Judging the intensity of emotional expression in faces: the effects of colored tints on individuals with autism spectrum disorder

Lydia Whitaker[1] , Catherine R.G. Jones[2], Arnold J. Wilkins[1] & Debi Roberson[1]

University of Essex

1. Department of Psychology, University of Essex, United Kingdom;
2. School of Psychology, Cardiff University, Tower Building, Park Place, Cardiff, United Kingdom;

Correspondence concerning this article should be addressed to Debi Roberson, Department of Psychology, Wivenhoe Park, University of Essex, Colchester, CO4 3SQ, UK. Telephone: +44 (0)1206 873710; email address: robedd@essex.ac.uk

Grant sponsor: A University of Essex Studentship to the first author supported this study.

Page lay abstract:

Individuals with autism spectrum disorder (ASD) display impairments in social interaction as well as difficulties processing sensory information, which may explain, in part, impairments in the perception of emotion in facial expressions. Parallels have recently been drawn between the symptoms of visual stress and the sensory difficulties experienced by individuals with ASD. Visual stress refers to the experience of discomfort and perceptual distortions (particularly from text), and can be reduced with the use of colored overlays/tints when reading. Sixteen children with ASD and a typically developing (TD) comparison group were assessed for their ability to discriminate correctly between the emotional intensities expressed in pairs of faces. Faces were presented on a computer screen that was tinted either gray or with a color previously chosen by the participant as comfortable. Judgments of emotional intensity improved with the addition of the individual preferred colored tint in the ASD group but not in the control group. Children with ASD appear to have atypical face processing that may be related to visual stress and difficulties processing sensory information.

Scientific Abstract

Individuals with autism spectrum disorder (ASD) often show atypical processing of facial expressions, which may result from visual stress. In the current study, children with ASD and matched controls judged which member of a pair of faces displayed the more intense emotion. Both faces showed anger, disgust, fear, happiness, sadness or surprise but to different degrees. Faces were presented on a monitor that was tinted either gray or with a color previously selected by the participant individually as improving the clarity of text. Judgments of emotional intensity improved significantly with the addition of the preferred colored tint in the ASD group but not in controls, a result consistent with a link between visual stress and impairments in processing facial expressions in individuals with ASD.

Keywords: facial expressions; sensory; autism spectrum disorder; tints; overlays; visual stress

Individuals with autism spectrum disorder (ASD) often display impairments in social interaction as well as heightened or diminished sensory processing (Stevenson et al., 2014, also see Harms, et al., 2010 and Simmons et al., 2009 for recent reviews). Impairments in social interaction may include a preference for objects over people (Hobson, et al., 1988; Klin et al., 1999; Langdell, 1978; Lord, et al., 1994; Osterling & Dawson, 1994) as well as atypical processing of facial expressions (Behrmann et al., 2006; Greimel et al., 2014; Kliemann et al., 2010; Uljarevic & Hamilton, 2012). However, the link between visual sensory processing and social communication difficulties in ASD has received comparatively little study (see Ludlow, et al., 2012; Harms, et al., 2010; Philip et al., 2010; Uljarevic & Hamilton, 2012).

Individuals with ASD have also been reported to show differences in visual acuity compared to typically developing (TD) controls, measured using Gabor and Gaussian patches (Bertone et al., 2005; Maguire, 2014; Sanchez-Marin & Padilla-Medina, 2008; Spencer & O'Brien, 2006), as well as abnormal color processing (Franklin et al., 2008) and color memory (Heaton, et al., 2008). Some individuals with ASD also report experiencing headaches and nausea when viewing certain colors (Ludlow & Wilkins, 2009; Williams, 1999). Recent research has drawn parallels between the symptoms reported by individuals who suffer from visual stress and the sensory difficulties experienced by individuals with ASD (Wilkins, 2012). Visual stress (also referred to as Meares-Irlen syndrome) refers to visual discomfort and distortions, particularly when viewing text, including blurring or apparent movement, or colors around letters (Wilkins & Nimmo-Smith, 1984; 1987). Some individuals with ASD report these symptoms and may also be diagnosed with visual stress (e.g. Ludlow & Wilkins, 2009; Ludlow, et al., 2008). People show consistency with respect to the images that they judge to be uncomfortable, and this discomfort can be predicted from an image's Fourier amplitude spectrum. This applies to images ranging from photographs of everyday scenes, to modern art and geometric arrays (Fernandez & Wilkins 2008). Images are generally rated as uncomfortable to view if their characteristics depart from those that occur in natural images. For example, they are less comfortable to view if the slope of the Fourier amplitude spectrum differs from 1/f (Juricevic et al., 2010) and if the chromatic contrast is unnaturally high, regardless of the particular chromaticities within a large gamut (Haigh et al., 2013). For those individuals who experience visual stress when reading text, Wilkins (2003) showed that transparent colored overlays could reduce perceptual distortions leading to alleviation of symptoms and improved reading speed.

Individuals with ASD are four times more likely to benefit from colored overlays than controls (Ludlow et al., 2008). However, the evidence for the improvements in reading speed remains controversial (Albon et al., 2008; Galuschka, & Schulte-Körne, 2014). The improvements have been assessed in terms of the rate with which randomly ordered words are read aloud. Henderson et al., (2014) have argued that this is an unrealistic measure of reading speed. A recent systematic review concludes that *"[sic]given … contradictory findings, a precautionary, prudent position … on the use of colored overlay seems desirable, especially in clinical or educative contexts, but from another side, given that some evidence that the colored overlays work exists, concluding that colored overlays proved not worth in allaying reading problems is premature and, possibly, incorrect."* Uccula, Enna and Mulatti (2014, p. 3-4).

Individuals who experience visual stress may show a large cortical haemodynamic response to a visual stimulus that they find uncomfortable to look at. Increased cortical hyperexcitability, measured by increased blood oxygenated level-dependent (BOLD) response, has been found in both individuals who experience migraines (Huang, et al., 2003) and those who experience visual distortions without migraines (Chouinard et al., 2012) when viewing visually disturbing stimuli. The abnormal cortical reaction may reflect inefficient neuronal processing (Wilkins & Hibbard, 2014).

The cortical hyperexcitability account is not the only explanation for visual stress. The magnocellular deficit (Chase et al., 2003; Chouinard, Zhou, Hrybouski, Kim, & Cummine, 2012) and noise exclusion deficit theories (see Facoetti, et al., 2010 and Sperling et al., 2005 for examples) also provide explanations for visual stress. Magnocellular layers form part of a pathway that leads from the retina to the primary visual cortex (Stein, 2003). A primary function of the magnocellular pathway is to process rapid changes in the visual field. Post mortem evidence of abnormal growth of the magnocellular pathway in individuals with dyslexia has been used to support the magnocellular deficit as the underlying mechanism for visual stress in dyslexia. Stein (2003; Stein & Kapoula, 2012) proposes that abnormalities in the magnocellular pathways would impair binocular coordination, resulting in symptoms of visual stress such as words jumping and moving on the page. Deficits in magnocellular function have also been observed in ASD, although data are equivocal (see Greenaway et al., 2013 for a recent summary). The contrasting results may reflect that magnocellular deficits are only common to a proportion of individuals with ASD (e.g. Greenaway et al., 2013).

In contrast, noise exclusion deficit theories propose that any difficulties for individuals with dyslexia when reading are due to deficits in excluding noise from the visual world (Sperling et al., 2005). Irrelevant stimuli lead an individual to ignore the important information, such as the text on a page (Ruffino et al., 2010). This difficulty may not be specific to text and may cause processing difficulties across domains (Facoetti, et al., 2010 and Sperling et al., 2005). It has been proposed that individuals with ASD experience levels or neural noise that are either atypically high (Rubenstein & Merzenich, 2003; Simmons et al., 2007, 2009) or low (Davis & Plaisted-Grant, 2014).

From an alternative perspective, the Enhanced Perceptual Functioning model (EPF; Mottron & Burack, 2001; Mottron et al., 2006a) asserts that aspects of low level processing are enhanced in ASD and that they are relatively immune to top-down influences. Atypical visual perceptual experiences are argued to associate with unusual looking behaviours in young children with ASD (Mottron et al., 2007). It is conceivable that fundamental perceptual atypicalities have downstream effects on higher order social cognitive processing, either directly (atypical perceptual input) or indirectly (e.g. atypical attentional focus).

