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Diminished sensitivity and specificity at recognising facial emotional expressions of varying intensity underlie emotion-specific recognition deficits in autism spectrum disorders

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ABSTRACT

Background: A plethora of research on facial emotion recognition in autism spectrum disorders (ASD) exists and reported deficits in ASD compared to controls, particularly for negative basic emotions. However, these studies have largely used static high intensity stimuli. The current study investigated facial emotion recognition across three levels of expression intensity from videos, looking at accuracy rates to investigate impairments in facial emotion recognition and error patterns ('confusions') to explore potential underlying factors.
Method: Twelve individuals with ASD (9 M/3F; M(age) = 17.3) and 12 matched controls (9 M/3F; M(age) = 16.9) completed a facial emotion recognition task including 9 emotion categories (anger, disgust, fear, sadness, surprise, happiness, contempt, embarrassment, pride) and neutral, each expressed by 12 encoders at low, intermediate, and high intensity.
Results: A facial emotion recognition deficit was found overall for the ASD group compared to controls, as well as deficits in recognising individual negative emotions at varying expression intensities. Compared to controls, the ASD group showed significantly more, albeit typical, confusions between emotion categories (at high intensity), and significantly more confusions of emotions as 'neutral' (at low intensity).
Conclusions: The facial emotion recognition deficits identified in ASD, particularly for negative emotions, are in line with previous studies using other types of stimuli. Error analysis showed that individuals with ASD had difficulties detecting emotional information in the face (sensitivity) at low intensity, and correctly identifying emotional information (specificity) at high intensity. These results suggest different underlying mechanisms for the facial emotion recognition deficits at low vs high expression intensity.

1. Introduction

Autism-Spectrum-Disorder (ASD) is defined by repetitive patterns of behaviour and difficulties in communication skills and social functioning, including non-verbal communication (American Psychiatric Association, 2013). Facial expressions of emotion are one form of non-verbal communication, and the ability to infer emotional states from facial expressions has

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been a major research interest in ASD. Literature reviews and meta-analyses have reported deficits in facial emotion recognition in ASD compared to controls (see Gaigg, 2012; Harms, Martin, & Wallace, 2010; Lozier, Vanmeter, & Marsh, 2014; Nuske, Vivanti, & Dissanayake, 2013; Uljarevic & Hamilton, 2013).

While much facial emotion recognition research has used high intensity facial emotional expression stimuli, daily social interactions typically involve subtler displays (Cassidy, Ropar, Mitchell, & Chapman, 2014; Motley & Camden, 1988). Low intensity facial emotional expressions provide less emotional cues to the observer and are harder to recognise than more intense expressions (Wingenbach, Ashwin, & Brosnan, 2016). Only a very limited number of studies have been published including intensity variations of emotional expression in ASD populations. These studies have reported an overall facial emotion recognition deficit in children and adults with ASD compared to controls using both static and video stimuli (Mazefsky & Oswald, 2007; Rump, Giovannelli, Minshew, & Strauss, 2009). However, those studies did not report group comparisons across the different expression intensities. Law Smith, Montagne, Perrett, Gill, and Gallagher (2010) investigated emotion recognition in male adolescents with ASD and controls using morphed dynamic stimuli of low, medium, and high expression intensity of the six basic emotions of anger, disgust, fear, sadness, surprise, happiness (Ekman, 1992). The authors reported that those with ASD performed significantly worse than controls on some emotion categories of low expression intensity (disgust, surprise, anger), medium expression intensity (disgust, anger), and high expression intensity (disgust). These results demonstrate that the level of intensity is important in emotion recognition, and that further research is needed including intensity variations and also a broader range of emotions.

Next to basic emotions, there are complex emotions, typically including a greater cognitive component than basic emotions. Some complex emotions are called self-conscious emotions (e.g. embarrassment), indicating the necessity of self-evaluation and assumptions about how others perceive oneself (Tracy & Robins, 2007), and are thought to regulate social behaviour (Adolphs, 2002). Thus, recognition of these emotions plays a crucial role in social interactions. However, complex emotions are rarely investigated alongside basic emotions in studies on facial emotion recognition in ASD. However, complex emotions are rarely investigated alongside basic emotions in studies on facial emotion recognition in ASD.

