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Can children with Autism read emotions from the eyes?

The Eyes Test revisited.

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Abstract

This study aimed to test two new, simplified tasks related to the eye-test, targeting children with Autism Spectrum Disorder (ASD) and typically developing controls (TD). Test-1 assessed the recognition of emotion/mental states with displays using one word and two eye-pictures, whereas Test-2 presented displays using two words and one eye-picture. Black and white photographs of children were used as materials. A cross-cultural study (Caucasian/East-Asian) with adults was initially carried out to verify generalizability across different ethnic groups. Cross-sectional trajectory analyses were used to compare emotion recognition from the eyes in the two tests. Trajectories were constructed linking performance on both tests either to chronological age or to different measures of mental age (receptive vocabulary based on the BPVS, CARS or ASQ for the ASD group). Performance improved with chronological age in both the ASD and TD groups of children. However, performance in Test-1 was significantly superior in children with ASD, who showed delayed onset and slower rate of improvement than TD children in Test-2. In both the ASD and TD groups the lowest error rate was recorded for the item '*anger*', suggesting that threat-detection cue mechanisms may be intact in Autism. In general, all children showed good performance on our novel tests, thus making them good candidates for assessing younger children and those with lower general abilities.

Keywords:

ASD, emotion recognition, eye-test, developmental disorders, Theory of Mind (ToM)

"*Her complexion varied with every emotion of her soul, and* ***her eyes****, the heralds of her speech, now beamed with understanding and now glistened with sensibility*"

(Mullan, THE 7 June 2012 - Cecilia character in Fanny Burney's novels, 1782)

1. INTRODUCTION

Since the work of Premack and Woodruff (1979), research on "mind-reading" abilities has expanded into numerous areas of neuroscience and psychology. Mind-reading refers here to the propensity to conceptualize and predict the behavior of others in terms of motivational states, thoughts and beliefs, e.g., "the little girl is skipping down the road because she *thinks* the ice-cream van is there and she *wants* an ice-cream". Development of such abilities emphasizes the separability of mind-reading skills from other cognitive factors (Leslie, 1987). Some evidence comes from studies of high-functioning individuals with autism who failed simple false-belief tasks (Baron-Cohen, Leslie & Frith, 1985; Baron-Cohen, Tager-Flusberg & Cohen, 1993; Kaland, Callesen, Møller-Nielsen, Lykke Mortensen & Smith, 2008), while passing logically-equivalent tasks not involving the thoughts/mental states of another (Charman & Baron-Cohen, 1992). Subsequent research has acknowledged that many individuals with autism, and those with other conditions such as traumatic brain injury (Apperly, Samson, Chaivarino, Bickerton & Humphrey, 2007; Happe, Malhi & Checkley, 2001), schizophrenia (Lee, Farrow, Spence & Woodruff, 2004), sometimes focal epilepsy (Farrant, Morris, Russell, Elwes, Akanuma, Alarcon & Koutroumanidis, 2005), appear to be impaired on mind-reading abilities, albeit not completely lacking the capacity to interpret the behavior of others with respect to desires and beliefs.

Despite the complexity of mind-reading behavior, in terms of interpreting subtle non-verbal cues and integrating contextual information, finding a way of assessing such abilities to yield consistent findings in both clinical and non-clinical populations has remained surprisingly elusive (Apperly & Butterfill, 2009). While recent work has gone some way to address this gap with a revised “reading the mind in films” task for adults and children (Golan et al., 2006), as well as the earlier revised child “Emotion in the Eyes task”, no study has yet charted the developmental trajectory of this ability using a child-friendly task in both young children with ASD and typically developing children (TD).

The present study thus aims to fill this gap by providing a novel and simpler emotion-in-the-eyes-reading task suitable for very young children and for those with limited vocabulary.

ASD is a common neurodevelopmental syndrome with a strong genetic basis (Abrahams & Geschwind, 2008), characterised by two core components: social interaction/communication impairments and stereotypic behaviours. However, there are marked differences in the extent and quality of the symptoms found in individuals with ASD. However, one of the most common features of ASD is their striking difficulties with social skills such as understanding emotions and the mental states of others (Baron-Cohen, 1995).

Amongst the more salient impairments for ASD in the social communication arena is the failure to process information from the faces of others such as facial expression, eye gaze and facial recognition which play a significant role in social cognition (Hadjikhani, Joseph, Snyder, Chabris, Clark et al., 2004; Pellicano, Jeffery, Burr and Rhodes, 2007; Ramachandran, Mitchell & Ropar, 2010). A number of studies have reported that children with ASD show greater attention to the mouth rather than to the eye region (e.g., Annaz, Karmiloff-Smith, Johnson, & Thomas, 2009; Klin, Jones, Schultz, Volkmar, &Cohen, 2002; Riby, Doherty-Sneddon, & Bruce, 2009). Furthermore, compared to typical controls, individuals with ASD show reduced looking times to people, and to faces in particular, in both static and dynamic social scenes (e.g., Annaz, et al. 2010, 2012; Klin, et al., 2002; Riby

& Hancock, 2008). Several functional imaging studies report atypical or weak activation of the fusiform gyrus in ASD, an area that is activated during face recognition in typical individuals (Dalton et al., 2005; Schultz et al., 2000), perhaps related to atypical scanning pathways or reduced attention to the eyes (Dalton et al., 2005).

