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Title: Immediate effects of coloured overlays on the reading performance of preschool children with an Autism Spectrum Disorder using eye tracking

Article Type: Research Paper

Keywords: Coloured overlays; ocular performance; reading speed; preschool; Autism Spectrum Disorder

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Abstract: Background: Coloured overlays have often been used to improve reading performance in preschool children with an autism spectrum disorder (ASD), however, previous evidence shows conflicts in its application.

Aims: To investigate the immediate effects of coloured overlays on reading performance using eye tracking in preschool children with ASD and their typical development (TD) counterparts closely matched by chronological age.

Methods: Forty participants with ASD (n = 20) or TD (n = 20) were recruited by convenience sampling and asked to read aloud numbers randomly arranged on paper. Participants' ocular performance (fixation duration, fixation count, total visit duration), reading speed and number of errors were recorded by eye tracker and digital stopwatch respectively throughout testing with and without coloured overlays.

Results: The findings show that coloured overlays had no significant immediate effect in improving ocular performance and reading speed of children with ASD or TD, although individual improvements were identified in some children with ASD.

Conclusions: Use of coloured overlays may not be useful to improve reading and ocular performance in children with ASD in one single occasion. The potential effect on reading ability of using coloured overlays repetitively for a longer period needs further investigation.

What this paper adds?
Coloured overlays has often been used to improve reading performance in preschool children with an autism spectrum disorder (ASD) by clinicians and therapists, however, previous evidence shows conflicts in its application, and that the use of coloured overlays in preschool children with ASD has not previously been examined. Our study contributes to the

evidence that as measured by means of eye tracking, there was no immediate effects of the coloured overlays in improving reading and ocular performance in both preschool children with ASD and their typically developing peers, as opposed to the effects previously examined in school-age counterparts, however, the potential effect on reading ability of using coloured overlays for longer period needs further investigation.

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(Words: 195)

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Introduction

The functioning of sensory processing among children with Autism Spectrum Disorders (ASD) has received increasing attention in recent years. According to the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders*, an ASD is characterized by impairment in social interaction and communication in addition to the presence of repetitive and restricted behaviors (American Psychiatric Association, 2013). The manual's sub-items under restricted, repetitive patterns of behavior, interests or activities state more clearly that the symptoms of ASD include hyper- or hyporeactivity to sensory input or unusual interest in sensory aspects of the environment (American Psychiatric Association, 2013). Sensory processing abnormalities have been widely reported in individuals with ASD in different areas including pain, temperature, audition, tactility, olfaction, touch, vision and movement (Jones, Quigney, & Huws, 2003). Children with visual hyposensitivity may present symptoms such as looking intensely at objects or people, attraction to light, a tendency to move their fingers or objects in front of their eyes, attraction to brightly coloured objects and running their hands around the edges of objects; children with visual hypersensitivity may tend to focus on tiny items, dislike bright lights, dim lights and sharp flashes of light, look down most of the time and cover their eyes against bright lights (Bogdashina, 2003). These signs indicate that children with ASD present unusual responses to colour and light which may have a great impact on their daily life since vision is an essential part of our interaction with the

environment.

Reading is one of the most important learning performances and has been mentioned to be influenced by colour processing which may be referred to ‘Irlen syndrome’ (Irlen, 1991). Those with ASD may experience visual information as a bombardment, overloading and overwhelming, and a reduction of sensory overload can enhance functioning and may even allow a better visual processing ability (Irlen, 1991). It has been suggested that coloured overlays or lenses could address the sensory issues related to visual processing by determining the exact wavelengths of light to which the individual is sensitive (Irlen, 1991).

The mechanism of photoreceptors may explain why different coloured overlays of an optimal colour help individuals to read. Light is brought to focus on the retina, which contains photoreceptors, the light-sensitive cells which are divided into two types, rod and cone cells (Wilkins, 2003). There are three types of cone cell, each of which responds to light of a different wavelength – the long and middle wavelength receptors are more sensitive than the short wavelength receptors, but there are considerable differences between individuals in the relative proportion of long and medium wavelength receptors, even in individuals with normal colour vision (Dobkins, Thiele, & Albright, 2000). Therefore, individuals may require different optimal colours for seeing and reading.