Investigation of errors in attributing emotion categories to facial expressions (i.e. confusions) can provide insight into mechanisms underlying facial emotion recognition deficits. Confusions of attributing an emotion to a neutral facial expression (e.g. fear as neutral) provide information regarding the recognition *sensitivity*, i.e. the ability to detect emotional content in the face. Confusions between two emotion categories (e.g. fear as surprise) provide information about the *specificity* of emotion recognition, i.e. the ability to differentiate between facial emotional expressions. Despite their informative nature, few studies have reported results about confusions. Some have reported that individuals with ASD tend to confuse the facial expressions of disgust as anger, and fear as surprise (Humphreys, Minshew, Leonard, & Behrmann, 2007; Jones et al., 2011). However, these specific confusions are also seen in typical individuals (see e.g. Recio et al., 2013). Statistical comparisons of the confusions made by individuals with ASD to controls provide information on whether individuals with ASD make more such confusions than typical individuals. We are aware of only one facial emotion recognition study in ASD that reported statistical comparisons of confusions to controls, which found (based on static stimuli) that individuals with ASD misinterpreted neutral faces as displaying an emotion more often than controls, showed reduced sensitivity, and lowered specificity (Eack, Mazefsky, & Minshew, 2015). Confusion analysis can thus provide valuable information about what is driving the facial emotion recognition deficits in ASD, and could be particularly informative at low and high expression intensity where the emotional information in the face is lowest and highest respectively.

The present study used a recently developed and validated video stimulus set including low, intermediate, and high intensity of basic and complex emotions to compare accuracy rates and confusions for emotion recognition in ASD to controls. It was hypothesised that: (1) individuals with ASD would show an overall deficit in facial emotion recognition compared to controls; (2) recognition of some emotional categories would be influenced differently by the level of expression intensity and emotion valence in ASD, with deficits expected mainly for negative emotions when expressed at lower intensities; and (3) the ASD group would make more confusions than controls with respect to both recognition sensitivity and specificity at low and high expression intensity.

2. Methods

2.1. Participants

The sample consisted of 12 adolescents and young adults with high-functioning ASD (9 M/3F; *M*(age) = 17.3) and 12 age- and sex-matched controls (9 M/3F; *M*(age) = 16.9), with no differences between the groups for mean age (see Table 1). All participants were British and had normal or corrected-to-normal vision. The ASD sample was recruited during an Autism Summer School run at the University of Bath for individuals diagnosed with ASD who were applying to start university. All participants in the ASD group had a diagnosis of ASD by a qualified clinical professional. The ASD diagnosis was confirmed by viewing a copy of their clinical report, which was brought to the Autism Summer School. The gold standard in confirming an ASD diagnosis is the Autism Diagnostic Observation Schedule (ADOS-2; Lord et al., 2012); the current study applied the self-report Autism-Spectrum Quotient (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) and the parent-report Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003) (see Table 1). An independent-samples *t*-test showed that the mean AQ score for the ASD group was significantly higher than that for the controls (see Table 1). The mean AQ score of the ASD group was similar to mean AQ scores for large previous ASD samples (Baron-Cohen et al., 2001;

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Table 1
Demographic Characteristics for the ASD and Control group.

	ASD *n* = 12	Controls *n* = 12	Statistical comparison
Sex (M:F)	9:3	9:3	$x^2(1) = .00$, $p = 1.00$
Mean Age	17.3 (*SD* = 0.75)	16.9 (*SD* = 0.29)	$t(14.16) = -1.43$ $p = .174$
Mean AQ	28.58 (*SD* = 10.24)	17.33 (*SD* = 4.33)	$t(14.82) = -3.51$ $p = .003$
Mean SCQ	22.60 (*SD* = 4.01)	–	–

Note: AQ = Autism Spectrum Quotient; SCQ = Social Communication Questionnaire.

Woodbury-Smith, Robinson, Wheelwright, & Baron-Cohen, 2005). The controls' mean AQ score was consistent with mean scores for large control groups in previous research (Ruzich et al., 2015). Although five participants in the ASD group scored under the recommended cut-off of 26 for a potential ASD (Woodbury-Smith et al., 2005), the ratings from the SCQ (Rutter et al., 2003) pointed towards an ASD in all participants with a minimum score of 19 (recommended cut-off score for a potential ASD = 15); though, the parent data of two participants were missing (*n* = 10). The mean SCQ score for the ASD group was comparable to reports in an efficacy study (Charman et al., 2007). Controls were students applying to university who were recruited at a University of Bath Open Day. No measure of IQ was completed due to time limitations, but all of the participants were high-functioning enough to be accepted to a UK university.

2.2. Facial emotion recognition videos

The Amsterdam Dynamic Facial Expression Set (ADFES; van der Schalk, Hawk, Fischer, & Doosje, 2011) adapted to the Bath Intensity variations (ADFES-BIV; Wingenbach et al., 2016) was used as the emotion stimuli. The ADFES-BIV contains 360 videos (+10 practice videos) including the expressions of anger, disgust, fear, happiness, sadness, surprise, contempt, embarrassment, pride, and neutral, each displayed by 12 different encoders (7 male, 5 female), and expressed at low, intermediate, and high intensity. Each video is 1040 ms in length and begins with a neutral facial expression (blank stare) which develops into an emotional expression at one of the three intensities (see Fig. 1).