Individuals with ASD have also been shown to lack the ability to mentalize and gain social insight into the goals and intentions of other people's behaviours (Castelli, Frith, Happé, & Frith, 2002; Hamilton, 2009). Children with ASD experience difficulties with false-belief tasks, pretend play and representing other people's mental states (Hamilton, 2009) while they also show impaired empathizing skills on both cognitive (recognizing other people's mental states) and affective levels (emotion reaction deciphered from the person's mental states) (Baron-Cohen, Golan, & Ashwin, 2009). For instance, lower performance on the "Reading the Mind in the Eyes Test" (the Eyes Test henceforth) developed by Baron-Cohen et al. (1997) and later revised (Baron-Cohen, Wheelwright, Spong, Scahill & Lawson, 2001; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001) has been linked to theory of mind (ToM) or "mentalizing" deficits. This test is thought to reflect the ability of participants to demonstrate their "mentalizing" abilities, i.e., their understanding of another person's mental states such as their emotions, thoughts, desires, beliefs, goals and how they might influence their behaviour (Peterson, & Slaughter, 2009). Hence, the Eyes Test appeared to be tapping into a well-known deficit in ASD.

However, several limitations of the Eyes Test require attention. First, the test uses posed facial expression of emotions thereby lacking a genuine and naturalistic setting (Johnston, Miles & McKinlay, 2008). Second, initial validation of the task was based on the poorer scores obtained from high-functioning individuals with Autism or Asperger syndrome relative to matched controls (Baron-Cohen et al., 1997, Baron-Cohen et al., 2001), a result which has been generally replicated (Back, Ropar & Mitchell, 2007). However, it did not cover children with more severe expression of autistic traits. Third, it assumed quite a good level of literacy, advanced vocabulary, and reading skills, since it included low frequency words such as "incredulous" and "dispirited" (Peterson & Slaughter, 2009). A child version of the Eyes Test was subsequently devised by Baron-Cohen, Wheelwright, Scahill, Spong, and Lawson (2001), using somewhat simpler words. However, children were still shown four written words stimuli (one target word and three foils), resulting in a considerable cognitive load to retain in memory and calling on good literacy skills (the need to read, for example, words like "surprised", "joking", "sure about something" and "happy" - p.45). Peterson and Slaughter (2009) modified this test to a "simplified eye-reading" task (SERT) to make it suitable for children who have not yet learned to read yet, albeit conserving its ability to assess ToM through observing people's thoughts and feelings by looking at their eyes. Johnston et al. (2008) have also pointed out a number of methodological factors limiting the reliability of the Eyes Test, such as the posed *vs.* genuine emotion, quality of the images (orientation etc.), lack of control on the four words used in the test (target *vs.* foils). Finally, there is still a surprising lack of data examining children with lower functioning autism, although these individuals form around 70% of the total diagnosed with ASD (Baird, Simonoff, Pickles, Chandler, Loucas, Meldrum & Charman, 2006).

The materials developed for the Eyes Test of the present study were derived from naturalistic pictures of children (rather than adults) and included reduced cognitive demands by showing children only two eye-pictures with one word (Test-1) or one eye-picture with two words (Test-2). Since all our participants came from a cosmopolitan multi-ethnic environment, a cross-cultural study (Caucasian/East-Asian) with adults was initially carried out to verify generalizability across different ethnic groups.

The aim of the current study was twofold: [1] to investigate performance in children with ASD and TD controls on emotion recognition derived from the eye-region of a face; and [2] to compare the ASD and TD groups' performance trajectories on two different tasks (Test-1 and Test-2), with one task relying on language less than the other (Test-1). Based on results from previous research and our current test modifications, we predicted that primary emotions would be easier to distinguish than mental states and that children with more advanced languages skills (based on their BPVS scores) would show better performance on the tests, particularly with respect to Test-2 (one eye-picture, two words). Comparison of the two tests will also inform us as to whether the difficulty of the task for children with ASD is more likely due to their difficulty in processing facial emotions (particularly from the eye region – e.g., Klin et al., 2002) or to accessing emotionally-loaded linguistic information (e.g., Tager-Flusberg & Joseph, 2005).

2. METHOD

2.1 Generalisation of the experimental task

The materials were tested cross-culturally (Caucasian/East-Asian) in order to assess generalisation and level of difficulty of the test. As the data for the main study were collected in a multi-ethnic city, it was important to control for possible *same-race* biases, without increasing the number of items (e.g., representing various ethnicities) or confounding emotion and ethnicity in the materials for the developmental samples. One cross-cultural comparison was conducted. Forty university students (50% female), including 20 British participants (tested in London UK, from a similar multi-ethnic background as the child samples) and 20

Japanese participants (tested in Kyoto), took part. The test display included one picture of the eye-region and two words (one for the target emotion or mental state, one foil) against a dark background (see 2.3).

Displays contained black and white photos of Caucasian children's eye region, portraying either mental states or primary emotions. Care was taken to use facial displays that were upright and frontal (± 15^{o} from midline). Type of expression and valence were controlled across the stimuli, including four items in each category for primary emotions and mental states respectively, with two neutral/positive and two negative valence expressions in each category. The selection of expressions was chosen following a detailed review of the literature, which indicated young children's knowledge of terms referring to emotions or mental states (e.g., Astington & Jenkins, 1995, 1999; Jenkins & Astington, 1996, 2000). The expressions included as primary emotions were *happy* and *surprised* (positive/neutral valence), and *sad* and *angry* (negative valence), while *excited* and *thinking* (positive/neutral valence), and *worried* and *shy* (negative valence) were selected to represent mental states. Although in most cases it is unknown what the child was actually feeling at the time of taking the photographs, they were all derived from naturalistic settings (e.g., taken by parents) rather than being posed specifically for an experiment.

For the test, 56 slides were prepared with each of the eight above-described target emotion/mental states paired with each of the seven remaining emotion/mental states in the Caucasian series – see Appendix 1. The displays were randomized across participants and the positioning of words within the displays (aligned with left/right bottom edge of the picture) was counterbalanced to avoid spatial bias. In the cross-cultural preliminary study, the 56 Caucasian slides were used, with the addition of an equivalent set of 56 black and white photos of East-Asian children with the same characteristics and covering the same primary emotion/mental state x valence design, yielding a total of 112 displays. Target emotions/states were produced by different children in each ethnic group. Displays with the stimuli were presented as PowerPoint slides on a PC laptop with 15” screen, and accuracy scores were recorded.

