 item standardised measure is used to ascertain the range of autistic symptoms and includes items that identify a child's social impairments, assess social awareness, social information processing, capacity for reciprocal social communication, social anxiety/avoidance and autistic preoccupations and traits. Teachers completed the scale, and ratings were given on a scale from 1 (not true) to 4 (almost always true) on the basis of the frequency of behaviour. For example, items included "Has difficulty making friends even when trying his or her best", "Avoids starting social interactions with peers or adults", and " has more difficulty than other children to changes in his or her routine". Use of this measure with TD children allowed us to confirm that they were functioning within the normal range. SRS data were obtained for all of the children with ASD, and all but two TD children. Children with autism had significantly higher SRS T scores (M = 86.88) than TD children (M = 46.52), $t(30) = 16.874$, $p<.001$, $d = 5.84$.

Insert table 1 here

Experimental Stimuli

Video stimuli designed to simulate classroom activities were made for the purposes of the study. The videos simulated two types of classroom activities, i) 2 storybook read-aloud tasks and ii) 2 mini lessons. Storybook read aloud videos required children only to listen, but mini lessons required children to listen and answer questions at the end. Therefore the instructions given to children differed between the story and lesson videos. The content used for the storybook videos involved two-short stories (approx. 5 minutes) suitable for primary school aged children. The mini-lessons (also approx. 5 minutes) were taken from history lessons on the Irish primary school curriculum. Both lessons were about Irish myths or legends (The Salmon of Knowledge; Oisin and the Land of Youth). Each lesson covered the complete myth/legend. The rationale for this was that the material was highly appropriate for a mini lesson, but highly unlikely to have been exposed to the children previously.

Critical to the making of the video stimuli was the manipulation of visual distraction. Each video involved a teacher facing out and looking directly ahead, verbally relaying either the story or the lesson material. However, for each video a no display version (NVD) and a high display version (HVD) was made (see Figure 1). This was possible as the teacher was filmed in front of a green screen, and the visual distraction manipulation was made afterwards with computer software. This ensured that the only difference between low and high distraction versions of each video was the difference in level of background visual distraction. The materials used to make the visually distracting background were taken from a primary school. All children saw the videos in the same order (i.e. story 1, 2, lesson 1, 2) but the order in which they saw visual distraction was counterbalanced.

Insert Figure 1 here

The worksheets to measure learning following the lessons were adapted from existing lessons on the Irish primary school curriculum. Each worksheet had 8 multiple-choice questions and 5 open ended questions. The experimenter read out the questions from the worksheet, and answers given by the participants were recorded verbatim. Marks were given according to the degree of accuracy and detail following a strict marking guideline, to a maximum of 18 marks per lesson. The 8 multiple choice questions were awarded one point each for a correct answer, and the comprehension questions were awarded 2 points each for correct answers, therefore given a maximum possible score of 18 for each lesson. Scores on the NVD lesson ranged from 2.5 to 17, and on the HVD lesson from 1 to 16. Two markers, blind to participant group and condition, marked each child's answers. They also marked 25% of each other's answers to check for reliability, and agreement was found to be high, $r(306) = .887$, $p<.001$.

Eye-tracking

An SMI Remote Eye tracking Device (RED) 250 (SMI Germany) was used to record participants' eye movements. This was a portable system comprising a 22- inch desktop monitor with an infrared eye-tracking device attached under it. The eye-tracking device used infra-red light technology to track the movements of the eyes, which is invisible to participants and therefore completely non-invasive. The eye-tracker sampled at 250Hz and had an accuracy of less than 0.5 degrees visual angle. Each participant underwent a 9-point calibration procedure followed by a 4-point validation. The validation procedure allowed us to check that all participants were being eye-tracked with an accuracy of less than .5 degrees of the visual angle before data were recorded. An in-built high-speed event detection algorithm was used to detect eye movements such as saccades, fixations and blinks (SMI, Germany). A bespoke program was made for data analysis in relation to predefined Regions of Interest (ROI). The program allowed for ROI to be defined on each frame of the videos (resulting in 33,734 videos frames for analysis). The ROI were: teacher's face (including eyes and mouth), body; the book (for story videos only); the background; and a final ROI called 'Out of Bounds' which represented fixation data that did not fall in any of the predefined categories (e.g. fixation towards the eye-tracker but off-screen). Using this program it was possible to calculate how much time participants spent looking at the predefined areas on the screen. The ASD group had a tendency to make less fixations overall to the ROIs than the TD group. This difference was significant for the HVD story, $t(32) = -2.175$, $p = .03$.Therefore, as is common in eye-tracking studies, the data were considered in terms of proportion of total fixations. Fixations to either the teacher's face or the background were calculated as a proportion of all fixations made to ROIs on the screen (summed from adding fixations made to the teacher's face, body and background). The body region was not part of the analysis as it was not central to the research questions and including it would mean that the looking time data added to 1, which is problematic for ANOVA.