2.3. Procedure

The study took place in a laboratory at the Department of Psychology, University of Bath, and included between one to seven participants at a time. Each participant was tested on their own individual computer with headphones and seated approximately 60 cm from screen. Testing sessions started with an affective state check, which involved arousal and valence ratings using the non-verbal 5-point Likert-scales Self-Assessment-Manikins (Bradley & Lang, 1994). A short neutral film clip was presented followed by a second arousal and valence rating, to ensure all participants began the emotion recognition task in a comparable affective state. Afterwards, the facial emotion recognition task was completed. A practice trial for each emotion was conducted first to allow participants to familiarise themselves with the task procedure; these 10 additional videos did not appear in the experiment itself. Each trial started with a fixation cross in the centre of the screen for 500 ms followed by the video stimulus, after which a blank screen was presented for 500 ms before the answer screen appeared. On the answer screen participants were presented with the 10 possible answers, producing a chance level of responding of 10%. Participants were instructed to answer immediately, though no time limit was included. After a choice was made, a new trial started. The screen size was 1280 $\times$ 1024 matching the resolution of the stimuli and displaying the faces in a size comparable to face-to-face interactions. Facial emotion stimuli were displayed and responses recorded using the software E-Prime 2.0

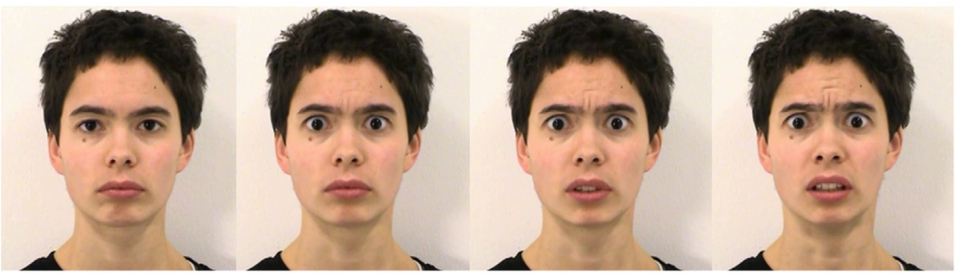

Fig. 1. Examples of the last frame showing the varying intensity levels of expression in the video stimuli, including a neutral expression, low intensity fear expression, intermediate intensity fear expression, and high intensity fear expression (from left to right).

(Psychology Software Tools, Pittsburgh, PA). The study received ethical approval from the University of Bath Psychology Research Ethics Committee, and the control participants received £5 for participating. All participants gave written informed consent; parents gave additional written informed consent for those participants aged < 18.

2.4. Data analysis

Mann-Whitney *U* tests were conducted to compare the two groups on their affective states prior to the emotion recognition experiment and on recognition of 'neutral'.[1] A generalized linear mixed model (GLMM) was conducted on the accuracy of response data.[2] The presented *p*-values of the contrasts include sequential Bonferroni-correction. Accuracy of responses are presented in decimal fractions. Confusion matrices at low and high intensity were created for both groups separately. To minimise the number of comparisons, the emotion categories were combined to 'negative basic emotions' including anger, disgust, fear, and sadness; 'positive basic emotion', i.e. happiness; 'negative complex emotions' including contempt and embarrassment; 'positive complex emotion', i.e. pride; and 'neutral' and 'surprise', which do not fit in any of the categories, 'neutral' because it is has no valence and 'surprise' due to its unclear valence. For confusions that occurred more often than just by chance in any group (10% chance level of responding) based on visual inspection, Kruskal-Wallis tests were conducted testing the distributions of both groups for significant differences. Effect sizes were calculated (eta squared = test statistic/(N - 1)).

3. Results

3.1. Affective state check/neutral recognition check

At the start of the experiment the groups showed a trend for differences in their arousal and valence ratings. After the documentary, the groups did not differ on their arousal or valence ratings. Results also showed that the groups did not differ in their labelling of neutral faces (see Table 2).

3.2. Accuracy of response

The GLMM showed a significant main effect of *group* ($F(1594) = 6.80$, $p = .009$), with the controls ($M = .76$, $SE = .02$) having greater accuracy overall compared to those with ASD ($M = .63$, $SE = .05$; see Fig. 2).