Participants were tested individually and asked to indicate verbally which word would best describe the picture presented on each slide. They first had two practice trials in which the experimenter provided feedback on their accuracy. Since each target emotion/mental state was paired with each of the remaining emotion/mental state as foils (i.e., seven times – see Appendix 1), the accuracy score could range from 0 (never identified correctly) to 7 (always identified correctly) in each sub-set (Western vs. East-Asian). Testing lasted approximately 15 minutes.

A minimum 70% correct score was set for an individual stimulus to be included in the materials. In order to obtain generalization baselines, Positive/Neutral Primary Emotion, Negative Primary Emotion, Positive/Neutral Mental State, and Negative Mental State scores were computed by averaging scores from items of the same type (e.g., ‘happy’ and ‘excited’) - see Table 1. All accuracy scores generated for the above categories were ≥ .70 (5/7 items) for all categories, with most being ≥ .85 (6/7 items) for both Western and East-Asian groups[1]. Thus, the materials used in the newly developed tasks did not produce *the other race effect* which could have impacted on reliable identification of facial expressions investigated in this

[1] A 2 (cultures) x 2 (ethnicities) item analysis was performed for each individual item. The culture x ethnicity interaction was never significant, with $p > .05$ before correcting for multiple comparisons in all ANOVAs. The only exception was ‘thinking’, in which the interaction was $F(1,38)=7.46$, $p = .009$, due to slightly higher identification scores achieved for the ‘other’ race: Japanese > British participants on Caucasian eyes (6.8 and 6.05, respectively) but British > Japanese participants on East-Asian eyes (6.3 and 6.1, respectively). In sum, the only exception was in the opposite direction with respect to the ‘same race bias’ prediction.

study. In other words, these results do not support the hypothesis that a same-race bias (Kelly, Liu, Rodger, Miellet, Ge & Caldara, 2011; Vizioli, Rousselet & Caldara, 2010) may confound the results with our multi-ethnic developmental samples, using the same materials.

Table 1. Mean accuracy scores in a cross-cultural adult sample (London UK / Kyoto).

	Stimuli	Western-Caucasian				East-Asian			
	Experience	Primary Emotions		Mental States		Primary Emotions		Mental States	
Culture	**Valence**	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
British (N=20)	Mean Score	6.8	6.6	5.9	6.3	6.7	6.4	6.1	5.7
	SD	*0.3*	*0.5*	*0.7*	*0.7*	*0.5*	*0.5*	*0.7*	*0.1*
Japanese (N=20)	Mean Score	7	6.6	6.6	5.4	6.8	6.2	6.0	5.5
	SD	*0.0*	*0.3*	*0.7*	*0.8*	*0.3*	*0.5*	*0.7*	*0.8*

2.2 ASD group

Twenty-two children with ASD (20 males, 2 females), and 62 TD control children (28 males, 29 females) participated in the current study. The gender bias for the ASD group was characteristic of the disorder (Baird et al., 2006). Two of the participants with ASD were excluded due to their extremely high BPVS scores and CARS scores within the normal values (outliers), and five TD children were excluded from the data analysis due to experimental error. The final sample included 20 children with ASD and 57 TD children. Children in the TD group had no known developmental disorder or other medical conditions. Participant characteristics provided in Table 2. Both ASD and TD samples were multi-ethnic and attended publicly-funded schools across London, UK.

The age range and large group size of the TD children permitted comparisons to be made between disorder and TD trajectories, either on the basis of chronological age (CA) or on the basis of verbal mental age (MA), where the ASD group may have lower mental ages. Children in the ASD group met established criteria for ASD, such as those specified in the DSM-IV (American Psychiatric Association, 2000) and ADOS (Autism Diagnostic Observation Schedule) (Lord, Rutter, DiLavore, & Risi, 1999). Verbal mental age was assessed with the British Picture Vocabulary Scale (BPVS II) (Dunn et al., 1996). Children in the ASD group were also assessed on the Childhood Autism Rating Scale (CARS)(Schopler et al., 1993) and ASQ (Autism Screener Questionnaire) (Berument, Rutter, Lord, Pickles & Bailey, 1999), in order to provide additional screening. Table 2 provides group details, confirming that children with ASD in this sample scored above the cut-off for ASD.

Children in the ASD group were recruited from specialist schools for children with ASD, support groups for parents and after-school clubs for children with ASD. TD control children were recruited from nurseries, schools and play schemes. All individuals in both groups had normal or corrected-to-normal vision. None of the children had any co-morbid medical or psychiatric disorders, noted from the children’s records or, if missing, from oral interview with the parents. All the children had English as their first language.

The Psychology Ethics Committee at Middlesex University approved the experimental protocol prior to the recruitment of participants. Both parental informed consent and the child’s assent were obtained before participation.

Table 2. Sample characteristics for TD - typically developing children, and ASD – children with ASD.