Typical individuals who suffer from visual stress have also been shown to have impaired processing of facial expression: Robinson and Whiting (2003) and Whiting and Robinson (2001) found that typical individuals suffering from visual stress had impaired recognition of facial expressions compared to controls, which improved with the use of colored overlays. The benefits of colored overlays have also been documented for complex emotions. In a paper version of the '"Reading the Mind in the Eyes" task (Baron-Cohen & Cross, 1992), Ludlow, et al., (2012) demonstrated an improvement in the classification of facial emotional expressions from the eye area, in individuals with ASD, using colored overlays. A single case study of an individual with ASD showed an improvement in social and communication abilities when individually tinted colored glasses were worn (Ludlow & Wilkins, 2009). These findings, involving not only textual but social stimuli, are consistent with a link between visual stress and impairments in social and communication abilities.

The present experiment extended previous research by examining whether a colored tint would improve judgments of relative emotional intensity rather than simply the categorization of emotions. The discrimination of emotional intensity was examined in the light of previous research, which has documented that individuals with ASD have difficulty judging the intensity of some emotional expressions and this may lead to social and communication difficulties in day-to-day life (Rump et al., 2009; Rutherford & McIntosh, 2007; Rutherford & Towns, 2008). In contrast to Ludlow et al., (2008), who used images showing only the eye region of the face (Baron-Cohen & Cross, 1992), we used the whole face to simulate a more realistic social-emotional scene. Intensity judgments may require more holistic processing than categorization but do not require access to verbal labels for emotion categories, so even individuals with language impairments could be tested (Harms et al., 2010). We also, used whole faces because different areas of the face are diagnostic of different facial expressions (Roberson, et al., 2010; Roberson et al., 2012; Smith et al., 2005) and we wanted to investigate the generality of the effects. We compared 16 colored tints to a neutral gray tint to rule out the possibility that improvements in performance were due to reduced contrast between face and background that would have occurred with any tint, rather than one specifically selected as improving clarity (Ludlow et al., 2008).

In contrast to previous research, which adopted the use of 10 colored overlays in the Intuitive Overlays task, we opted for 16 colored tints. The use of 16 instead of 10 colors ensured we had a greater range of chromaticities (see Wilkins et al., 1992 for a discussion of the importance of chromaticity when choosing colored overlays).

Method

Participants

16 children diagnosed with ASD (1 female), aged 7 - 15 years, and all attending schools for children with learning difficulties were compared to 16 typically developing (TD) children (3 females), aged 7 - 16 years and matched on performance IQ [PIQ; ASD: mean = 90.75 (14.26), TD: mean = 86.44 (13.78),($t(30)$, .870, p=.40)], verbal IQ [VIQ; ASD: mean = 87.50 (17.03), TD: mean = 92.06 (12.32),($t(30)$, -.868, p=.40)], full scale IQ [FSIQ; ASD: mean = 87.93 (16.39), TD: mean = 89.20 (12.45),($t(30)$, -.243, p=.98)] and chronological age [CA; ASD: mean = 11;6 (2.74), TD: mean = 11;3 (2.38), ($t(30)$, .270, p=.28)]. All participants with ASD had a confirmed clinical diagnosis and scored above the ASD threshold on the Autism Diagnostic Observation Schedule –Generic (ADOS-G, 2000) (See Table 1). The Weschler Abbreviated Scale of Intelligence provided a measure of FSIQ (WASI; Wechsler, 1999) (See Table 1 for standardized scores). No participants had color vision deficiencies, as measured by the City University Color Vision test (3rd ed., Fletcher, 1998) and the Ishihara test (Ishihara, 1972). All participants had normal or corrected to normal vision (the benefit from tints is largely independent of routine optometric findings (Monger, Wilkins & Allen; in press). Ethical approval was obtained from the University of Essex ethics committee and informed consent was obtained from the parents of all participants.

Materials

Tint selection task

To determine which colored tint best improved the clarity of text, two passages of identical text, 107mm wide by 60mm high, were presented in black 12-point Times font side by side with their inner margin 40mm from the center of a computer screen. The same 15 common words (come see the play look up is not for and my dog you to cat) appeared in a different random order on each of 10 lines, similarly for both passages. The text was black (unlit pixels) on a lit background that was either given a shade of colour or was gray. The lit background comprised the entirety of the screen. For the first 16 trials text was presented on two sides of the screen, and the background was colored one side of a vertical midline and gray on the other side, the side chosen at random. For the remaining trials the text was presented in the centre of the screen and the background was colored. The luminance of a surface is a photometric measure corresponding to the sensation of brightness and indicates how much light will be detected by an eye looking at the surface. The contrast between two surfaces is the difference in their luminance expressed as a proportion of the mean luminance of a reference surface, here the background surface. The superimposed colored tint reduced the contrast of the text on the background by less than 4%. Each background had one of the chromaticities shown by the inner ends of the lines in Figure 1. All the colored tints had an approximately equal saturation (strength of color, Commission Internationale de L'Eclairage: CIE 1976 s_{uv}) and were separated from neighboring colors by an approximately equal difference in hue (see Wilkins, 2003; 2012 for further information). Luminance contrast was measured for each of the tints in terms of Weber's contrast (see Whittle, 1994: $\Delta L/L_b$).

Wilkins Rate of Reading Test

The Wilkins Rate of Reading Test (WRRT; Wilkins, et al., 1996) is a well-established speeded reading test, with four passages of text similar to that used in the tint selection task, and was tinted with the self-selected color (see above) or a gray.

Emotional Intensity Discrimination

Faces showing a range of facial expression were taken from a well-validated database (Montagne et al., 2006), which includes six emotional expressions at differing levels of intensity. Variation in intensity was achieved by morphing expressions with a neutral expression to yield 100%, 80% and 60% intensity expressions, for example: 100% happy, 80% happy+ 20% neutral, 60% happy + 40% neutral. This set of stimuli was preferred over other sets because expressions are morphed with a neutral face, rather than with another expression (e.g. 50% happy + 50%

angry, see Roberson et al., 2012). The grayscale face images were shown behind an oval aperture (height 133mm (600 pixels - major axis) width 112mm) in a gray mask, cropped of external features, such as hair and ears, with the oval shaped mask. Faces were presented in pairs side by side, with the center of the ovals on the horizontal midline of the screen and their inner margins separated by 21mm. Each oval subtended 23° high by 19° wide and both were covered by a tinted or gray transparent rectangular Photoshop object 275mm wide by 166mm high, on the 333mm by 210mm screen of a MacBook Pro, the remainder of which was gray (CIE 1976 u'v' chromaticity 0.230, 0.490). Both members of each pair of faces always displayed the same expression, which was either anger, disgust, fear, happiness, sadness or surprise, but one face displayed the expression at a lower emotional intensity than the other (see Figure 2). Forty-eight stimuli were presented twice each (colored and gray tint conditions), equally balanced across the six emotions. The face stimuli were both covered either by a gray or by the self-selected colored tint, as for the WRRT above. The Weber contrast for the face with a colored tint was lower than that for the same face with a gray tint. The chromaticities of the colored rectangles (measured from the tip of the nose) are shown in the outer circle of Figure 1. Therefore contrast was lower for colored tinted faces compared to gray tinted faces. The Weber contrast was measured at the tip of the nose of one face relative to the background and ranged across selected tint colors from 0.22 to 0.51 (average 0.38), less than for the gray tint (0.74).

Chromaticities of colored and grey tints in the Tint selection task and Emotional Intensity Discrimination:

The grey tint and 16 colored tints were created in Photoshop®. Corresponding RGB values, taken from the colors previously used in the Wilkins Rate of Reading Test, were used. Subsequent presentation of these tints in the Tint selection task and Wilkins Rate of Reading task were in Microsoft PowerPoint. Whereas presentation of tints in the Emotional Intensity Discrimination task was in Superlab®. As a result of the different software packages used chromaticities of the tints in the Wilkins Rate of Reading task and Emotional Intensity Discrimination task were slightly different (see Figure 1). As can be seen from the outer and inner points on Figure 1 saturation of each colored tint was different, with slightly greater saturation in the Emotional Intensity Discrimination task. However, points cluster together in the center, indicating that the hues of each tint in the two tasks are similar.