The main effect of *emotion* ($F(8594) = 25.18$, $p < .001$), the main effect of *intensity* ($F(2594) = 109.78$, $p < .001$), and the interaction of *emotion*intensity* ($F(16{,}594) = 15.65$, $p < .001$) were also significant.[3] The interactions of *group*intensity* ($F(2594) = 0.74$, $p = .470$) and *group*emotions* ($F(8594) = 1.23$, $p = .279$) were not significant. The three-way interaction of *group*emotions*intensity* was significant ($F(16{,}594) = 1.94$, $p = .015$). Most significant differences emerged for recognition at low intensity (anger, fear, sadness, embarrassment), followed by intermediate intensity (anger, fear, sadness) and high intensity (fear, sadness); contrast results are shown in Fig. 3 and Table 3.

3.3. Confusion matrices

Visual inspection of the confusion matrices for the low intensity facial emotional expressions revealed that 6 confusions occurred more often than the 10% chance level of responding (see Table 4).[4] Three of the confusions relate to sensitivity as they were between an emotion category and neutral; 3 confusions relate to specificity as they were between emotion categories. Kruskal-Wallis tests showed that the ASD group perceived *negative basic emotions* as *neutral* significantly more often than controls ($H(1) = 4.13$, $p = .042$, $\eta^2 = .180$). All other comparisons were not statistically significant (p's $> .05$).[5]

Visual inspection of the confusion matrices for the high intensity facial emotional expressions revealed that in total 3 confusions occurred more often than the 10% chance level (see Table 5). One of the confusions was between an emotion category and neutral; 2 confusions were between different emotion categories. The groups' distributions for the confusion of

[1] Neutral was not included in the main analysis, because there are no varying intensities for this category.

[2] A GLMM was run with 'subject' and 'group' as subject specifications, and 'emotion' and 'intensity' as repeated statements with diagonal covariance structure. 'Subject' was included as random factor including the intercept. The fixed factors were 'intensity', 'emotion', and 'group', including all factor interactions. A binomial distribution with logit link function was specified, as appropriate for proportion data. The residual method was used for the degrees of freedom. Estimation of fixed effects and coefficients was based on robust covariances to account for potential model violations. Simple contrasts were requested to compare the groups and pairwise contrasts were requested to compare the emotions and intensities among each other. Sequential Bonferroni corrections were applied to correct the *p*-value for multiple comparisons within the contrasts.

[3] The post-hoc results for these results can be found in the Supplementary material as they were not the central focus of this study.

[4] The confusion matrices by emotion can be found in the supplement.

[5] The groups' distributions for the confusions of *negative complex emotions* as *neutral* ($H(1) = .75$, $p = .385$, $\eta^2 = .033$), and *happiness* as *neutral* ($H(1) = .25$, $p = .620$, $\eta^2 = .011$) were not significantly different. The groups' distributions for the confusions of *negative basic emotions* as surprise ($H(1) = .25$, $p = .620$, $\eta^2 = .011$), *negative complex emotions* as *happiness* ($H(1) = 2.56$, $p = .133$, $\eta^2 = .111$), and *pride* as *happiness* ($H(1) = .10$, $p = .749$, $\eta^2 = .004$) were not significantly different.

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Table 2
Affective State Ratings and Recognition Accuracy for Neutral Facial Expressions for the Two Groups.

	ASD	Controls	Group comparison
Median first arousal rating	3.00 *ran* = 2.00	2.00 *ran* = 2.00	$U = 34$, $z = -1.67$ $p = .067$
Median second arousal rating	2.00 *ran* = 2.00	2.00 *ran* = 3.00	$U = 55.50$, $z = -1.02$ $p = .399$
Median first valence rating	4.00 *ran* = 3.00	4.00 *ran* = 2.00	$U = 42.50$, $z = -1.92$ $p = .072$
Median second valence rating	3.00 *ran* = 3.00	4.00 *ran* = 2.00	$U = 61$, $z = -.71$ $p = .614$
Mean neutral recognition	.89 *Mdn* = 0.90, *SD* = .11	.90 *Mdn* = 0.90, *SD* = .08	$U = 67.50$, $z = -.26$ $p = .793$

Note. Ran = range.

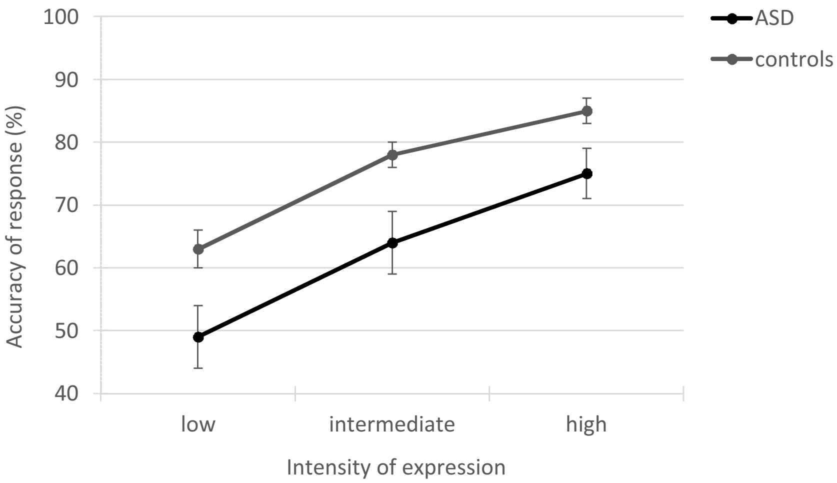

Fig. 2. Accuracy of responses across the three intensity levels for the ASD and control group. Accuracy of responses are expressed in percentages. Error bars represent standard errors of the means.