Procedure

The majority of children were tested at school (26/34). Eight out of the 34 children were tested in their homes due to the school holidays. Every effort was made to ensure the conditions of testing between schools and homes were comparable. All children were tested individually in a quiet room while sat at a desk with the experimenter. Children were visited at school or at home for three visits to complete the testing. In the first session, children completed the cognitive measures (BPVS, RCPM, TeaCH) which took approximately 40 minutes. In the second session, children completed the first set of eye-tracking tasks, stories 1 and 2. In the final session, children completed the second set of eye-tracking tasks, lessons 1 and 2, and completed the worksheets to measure learning following each lesson.

Results

For both the story and lesson videos, the eye movement data were analysed in the same way.

Stories

Does visual distraction impact upon attention during mini-lessons (active viewing)?

To explore the impact of visual distraction on attention during the lessons and possible group differences, a three way mixed factors ANOVA was conducted with factors distraction (NVD, HVD), region (Teacher's face, Background) and group (ASD, TD)[1]. There were main effects of distraction, F(1, 32)=9.757,p=.004, η^2 = .22 region, F(1, 32)=7.224, p=.01, η^2 = .12, but not for group, F(1, 32)=2.207,p= .164, η^2 = .06. The main effect of distraction was due to a greater proportion of fixations overall having been made to the regions of interest during the HVD story as opposed to the NVD story (see figure 2). The main effect of region was due to participants directing more attention to the teacher's face than the background across both lessons (see figure 2)

There were interactions between region and group, F(1, 32) = 18.816, p <.001, η^2 = .324, and distraction and region, F(1, 32)=55.734,p<.001, η^2 = .63. Significant interactions were not found for distraction and group, F(1, 32)=2.721,p=.109, η^2 = .06, or for the three way interaction between group, region and distraction, F(1, 32)=.139,p= .712, η^2 = .36. In terms of the interactions, it is clear from Figure 2 that when watching videos of a teacher reading a story book aloud TD children always prioritised attention to the teacher, regardless of visual distraction (NVD: t (16) = -13.210, p <.001, d = -5.44; HVD: t(16) = -2.071, p = .05, d = -.91). However, the visual distraction did impact their attention, in that in HVD they decreased their attention to the teacher and increased their attention to background (NVD teacher vs. HVD teacher: t(16) = 5.739, p <.001, d = 1.21; NVD background vs. HVD background: t(16) = -5.592, p <.001, d = -1.69). This pattern was different for children with

[1] We confirmed that there were no differences in visual attention according to whether the participants saw the NVD background first or the HVD background first for the story videos. A 3-way mixed factorial ANOVA with factor group (NVD first, HVD first), region (teacher's face, background) and distraction (NVD, HVD) was conducted on the looking time data. Critically, there was no main effect of counterbalanced group, F(1, 32) = 3.668, p=.07, η^2 = .11 and no interaction with either region, F(1, 32) = .422, p=.521, η^2 = .01, or distraction F(1, 32) = .635, p=.431, η^2 = .015, and no three-way interaction between group, region and distraction, F(1, 32) = .040, p>.05, η^2 <.001. Therefore, the order with which the videos were seen did not influence how attention was allocated during each condition or to the regions of interest

ASD. In NVD, the proportion of attention to the teacher and the background was not significantly different ($t(16) = -1.007$, $p = .329$, $d = -.46$), whereas in HVD it was, $t(16) = 2.780$, $p = .01$, $d = 1.32$. Therefore children with ASD did not prioritise attention to the teacher in NVD, and prioritised attention to the background in HVD. The impact of visual displays for children with ASD was similar as for TD children, in that they decreased attention to the teacher and increased attention to the background which exaggerated the differences between the groups in NVD (NVD teacher vs. HVD teacher: $t(16) = 5.739$, $p < .001$, $d = .53$; NVD background vs. HVD background: $t(16) = -5.592$, $p < .001$, $d = -1.3$.