(Figure 1 top)

Procedure

Tints selection task

Participants viewed the screen from a distance of 0.4m, with line of sight to the center of the display perpendicular to the surface. Figure 1 gives details of the chromaticity measurements for all tints. For the first 16 trials, each of the 16 colors was randomly presented once on one side of the screen while the comparison gray tint was presented on the other side and participants were asked to choose which passage of text was clearest and most comfortable, without reading them. Each of the colors they shortlisted (between 1 and 14) was then paired with another shortlisted color so that by successive elimination the clearest/most comfortable color was ultimately selected. For this part of the tint selection procedure tints were presented consecutively.

Choice of tint

Participants were asked to decide, in the first 16 trials, which of two passages of text (one with gray tint one with colored tint) improved the clarity of text. Individuals with ASD and TD individuals showed similar variation in the number of colored tints chosen. Individuals chose between 1-to-14 colors as improving clarity, compared to the gray tint, [ASD: mean (SD): u': 0.18 (0.02), v': 0.48 (0.04), range: 1-14 different colored tints chosen, TD: mean (SD): u': 0.17 (0.03), v': 0.49 (0.02), range: 2-12 different colored tints chosen]. There was no systematic difference in the range or type of colours selected between groups.

(Figure 2 top)

Wilkins Rate of Reading Test

WRRT standard procedure was followed. The color finally selected was used to tint Passage 1 (99mm width x 50mm height) of the WRRT. The participant read the passage aloud as quickly and as accurately as possible for one minute, or until they finished the passage. Passage 2 was then presented with a gray tint (the same as used previously) and the reading repeated. Passages 3 and 4 followed, using the gray and colored tint respectively. The score was the number of words correctly read per minute, and words were counted as correct only if they were in the appropriate sequence. The average rate of reading (number of words per minute) for each condition was calculated.

Emotional intensity discrimination task

Participants were asked to decide which of a pair of faces on the screen had the strongest emotion. All participants successfully completed four practice trials for each condition, with feedback. The same instructions were given for the test phase, but without feedback. Order of face pairs was randomized and the task conditions were counterbalanced in two blocks (e.g. block 1: color tinted face pairs, block 2: gray tinted face pairs), separated by at least 2 hours to reduce practice effects. The participants' responses were made using a button box. The proportion of correct responses (out of 48) was calculated for each condition. The reaction time for each response was measured to the nearest millisecond.

Results

WRRT - Figure 3 shows the mean rate of reading speed on the WRRT for ASD and TD individuals with and without colored tints.

(Figure 3 top)

9/16 individuals with ASD had an improvement in the discrimination of the intensity of expressions of emotion of more than 5% with the colored tints, in contrast to 4/16 TD individuals. Significantly more individuals' with ASD than TD individuals showed an improvement of more than 5% (χ^2 (1, N=32) =3.24, p=.036).

Average WRRT scores were compared in a 2 (Group: ASD vs. TD) x 2 (Tints: colored vs. gray) mixed design ANOVA. It revealed no significant between-group differences in reading speed [$F(1, 30) < 1$], but a significant effect of tint [$F(1, 30) = 8.17$, p=.008, partial $\eta 2$ =.21]. More words were read per minute with a colored tint than with a gray tint. There was also a significant interaction [$F(1, 30) = 6.97$, p=.013, partial $\eta 2$ =.19]. Simple main effects analysis revealed that the TD group's rate of reading did not differ between a colored or gray tint (p>.8). However, individuals with ASD read significantly more words with a colored than a gray (p=.006) (see Figure 3).

Emotional intensity discrimination task-Figure 4 depicts the results of the emotional intensity discrimination task for the ASD and TD groups.

(Figure 4 top)

A 2 (Group: ASD vs. TD) x 2 (Tints: colored vs. gray) mixed design ANOVA conducted on the proportion of correct responses found no significant main effect of group or tint. The ASD group's judgments of the intensity of facial expressions did not differ to controls for gray or colored tints. There was a significant interaction [$F(1, 30) = 5.703$, $p = .023$, partial $\eta 2$=.16]. Only the ASD group were significantly more accurate with a colored tint than a gray one ($p<.05$). There was no difference for the TD group (see Figure 4).

Latency in the emotional intensity discrimination task

The speed at which participants responded in the emotional intensity discrimination task were compared in a 2 (group) x 2 (Tints: colored vs. gray) mixed design ANOVA. There was no significant main effect of group [F(1, 30) $p > .5$] or of tint [$p > .09$]. There was no significant interaction between group and tint [$p > .2$].

Choice of tint

To determine whether the difference in performance in the emotional intensity task was the result of differences in the contrast levels of tints chosen, the relative benefit of the tints in the emotional intensity task were compared to the contrast levels of the tints chosen by each group. Contrast level was calculated for each of the tints using Weber's contrast ($\Delta L/L\mathrm{b}$). Contrast levels of the tints chosen by each group did not correlate with the relative benefit of the tints in the emotional intensity task in either group (ASD: $r_s = -.33$; p>.2; TD: $r_s = -.10$; p>.7). To determine whether the hue of the tints chosen by each group affected performance in the emotional intensity task, a median split grouped tints into the 8 coolest and 8 warmest colors. There was no difference in the number of instances in which both groups chose tints of cool and warm colors [χ^2 (1, N=32) =2.133, $p>.1$]: 9/16 children with ASD chose warm colors whereas the TD group's choices of cool and warm colors were equal.

Correlations between social and communication ability and discrimination of the emotional intensity of faces

The social ability and communication ability (ADOS-G, 2000) of children with ASD were not significantly correlated with the discrimination of gray tinted [social ability: r =.31, p=.23, communication ability: r =.26, p=.34] or color tinted [social ability: r =.21, p=.43, communication ability: r =.42, p=.13] faces. Neither was the improvement in discriminations of emotional intensity with a colored tint significantly correlated with social ability or communication ability (social ability: r =.004, p=.99, communication ability: r =.24, p=.37).

Correlations between the WRRT and emotional intensity discrimination task

(Figure 5 top)

In the ASD group the improvement in performance with a tint on the WRRT was marginally correlated with improvement on the emotional intensity discrimination task (r =.41, p=.06); 17% of the variance was accounted for by colored tints.

Discussion

This study found that self-selected colored tints improved judgments of the intensity of facial expressions for individuals with ASD but not for TD individuals, in line with the findings of Ludlow et al. (2012). In contrast to TD individuals, whose judgments were (non-significantly) poorer when colored tints were added to faces, individuals with ASD showed a significant improvement in their judgments of the intensity of facial expressions. By displaying whole faces rather than single features, we demonstrate that the improvement is not restricted to the eyes (Ludlow et al., 2012), and may extend to judgments that involve some degree of configural or holistic processing (Calvo & Fernandez-Martin, 2013). Our task could be completed without accessing emotional labels, and in this respect differs from tasks used in previous studies. This improvement suggests that sensory abnormalities, such as visual stress, may relate to difficulties processing social stimuli, such as faces (Kliemann et al.,2010; Leekam, et al., 2000; Simmons et al., 2009).

However, the social and communication abilities of children with ASD, as assessed by the ADOS, did not correlate significantly with the discrimination of emotional intensity with a gray or colored tint nor with the improvement with color. Previously reported atypical attention to faces as well as a hypo- or hypersensitivity to faces (Hirstein et al., 2001; Hobson et al., 1988; Jones et al., 2008; Kylliainen & Hietanen, 2006; Langdell, 1978; Senju, 2007; Stagg, et al., 2013; Stagg et al., 2014; Yi et al., 2014) suggests that differences in visual processing may be stimulus specific. Future research could investigate visual processing of non-social objects to examine whether this effect is more pronounced for social stimuli.

The colored tints improved reading speed in the ASD group to an extent similar to that found by other studies (Ludlow et al., 2006; Ludlow et al., 2008). The improvement in reading rate and intensity discrimination supports the hypothesis that individuals with ASD experience visual stress that is not specific to social stimuli. A plausible neurological explanation for visual stress in ASD is a hyperexcitability of the cortex, suggested by the fact that migraine and ASD (Huang, et al., 2003) and epilepsy and ASD (Canitano, 2007; Tuchman & Cuccaro, 2011) tend to co-occur. Wilkins (2003; 2012) has proposed a possible cortical mechanism whereby a colored overlay, chosen on an individual basis, may make a visual scene more comfortable to view.