A coloured overlay is a sheet of coloured plastic to be placed over a print out without interfering with the clarity of text (Williams et al., 2004). It is claimed to improve visual perception and reading ability, to sustain attention in reading and to reduce symptoms associated with reading, for example, light sensitivity, eyestrain, headaches, blurring of print, loss of place, etc., for individuals with reading difficulty (Williams et al., 2004). A study demonstrated significantly improved eye movements among children with reading disability when reading words through blue filters (Solan et al., 1998). However, a meta-analysis on the effectiveness and cost-effectiveness of coloured filters for reading disability was published in 2008 (Albon, Adi, & Hyde, 2008). It included eight RCTs whose results showed that there were no obvious benefits in using coloured overlays in the majority of these studies (Albon, Adi, & Hyde, 2008). No positive influences were identified in terms of reading accuracy, reading speed and comprehension in 50% to 66% of the research. Although, 10 of the 15 non-RCTs included reported positive effects on reading performance, this was not considered evidence of the effectiveness of coloured overlays as the studies' poor quality, such as small sample sizes, inadequate controls, lack of reporting of randomization methods, difficulty in the maintenance of any blinding, and high levels of attrition, etc., affected their validity (Albon, Adi, & Hyde, 2008). One study reported an adverse effect that children who did not chose overlay and those who stopped using their chosen overlay performed better in reading

than those who continued to use the overlays (Northway, 2003). Two studies reported immediate effects in reading but no indication of the overlay leading to long-term improvement (Martin et al., 1993; Robinson & Conway, 1990). A recent study also demonstrated that coloured overlays are not effective in alleviating reading difficulties in a single session in school-age children with reading difficulties (Ritchie, Della Sala, & McIntosh, 2011).

There is also conflicting evidence on the effects and outcomes of using coloured overlays in children with ASD. Ludlow and colleagues undertook three studies to explore the application of coloured overlays among school-aged children with ASDs and compared their reading speed and visual stress with and without coloured overlays (Ludlow, Taylor-Whiffen, & Wilkins, 2012; Ludlow, Wilkins, & Heaton, 2006; Ludlow, Wilkins, & Heaton, 2007). The improvement in reading speed in both ASD and typical development (TD) participants is consistent across all three studies: 79%, 83% and 80% in the ASD group and 19%, 17% and 33% in the control group (Ludlow, Taylor-Whiffen, & Wilkins, 2012; Ludlow, Wilkins, & Heaton, 2006; Ludlow, Wilkins, & Heaton, 2007). These results show that children in the ASD groups presented with a significant improvement in reading speed when using coloured overlays, and a larger percentage of participants presented significant incremental improvement than in the control group. However, apart from improvement in the reading speed of participants with ASD only, other improvements in reading accuracy and ocular

performance in children with ASD had not yet been determined with certainty.

Eye tracking provides a non-invasive method for elucidating a wide variety of cognitive processes, from visual spatial perception to object perception, memory, and language (Karatekin, 2007, p. 284). Eye tracking measures (saccades, smooth-pursuit eye movements, fixations during scene and face perception, and pupillary dilation, etc.) have been used for children from 4 years of age through adolescence since the 1980s' (Karatekin, 2007, p. 284), and also in research on eye movements that have been recorded during reading (Liversedge & Findlay, 2000; Rayner, 1998; Starr & Rayner, 2001), reading fluency studies in adults with dyslexia (Jones et al., 2008), and children with Attention Deficit Hyperactivity Disorder (ADHD) and reading disability (Deans et al., 2010).

Therefore, though some of the studies reported positive effects of coloured overlays on reading performance, they presented conflicting evidence on the effects and outcomes, and so the findings on the use of coloured overlays in reading from the literature reviewed above can hardly be considered conclusive. Although eye tracking is not a new technology, because of recent advances in computer technology it has become a user-friendly and robust method to study gaze performance, in infants and young children with ASD (Falck-Ytter, Bölte, & Gredebäck, 2013). Given that the use of coloured overlays in reading performance in preschool children with ASD, to the best of our knowledge, has not previously been examined, therefore, the objective of the current study was to investigate the immediate effects of the

coloured overlays in preschool children with ASD, specifically by means of eye tracking, as opposed to the effects previously examined in school-age children, and to compare their reading performance with their counterparts, i.e. TD children closely matched by chronological age.