Within-group analysis showed that those children with ASD with more autistic symptoms and poorer sustained attention spent a greater proportion of time looking at the displays (SRS & HVD background, $r(17) = .550$, $p<.05$; sustained attention & HVD background, $r(17) = -.405$, $p=.05$ (correlations with BPVS, Ravens, age or divided attention r's <-.327, p's > .06). Younger and less cognitive able/mature (poorer verbal/non-verbal/attention abilities) TD children spent more time looking at the displays (age & HVD background, $r(17) = -.595$, $p<.01$; BPVS raw score & HVD background, $r(17) = -.600$, $p<.01$; Ravens & HVD background, $r(17) = -.550$, $p<.05$; sustained attention & HVD background, $r(17) = -.399$, $p=.05$; divided attention, $r(17) = -.518$, $p<.05$). Furthermore, higher scores on the SRS correlated with more looking at the HVD background $r(17) = .532$, $p<.05$.

Insert Figure 2 here

Lessons

Does visual distraction impact upon attention during mini-lessons (active viewing)?

To explore the impact of visual distraction on attention during the lessons and possible group differences, a three way mixed factors ANOVA was conducted with factors distraction (NVD, HVD), region (Teacher's face, Background) and group (ASD, TD)[2]. There was a main effect of region, $F(1, 32) = 42.180$, $p<.01$, $\eta^2=.54$, a main effect of distraction, $F(1, 32) = 5.664$, $p=.02$, $\eta^2=.15$, and no main effect of group, $F(1, 32) = .756$, $p=391$, $\eta^2=.02$. The main effect of region was due to participants directing more attention to the teacher's face than the background across both lessons (see figure 3). The main effect of distraction was due to a greater proportion of fixations overall having been made to the regions of interest during the HVD story as opposed to the NVD story (see figure 3).

There was a trend towards significance for the interaction between group and region, $F(1, 32) = 3.787$, $p=.060$, $\eta^2=.05$ but no interaction between distraction and group, $F(1, 32) = .374$, $p=.545$, $\eta^2=.011$. There was however, a significant interaction between region and distraction, $F(1, 32) = 66.481$, $p<.001$, $\eta^2=.61$ and a three-way interaction between region, distraction and group, $F(1,32) = 9.484$, $p=.04$, $\eta^2=.09$. As the three-way interaction is the overarching one, it will be detailed.

Insert Figure 3 here

It was evident from Figure 3 that the three-way interaction between group, region and distraction was driven by the way HVD changed viewing preferences, particularly for the children with ASD. In the NVD condition, children in both groups looked more at the teacher's face than the background, and independent *t* tests confirmed that the proportion of time looking spent looking at these regions was not different between children with ASD and TD children [teacher's face, $t(32) = -.484$, $p=.632$, $d=-.16$; background, $t(32) = .912$, $p=.792$, $d=-.09$]. Paired *t* tests showed that although TD children reduced the proportion of time looking at the teacher's face in HVD compared to NVD, this

[2] We confirmed that there were no differences in visual attention according to whether the participants saw the NVD background first or the HVD background first for the lesson videos. A 3-way mixed factorial ANOVA with factor group (NVD first, HVD first), region (teacher's face, background) and distraction (NVD, HVD) was conducted on the looking time data. Critically, there was no main effect of counterbalanced group, $F(1, 32) = .704$, $p=.408$, $\eta^2 = .02$ and no interaction with either region, $F(1, 32) = .091$, $p=.765$, $\eta^2 = .001$, or distraction $F(1, 32) = 1.157$, $p=.290$, $\eta^2 = .03$, and no three-way interaction between group, region and distraction, $F(1, 32) = 2.542$, $p=.121$, η^2 .03. Therefore, the order with which the videos were seen did not influence how attention was allocated during each condition or to the regions of interest

difference was not significant, $t(16) = 1.964$, $p=.07$, $d=.06$; however, they did increase the proportion of time spent looking at the background, $t(16) = -4.646$, $p<.001$, $d=-1.13$. In contrast, children with ASD significantly reduced the time spent looking at the teacher's face in HVD (compared to NVD), $t(16) = 8.924$, $p<.001$, $d=1.35$, and significantly increased the time spent looking at the background, $t(16) = -8.054$, $p<.001$,$d=-2.12$. Furthermore, independent t tests showed that the children with ASD spent significantly less time looking at the teachers' face than the TD children in HVD, $t(32) = -2.745$, $p=.01$, $d=-.9$, and significantly more time looking at the background than TD children , $t(32) = 2.782$, $p=.009$, $d=.95$. Therefore, while watching video lessons children with ASD behaved similarly to TD children when there are no visual displays, thus prioritising attention to a teacher's face. Although TD children looked at visual displays when they were present, it did not impact the proportion of attention given to the teacher's face; they still looked significantly more at the teacher's face than the background with visual displays, t(16) = -3.210, p=.005, $d=1.54$. However, visual displays changed the viewing preferences for children with ASD, as they allocated just as much attention to the visual displays as they did to the teacher's face in HVD, $t(16) = .872$, $p=.396$, $d=-.42$.