negative basic emotions as *surprise* were significantly different ($H(1) = 5.17$, $p = 0.023$, $\eta^2 = .225$). The other comparisons were not statistically significant (p's > .05).[6]

4. Discussion

The current study investigated the accuracy and confusions in recognition of facial expressions of a wide range of emotions at varying intensities in ASD compared to controls using dynamic videos. Overall, those with ASD had impaired facial emotion recognition, but accuracy rates increased comparably for the ASD group and controls with increasing expression intensity. For specific emotions with a negative valence, deficits in ASD were also evident at varying levels of expression intensity. Confusion analysis revealed differences in ASD compared to controls regarding recognition sensitivity and specificity that suggest different problems are underlying emotion recognition deficits in ASD at low vs high expression intensity, hinting on anomalies in face processing and impairments in visual perception.

The ASD group's deficit in facial emotion recognition compared to controls aligns with the published literature including intensity variations (Law Smith et al., 2010; Mazefsky & Oswald, 2007; Rump et al., 2009). Using dynamic video stimuli, the deficit was consistent across intensity levels, whereas Law Smith et al. (2010) reported greatest differences at medium expression intensity, based on computer-morphs. The emotion-specific deficits between the groups identified depended on

[6] The groups' distributions for the confusion of *pride* as *happiness* ($H(1) = 2.66$, $p = .103$, $\eta^2 = .116$), and *negative complex emotions* as *neutral* ($H(1) = .95$, $p = .331$, $\eta^2 = .041$) were not significantly different.

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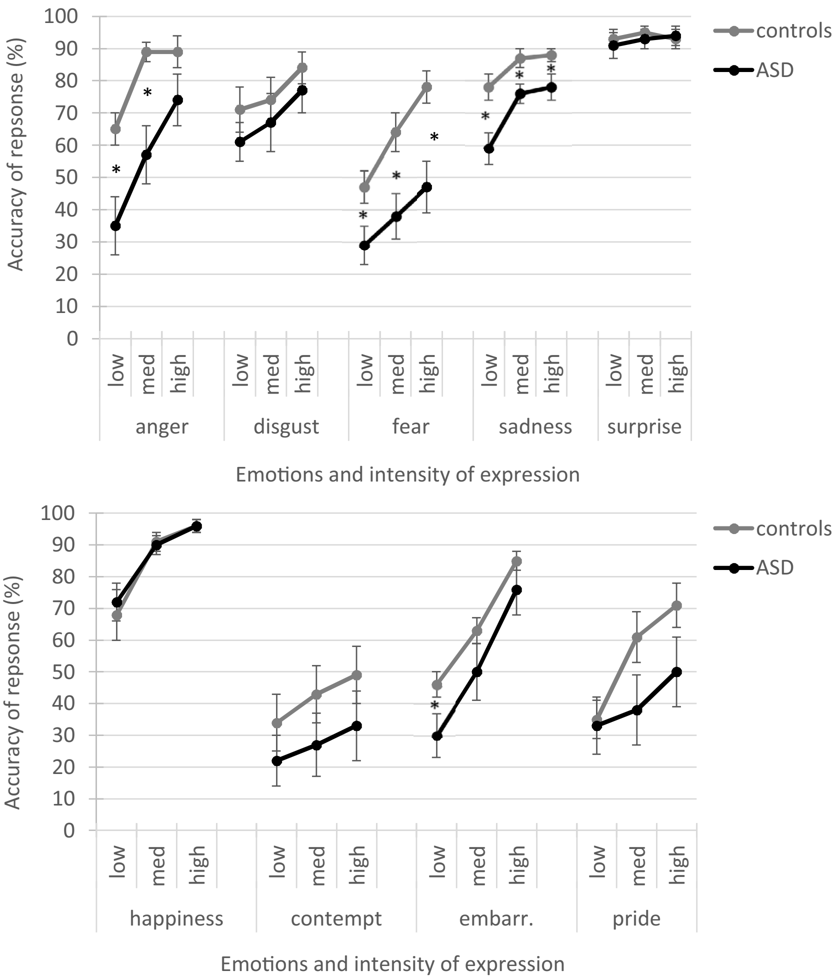