The addition of a colored tint reduced the contrast of the face stimuli more than the gray tint but, this change in contrast was not correlated with performance (see also Jeanes et al., 1997; Wilkins et al., 2001). Moreover, improved intensity discrimination was not specific to any particular color. Nor was there a speed-accuracy trade-off because there were no differences in reaction times.

One important consideration is that the participants' perceived visual stress/ visual perceptual distortions were not quantified using a standardized measure. Therefore, it is unclear whether the perceived visual stress differed in children with ASD and TD controls. Previous research has highlighted that pattern glare; a visual perceptual distortion, and a correlate of Meares-Irlene syndrome, is reduced with colored overlays (Conlon et al., 1998; Evans, Patel & Wilkins, 2002; Evans et al. 1996; 2001; Wilkins & Neary, 1991). Future research could consider administering a standardized measure of visual perceptual distortions, such as the pattern glare test (I.O.O. Marketing Ltd, London, UK), which has previously been conducted in the field (Evans & Stevenson, 2008; Evans et al., 2002).

In conclusion, we have shown an improvement, with tints, in the discrimination of facial expressions using a two-alternative forced choice task without the use of emotional labels. The improvement occurred in the ASD group but not in controls. Our findings are consistent with the literature that suggests that abnormalities in sensory processing may in part account for impaired processing of faces (Behrmann et al., 2006; Greimel et al., 2014; Kliemann et al., 2010; Uljarevic & Hamilton, 2012). Furthermore, this pattern of performance speaks to previous research suggesting that atypical perceptual processing, of social and non-social information alike, may underpin differences in ASD face processing (Mottron et al., 2006a, 2006b).

Acknowledgements

This is to confirm that none of the above named authors have a conflict of interest to declare.

References

Albon, E., Adi, Y., & Hyde, C. (2008). *The effectiveness and cost-effectiveness of coloured filters for reading disability: A systematic review*. West Midlands Health Technology Assessment Collaboration, Department of Public Health and Epidemiology, University of Birmingham.

Allen P.M., Evans, B.J.W. and Wilkins, A.J. (2012) The uses of colour in optometric practice to ameliorate symptoms of visual stress.*Optometry in Practice* 13 (1) 1-8

Barkley, G. L., Tepley, N. & Ramadan, N.M. (1993). Central neurogenic mechanisms of migraine.*Neurology*,*43,* 21-5.

Baron-Cohen, S., & Cross, P. (1992). Reading the eyes: evidence for the role of perception in the development of a theory of mind. *Mind and Language*, *6*, 173–186.

Behrmann, M., Avidan, G., Leonard, G. L., Kimchi, R., Luna, B., Humphreys, K., & Minshew, N. (2006). Configural processing in autism and its relationship to face processing. *Neuropsychologia, 44*, 110-129.

Bertone, A., Mottron, L., Jelenic, P., & Faubert, J. (2005). Enhanced and diminished visuo-spatial information processing in autism depends on stimulus complexity. *Brain, 128*, 2430-2441.

Brosnan, M. J., Scott, F. J., Fox, S., & Pye, J. (2004). Gestalt processing in autism: Failure to process perceptual relationships and the implications for contextual understanding. *Journal of Child Psychology and Psychiatry, 45*(3), 459-469. Burack, J. A., Charman, T., Yirmiya, N., & Zelazo, P. (2001). The development of autism: Perspectives from theory and research. In Mottron, L., & Burack, J. A. *Enhanced perceptual functioning in the development of autism* (pp. 131-148). New Jersey, USA: Lawrence Erlbaum Associates Publishers.

Calvo, M. G., & Fernandez-Martin, A. (2013). Can the eyes reveal a person's emotions? Biasing role of the mouth expression. *Motivation and Emotion, 37*, 202-211.

Canitano, R. (2007). Epilepsy in autism spectrum disorders. *Eur Child Adolesc Psychiatry, 16*, 61-66.

Casanova, M. F. (2008). The minicolumnopathy of autism: A link between migraine and gastrointestinal symptoms. *Med Hypotheses, 70*, 73-80.

Chase, C., & Stein, J. (2003). Visual magnocellular deficits in dyslexia. *Brain*, *126*(9), e2-e2.

Chouinard, B. D., Zhou, C. I., Hrybouski, S., Kim, E. S., & Cummine, J. (2012). A functional neuroimaging case study of Meares-Irlen syndrome/visual stress (MISViS). *Brain Topogr, 25*, 293-307.

Conlon, E.G., Hine, T., Lovegrove, W.J., Chekaluk, E., Piatek, K., & Hayes-Williams, K. (1998). The influence of visual discomfort and pattern structure on attention in a visual search task. *Perception, 27,* 21–33.

Damjanovic, L., Roberson, D., Athanasopoulos, P., Kasai, C. & Dyson, M. (2010) Searching for happiness across cultures. *Journal of Cognition and Culture, 10*, 85-107.

Davis, G., & Plaisted-Grant, K. (2014). Low endogenous neural noise in autism. *Autism*, 1362361314552198.

Evans,B. J. W. (2001) Dyslexia and Vision. Whurr Publishers, London.

Evans, B. J. W., & Stevenson, S. J. (2008). The Pattern Glare Test: a review and determination of normative values. *Ophthalmic and Physiological Optics*, *28*(4), 295-309.

Evans, B. J. W., Patel, R., & Wilkins, A. J. (2002). Optometric function in visually sensitive migraine before and after treatment with tinted spectacles. *Ophthalmic and Physiological Optics*, *22*(2), 130-142.

Evans, B. J. W., Wilkins, A. J., Brown, J., Busby, A., Wingfield, A., Jeanes, R., & Bald, J. (1996). A preliminary investigation into the aetiology of Meares–Irlen syndrome. *Ophthalmic and Physiological Optics*, *16*(4), 286-296.

Fernandez, D. and Wilkins A.J. (2008). Uncomfortable images in art and nature. *Perception*, 37(7), 1098-1113.

Facoetti, A., Trussardi, A. N., Ruffino, M., Lorusso, M. L., Cattaneo, C., Galli, R., ... & Zorzi, M. (2010). Multisensory spatial attention deficits are predictive of phonological decoding skills in developmental dyslexia. *Journal of cognitive neuroscience*, *22*, 1011-1025.

Fletcher R (1998), 3rd Edition, *City Color Vision Test* (Keeler, Windsor, Berks, United Kingdom).

Franklin, A., Sowden, P., Burley, R., Notman, L., & Alder, E. (2008). Color perception in children with autism. *J Autism Dev Disord, 38*, 1837-1847.

Galuschka, K., Ise, E., Krick, K., & Schulte-Körne, G. (2014). Effectiveness of treatment approaches for children and adolescents with reading disabilities: A meta-analysis of randomized controlled trials. *PloS one*, *9*(2), e89900.

Greenaway, R., Davis, G., & Plaisted-Grant, K. (2013). Marked selective impairment in autism on an index of magnocellular function. *Neuropsychologia*, *51*(4), 592-600.

Greimel, E., Schulte-Rüther, M., Kamp-Becker, I., Remschmidt, H., Herpertz-Dahlmann, B., & Konrad, K. (2014). Impairment in face processing in autism spectrum disorder: a developmental perspective. *Journal of Neural Transmission*, 1-11.

Harms, M. B., Martin, A., & Wallace, G. L. (2010). Facial emotion recognition in autism spectrum disorders: a review of behavioral and neuroimaging studies. *Neuropsychology Review, 20*, 290-322.

Haigh, S.M., Barningham, L., Berntsen, M,, Coutts, L.V., Hobbs, E.S.T., Irabor, J.,Lever, E.M., Tang, P., Wilkins A.J. (2013). Discomfort and the cortical haemodynamic response to coloured gratings. *Vision Research* **89**, 47-53.

Harms, M. B., Martin, A., & Wallace, G. L. (2010). Facial emotion recognition in autism spectrum disorders: a review of behavioral and neuroimaging studies. *Neuropsychol Rev, 20*, 290-322.