Does distraction (by visual displays) impact upon learning?

Firstly, we confirmed that scores did not differ between lessons 1 and 2, $t(33) = 1.244$, $p=.222$, $d=.15$. Therefore there was no difference in performance due to lesson content between lessons 1 and 2. Learning scores were then compared between the low and high visual distraction conditions (max score on each lesson was 18). On average all children performed slightly better in the NVD condition M = 10.1) than the HVD condition (M = 9.6). For children with ASD the mean difference between the conditions was .65 and for TD children this difference was .45 points. To look at the difference in learning between the conditions for the entire sample, it was necessary to consider the role of age and non-verbal ability as the children with ASD were older and had higher Ravens scores. For the entire sample, the difference between learning scores in the NVD compared to the HVD condition approached significance when age was controlled for, $F(1, 30) = 3.704$, $p=.06$,but not when non-verbal ability was controlled for, $F(1, 30) = .674$, $p=.418$.

In terms of comparing the groups, the children with ASD performed poorer than the TD children in both conditions (NVD: ASD M = 9.8, TD M = 10.5; HVD: ASD M = 9.1, TD M = 10.05). The difference was not significant in the NVD condition (co-varied age, $F(1, 30) = .736$, $p=.398$; co-varied non-verbal ability, $F(1, 30) = 2.914$, $p=.098$). The difference was significant in HVD when non-verbal ability was controlled for, $F(1, 30) = .515$, $p=.04$, but not when age was controlled for, $F(1, 30) = 4.347$, $p=.216$.

To summarise, when looking across all children it was possible to see a small negative effect of HVD on learning when the children's age was taking into account. Both groups showed a small negative change in learning scores between NVD and HVD. When comparing the groups for their learning scores in both conditions, it was possible to see that although there were no differences between the groups for learning in NVD, the ASD children performed significantly poorer than the TD children in HVD when the differences in non-verbal ability were controlled for.

How are participant characteristics related to learning performance?

In order to explore factors important for learning performance, we looked specifically at learning in the HVD condition given understanding the impact of visual displays was a key focus of the study. For children with ASD, better HVD learning scores were associated with better verbal ability (BPVS Raw), $r(17) = .493$, $p=.02$, better sustained attention (RAW), $r(17) = .515$, $p=.017$, sustained attention (Age standardised), $r(17) = .445$, $p=.03$, and less looking at the visual displays, $r(17) = -.531$, $p=.014$. HVD learning scores did not correlate with non-verbal ability or divided attention (all r's $<.306$, all p's $>.116$, one-tailed).

For TD children, better HVD learning scores were associated with better non-verbal ability (RCPM), $r(17) = .436$, $p=.04$, better sustained attention (RAW), $r(17) = .506$, $p=.01$, sustained attention (Age standardised), $r(17) = .443$, $p=.04$, and less looking at the visual displays, $r(17) = -.777$, $p<.001$. HVD learning scores did not correlate with BPVS raw scores, or divided attention for these children (all r's $< .323$, all p's $>.103$, one-tailed).

What best predicts learning?

A multiple linear regression was run to explore which factors best predicted learning scores in the HVD condition. The predictors were: Age, BPVS raw, Ravens, Sustained attention raw, SRS t scores and attention to the HVD background (visual displays). The model was significant, $F(2, 25) = 8.085$, $p<.001$, and the adjusted R square indicated that the model predicted 57.8% of the variance in HVD learning. All predictors except for Ravens were significant. Attention to the HVD background had the highest Beta value (-.656), followed by SRS t scores (.466), then age (-.438), then BPVS Raw (.431).