Methods

Participants

Forty preschool children were assessed – 20 of them (two female and 18 male) with an ASD, aged between four years and six years and seven months, were recruited from a local rehabilitative support centre, and 20 preschool TD children (11 female and nine male) aged between four years and two months and six years and 11 months, who were pair matched closely with the children with ASD in chronological age, were recruited in the community in Hong Kong. All of them attended kindergarten. The inclusion criteria for the ASD group were: a) clinical diagnosis of autism or an ASD; b) chronological age of four to six years; c) intelligence quotient above 70 (IQ > 70) from their medical and school records; d) able to read the top line of characters on the computer screen with both eyes open and then with each eye at about 50 cm away with or without wearing corrective lenses; and e) able to recognize the single-digit numbers (1-9). Criteria for exclusion were: a) neurological or psychopathological disorders; b) visual impairments; c) co-morbidity with other syndromes or

illnesses such as seizure, Attention Deficit Hyperactive Disorder (ADHD), etc.; and d) unable to comprehend instructions in the experiment due to language impairments. The choice of an IQ above 70 as an inclusion criterion for participants was to reduce the probability of lower performance in reading as a function of lower Performance IQ (Jiménez et al., 2003). Approval was obtained from the human ethics committee before data collection (reference number HSEARS20150128007), and informed written consent was obtained from the parents/guardians of participants before enrolment.

Equipment

Coloured overlays

Irlen's coloured overlays[a] were used. These were plastic A4 sheets in ten colours: aqua, blue-grey, grey, green, golden rod, peach, purple, rose, turquoise and yellow. The overlays were placed over a print out without interfering with the clarity of the text (Ludlow, Wilkins, & Heaton, 2006).

Eye tracker

The Tobii X2-60 Eye Tracker[b] was used to measure eye fixations on the visual display and to generate precise eye gaze data. The Tobii Eye Tracker uses infrared illuminators to generate reflection patterns on the participant's corneas during tracking on a computer screen.

It offers freedom of head movement and does not require fixing the participant's head during tracking. Its exceptional tolerance of substantial, dynamic head movement allows for minimal restrictions on the subjects' natural actions, particularly young children who cannot sit still for long periods. Accurate visual data can be recorded when the head is moved within 50 cm on the vertical plane and 30 cm on the horizontal plane. This characteristic of the equipment creates a distraction-free test environment and ensures natural behavior in participants. The binocular accuracy of the eye tracker is 0.4° under both ideal conditions and a 30° gaze angle, and according to the operation manual of the equipment, the suggested operating distance between sensor and participant ranges from 50 to 80 cm. During the experiment, the height of the desk and the chair is adjusted so that the first line of screen display should be at or slightly below the eye level of the participant.

Reading sample

The reading sample used in the study contained 48 randomized single-digit numbers (1-9) in six rows of eight (Figure 1a). A randomized order of digits was used for reading each time. Digits were used in this reading speed test since, due to their educational level, the preschool children were more familiar with single digits than Chinese characters or the English alphabet. The use of digit in this study was to eliminate the effect of child's knowledge on characters or alphabets.

Outcome measurement

Two raters were involved in the tests and they were not blinded in the reading test. Both were responsible for recording the children's reading accuracy and speed. The outcome measurement included adjusted time, number of errors, and eye fixation and visit.

Adjusted time

The total time taken to read the whole sample was measured by digital stopwatch. 'Adjusted time' is used in the analysis section to calculate the actual reading speed for each digit. The total reading time is adjusted by considering the total number of digits read within the period, which includes the omission, repetition and addition of digits. Adjusted time equals 48 times total reading time, divided by the total count of digits read by the participant.

Number of errors

The number of errors is used in the analysis section to reflect reading accuracy. The errors were counted, and included omission error, repetition error and additional numbers read out.

Eye fixation and visit

The Tobii studio software was used to analyse fixations in the reading test. Area of Interest (AOI) was set by the investigators to capture around the third to fifth rows for analysis of participants' reading performance during the reading test (Figure 1b). Four parameters were used in this study: Total Fixation Duration, Fixation Count, Total Visit Duration and Visit Count. Total Fixation Duration is the sum of the duration for all fixations within an AOI. Fixation Count is the number of times the participant fixates on an AOI. Total Visit Duration is the sum of visit duration to an AOI; an individual visit is defined as the time interval between the first fixation on the active AOI and the end of the last fixation on the same active AOI where there have been no fixations outside the AOI. Visit Count is the number of visits to an AOI.