Heaton, P., Ludlow, A. & Roberson, D. (2008) When less is more: poor discrimination but good color memory in Autism. *Research in Autism Spectrum Disorders, 2*, 147-156.

Henderson, L. M., Taylor, R. H., Barrett, B., & Griffiths, P. G. (2014). Treating reading difficulties with colour. *British medical journal*, *349*, g5160.

Hernandez, N., Metzger, A., Magne, R., Bonnet-Brilhault, F., Roux, S., Barthelemy, C., & Martineau, J. (2009). Exploration of core features of a human face by healthy and autistic adults analyzed by visual scanning. *Neuropsychologia, 47*, 1004-1012.

Hirstein, W., Iversen, P., & Ramachandran, V. S. (2001). Autonomic responses of autistic children to people and objects. *Proceedings:Biological Sciences/The Royal Society, 268*(1479),1883–1888.

Hobson, R. P., Ouston, J., & Lee, A. (1988). What's in a face? The case of autism. *Br J Psychol, 79*, 441-453.

Huang, J., Cooper, T. G., Satana, B., Kaufman, D. I., & Cao, Y. (2003). Visual distortion provoked by a stimulus in migraine associated with hyperneuronal activity. *Headache, 43*, 664-671.

Hunt, R. W. G., Pointer, M. R., & Pointer, M. (2011). *Measuring colour*. John Wiley & Sons.Ishihara, S. (1972). *The series of plates designed as a test for color-blindess 38 plates edition*. Tokyo: Kanehara Shuppan Co ; London : H. K. Lewis & Co.

Ishihara, S. (1972). *The series of plates designed as a test for colour-blindess 38 plates edition*. Tokyo: Kanehara Shuppan Co ; London : H. K. Lewis & Co.

Jeanes, R. Busby, A., Martin, J., Lewis, E. Stevenson, N., Pointon, D., & Wilkins, A. J. (1997). Prolonged use of colored overlays for classroom reading. B*ritish Journal of Psychology,* 88, 531-548.

Jones, W., Carr, K., & Klin, A. (2008). Absence of preferential looking to the eyes of approaching adults predicts level of social disability in 2-year-old toddlers with autism spectrum disorder. *Arch Gen Psychiatry, 65*, 946-954.

Juricevic, I, Land, L, Wilkins, A.J. and Webster, M.A. (2010). Visual discomfort and natural image statistics. *Perception*, 39(7), 884-899.

Kliemann, D., Dziobek, I., Hatri, A., Steimke, R., & Heekeren, H. R. (2010). Atypical reflexive gaze patterns on emotional faces in autism spectrum disorders. *J Neurosci, 30*, 12281-12287.

Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Defining and quantifying the social phenotype in autism. *Am J Psychiatry, 159*, 895-908.

Klin, A., Sparrow, S. S., de Bildt, A., Cicchetti, D. V., Cohen, D. J., & Volkmar, F. R. (1999). A normed study of face recognition in autism and related disorders. *J Autism Dev Disord, 29*, 499-508.

Kylliäinen, A., & Hietanen, J. K. (2006). Skin conductance responses to another person's gaze in children with autism. *Journal of autism and developmental disorders*, *36*(4), 517-525.

Langdell, T. (1978). Recognition of faces: an approach to the study of autism. *J Child Psychol Psychiatry, 19*, 255-268.

Leekam, S. R., Lopez, B., & Moore, C. (2000). Attention and joint attention in preschool children with autism. *Dev Psychol, 36*, 261-273.

Leonard, H. C., Annaz, D., Karmiloff-Smith, A., & Johnson, M. H. (2011). Developing spatial frequency biases for face recognition in autism and Williams syndrome. *J Autism Dev Disord, 41,* 968-973.

Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Jr., Leventhal, B. L., DiLavore, P. C., . . . Rutter, M. (2000). The autism diagnostic observation schedule-generic: a standard measure of social and communication deficits associated with the spectrum of autism. *J Autism Dev Disord, 30*, 205-223.

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism Diagnostic Interview-Revised: a revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *J Autism Dev Disord, 24*(5), 659-685.

Ludlow, A. K., Taylor-Whiffen, E., & Wilkins, A. J. (2012). Colored filters enhance the visual perception of social cues in children with autism spectrum disorders. *ISRN Neurol, 2012*, 298098.

Ludlow, A. K., & Wilkins, A. J. (2009). Case report: color as a therapeutic intervention. *J Autism Dev Disord, 39*, 815-818.

Ludlow, A. K., Wilkins, A. J., & Heaton, P. (2006). The effect of colored overlays on reading ability in children with autism. *J Autism Dev Disord, 36*, 507-516.

Ludlow, A. K., Wilkins, A. J., & Heaton, P. (2008). Colored overlays enhance visual perceptual performance in children with autism spectrum disorders. *Research in Autism Spectrum Disorders, 2*, 498-515.

Maguire, R., (2014). I Dream In Autism. Buckinghamshire, UK: A PENN PR 2014,

Monger, L., Wilkins, A., & Allen, P., (in press). Identifying visual stress during a routine eye examination. Journal of Optometry.

Mottron, L., Dawson, M., Soulieres, I., Hubert, B., & Burack, J. (2006a). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders, 36*, 27-43.

Mottron, L. A, Arguin, M., Berthiaume, C., Jemel, B., & Saumier, D. (2006b). Face perception in high-functioning autistic adults: Evidence for superior processing of face parts, not for a configural face-processing deficit. *Neuropsychology, 20*, 30-41.

Mottron, L., Mineau, S., Martel, G., Bernier, C. S. C., Berthiaume, C., Dawson, M., ... & Faubert, J. (2007). Lateral glances toward moving stimuli among young children with autism: Early regulation of locally oriented perception?. *Development and psychopathology*, *19*(01), 23-36.

Neumann, D., Spezio, M. L., Piven, J., & Adolphs, R. (2006). Looking you in the mouth: abnormal gaze in autism resulting from impaired top-down modulation of visual attention. *Soc Cogn Affect Neurosci, 1*, 194-202.

Osterling, J., & Dawson, G. (1994). Early recognition of children with autism: a study of first birthday home videotapes. *J Autism Dev Disord, 24*, 247-257.

Philip, R. C., Whalley, H. C., Stanfield, A. C., Sprengelmeyer, R., Santos, I. M., Young, A. W., . . . Hall, J. (2010). Deficits in facial, body movement and vocal emotional processing in autism spectrum disorders. *Psychol Med, 40*, 1919-1929.

Roberson, D., Damjanovic, L. & Kikutani, M. (2010) Show and tell: The role of language in categorizing facial expressions of emotion. *Emotion Review, 2*, 255-260.

Roberson, D. & Davidoff, J. (2000) The categorical perception of colours and facial expressions: The effect of verbal interference. *Memory & Cognition, 28*, 977-986.

Roberson, D., Davidoff, J. & Braisby, N. (1999) Similarity and categorisation: Neuropsychological evidence for a dissociation in explicit categorisation tasks. *Cognition 71*, 1-42.

Roberson, D., Kikutani, M., Döge, P, Whitaker, L. & Majid, A. (2012) Shades of emotion: What the addition of sunglasses or masks to faces reveals about the development of facial expression processing. *Cognition, 125*, 195-206.

Rubenstein, J. L. R., & Merzenich, M. M. (2003). Model of autism: increased ratio of excitation/inhibition in key neural systems. *Genes, Brain and Behavior*, *2*(5), 255-267.

Ruffino, M., Gori, S., Franceschini, S., & Facoetti, A. (2010). Developmental dyslexia: Perceptual noise exclusion deficit or spatial attention dysfunction? *Perception,* 39, 80).

Rump, K. M., Giovannelli, J. L., Minshew, N. J., & Strauss, M. S. (2009). The development of emotion recognition in individuals with autism. *Child development*, *80*, 1434-1447.

Rutherford, M. D., & McIntosh, D. I. (2007). Rules versus prototype matching: Strategies of perception of emotional facial expressions in the autism spectrum. *Journal of Autism and Developmental Disorders*, 37, 187–196.

Rutherford, M. D., & Towns, A. M. (2008). Scan path differences and similarities during emotion perception in those with and without autism spectrum disorders. *Journal of Autism and Developmental Disorders, 38*, 1371-1381.