Discussion

The aim of this study was to systematically explore the impact of classroom visual displays on attention and learning for children with and without autism. Recent evidence has indicated that too much visual stimulation from the physical classroom environment can impact upon typically developing children's ability to focus and learn (Barrett et al., 2015; Fisher et al., 2014). We used innovative eye-tracking techniques and video based lessons to explore precisely how classroom displays influenced children's attention and subsequent learning performance. This approach to understanding attention, learning and visual distraction is innovative because it provides a systematic and in-depth way of understanding the impact of classroom visual distraction for a range of children, including those with and without developmental conditions. Importantly, we investigated these issues in children developing typically and with children functioning on the autism spectrum for the first time.

Overall we found a clear effect of the presence of visual displays on attention for all children. Whether viewing stories or lessons, children spent more time looking at the background in HVD compared to NVD. Interestingly, although TD children increased attention to the background in the presence of visual displays, they still prioritised their attention to the teacher in the HVD videos for both stories and lessons. However, as hypothesised the presence of visual displays had a much greater effect for children with ASD. Not only did they look at the visually distracting background more than TD children in both story and lesson videos, but they looked more at the background than the teacher in HVD. This pattern mirrors much of what has been reported in the eye-tracking literature on social attention in ASD, and our data supports previous studies showing that the priority for attending to social information is atypical in ASD (Hanley et al., 2013; Klin et al., 2002; Riby & Hancock, 2008; Sasson et al., 2008). However, we also showed how this atypicality was context dependent. When viewing stories, children were simply instructed to watch and listen. When viewing lessons, children were instructed to pay attention as they would be asked questions at the end of the lesson. The attention of children with ASD was atypical in all conditions, except in the NVD lesson. Thus, when viewing stories without specific instruction (spontaneous viewing) children with ASD had atypically reduced attention to a teacher in NVD and HVD, and visual displays had a greater impact on their attention compared to TD children. When instructed to pay attention to the lessons, children with ASD showed a more typical pattern of attention to the teacher and background, although this was not maintained in the presence of visual displays. This pattern is similar to that reported by Falck-Ytter (2015) and Falck-Ytter et al. (2015) across two studies involving children with ASD, showing that attention patterns were different when children were engaged in different tasks in a one-on-one interaction. They showed that attention was atypical when children with ASD were engaged in a passive listening task, but typical when they were engaged in an active task requiring a response (digit-span task). It also mirrors findings of context dependent attention atypicalities by toddlers with ASD. Chawarska et al. (2012) found the most pronounced differences (less face and mouth looking ,more looking at toys) between toddlers with ASD compared to TD and developmental delayed toddlers in sections of the video involving dyadic cues , i.e. where the women in the video engaged in child-directed speech to the toddlers. Differences were not found between the groups in sections of the video where for example the woman is engaged in an activity (making a sandwich) without looking at the camera or verbalising. We add to the literature and support studies that show that atypicalities of social attention in ASD are context dependent (Hanley et al., 2013; Speer et al., 2007), and that the presence of lots of non-social information is particularly attention capturing for children with ASD, even when they are engaged in a task that requires a response (Sasson et al., 2008).

These findings support Fisher et al. (2014) who showed that young TD children displayed more off-task behaviour, specifically more looking at information on the walls of the lab classroom, when the physical environment was heavily decorated. We extend this by showing this effect in TD children across a broader age range (5 to 13 years), indicating that the impact of visual displays in the classroom is not just relevant for young children, but for children throughout the primary school. However, more looking at the visual displays was related to age and developmental level (in terms of verbal, non-verbal and attention abilities). Younger children and those with lower scores on the BPVS, Ravens and attention subscales of the Tea-CH spent more time looking at the visual displays. Therefore, although our findings suggest a heavily decorated background has implications for all primary school children, it may be more of an issue for younger (and developmentally less mature) children. For children with ASD, more looking at the visual displays was associated with poorer sustained attention and greater autism severity, indicating that staying focussed on-task is linked to a different profile of abilities/needs for children with ASD compared to TD children. We do note however that divided attention scores from the Tea-Ch for both groups were low. Although not associated with performance on the lesson for either group, this is something that should be followed up in future work.