Group (sample size)	*Statistic*	*CA (in years and months)*	*BPVS age equivalent score (verbal age)*	*CARS raw score*	*ASQ*
ASD	Mean	7:05	5:02	36,5	26.4
(n= 20)	Std	2:02	1:06	7	12.6
	Min	3:07	3:00	26.5	18
	Max	11:04	8:10	45.5	32
TD	Mean	4:06	5:06	--	--
(n=57)	Std	1:02	1:06	--	--
	Min	3:00	3:02	--	--
	Max	7:09	11:03	--	--

2.3 Design and Materials

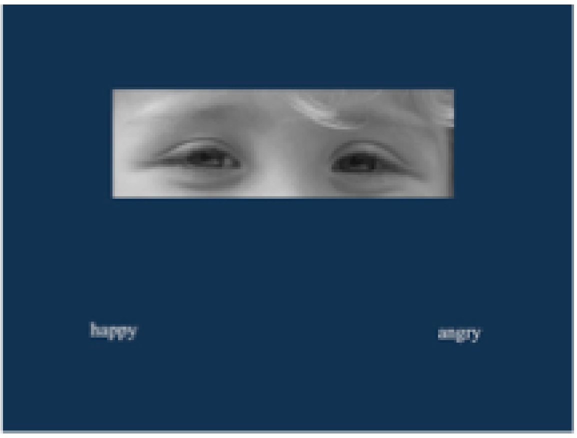
Two tasks were used: Test-1 included two photos of the eye-region with one word between them (one picture for the target emotion or mental state described by the word and one foil), against a dark background (Figure 1A). In Test-2, one picture with two words underneath was presented (one for the target emotion or mental state and one foil), also against a dark background (Figure 1B), as used in the validation study. Primary emotions were contrasted to mental states with either positive/neutral or negative valence.

For each test, 56 slides were prepared with each target emotion/mental state paired with each of the remaining emotion/mental states (see 2.1 and Appendix 1). Both Test-1 and Test-2 displays were randomized across participants. Positioning of pictures/words within the displays was fully counterbalanced, and every target primary emotion/mental state was paired with each of the seven remaining items. Accuracy scores ranged from 0 - never identified correctly, to 7 - always identified correctly.

Figure 1. Displays used for Test-1 (two eye-pictures / one word – 1A) and for Test-2 (one ye-picture / two words – 1B). Photos © F. Franco.

1A) Test-1 example

1B) Test-2 example



2.4 Apparatus

Slides with sets of stimuli for Tests 1 and 2 were presented on a PC laptop with a 15” screen via SuperLab software.

2.5 *Procedure*

Each child was individually tested in a quiet place. The experimenter was already familiar with all the children with ASD, and care was taken to allow for some familiarization time also with the TD participants. First, participants were administered the BPVS. There was a break of about five minutes between the completion of the BPVS and the start of Tests 1 or 2. All the children took part in both Tests 1 and 2, with the order of the test presentation being randomized across participants and allowing for a minimum gap of half an hour between the two testing sessions. Prior to the first experimental testing, each child was seated in front of the computer, at a comfortable distance (approximately 40 cm from the screen), and took part in a practice trial. For Test-1, participants were asked to look at the pictures of children (two displays, one with the target picture on top and one with the target picture at the bottom of the slide) and asked to indicate which one best matched the word presented along with the pictures (e.g., "*Look, there is a sad child here. Can you tell me which one is the sad child*?"). A similar procedure was applied for Test 2: two displays were used for practice, one with target word on the left and the other with target word on the right edge of the slide. Participants were asked to indicate which word best described the picture presented (e.g., "*Look at this child – is this child happy or sad?").* In both tests, children were given feedback on accuracy during the practice trials.

The experimenter coded children's choices by key-press, specifying the left/right word or top/bottom picture in each slide; these responses were subsequently transformed into correct/incorrect matches with respect to the target emotion/mental state. For each test, the testing session took approximately 10 minutes. Children were monitored for tiredness, and were provided with stickers as rewards during the breaks. For some children, it was necessary to have a short extra break due to a decrease in attention.

3. RESULTS

3.1 Background measures

There was no difference between the groups on the BPVS raw scores; $F(2,2.47) = 29.6$, $p = 0.144$[2]. Due to the exploratory nature of the test and flexible use of multiple comparisons to the TD data-points, the developmental trajectories method was employed. A fully factorial ANCOVA was used with MA (based on verbal BPVS scores) and CA as the covariates and task transformation (two words / one picture or one word / two pictures) as within-participant factors (see Thomas, Annaz, Ansari, Scerif, Jarrold, & Karmiloff-Smith, 2009, for more details of the developmental trajectory method). Test performance was analysed for each group separately, and then the ASD group was compared to the TD group, by adding a between-participant factor of group to the design. In addition, we performed two planned comparisons. These were: (i) to assess each group's performance on individual emotion/mental types (Test 1 and Test 2 respectively), (ii) to compare performance on Test-1 and Test-2 for each group, and (iii) compare error types for each group. The overall results are displayed in Table 3 (expressed as percentage performance correct for ease of comprehension).

[2] Welsh ANOVA was used since the homogeneity of variances assumption was violated.

Table 3. Performance accuracy scores (% correct, *SD*) in the developmental samples.

Test	TEST 1 (two photos, one word)				TEST 2 (one photo, two words)			
	Primary Emotions		Mental States		Primary Emotions		Mental States	
Group	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
TD	87	91	82	84	88	90	84	81
	13	*10*	*15*	*17*	*14*	*13*	*18*	*17*
ASD	84	91	76	77	80	86	76	77
	22	*11*	*14*	*15*	*17*	*13*	*11*	*13*

3.2 TEST 1 (TWO PICTURES AND ONE WORD)

3.2.1 TD group

Performance scores improved reliably with mental ages using BPVS scores: *happy/surprised* ($F(1,55) = 11.28$, $p < .001$, $\eta_p^2 = .17$); *sad/angry* ($F(1,55) = 9.40$, $p = .003$, $\eta_p^2 = .14$), and mental states: *excited/thinking* ($F(1,55) = 10.4$, $p = .002$, $\eta_p^2 = .16$), *worried/shy* ($F(1,55) = 17.30$, $p < .001$, $\eta_p^2 = .24$). Similar performance was observed when performance scores were linked to CA on primary emotions: *happy/surprised* ($F(1,55) = 19.3$, $p < .001$, $\eta_p^2 = .26$); *sad/angry* ($F(1,55) = 19.6$, $p < .001$, $\eta_p^2 = .26$) and mental states: *excited/thinking* ($F(1,55) = 18.1$, $p < .001$, $\eta_p^2 = .25$), *worried/shy* ($F(1,55) = 21.2$, $p < .001$, $\eta_p^2 = .28$).