Robinson, G. L., & Whiting, P. R., (2003). The interpretation of emotion from facial expression for children with visual processing problems. *Australian Journal of Special Needs Education,27*, 50–67.

Sanchez-Marin, F. J., & Padilla-Medina, J. A. (2008). A psychophysical test of the visual pathway of children with autism. *J Autism Dev Disord, 38*, 1270-1277.

Senju, A. (2007). Atypical development of gaze processing in autism: An approach from developmental cognitive neuroscience. Japanese Psychological Review, 50(1), 13–30.

Simmons, D. R., Robertson, A. E., McKay, L. S., Toal, E., McAleer, P., & Pollick, F. E. (2009). Vision in autism spectrum disorders. *Vision Res, 49*, 2705-2739.

Simmons, D. R., McKay, L., McAleer, P., Toal, E., Robertson, A., & Pollick, F. E. (2007). Neural noise and autism spectrum disorders. Perception, 36. ECVP abstract supplement.

Smith, M. L., Cottrell, G. W., Gosselin, F., & Schyns, P. G. (2005). Transmitting and decoding facial expressions. *Psychological Science, 16*, 184-189.

Spencer, J. V., & O'Brien, J. M. (2006). Visual form-processing deficits in autism. *Perception, 35*(8), 1047-1055.

Sperling, A. J., Lu, Z. L., Manis, F. R., & Seidenberg, M. S. (2005). Deficits in perceptual noise exclusion in developmental dyslexia. *Nature neuroscience*,*8*(7), 862-863.

Stagg, S. D., Davis, R., & Heaton, P. (2013). Associations Between Language Development and Skin Conductance Responses to Faces and Eye Gaze in Children with Autism Spectrum Disorder. *Journal of autism and developmental disorders*, *43*(10), 2303-2311.

Stagg, S. D., Linnell, K. J., & Heaton, P. (2014). Investigating eye movement patterns, language, and social ability in children with autism spectrum disorder. *Development and psychopathology*, *26*(02), 529-537.

Stein, J. (2003). Visual motion sensitivity and reading. *Neuropsychologia*, 41, 1785-1793.

Stein, J., & Kapoula, Z. (2012). *Visual aspects of dyslexia*. Oxford: Oxford University Press.

Stevenson, R. A., Siemann, J. K., Schneider, B. C., Eberly, H. E., Woynaroski, T. G., Camarata, S. M., Wallace, M. T. (2014). Multisensory temporal integration in autism spectrum disorders. *The Journal of Neuroscience*, *34*(3), 691-697.

Stoodley, C. J., Harrison, E. P. D., & Stein, J. F. (2006). Implicit motor learning deficits in dyslexic adults. *Neuropsychologia*, *44*, 795-798.

Tuchman, R., & Cuccaro, M. (2011). Epilepsy and autism: neurodevelopmental perspective. *Curr Neurol Neurosci Rep, 11,* 428-434.

Uccula, A., Enna, M., & Mulatti, C. (2014). Colors, colored overlays, and reading skills. Frontiers in Psychology, 5, 833.

Uljarevic, M., & Hamilton, A. (2012). Recognition of Emotions in Autism: A Formal Meta-Analysis. *J Autism Dev Disord*, *43*, 1517-26

Vlamings, P. H., Goffaux, V., & Kemner, C. (2009). Is the early modulation of brain activity by fearful facial expressions primarily mediated by coarse low spatial frequency information? *J Vis, 9*(5), 12 11-13.

Wechsler, D. (1999). The Wechsler Abbreviated Scale of Intelligence – UK. San Antonio, TX: The Psychological Corporation.

Whiting, P., & Robinson, G. (2001). The interpretation of emotion from facial expressions for children with a visual sub-type of dyslexia. *Australian Journal of Learning Disabilities*, 6, 6–14,

Whittle, P. (1992). Brightness, discriminability and the "crispening effect". *Vision research*, *32*(8), 1493-1507.

Wilkins, A. J. (2003). *Reading through color : how colored filters can reduce reading difficulty, eye strain, and headaches*. Chichester: Wiley.

Wilkins, A.J. (2012). Origins of visual stress. In J. Stein and Z. Kapoula (ed.) *Visual aspects of dyslexia*. Oxford University Press: Oxford. pp 63-78.

Wilkins, A.J. (1995). *Visual Stress*. Oxford: Oxford University Press.

Wilkins, A.J. (1992) Possibilities for migraine therapy using coloured glasses? In Proceedings of the Anglo Dutch Migraine meeting, (ed. T.J. Steiner) Canterbury.

Wilkins A.J. and Hibbard P.B. (2014). Discomfort and hypermetabolism. Proceedings of the 50th Anniversary Convention of the AISB,1st 4th April 2014, Goldsmiths, University of London.Wilkins, A. J., Jeanes, R. J., Pumfrey, P. D., & Laskier, M. (1996). Rate of Reading Test: its reliability, and its validity in the assessment of the effects of colored overlays. *Ophthalmic Physiol Opt, 16*(6), 491-497.

Wilkins, A. J., Lewis, E., Smith, F. & Rowland, E. (2001). Colored overlays and their benefit for reading. *Journal of Research in Reading, 24,* 41-64.

Wilkins, A.J. and Neary, C. (1991) Some visual, optometric and perceptual effects of coloured glasses. Ophthalmic and Physiological Optics, 11, 163-171.

Wilkins, A. J., & Nimmo-Smith, M. I. (1987). The clarity and comfort of printed text. *Ergonomics, 30*, 1705-1720.

Wilkins, A. J., & Nimmo-Smith, I. (1984). On the reduction of eye-strain when reading. *Ophthalmic Physiol Opt, 4*, 53-59.

Williams, D. (1999). *Like color to the blind : soul searching and soul finding*. London: Jessica Kingsley.

Wilmer, J. B., Richardson, A. J., Chen, Y., & Stein, J. F. (2004). Two visual motion processing deficits in developmental dyslexia associated with different reading skills deficits. Journal of Cognitive Neuroscience, 16, 528-540.

Yi, L., Feng, C., Quinn, P. C., Ding, H., Li, J., Liu, Y., & Lee, K. (2014). Do Individuals with and without Autism Spectrum Disorder Scan Faces Differently? A New Multi-Method Look at an Existing Controversy. *Autism Research*, *7*(1), 72-83.

Footnotes

[1] Although participants may automatically access category labels even without specific instruction (see e.g. Roberson, et al., 1999; Roberson, et al., 2010; Roberson et al., 2012).

Table 1: Mean (standard deviation in brackets) chronological age, verbal IQ (VIQ), performance IQ (PIQ), full-scale IQ (FSIQ) of all participants, and Autistic Diagnostic Observation Schedule scores for participants with ASD. IQ was assessed using the Weschler Abbreviated Scale of Intelligence (WASI) and are reported as standard scores

	Age (years; months)	VIQ	PIQ	FSIQ	Autistic Diagnostic Observation Schedule		
					Communication	Social	Restrictive and Repetitive behaviours
ASD (n=16)	11;6 (2.74)	87.50 (17.01)	90.75 (14.26)	87.93 (16.39)	3.38 (1.67)	8.69 (2.39)	1.50 (1.03)
TD (n=16)	11;3 (2.38)	92.06 (12.32)	86.44 (13.78)	89.19 (12.49)	N/A	N/A	N/A

Figures caption sheet

Figure 1. CIE Uniform chromaticity scale diagram showing the chromaticities of the tints. The chromaticities used in the tint selection task are shown by the inner ends of the lines. The outer ends show the chromaticities used in the emotion discrimination task. The lines connect similar hues. Verbal descriptions of the colors represented by the diagram are shown for reference. (For a description of u' and v' see Hunt & Pointer, 2011).

Figure 2. Emotional intensity discrimination task: Example of male stimuli expressing surprise at 60% vs. 80% (first pair) and 80% vs. 100% (second pair) in the gray tint condition.

Figure 3. Average rate of reading (words per minute) for the ASD and TD groups

Figure 4. Proportion of correct face discriminations for the ASD and TD groups, averaged for all emotions.

Figure 5. Improvements in performance with a tint in the WRRT as a function of the improvements in performance with a tint in the emotional intensity discrimination task for the ASD group.