Fig. 3. Accuracy of responses for the ASD group and the controls for all emotion categories at each intensity level. Accuracy of responses are expressed in decimal fractions. Error bars represent standard errors of the means. *$^*p<.05$.*

the intensity of the expression, which overall is in line with the reports by Law Smith et al. (2010). That no recognition deficit for disgust, surprise, happiness, pride, and contempt emerged at any intensity level, can potentially be explained by the saliency of the mouth region for these emotions and the preference for the mouth region in ASD (Kliemann, Dziobek, Hatri, Steimke, & Heekeren, 2010; Spezio, Adolphs, Hurley, & Piven, 2007). Results showed deficits in the ASD group in recognition of anger at low and intermediate intensity, embarrassment at low intensity, and fear and sadness at all three intensity levels. The results on anger recognition are in common with reports by Law Smith et al. (2010), as no significant group differences emerged for at high intensity, but at the lower intensities. However, Law Smith et al. (2010) found deficits in ASD for recognition of surprise and disgust. A possible explanation for the deviations in the results from the current study is that video recordings facilitate recognition compared to morphed sequences as used by Law Smith et al. (2010). Alterations of the timings of an unfolding facial emotional expression, which naturally occurs using morphing, can affect perception based on the temporal characteristics that are embedded in our emotion representations (Bould, Morris, & Wink, 2008; Kamachi et al., 2013; Sato & Yoshikawa, 2004). Disgust and surprise are both fast developing facial expressions and if the development of the facial expression is slower than typical for the emotion, then it is more difficult to recognise the emotion (see Recio et al., 2013). It is possible that for individuals with ASD this difficulty affects recognition rates more negatively than controls and could explain significant group differences based on morphed sequences as reported by Law Smith et al. (2010). It is further possible that video recordings offer temporal emotional information that is helpful for decoding of some emotions (e.g. surprise) to controls as much as to individuals with ASD.

Across intensity levels, controls outperformed the ASD group at recognition of all negative emotions included in the current study, but significance was only reached for anger, fear, sadness, and embarrassment – at certain levels of expression intensity. That no significant group differences were found for non-negative emotions leads to conclude that the valence (and intensity) of an emotion affects recognition performance by individuals with ASD. This result is consistent with the literature, as valence and intensity are reported in a literature review as core factors influencing recognition performance

Table 3
Accuracy of Response for Each Emotion at the Three Levels of Intensity for the ASD Group and Controls.

		Emotion								
		Anger	Disgust	Fear	Sadness	Surprise	Happiness	Contempt	Embarr.	Pride
Intensity	**Group**	***M (SE)***	***M (SE)***	***M (SE)***	***M (SE)***	***M (SE)***	***M (SE)***	***M (SE)***	***M (SE)***	***M (SE)***
low	**ASD**	.35 (.09)	.61 (.06)	.29 (.06)	.59 (.05)	.91 (.04)	.72 (.06)	0.22 (.08)	0.30 (.07)	.33 (.09)
	Controls	.65 (.05)	.71 (.07)	.74 (.05)	.78 (.04)	.93 (.03)	.68 (.08)	0.34 (.09)	0.46 (.04)	.35 (.06)
		$t(594) = 2.92$	$t(594) = 1.06$	$t(594) = 2.32$	$t(594) = 3.34$,	$t(594) = .54$	$t(594) = -.40$	$t(594) = 1.04$	$t(594) = 2.13$	$t(594) = .24$
		$p = .004$	$p = .290$	$p = .021$	$p = .001$	$p = .592$	$p = .692$	$p = .301$	$p = .033$	$p = .813$
inter-mediate	**ASD**	.57 (.09)	.67 (.09)	.38 (.07)	.76 (.03)	.93 (0.03)	.90 (.03)	.27 (.10)	0.50 (.09)	.38 (.11)
	Controls	.89 (.03)	.74 (.07)	.64 (.06)	.87 (.03)	.95 (0.02)	.91 (.03)	.43 (.09)	0.63 (.04)	.61 (.08)
		$t(594) = 3.44$	$t(594) = .65$	$t(594) = 2.83$,	$t(594) = 2.35$	$t(594) = 0.70$	$t(594) = .16$	$t(594) = 1.21$	$t(594) = 1.30$	$t(594) = .67$
		$p = .001$	$p = .518$	$p = .005$	$p = .019$	$p = 0.484$	$p = .874$	$p = .225$	$p = .193$	$p = 0.097$
high	**ASD**	.74 (.08)	.77 (.07)	.47 (.08)	.78 (.04)	.94 (.03)	.96 (.02)	.33 (.11)	.76 (.08)	.50 (.11)
	Controls	.89 (.05)	.84 (.05)	.78 (.05)	.88 (.02)	.93 (.03)	.96 (.02)	.49 (.09)	.85 (.03)	.71 (.07)
		$t(594) = 1.61$	$t(594) = .77$	$t(594) = 3.26$,	$t(594) = 2.40$	$t(594) = -.39$	$t(594) = -.14$	$t(594) = 1.07$	$t(594) = 1.05$	$t(594) = 1.66$
		$p = .108$	$p = .440$	$p = .001$	$p = .017$	$p = .697$	$p = .890$	$p = .285$	$p = .294$	$p = .098$