3.2.2. ASD group

Performance scores on the test plotted against the BPVS scores did not improve on *happy/surprised* trials ($F(1,18) = 1.5$, $p = .23$, $\eta_p^2 = .10$) and mental states: *excited/thinking* ($F(1,18) = .38$, $p = .54$, $\eta_p^2 = .10$), *worried/shy* ($F(1,18) = .95$, $p = .34$, $\eta_p^2 = .10$). The only improvement in performance was seen on *sad/angry* trials ($F(1,18) = 6.4$, $p = .02$, $\eta_p^2 = .26$).

In contrast, performance scores improved reliably with CA on all primary emotions: *happy*/*surprised* trials ($F(1,18) = 6.9$, $p = .017$, $\eta_p^2 = .30$), *sad*/*angry* trials ($F(1,18) = 16.7$, $p = .001$, $\eta_p^2 = .48$), and mental states: *excited*/*thinking* ($F(1,18) = 7.7$, $p = .012$, $\eta_p^2 = .30$) and *worried*/*shy* ($F(1,18) = 6.3$, $p = .022$, $\eta_p^2 = .26$). Lastly, performance scores plotted against the CARS and ASQ also did not serve as better predictors of performance than CA.

3.2.3 Comparison of ASD to TD group

Children in the ASD group showed a delayed onset and slower rate of improvement with CA on: *happy*/*surprised* (group: $F(1,77) = 6.2$, $p = .015$, $\eta_p^2 = .10$; group x age: $F(1,77) = 9.2$, $p = .003$, $\eta_p^2 = .11$) and *worried*/*shy* (group: $F(1,77) = 4.8$, $p = .032$, $\eta_p^2 = .10$; group x age: $F(1,77) = 6.2$, $p = .015$, $\eta_p^2 = .10$). However, this was not the case for *sad*/*angry* (group: $F(1,77) = 1.3$, $p = .26$, $\eta_p^2 = .024$, group x age: $F(1,77) = 1.3$, $p = .257$, $\eta_p^2 = .10$), and *excited*/*thinking* (group: $F(1,77) = 1.3$, $p = .26$, $\eta_p^2 = .02$; group x age: $F(1,77) = 1.0$, $p = .317$, $\eta_p^2 = .10$) where the ASD group showed a similar onset and rate of performance increase on the tasks as the TD group.

3.3 TEST 2 (ONE PICTURE AND TWO WORDS)

3.3.1. TD group

In TD children, performance scores improved reliably with mental age (based on BPVS scores) on all primary emotions: *happy*/*surprised* ($F(1,55) = 25.8$, $p < .001$, $\eta_p^2 = .32$); *sad*/*angry* ($F(1,55) = 11.3$, $p < .004$, $\eta_p^2 = .17$), and mental states: *excited*/*thinking* ($F(1,55) = 10.4$, $p = .002$, $\eta_p^2 = .16$), *worried*/*shy* ($F(1,55) = 18.9$, $p < .001$, $\eta_p^2 = .26$). Similar performance was achieved when examining performance scores with CA: *happy*/*surprised* ($F(1,55) = 26.6$, $p < .001$, $\eta_p^2 = .33$); *sad*/*angry* ($F(1,55) = 9.1$, $p < .004$, $\eta_p^2 = .14$), and mental states: *excited/thinking* ($F(1,55) = 12.1$, $p < .001$, $\eta_p^2 = .18$), *worried/shy* ($F(1,55) = 13.1$, $p < .001$, $\eta_p^2 = .19$).

3.3.2. <u>ASD group</u>

Performance scores of the ASD group improved reliably with CA only on *excited/thinking* trials ($F(1,18) = 7.7$, $p = .013$, $\eta_p^2 = .30$). Also when accuracy scores were linked to MA (based on BPVS scores), CARS and ASQ respectively to ascertain whether these would serve to normalise the disorder trajectories, none of them turned out to be significant (all $p > .1$).

3.3.3. <u>Comparison of TD vs. ASD performance</u>

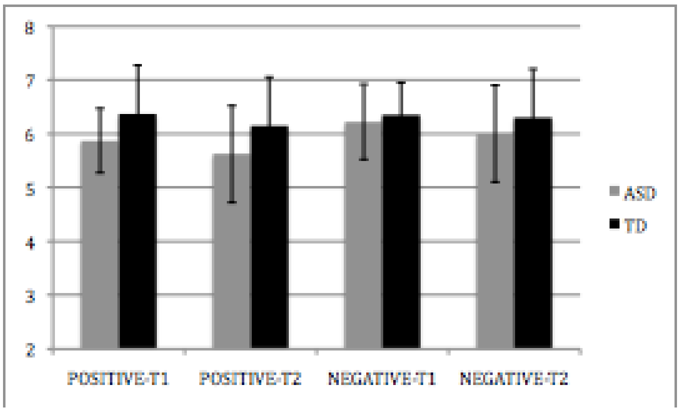
Children in the ASD group were less accurate compared to the TD group on the primary emotions*: happy/surprised* (group: $F(1,77) = 5.14$, $p = .034$, $\eta_p^2 = .11$); *sad/angry* (group: $F(1,77) = 4.01$, $p = .028$, $\eta_p^2 = .13$). Also, the ASD group had a much slower rate of improvement on mental states: *excited/thinking* (effect of group x age: $F(1,77) = 4.90$, $p = .030$, $\eta_p^2 = .06$), *worried/shy* (effect of group x age: $F(1,77) = 4.45$, $p = .038$, $\eta_p^2 = .057$).