Fisher et al. (2014) showed that looking at the heavily decorated physical classroom negatively impacted learning. A key question in the current study was whether increased attention to the HVD background impacted children's learning performance. In order to explore this in our data both within and between groups, it was important to control for age and non-verbal ability given the differences between the children with ASD and TD children. For all children, it was possible to see that learning scores were lower in the HVD compared to the NVD condition, when age was controlled for. Furthermore, although verbal ability and autism symptoms were important predictors of learning, time spent looking at the HVD background was the most important predictor in the regression model. Collectively, this indicates that while individual differences in development (age, social functioning) and cognition (verbal ability) were important predictors of learning performance in this task, visual distraction by classroom displays was also very important. Visual distraction was particularly important for children with ASD. When non-verbal ability was controlled for it was possible to see that HVD learning scores were significantly poorer for children with ASD than TD children (even though this was not the case in NVD). Thus we have supported Fisher et al., (2014) but also provide preliminary insights into these issues for children with ASD. More work is needed to understand these issues in children with ASD to explore further the role of cognitive abilities and age. Matching based on verbal ability was deemed the most appropriate strategy in the current study given the verbal nature of the task. Given the developmental delay in the ASD group, this meant that they were in fact older than the TD children, a common issue in the when matching TD and ASD children on ability. It would be useful in future work to try to have additional comparison groups to explore further the roles of age and non-verbal ability in these issues.

More work is needed to fully understand the impact of visual distraction for children with ASD, especially in the real-world as opposed to experimental scenarios. One issue that will be particularly important to follow up on in future is whether children with and without autism find visual displays less distracting after a long period of exposure. Our videos were approximately 5 minutes long each. Children are exposed to classroom displays for most of the school year. Therefore, it will be very important to establish if length of exposure to classroom displays influences off-task behaviour. Indeed, future work should try to focus more on studying these effects in the real classroom. The task developed in this study offered high levels of experimental control and could be used with a range of children from different schools, thus circumventing school/teacher specific effects on attention and learning. Although efforts were made to make this task as ecologically valid as possible, the experience of learning in the classroom where children are surrounded by other sources of distraction both visual and auditory (e.g. peers), is obviously very different to watching video lessons. Therefore, future work should try to map what has been found on the lab, both from the current study and from Fisher et al. (2014), to the real classroom.

The work of Barrett et al. (2015) can lend some support to the idea that visual displays can impact upon learning over a long period of time. They found that physical aspects of the classroom accounted for 16% of the variance in academic progression over the course of 1 year. However, they also reported that both too much *and* too little complexity is linked with poorer learning outcomes. Our study was set up to compare extremes of all or nothing in terms of background visuals, and future work is needed to explore whether there is an optimal level of environmental stimulation that creates a positive environment without leading to distraction from task. It may be, for example, more about type of display then number of displays, such that certain types of displays are less distracting than others. Future work using eye-tracking techniques could address this question by manipulating the types of visual display (e.g. multiplication table vs. art work) that appear in the background.

The results from this study have provided timely evidence of the impact of classroom visual displays on attention and learning for primary school aged children using novel eye-tracking techniques.

Importantly, we have highlighted for the first time how these issues are particularly important for children functioning on the autism spectrum. We have also emphasised the importance of accounting for individual differences in cognition, behaviour and development when thinking about classroom visual distraction. Although the sample size in the current study is relatively small, it is in line with the majority of eye-tracking studies in the area (Falck-Ytter, 2015; Hanley et al., 2013; Klin et al., 2002; Riby & Hancock, 2008). Future work is needed with larger sample sizes which will allow for greater power and more in-depth analysis of relevant individual differences. For example, it may be possible in future work to look in more detail at attention patterns to the eye and mouth region of the teacher/instructor to explore the predictive value of attention to these regions in terms of learning. The use of eye-tracking techniques with video based lessons provided a systematic and precise method of measuring attention and learning, and future work should continue to exploit the advantages of this method to further understand the impact of classroom visual displays. However, ecological validity is obviously a critical issue to consider going forward, and more real-world work is needed to understand how the findings from structured lab tasks on this issue translate to the classroom.

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Table 1: Table showing participant characteristics and performance on cognitive and behavioural measures

	ASD **N = 17** ***M (SD)***	**TD** **N = 17** ***M (SD)***
Age *(months)*	126.7 (15.4)	108 (24.5)
BPVS *(raw)*	114.8 (24.4)	114 (24.6)
BPVS *(standard)*	91.6(20.24)	94.58 (14.4)
Ravens *(raw)*	27.23 (3.64)	23.52 (5.33)
Ravens *(percentiles)*	86.07 (13.03)	85.93 (12.)
Sustained Attention *(raw)*	6.8 (3.1)	8 (1.9)
Sustained Attention *(age scaled)*	7.3 (3.9)	9.75 (3.69)
Divided Attention *(raw)*	7.67 (9.5)	8.5 (12.1)
Divided Attention *(age scaled)*	4.94 (4.6)	5.43 (3.9)
SRS *T scores*	86.88 (3.5)	46.52 (8.9)

* There were 4 ASD participants for whom BPVS standard scores could not be computed as verbal ability too low for their age, mean based on N= 13. There were 2 participants with ASD for whom Ravens standard scores could be computed as they were older than the age range provided for in the norm tables.