Procedures

Coloured overlay selection

We have adopted the protocol for selection of the coloured overlays from a previous study (Ludlow, Wilkins, & Heaton, 2006). First, each child was invited to sit on a chair positioned beside a table of a suitable height, and then asked to select a coloured overlay for the reading tests. In the coloured overlay selection process, the children were presented with A4-sized samples with passages of text. The coloured overlays were assembled in a pile in the following order: rose, green, aqua, peach, blue-grey, golden rod, grey, purple, yellow and

turquoise - this order was adopted in order to reduce the chances of complementary colours being placed next to each other (Ludlow, Wilkins, & Heaton, 2006). First, the rose overlay was placed over the left side of the text, covering half of the print out. The next (green) overlay was put over the right side of the text. The children were asked to compare the two overlays and choose the favourite one which made reading easier. Preferred overlays were kept while the other was replaced by one of a different colour. This process was repeated until all the overlays in the pile had been shown. The average duration of the selection process was about 15 minutes.

When the child was unable to choose between two colours, both were noted and one of the colours was removed and placed at the bottom of the pile to be reintroduced later. Eventually, the final choice of overlay was checked by placing it over the whole reading test and confirmed by the child, who was asked if the text was clearest and most comfortable with this overlay. If the child changed his or her mind, then the whole selection process was repeated until a final choice was made.

Reading test procedure

Once each child had selected a coloured overlay, he or she was asked to sit in front of another table upon which was placed the Tobii eye tracker. This was positioned at a distance

of approximately 50 cm from the child, who was asked to sit upright and hold his or her head steady in order to ensure that the tracker could detect his or her eyes. The eye tracker was calibrated to each individual prior to the reading tests with and without coloured overlay. The reading test was placed on the computer screen in which the position of the print out had been calibrated with the exact location of the computer screen in the eye tracker. Each child undertook a trial test in order to familiarize themselves with the reading sequence. This consisted of three rows of eight single-digit numbers. The children were given a demonstration prior to reading independently, and they were prompted if they had difficulties understanding the instructions.

The overlays were affixed to the Tobii eye tracker screen. The children were required to read aloud the numbers on the test paper one by one, line by line, from left to right. They had to read the test paper once with and once without their chosen coloured overlay. The total duration of the reading tests was recorded by digital stopwatch. There were 4 test sessions per participants. The sequence of the reading test session with and without coloured overlay was randomized in pair and chosen by heads or tails of a tossing coin for each participant. The randomization was conducted before the tests and the sequence was recorded on the assessment form of each child.

Statistical analysis

All statistical analyses were conducted using IBM SPSS software, version 22.0. The results of the normality test indicate that the assumption of population normality was violated (Table 2). Non-parametric tests were thus performed to compare the mean differences. The Pearson chi-square test and the Mann-Whitney U test were used to compare the baselines without overlays between the 2 groups. The Mann-Whitney U test was carried out to determine between-group differences in all dependent variables with and without a coloured overlay. The Wilcoxon signed-rank test was also conducted to determine within-group difference in all dependent variables with and without a coloured overlay.

Results

The demographic characteristics of the participants are shown in Table 1. The results for two participants in the ASD group were excluded due to behavioral problems such as frequent out of seats behavior who were unable to complete the experiment, and two participants in the TD group were excluded due to suspected developmental delay. Therefore, the results for 18 children in both groups were used for final analysis. The results of the normality test showed that the control participants were matched to the children with ASD on an individual basis by chronological age (p = 0.203) but the groups were not matched by gender (p = 0.011). There were no significant differences in the baselines of adjusted reading time, number of errors or AOI measurements (i.e. without an overlay) between the two groups (p = 0.393-0.887) (see

Table 1). The colours of the overlays selected in the two groups are shown in Figure 2.