3.4. COMPARISON OF TEST-1 AND TEST-2

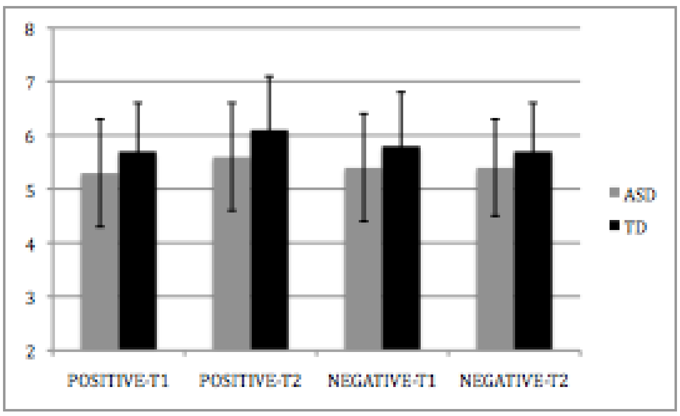
When we compared performance of each group on Tests 1 and 2, children in the TD group did not show any differences in performance on the positive emotion recognition trials (all $p>.1$). In contrast, children in the ASD group showed better performance on positive emotions on the Test-1 (main effect of test: $F(1,17) = 4.25$, $p = .05$) increasing with CA (test x CA: $F(1,17) = 5.43$, $p = .03$) but not with MA ($p >.1$). A similar outcome emerged for the primary negative emotion trials with no difference in performance between the tests for the TD group (all $p>.1$). Children in the ASD group achieved marginally better scores on Test-1 (main effect of test: $F(1,17)= 3.82$, $p= .067$) which was modulated by CA (interaction of test x CA: $F(1,17)= 6.01$, $p= .025$). For the positive mental states recognition, both groups showed no difference in performance scores between the Tests 1 and 2 (all $p>.1$) On the negative mental states recognition, only children with ASD achieved marginally better scores on Test-1 (main effect of test: $F(1,17)= 3.92$, $p= .065$) which was modulated by CA (interaction of test x CA: $F(1,17)= 5.31$, $p= .034$). Figure 2 summarises the findings.

Figure 2. Accuracy scores in recognition performance of children with ASD and TD on Test-1 and Test-2 for Primary emotions (2A) and Mental States (2B) with positive/neutral *vs*. negative valence (error bars represent SD).

2A) Primary emotions



2B) Mental states



Lastly, since there was an even split of gender in the TD group, each variable was also co-varied with gender. There were no differences between TD boys and girls on the tests (p >.1).

3.5. ANALYSIS OF ERRORS

In order to gain an insight into the kind of errors committed by children, we conducted an exploratory item analysis - see Table 4. Binomial tests were computed on each item within Tests 1 and 2 separately, assessing the distribution of incorrect responses – all tests were significant at $p \leq .0001$, indicating that both groups performed well above chance level. Remarkably, the negative primary emotion of *anger* was associated with the lowest proportion of errors in both groups of children and in both tests. As we have seen from the quantitative analyses presented in the previous section, mental states were associated with higher proportions of errors. In Test-1, both groups had the highest error rate on *'shy'* (negative/mental state), while in Test-2 the highest error rate was seen on *'worry'* in the ADS group and *'excited'* in the TD group.

Table 4. Number and % (with respect to total number errors) recognition errors by item in both tests and groups (TD and ASD) – lowest error rate in bold, highest error rate underlined.

TARGET	GROUP			
	TD		ASD	
	Test 1	*Test 2*	*Test 1*	*Test 2*
Happy	37 (6.26%)	68 (10.62%)	8 (5.48%)	15 (9.38%)
Surprised	92 (15.6%)	94 (14.66%)	17 (11.64%)	19 (11.88%)
Sad	71 (12.35%)	88 (13.73%)	21 (14.38%)	20 (12.50%)
Angry	**18 (3.05%)**	**23 (3.59%)**	**3 (2.05%)**	**8 (5.00%)**
Think	86 (14.55%)	83 (12.95%)	25 (17.12%)	21 (13.33%)
Excited	104 (17.6%)	105 (16.38%)	25 (17.12%)	23 (14.37%)
Worried	65 (11.08%)	82 (12.79%)	15 (10.27%)	29 (18.13%)
Shy	118 (19.97%)	98 (15.29%)	32 (21.92%)	25 (15.63%)
TOTAL	591	641	146	160

Finally, when considering the nature of confusions (see Appendix 2), the younger TD children appeared to mistake *'surprised'* and '*shy*' for a variety of other displays, while *'sad'* was only confused with '*worried*' (and vice versa), '*excited*' mostly with positive primary emotions, and 'think' equally between '*sad'*, '*worried*' and '*shy*', with the distribution of errors presenting less dispersion across categories in Test-2 than in Test-1. The TD children at the end tail of the developmental trajectory presented a much more specific confusion matrix, with less difference between Tests 1 and 2. For example, '*excited*' was mistaken for '*happy*' and vice versa, *'sad'* with '*worried'* and vice versa, and '*shy*' with *'worried'*. They thus tended to make mistakes mostly within affect valence. In contrast, children with ASD made mistakes across both types of state and valence; for example, '*surprised'* was confused with '*worried*' and '*sad'*, '*thinking*' with '*worried*' and '*shy*', and *'shy'* mostly with *'angry'* and '*thinking*' (see also Brennand, Schepman & Rodway, 2011).

4. DISCUSSION

Understanding emotions is one of the most important abilities for social interaction and human survival. Mixed findings regarding this ability in autism have resulted in a heated debate. In the current study, we examined the performance of children with ASD and TD control children on newly-developed emotion recognition tasks targeting the eye-region and using real children's naturally occurring emotions on faces and materials tested cross-culturally. Overall, our results show above-chance correct emotion/mental state match to the eye-pictures in both groups of children. Thus, the simplification of the Eyes Test was successful in facilitating performance in children with ASD from a younger age range than hitherto found in the majority of the studies in this field. As most emotion research has so far been carried out with high-functioning individuals with ASD and little with children from a wide range of ASD features, and as performance on our new tasks was similar across the individuals with ASD, the results demonstrate that the simplified tasks created for the present study are suitable for individuals with lower-functioning autism, a rather neglected group of individuals on the spectrum. Although no gender effects were found in the present study, future developments of our methodology would benefit from using gender-matched samples.