*Sustained attention measured by the Score! subtest on the TeaCh and Divided Attention measured using the SkySearch DT subtest from the TeaCh (Manly et al., 2001)

Figure 1

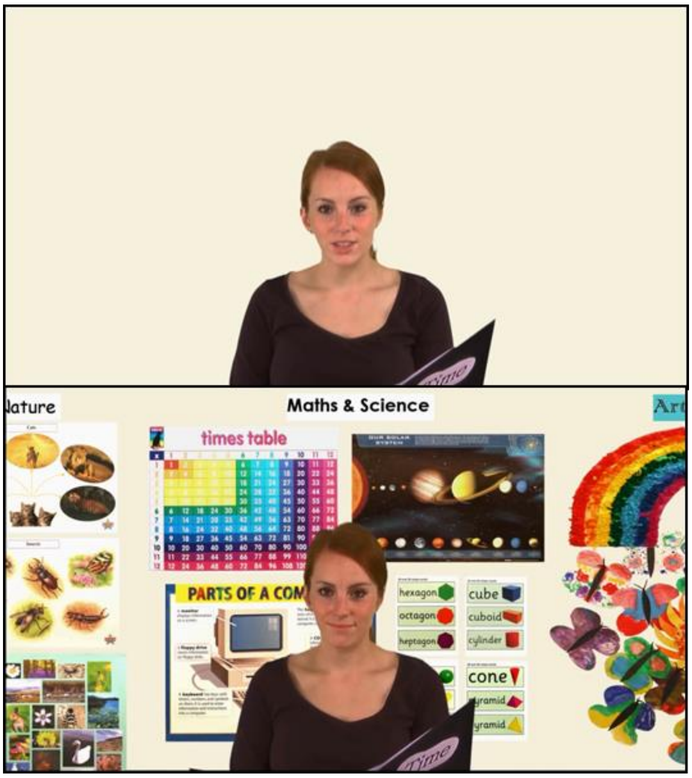

Figure 1: Example screen shots from an NVD video (on top) and a HVD video (on the bottom)

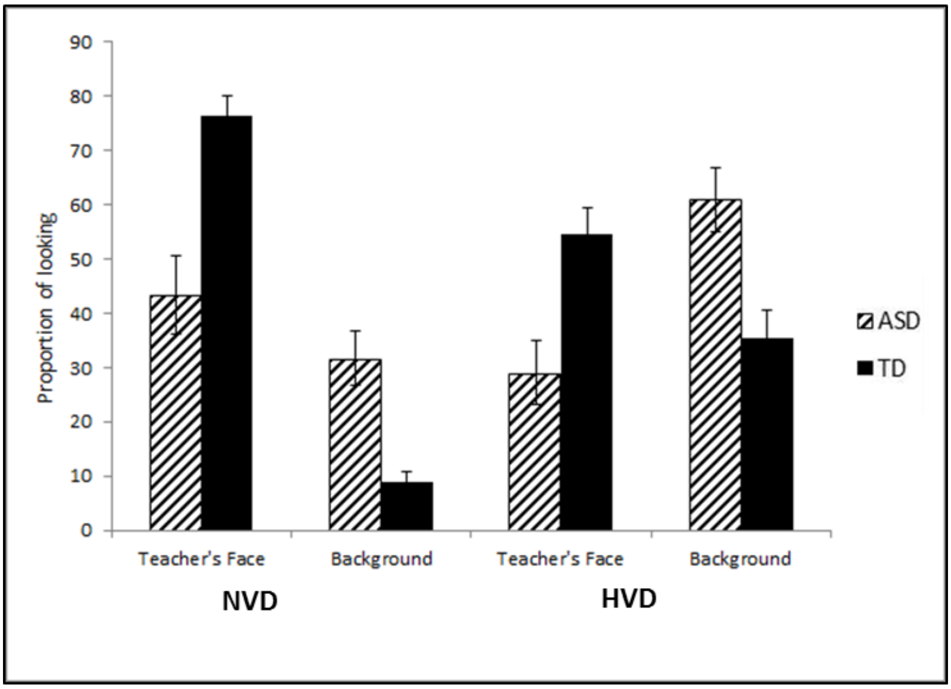

Figure 2: Proportion of time spent looking at the teacher's face and the background in the No Visual Display (NVD) and High Visual Display (HVD) stories by the children with ASD compared to the TD children