For the pre/post differences of all dependent variables within the ASD and TD groups (Table 2), no significant differences were identified between the adjusted reading time (p = 0.777 and p = 0.507) or number of errors (p = 0.775 and p = 0.556) with and without coloured overlay in the ASD and TD groups respectively. No significant differences were identified between the AOI measurements with and without coloured overlay in the ASD group (Total Fixation Duration: p = 0.728; Fixation Count: p = 0.777; Total Visit Duration: p = 0.647; Visit Count: p = 0.757). Similarly, no significant differences were identified between the AOI measurements with and without coloured overlay in the TD group (Total Fixation Duration: p = 0.145; Fixation Count: p = 0.237; Total Visit Duration: p = 0.117; Visit Count: p = 0.569). Previous studies reported that using coloured overlays had produced a 5% increase in reading speed in word recognition, which is a criterion for clinically significant improvement (Ludlow, Taylor-Whiffen, & Wilkins, 2012; Ludlow, Wilkins, & Heaton, 2006; Ludlow, Wilkins, & Heaton, 2007; Wilkins, 2003; Wilkins et al., 2001). In this study, although we used digit which might be different from word recognition, 4 out of the 18 (22%) children with ASDs and 5 of the 18 (28%) TD children read more than 5% faster with a coloured overlay (Table 3).

There were no significant differences in adjusted time (p = 0.569) or number of errors (p = 0.737) between the two groups when reading with a coloured overlay (Table 2). The AOI measurement with a coloured overlay was analysed, and no significant differences were found in Total Fixation Duration (p = 0.255), Fixation Count (p = 0.763), Total Visit Duration (p = 0.189 or Visit Count p = 0.465) between groups when participants read with a coloured overlay (Table 2).

Discussion

The current study focused on the immediate relative effects of using coloured overlays on reading and ocular performances in preschool children with ASD and their TD counterparts. Given that the use of coloured overlays in preschool children with ASD has not previously been investigated, this study might have a contribution to the literature. The results of this study show that there were no significant differences in the ocular performance and reading speed of the TD or ASD groups with or without coloured overlays. There was no significant difference in AOI measurements between or within the two groups when participants read with or without a coloured overlay. This shows that the use of coloured overlays may not improve reading and ocular performance in either group.

Eye tracking is a relatively simple and non-invasive technique that can be tolerated by

young children, thus, provide a powerful measure on saccades, pursuits and fixations, etc. to compare performance across a wide range of ages and clinical groups without the confounding factors of complex motor skills in different kinds of translational research (Karatekin, 2007). It has been used as a promising objective measurement tool in social attention studies for the preschool children with autism in terms of using video clips with social contexts presented together with objects (Chawarska et al., 2012; Hosozawa et al., 2012; Murias et al., 2017). One of the biggest advantages with eye tracking over other methods is its ability to capture the gaze performance with high spatial and temporal resolution, in complex situations that resemble social and non-social contexts, making it ideal for the study of young children and infants (Falck-Ytter, Bölte, & Gredebäck, 2013).

However, some qualitative improvements were observed in this study when ASD participants read with coloured overlays. For instance, the fixation time on each number was shorter, implying that these children required less time to look at each number before reading it aloud. Also, some of the children showed greater accuracy in reading the numbers, which means that the frequency of looking at the space between the numbers was reduced in the coloured overlay trial. Although these findings demonstrate that coloured overlays may have a positive effect on the visual attention and eye scanning performance of some ASD children, there were no statistically significant improvements in AOI measurements between and within

the two groups with which to draw positive conclusions about the effectiveness of coloured overlays.

Previous studies (Ludlow, Taylor-Whiffen, & Wilkins, 2012; Ludlow, Wilkins, & Heaton, 2006; Ludlow, Wilkins, & Heaton, 2007) have shown significant differences in reading speed among school-aged children with ASD when using overlays; however, their results show improvement in the reading speed only. Numerous authors have questioned the theoretical premise upon which Irlen syndrome is based, because there is no scientific evidence supporting the syndrome or the use of coloured overlays. Only three studies have focused on the use of coloured overlays among children with ASD and all three were conducted by Ludlow and their research team (Ludlow, Taylor-Whiffen, & Wilkins, 2012; Ludlow, Wilkins, & Heaton, 2006; Ludlow, Wilkins, & Heaton, 2007). The hypothesis that coloured overlays are effective because they avoid excessive cortical excitation, thus reducing the overreaction of the visual cortex and in turn improving reading performance (Wilkins & Evans, 2010), has been questioned because of a lack of strong empirical evidence (Henderson, Tsogka, & Snowling, 2013). Therefore, the underlying meaning of these positive results is not clear without further evidence.