Chronological age proved to be, in general, the most sensitive predictor of developmental trends, with CARS and ASQ scores failing to modulate any performance outcomes in the ASD group in any of the tasks. Thus, length of experience in a social milieu appears to be specifically associated with improved performance, consistent with what has been found in earlier studies (e.g., Annaz et al., 2009).

Based on previous research and current test modifications, we predicted that primary emotions will be easier to distinguish than mental states, and that children with more advanced languages skills (based on BPVS scores) would show better performance on the tests, particularly on Test-2 (one eye-picture, two words). As predicted, children in the ASD group showed better performance on Test-1, which was less cognitively demanding because it accessed mainly the visual domain and required less semantic processing. However, it should be noted that the ASD group was delayed but not impaired in their performance on Test-2, which is likely to be due to their difficulty in accessing emotionally-loaded linguistic information (e.g., Tager-Flusberg & Joseph, 2005).

Thus, the type of test significantly differentiated between the two groups (TD/ASD), with Test-1 (two pictures/one word) being associated with developmental progression in both groups when considering CA, but Test-2 failing to reveal developmental progression in the ASD group. Indeed, performance was similar across the two tests for the TD children but was significantly better in Test-1 than in Test-2 for the ASD group. However, when comparing directly TD and ASD groups in Test-1, children with ASD presented delayed onset and slower rate of improvement than TD children on a subset of states (positive/neutral primary emotions: happy/surprised, and negative mental states: (worried/shy).

The two tests were designed to tap into different cognitive demands, presenting the emotion/state forced choice either visually (as in 'face in the crowd' experiments, e.g., LoBue, 2009) or verbally (as in the classic Eyes Tests, e.g., Baron-Cohen et al., 1997) thereby allowing us to examine language *vs*. face processing deficits across the two tests. Given the worse performance of children with ASD on Test-2 (one eye-picture, two words), the results support the view that language deficits in the ASD group may well be responsible for lower performance or delayed onset and slower improvement with respect to TD children in the eye-test type of tasks (e.g., Tager-Flusberg & Joseph, 2005).

However, it is also possible that the kind of visual processing elicited in the two tests was qualitatively different. In Test-1 (visual forced choice), children were asked to match a target emotion/state word to one of two eye-pictures. In other words, once the word was understood, the child had to *recognise* the eye-picture corresponding to the semantic content verbally accessed (rapid recognition of a pattern of features). However, in Test-2 (verbal forced choice), not only did children have to process two verbal labels rather than one, but they also needed to *inspect* the eye-picture in order to select the word corresponding to the emotion/state visually depicted. In other words, they needed to understand the eye-picture in order to decide whether it represented state A or B. It appears therefore that Test-2 may require visual concentration on a region of the face that is known to be the least spontaneously looked at by individuals with ASD (reduced looking time at people and faces: Annaz, et al., 2010; Klin, et al., 2003; Riby & Hancock, 2008), and presented in a version (direct gaze) for which several recent studies have highlighted atypical neural responses already in infancy in the ASD phenotype (Elsabbagh et al., 2009, 2012; Senju & Johnson, 2009).

Finally, it is worth noting that the highest accuracy score in both ASD and TD groups was for the primary emotion of *anger*. It might simply be that anger is expressed more strongly or more unambiguously in the eye region than some of the other emotions tested in the present study. However, a predisposition to detect anger has been previously reported in Asperger Syndrome (Ashwin, Wheelwright, & Baron- Cohen, 2006) and in adults with ASD (Krysko & Rutherford, 2009). Results with adolescents with ASD yield inconsistent outcomes: Rosset et al. (2001) found an anger superiority effect in a 'face in the crowd' experiment but Farran, Branson & King (2011) failed to replicate such findings. The inconsistency was possibly due to the different types of materials used: drawings in Rosset et al. (2001) and real faces in Farran et al. (2011). Our results show that by using simplified tasks with real photos displaying natural rather than posed emotions, even younger children including individuals with lower functioning autism show biased sensitivity to the detection of threat-related cues. Even more importantly, such cues are recognized in our tasks from the eye-region only and in real (not schematic) peer faces. This bias may be explained by the high evolutionary value of recognizing *anger* in others which could be directed to the perceiver. This original bias may be strengthened or attenuated by other factors, such as experience or phenotype. When considering a particular type of experience, for example, Camras, Ribordy, Hill, and Martino (1990) and Pollak, Cicchetti, Hornung and Reed (2000) showed that maltreated children tended to perform better than controls in the recognition of *anger* in masked expressions of emotion, whereas adults with social anxiety disorder performed significantly less well than controls in the recognition of facial expressions of anger (Montagne , Schutters, Westenberg, Van Honk, Kessels & De Haan, 2006). Difference in RTs between women (faster) and men was found to be largest for facial expressions of *anger* in a study by Hampson, van Anders and Mullin (2006). More importantly, Ackerman et al. (2006) found that, particularly in conditions in which cognitive resources are limited, the typical in-group homogeneity effect for face recognition was reversed for *angry* faces: effective self-protection induces sensitivity to facial signals that may be particularly relevant for the perceiver's functional outcomes (Fox et al., 2000; Maner et al., 2003; Ohman, Flykt & Esteves, 2001; see Schupp et al., 2004 for ERP evidence). Facilitation in detecting *anger* over other emotions has been shown also in 5-year-old TD children (LoBue, 2009) but not in children with Williams Syndrome (Santos, Silva, Rosset & Deruelle, 2010), consistently with their profile that includes decreased sensitivity to social threat. Thus, the results from our study contribute to qualify the ASD profile at younger ages and including lower levels of functioning as displaying an *intact/typical* ability to process threat-related cues even when they are detected in conditions which are not favourable considering known impairments associated with ASD (see above: face/ eye-region and direct gaze). It is thus possible to speculate that, due to their evolutionary survival importance, threat-related cues are accessible to individuals with ASD in spite of documented hypoactivation of the amygdala and its direct modulatory role on the fusiform face area (FFA) (Schultz, 2005).