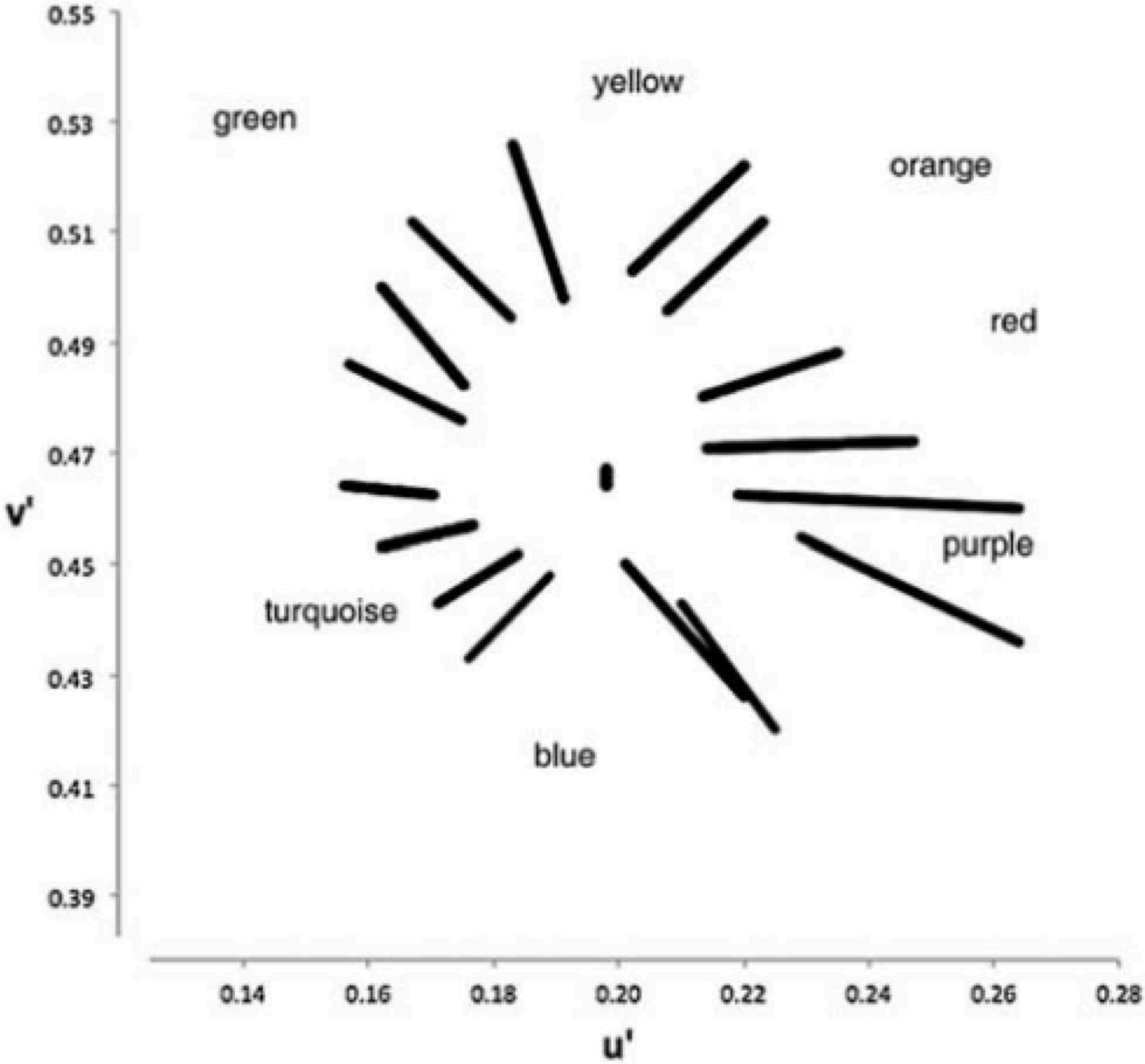

Figure 1. CIE Uniform chromaticity scale diagram showing the chromaticities of the tints. The chromaticities used in the tint selection task are shown by the inner ends of the lines. The outer ends show the chromaticities used in the emotion discrimination task. The lines connect similar hues. Verbal descriptions of the colors represented by the diagram are shown for reference. (For a description of u′ and v′ see Hunt, Pointer, & Pointer, 2011).

Figure 2. Emotional intensity discrimination task: example of male stimuli expressing surprise at 60% vs. 80% (first pair) and 80% vs. 100% (second pair) in the gray tint condition [Montagne et al., 2006].