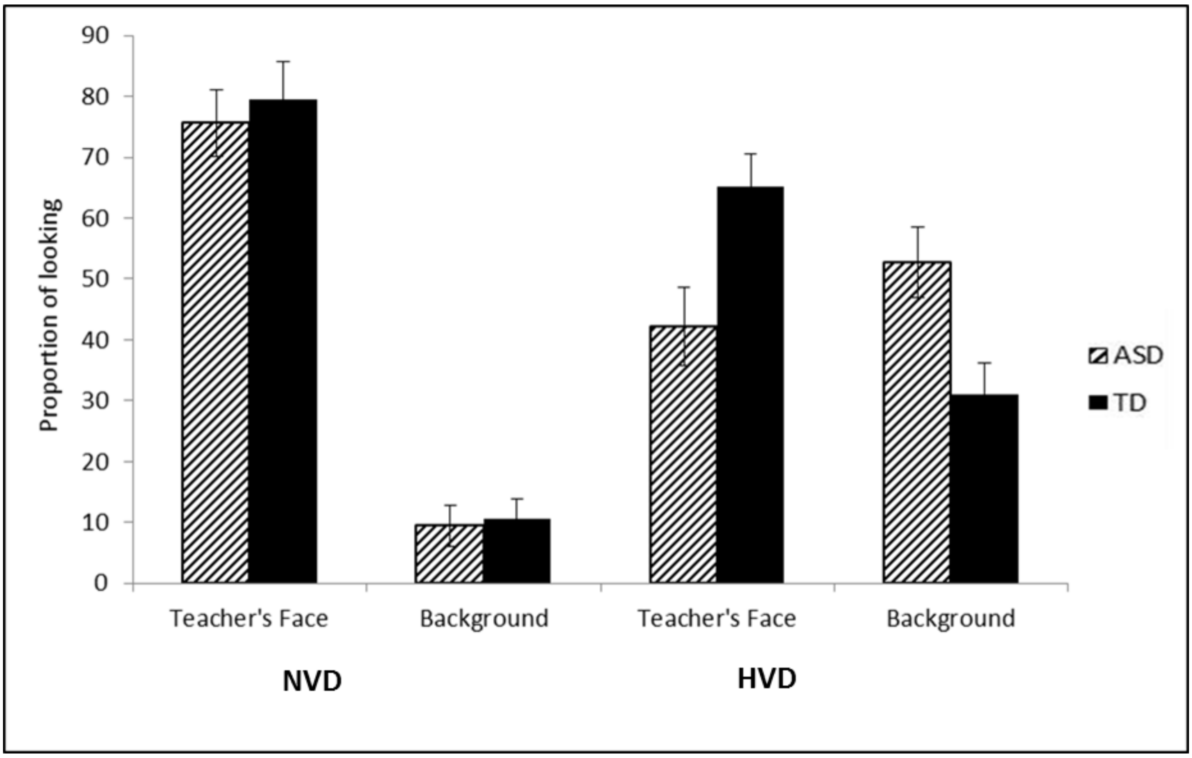

Figure 3: Proportion of time spent looking at the teacher's face and the background in the No Visual Display (NVD) and High Visual Distraction (HVD) lessons by the children with ASD compared to the TD children

Appendix

Correlation Matrix for Predictors in Regression

		BPVS Raw	**Ravens**	**Sustained Attention Raw**	**SRS T scores**	**HVD Background Fixation**
Age Months	Pearson r	.455**	.695**	0.14	0.32	-0.21
	Sig. (2-tailed)	0.01	0.00	0.45	0.08	0.23
	N	34.00	34.00	34.00	32.00	34.00
BPVS Raw	Pearson r		.588**	0.17	-0.04	-0.26
	Sig. (2-tailed)		0.00	0.33	0.84	0.14
	N		34.00	34.00	32.00	34.00
Ravens	Pearson r			0.09	.362*	-0.22
	Sig. (2-tailed)			0.61	0.04	0.22
	N			34.00	32.00	34.00
Sustained Attention Raw	Pearson r				-0.24	-.519**
	Sig. (2-tailed)				0.18	0.00
	N				32.00	34.00
SRS T scores	Pearson r					.486**
	Sig. (2-tailed)					0.01
	N					32.00