The current study has shown that use of coloured overlays does not demonstrate

improvement in reading or ocular performance of preschool children immediately. The results are consistent with other studies' findings that coloured overlays have no immediate effects on improving the reading speed and global reading ability of participants with reading difficulties (Ritchie, Della Sala, & McIntosh, 2011). As children with ASD may have the same reading difficulties in children with learning disabilities with Irlen syndrome (Irlen, 1991), our negative results are consistent to some studies (Martin et al., 1993; Northway, 2003; Ritchie, Della Sala, McIntosh, 2011; Robinson & Conway, 1990) that found the effect of coloured overlays on the reading performance of children with reading difficulties to be doubtful.

However, the duration of the use of coloured overlays may have an influence on their effect on reading performance. An RCT has studied the effect of coloured overlays on the reading speed of people with specific learning difficulties (Bouldoukian, Wilkins, & Evans, 2002). The results indicated that 16 out of 33 participants in the experimental group demonstrated a sustained benefit: 81% of them had a better reading rate than their counterparts in the control group. Seventeen of the 33 participants only demonstrated an immediate benefit from the coloured overlays while only 59% showed a better reading rate than the control group. The present study did not evaluate the use of coloured overlays over time but rather only at a single time point, the long-term effect of coloured overlays on

reading performance in preschool children with ASD is worth further investigation in the future.

There were other limitations to this study. First, it investigated the immediate positive effects of coloured overlays on reading speed; it may be reasonable to expect that the potential effect requires a longer duration in training. Second, the sample of this study was small. Third, more females were included in the control group than in the ASD group which might impact findings. It is also possible that some participants had undetected vision problems, such as near-sightedness, far-sightedness, astigmatism or strabismus that potentially interfered with their ability to read. The selection of participants in future studies should consider screening potential participants their history of vision problems. Participants in this study were required to read single-digit numbers. Some studies have indicated that children with ASD are overly fascinated with letters and digits; therefore, the beneficial effects of the reading test among preschool children with ASD may be a result of preference for and motivation to read numbers. Since the favourite coloured overlay was subjectively chosen based on the child's preference, we might not be certain that the overlay selected for the experimental task was effectively improving the reading conditions for each child. In future, several overlays should be used as a comparison and one control overlay could be pre-selected to be consistent across participants. Children with ASD often struggle to sit still and follow instructions due to a

short attention span, therefore, equipment for stabilizing the child's head during the reading test is recommended in future study. Although we had excluded only 2 participants due to behavioral problems such as frequent out of seats behavior who were unable to complete the experiment, we did not take into account the exact percentage of time the child is spent looking away during data collection and in statistical analysis.

Conclusion

This is the first eye-tracking study to investigate the use of coloured overlays in improving reading performance in pre-school children with ASD in comparison to their TD counterparts. Our findings indicate that single use of coloured overlays may not help to improve reading and ocular performance immediately in preschool children with ASD. The potential effect on reading ability of using coloured overlays for longer period needs further investigation.

(Words: 3,884)

Equipment

a. 9" x 12" Irlen coloured acetate overlays (http://irlen.com/colored-overlays/)

b. 'Tobii' X2-60 Eye Tracker, Tobii Technology, Inc., Sweden (https://www.tobiipro.com/fields-of-use/infant-child-research/)

Conflicts of interest

This manuscript is the original work of the authors and has not been submitted for publication before. No commercial party with a direct financial interest in the results of the research supporting this article has conferred or will confer a benefit upon the authors or upon any organization with which the authors are associated.

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Figure 1a. Reading sample

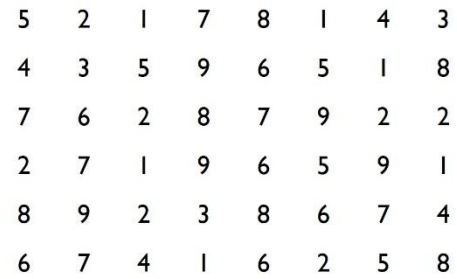

Figure 1b. Area of Interest (AOI) range reading sample

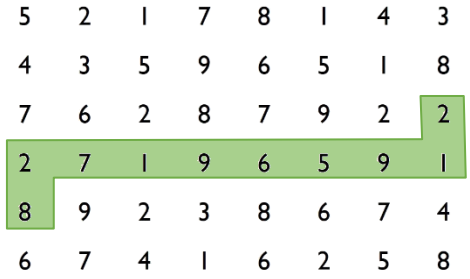

Figure 2. Selection of the coloured overlays in participants of both groups

Coloured Overlay	ASD Group	TD Group
Blue-grey	4	7
Rose	1	2
Golden rod	1	1
Turquoise	3	2
Yellow	1	2
Grey	1	0
Peach	0	3
Aqua	3	0
Green	2	0
Purple	2	1