Research examining the understanding of emotional recognition in children with low functioning autism is scant despite the fact that they form over of 70% of those on the autism spectrum (Baird, Simonoff, Pickles, Chandler, Loucas, Meldrum, & Charman, 2006; see also Kent, Carrington, Le Couteur, Gould, Wing, Maljaars, Noens, van Berckelaer-Onnes & Leekam, 2013). The novel tasks developed to test children from a wide range of abilities may contribute to gaining further understanding of all children on the spectrum, rather than merely the high-functioning ones. Our approach may also help to develop and optimise support materials and training strategies for educational settings in which children with social difficulties are identified.

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Appendix 1.

Description of experiment materials: 56 slides, each containing one target and one foil emotion/state.

56 SLIDES		FOILS						
		1	2	3	4	5	6	7
TARGET	1. Happy	surprised	sad	angry	excited	thinking	worried	shy
	2. Surprised	happy	sad	angry	excited	thinking	worried	shy
	3. Sad	happy	surprised	angry	excited	thinking	worried	shy
	4. Angry	happy	surprised	sad	excited	thinking	worried	shy
	5. Excited	happy	surprised	sad	angry	thinking	worried	shy
	6. Thinking	happy	surprised	sad	angry	excited	worried	shy
	7. Worried	happy	surprised	sad	angry	excited	thinking	shy
	8. Shy	happy	surprised	sad	angry	excited	thinking	worried

Appendix 2.

TEST 1 - Confusion matrix TD *vs.* ASD group (% of total errors)

		TARGET EMOTION								TARGET MENTAL STATE							
RESPONSE		HAPPY		SURPRISE		SAD		ANGRY		THINK		EXCITED		WORRRIED		SHY	
		TD	**ASD**	TD	**ASD**	TD	**ASD**	TD	**ASD**	TD	**ASD**	TD	**ASD**	TD	**ASD**	TD	**ASD**
	HAP	--	**--**	20.6	**17.6**	7.04	**9.5**	11.1	**0**	15.1	**12**	36.5	**44**	4.6	**0**	16.9	**12.5**
	SURP	10.8	**12.5**	--	**--**	7.04	**14.3**	11.1	**33.3**	13.9	**12**	16.3	**16**	7.7	**26.7**	9.3	**6.25**
	SAD	13.5	**0**	13.04	**11.8**	--	**--**	16.7	**0**	19.8	**16**	10.6	**4**	35.4	**20**	15.2	**18.75**
	ANG	5.4	**0**	1.1	**0**	9.9	**4.8**	--	**--**	4.6	**0**	2.9	**8**	9.2	**20**	9.3	**9.4**
	THIN	18.9	**37.5**	18.5	**17.6**	9.9	**19.04**	5.55	**66.6**	--	**--**	10.6	**20**	13.8	**6.7**	16.1	**25**
	EXC	29.7	**50.0**	16.3	**29.4**	5.63	**14.3**	11.1	**0**	16.3	**8**	--	**--**	7.7	**13.3**	11.02	**9.4**
	WOR	10.8	**0**	18.5	**23.5**	40.8	**28.6**	16.7	**0**	16.3	**28**	11.5	**4**	--	**--**	22.03	**18.75**
	SHY	10.8	**0**	11.96	**0**	15.5	**9.5**	27.8	**0**	13.9	**24**	11.5	**4**	21.5	**13.3**	--	**--**

TEST 2 - Confusion matrix TD *vs.* ASD group (% of total errors)

		TARGET EMOTION								TARGET MENTAL STATE							
RESPONSE		HAPPY		SURPRISE		SAD		ANGRY		THINK		EXCITED		WORRRIED		SHY	
		TD	**ASD**	TD	**ASD**	TD	**ASD**	TD	**ASD**	TD	**ASD**	TD	**ASD**	TD	**ASD**	TD	**ASD**
	HAP	--	**--**	4.2	**0**	4.5	**0**	8.7	**25**	8.43	**4.8**	30.5	**34.8**	7.3	**6.9**	10.2	**0**
	SURP	10.3	**13.3**	--	**--**	12.5	**15**	8.7	**0**	14.4	**4.8**	18.1	**21.7**	12.2	**6.9**	14.3	**12**
	SAD	4.4	**6.7**	10.6	**21.05**	--	**--**	4.3	**12.5**	10.8	**9.5**	4.8	**8.7**	23.2	**27.6**	10.2	**8**
	ANG	7.3	**6.7**	4.2	**0**	11.4	**5**	--	**--**	12.04	**9.5**	6.7	**8.7**	9.8	**6.9**	9.2	**36**
	THIN	14.7	**0**	22.3	**15.8**	18.2	**20**	4.3	**12.5**	--	**--**	17.1	**4.3**	15.8	**20.7**	12.2	**24**
	EXC	33.8	**46.7**	9.6	**15.8**	4.5	**5**	2.17	**37.5**	14.45	**9.5**	--	**--**	0	**6.9**	31.6	**12**
	WOR	13.2	**13.3**	27.6	**26.3**	27.3	**25**	26.1	**25**	16.86	**9.5**	11.4	**13.04**	--	**--**	12.2	**8**
	SHY	16.2	**13.3**	21.3	**21.05**	21.6	**30**	26.1	**0**	22.89	**52.4**	11.4	**8.7**	24.4	**24.1**	--	**--**