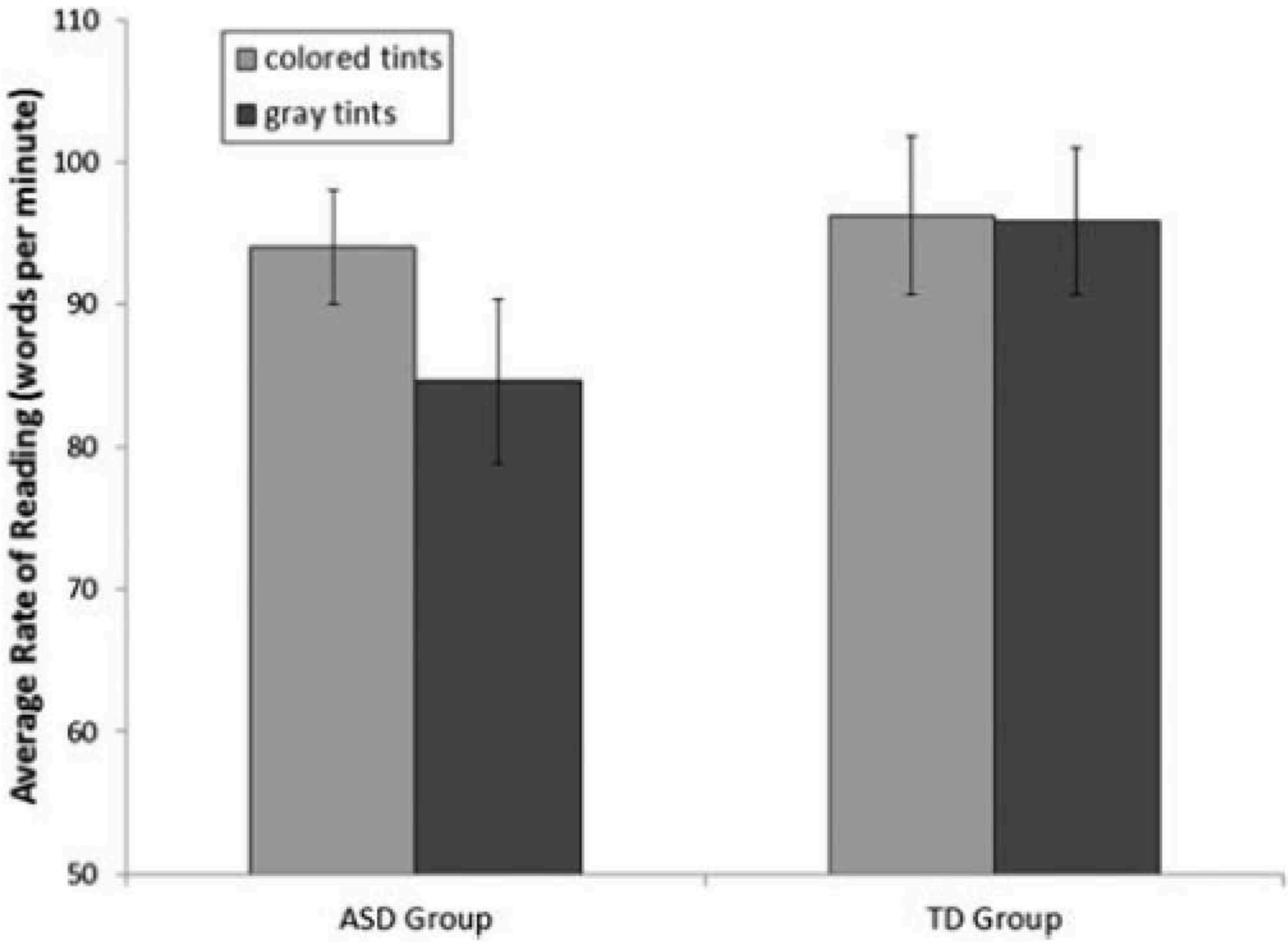

Figure 3. Average rate of reading (words per minute) for the ASD and TD groups

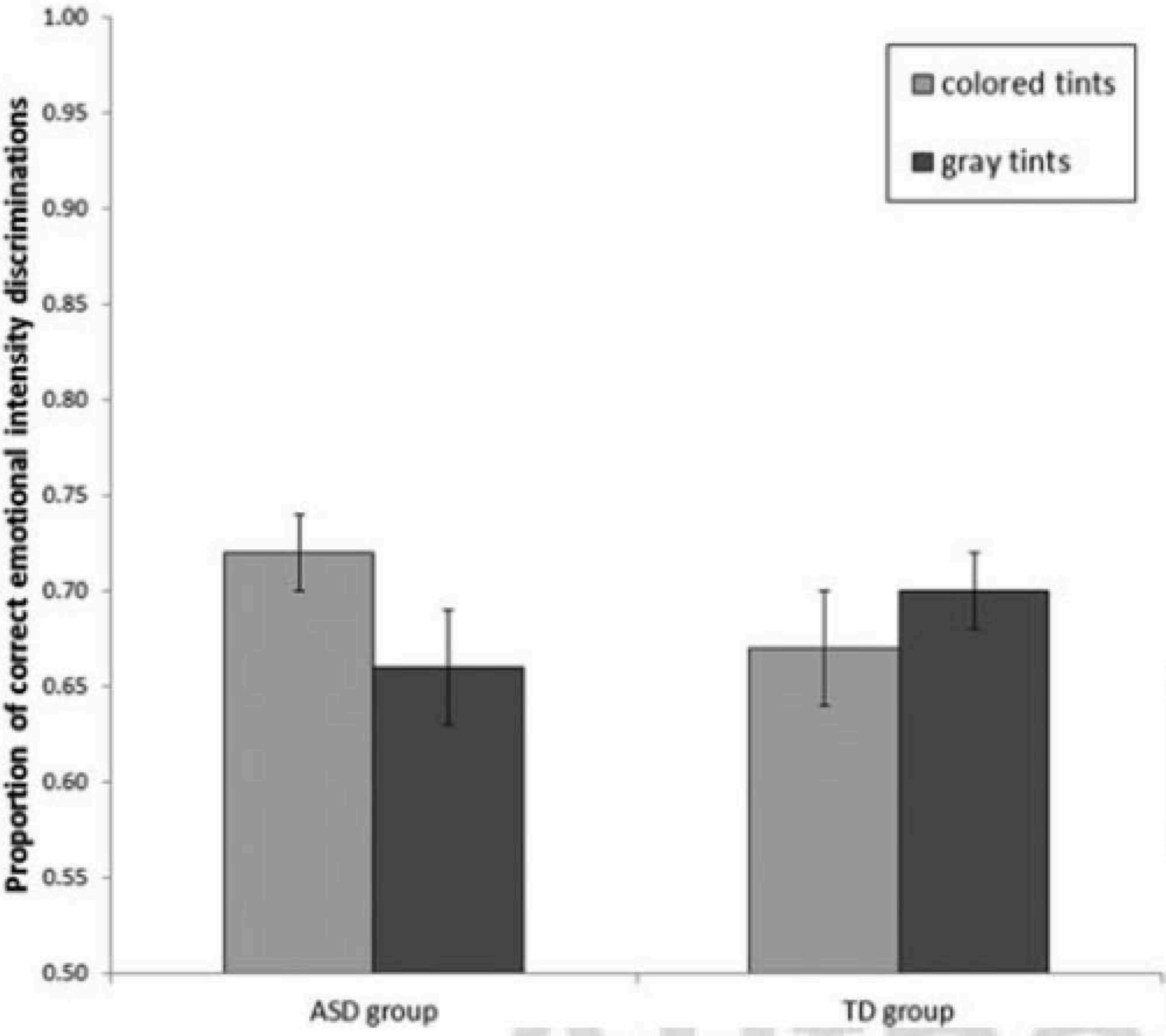

Figure 4. Proportion of correct face discriminations for the ASD and TD groups, averaged for all emotions.

Author

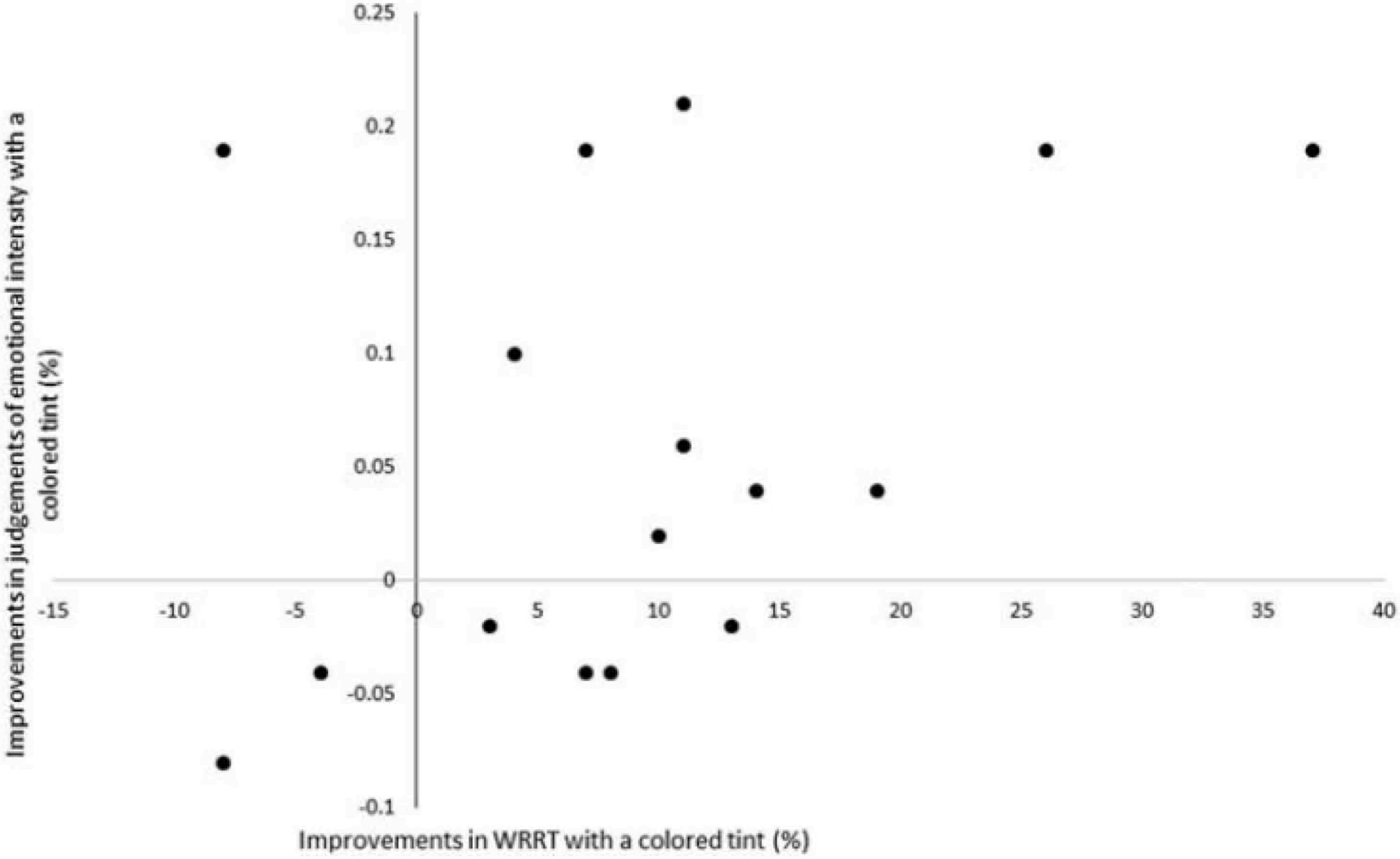

Figure 5. Improvements in performance with a tint in the WRRT as a function of the improvements in performance with a tint in the emotional intensity discrimination task for the ASD group.