Note: Autism spectrum disorder (ASD), typical development (TD)

Table 1. Comparison of baseline measurement parameters between the two groups

	Baseline (Without overlays)			
	ASD Group (n = 18) Mean (SD)	TD Group (n = 18) Mean (SD)	Mann-Whitney U	*p*
Demographic				
Age (months)	68 (8.72)	61 (9.45)		0.203¶
Gender, *n* (%)				0.011¶
Male	16 (88.9%)	9 (50%)		
Female	2 (11.1%)	9 (50%)		
Measurement				
Adjusted time, *sec.*	39.26 (14.44)	43.28 (16.36)	U = 135, Z = -0.854	0.393
No. of errors, *n*	3.0 (4.45)	2.5 (3.92)	U = 146, Z = -0.523	0.601
Total Fixation Duration, *sec.*	8.25 (7.00)	7.76 (4.12)	U = 157.5, Z = -0.142	0.887
Fixation Count, *n*	27.28 (17.59)	24.61 (12.58)	U = 157, Z = -0.158	0.874
Total Visit Duration, *sec.*	8.86 (7.93)	8.18 (4.39)	U = 151.5, Z = -0.332	0.740
Visit Count, *n*	11.5 (9.22)	10.44 (6.90)	U = 154, Z = -0.254	0.799

Note: ¶Pearson chi-square; Autism spectrum disorder (ASD), typical development (TD)

Table 2. Comparison of measurement parameters with the coloured overlays within and between the two groups

	ASD Group (n = 18)			TD Group (n = 18)			Between groups	
	Without Overlays	With Overlays	p^1	Without Overlays	With Overlays	p^1	Mann-Whitney U	p^2
	Mean (SD)			Mean (SD)				
Adjusted time, *sec.*	39.26 (14.44)	39.07 (13.37)	0.777	43.28 (16.36)	44.47 (20.25)	0.507	U = 144, Z = -0.570	0.569
No. of error, *n*	3.0 (4.45)	3.2 (3.69)	0.775	2.5 (3.92)	2.9 (3.58)	0.556	U = 151.5, Z = -0.336	0.737
Total Fixation Duration, *sec.*	8.25 (7.00)	7.67 (4.13)	0.728	7.76 (4.12)	9.41 (5.08)	0.145	U = 126, Z = -1.139	0.255
Fixation Count, *n*	27.28 (17.59)	27.61 (17.15)	0.777	24.61 (12.58)	29.56 (16.43)	0.237	U = 152.5, Z = -0.301	0.763
Total Visit Duration, *sec.*	8.86 (7.93)	8.86 (7.93)	0.647	8.18 (4.39)	9.97 (5.05)	0.117	U = 120.5, Z = -1.313	0.189
Visit Count, *n*	11.5 (9.22)	11.22 (9.12)	0.757	10.44 (6.90)	12.22 (7.66)	0.569	U = 139, Z = -0.730	0.465

Note: [1]Wilcoxon Signed Rank Test; [2]Mann-Whitney Test; Autism spectrum disorder (ASD), typical development (TD)

Table 3. Percentage of improvement in the reading speed of children with coloured overlays

	Percentage improvement in reading speed with overlays			
Children showing improvement with overlays, *n (%)*	0.1-5%	6-10%	11-20%	21-30%
ASD (n = 8) (out of 18)	4(22%)	2(11%)	1(6%)	1(6%)
TD (n = 8) (out of 18)	3(17%)	3(17%)	1(6%)	1(6%)

Note: Autism spectrum disorder (ASD), typical development (TD)

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Immediate effects of coloured overlays on the reading performance of preschool children with an Autism Spectrum Disorder using eye tracking

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