Note. Means (*M*) and standard errors of the means (*SE*) are expressed in decimal fractions. Embarr. = embarrassment.

Table 4
Confusion Matrices for the Low Intensity Facial Expressions for the ASD Group and Controls.

	ASD					
	Emotions displayed (high intensity)					
Response	**bas-neg**	**happiness**	**neutral**	**surprise**	**com-neg**	**pride**
bas-neg	**68**	0	1	1	1	0
happiness	0	**96**	1	1	8	**48**
neutral	3	1	**91**	0	**21**	1
surprise	**11**	1	1	**94**	2	1
com-neg	3	0	2	1	**54**	1
pride	0	2	0	0	5	**49**
	Controls					
	Emotions displayed (high intensity)					
Response	**bas-neg**	**happiness**	**neutral**	**surprise**	**com-neg**	**pride**
bas-neg	**84**	0	2	2	2	0
happiness	0	**96**	0	0	2	**27**
neutral	1	1	**89**	1	**10**	1
surprise	5	0	0	**92**	2	0
com-neg	1	1	2	0	**67**	1
pride	0	3	0	0	2	**70**

Note. This table shows the correct responses (diagonal) and confusions (above and below diagonal) in percentages for each group. Highlighted in boldface are the confusions that occurred to a degree greater than chance. Embarr. = embarrassment; bas-neg = basic negative (i.e. anger, fear, disgust, sadness); com-neg = complex negative (i.e. contempt, embarrassment).

specifically in ASD (Nuske et al., 2013). The results from the current study are in line with reports that the emotion recognition deficits in ASD are particularly evident for negative basic emotions (Ashwin et al., 2006; Gaigg, 2012; Wallace et al., 2008). Variations between studies in the specific negative emotions showing group differences may emerge due to differences in the nature of the stimuli (e.g. static vs dynamic), experimental parameters used (e.g. time limitations), or emotion categories included. There are fewer investigations on the recognition of complex emotions in ASD, although there are investigations reporting deficits in the *understanding* of embarrassment (e.g. Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999; Capps, Yirmiya, & Sigman, 1992; Hillier & Allinson, 2002; Losh & Capps, 2006). It is possible that the lack of understanding of embarrassment extents to the recognition of its facial expression.

At low intensity, the ASD group confused the facial expressions of negative basic emotions with a neutral expression significantly more often than the controls, which did not occur when the emotional cues were more intense (i.e. higher expression intensity). This result points towards diminished recognition sensitivity, in line with Wallace et al. (2011) who found diminished sensitivity in ASD compared to controls over the six basic emotions combined. Since motion perception performance decreases more in ASD compared to controls when viewing times are short (Robertson et al., 2014) and facial expressions are dynamic and fleeting, impaired motion perception (literature review by Dakin & Frith, 2005) could manifest in confusions of emotional facial expressions as neutral, especially at the low intensity level where movements are of small magnitude. This is particularly true for emotional facial expressions that include facial features of smaller magnitude, e.g. eyebrows pulled together (as opposed to smiling). Consequently, it is more likely to confuse the emotion anger than

Table 5
Confusion Matrices for the High Intensity Facial Expressions for the ASD Group and Controls.

	ASD					
	Emotions displayed (low intensity)					
Response	**bas-neg**	**happiness**	**neutral**	**surprise**	**com-neg**	**pride**
bas-neg	**46**	0	1	1	2	0
happiness	0	**71**	1	1	**12**	**56**
neutral	**19**	**15**	**89**	6	**38**	6
surprise	**13**	1	0	**90**	2	0
com-neg	3	4	3	1	**28**	3
pride	0	7	1	1	6	**33**
	Controls					
	Emotions displayed (low intensity)					
Response	**bas-neg**	**happiness**	**neutral**	**surprise**	**com-neg**	**pride**
bas-neg	**65**	1	2	1	3	0
happiness	0	**68**	0	1	3	**53**
neutral	7	**13**	**92**	1	**28**	6
surprise	**13**	1	0	**93**	1	1
com-neg	2	4	1	0	**41**	2
pride	0	9	0	0	4	**35**

Note. This table shows the correct responses (diagonal) and confusions (above and below diagonal) in percentages for each group. Highlighted in boldface are the confusions that occurred to a degree greater than chance. Embarr. = embarrassment; bas-neg = basic negative (i.e. anger, fear, disgust, sadness); com-neg = complex negative (i.e. contempt, embarrassment).

happiness with a neutral expression with a motion perception impairment underlying. The arising question is whether the motion perception deficit is enlarged for social stimuli compared to non-social stimuli.

Diminished specificity in facial emotion recognition suggests that emotional content was perceived yet misinterpreted, since emotion categories are confused. A specificity deficit was found at high intensity, as the ASD group perceived negative basic emotions significantly more often as surprise than controls (although this result was driven by the confusion of fear as surprise; see Supplementary confusion matrices). Featural overlap in facial emotional expressions can make recognition more difficult, therefore, lead to more confusions. In line with that, both groups confused the featurally similar emotional facial expression pairs: fear as surprise, disgust as anger, and pride as happiness (see Supplementary confusion matrices). Although the former two confusions are in line with previous reports (Humphreys et al., 2007; Jones et al., 2011), the confusion rates of disgust as anger and pride as happiness were not significantly different for the groups. However, the ASD group confused fear as surprise at high intensity significantly more than controls. (The statistical results on emotion-specific confusions can be retrieved from the corresponding author). In fear and surprise the eyes are wide open and sometimes the mouth as well; the featural distinct but subtle aspect is the inner brow that is lowered in fear expressions but not surprise (Ekman & Friesen, 1978), facilitating the confusion of fear as surprise. A potential explanation for the higher confusion of fear as surprise in ASD is a focus on single details rather than the whole face, as postulated by the weak central coherence theory of ASD (Frith, 1989 /2003; Happé & Frith, 2006). Individuals with ASD seem to rely on single feature processing more than controls (e.g. Behrmann et al., 2006; Doi et al., 2013), although holistic face processing is thought to be necessary for recognition of facial expressions of high featural overlap (Gauthier & Tarr, 1997; Mondloch, Le Grand, & Maurer, 2002). Calvo and Nummenmaa (2008) identified configural face processing as the necessary strategy for recognition of fear. If the attentional focus is on the 'wrong' single feature (e.g. open mouth as seen in fear and surprise), then differentiation between emotions is diminished, which is enhanced at high expression intensity where facial features are more apparent. Future research on confusions should thus include eye-tracking. Overall, the confusion analyses showed that at low intensity individuals with ASD have a deficit in perceiving the emotion and at high intensity individuals with ASD have a deficit at identifying the emotion.

4.1. Limitations

A limitation of the present study is the small sample sizes, and so the results need to be replicated in larger samples. There were only three females included in both groups in the present samples, which is too few in order to carry out meaningful statistical analyses of sex differences. While these ratios are representative of the high male ratios in ASD (1 in 4; Fombonne, 2005), an important area of current research is about females with ASD, which future studies of this type should address. Further, the sample is not very representative given the sampling procedure of sampling higher functioning individuals who were anticipating going to university. It is thus possible that the results are partly due to differences between groups in general intellectual skills, although this is unlikely given that the global group differences were further characterised by differences in the pattern of performance across emotions. That for some individuals from the ASD group the AQ sum scores fell below the suggested cut-off, whereas the parent-reports from the SCQ were indicative of autistic traits in all individuals, can be explained by variations in the phenotype of ASD. Autism traits should thus be assessed with other instruments alongside the AQ.

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4.2. Implications

The current study demonstrates that the differences in recognising specific emotions in ASD compared to controls depend on the intensity and valence of the emotional expressions. The dependency of the results on expression intensity helps explain why many studies using only high intensity expressions have not found a facial emotion recognition deficit in ASD. Inclusion of lower expression intensities in facial emotion recognition experiments further allows to obtain results that help explain day-to-day difficulties experienced by individuals with ASD. In social interactions, lower expression intensity is frequently encountered and the ASD group showed problems in detecting emotional content in the observed faces of low but not high intensity. The lowered social functioning typical in ASD might be explained by not being able to detect emotional cues, which hampers appropriate responding to emotional displays and sharing of emotions as outlined in the diagnostic criteria for an ASD in the DSM 5 (American Psychiatric Association, 2013). Anomalies in several processes of face perception and processing seem to culminate in the profound facial emotion recognition deficits seen in ASD. Future research should seek to combine video-based facial emotion recognition (and non-social stimuli) with eye-tracking and/or brain imaging to investigate more precisely the mechanisms of the diminished sensitivity and specificity of facial emotion recognition in ASD.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.rasd.2016.11.003.

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