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Title

Short report: Complex facial emotion recognition and atypical gaze patterns in autistic adults

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Conflict Of Interest

All authors declare no conflict of interest. Sven Bölte declares no direct conflict of interest related to this article. Bölte discloses that he has in the last 5 years acted as an author, consultant or lecturer for Shire, Medice, Roche, Eli Lilly, Prima Psychiatry, GLGroup, System Analytic, Kompetento, Expo Medica, and Prophase. He receives royalties for text books and diagnostic tools from Huber/Hogrefe, Kohlhammer and UTB.

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Abstract

While altered gaze behaviour during facial emotion recognition (FER) has been observed in autistic individuals, there remains marked inconsistency in findings, with the majority of previous research focused towards the processing of basic emotional expressions. There is a need to examine whether atypical gaze during FER extends to more complex emotional expressions, which are experienced as part of everyday social functioning. The eye gaze of 20 autistic and 20 IQ matched neurotypical (NT) adults was examined during a FER task of complex, dynamic emotion displays. Autistic adults fixated longer on the mouth region when viewing complex emotions compared to NT adults, indicating that altered prioritisation of visual information may contribute to FER impairment. Results confirm the need for more ecologically valid stimuli for the elucidation of the mechanisms underlying FER difficulty in autistic individuals.

Keywords: eye movement, eye tracking, social cognition, facial expression

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Short report: Complex facial emotion recognition and atypical gaze patterns in autistic adults

Individuals with a diagnosis of Autism Spectrum Disorder (ASD) commonly experience difficulty during facial emotion recognition (FER). During behavioural assessment, autistic[1] individuals demonstrate measurable impairment in accurately recognizing both basic (i.e. happy, angry, fear, disgust, surprise, sadness; Uljarevic & Hamilton, 2013) and complex (i.e. resentfulness, intimacy; Golan, Baron-Cohen, & Hill, 2006) emotions compared to their neurotypical (NT) counterparts.

This observed difficulty in FER, may, in part, be driven by aberrant gaze behaviour (Black et al., 2017; Harms, Martin, & Wallace, 2010). Atypical gaze behaviour is commonly observed in autistic individuals, typically characterised by a reduced fixation time to the eyes compared to NT individuals. These differences however appear to be largely stimulus-dependent and remain relatively equivocal (Guillon, Hadjikhani, Baduel, & Rogé, 2014). Many studies have failed to confirm the purported reduced gaze to the eyes (Black et al., 2017; Harms et al., 2010). Others have also noted atypical gaze patterns for other facial regions, such as increased fixation on the mouth, though these findings are also inconsistent (Black et al., 2017; Harms et al., 2010).

The vast majority of research exploring the gaze behaviour of autistic adults has employed static representations of basic emotions, which alone, may not fully represent the experience of everyday social functioning for autistic adults. Very few studies have employed complex emotions to explore the gaze-based correlates of FER in autistic adults, with these studies using only static representations of complex emotions, limiting their ecological validity (Black et al., 2017).

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Given the stimulus-dependent nature of gaze behaviour and the fact that everyday social functioning is both dynamic and complex, the current study sought to examine the gaze behaviour of autistic adults during the recognition of emotions which are both complex and dynamic in order to increase the real-world applicability of findings. It was predicted that autistic adults, compared to NT adults would exhibit poorer recognition performance, as well as reduced fixation time to eye regions.

Methods

Participants

Autistic (n=20) and NT (n=20) adults participated (Table 1). All autistic adults had a diagnosis of ASD according to the Diagnostic and Statistical Manual – 5th Edition (DSM-5, American Psychiatric Association, 2013) confirmed via self-report, with a formal diagnosis in Western Australia mandating consensus across a multi-disciplinary team (Glasson et al., 2008). Participants were matched on gender, Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), and Full-Scale IQ as measured by the Wechsler Abbreviated Scale of Intelligence (WASI-2; Wechsler, 2011), and Attention Switching as measured by the timed visual elevator scores of the Test of Everyday Attention (TEA; Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994). Groups differed significantly on age, autistic trait severity, as measured by the Social Responsiveness Scale (SRS-2; Constantino & Gruber, 2012), and map search sub-tests of the TEA, indicating that autistic adults had greater autistic-like traits and lower visual selective attention.

[Insert table 1 here]

Measures

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Social Responsiveness Scale – Second Edition (SRS-2*).*The SRS-2 Adult Self Report Form (Constantino & Gruber, 2012) was used to measure autism trait severity. The SRS-2 is a standardized 65-item questionnaire pertaining to social communication, social motivation, social awareness, social cognition, and rigid behaviors. Items are Likert-scaled ranging from 0=not true to 3= almost always true (max score = 195 and clinical cutoff of T-scores > 59).

Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-2). The WASI-2 (Wechsler, 2011) provided an estimate of performance, verbal, and full-scale IQ. This widely used short version of the Wechsler Adult Intelligence Scale and the Wechsler Intelligence Scale for Children includes the subtest for vocabulary, similarities, block design, and matrix reasoning. The WASI-2 is standardised for individuals aged 6 to 89 years and has demonstrated good psychometric properties (Wechsler, 2011).

Test of Everyday Attention (TEA). Four sub-tests of the Test of Everyday Attention (TEA) (Robertson et al., 1994) were administered. The map search (1 min. and 2 min.) subtests provided a measure of visual selective attention while visual elevator and timed visual elevator tasks provided a measure of attention switching (Robertson et al., 1994). These subtests were utilized to characterize the sample. The TEA is conceptualized for individuals 18 to 80 years of age. The four subtests applied in this study have adequate reliability (Robertson et al., 1994).

Facial emotion recognition task. A sub-set of stimuli were selected from the Cambridge Mind Reading Face-Voice Battery (CAMs; Golan, Baron-Cohen, & Hill, 2006), which has previously been used to demonstrate FER difficulties in autistic adults in the normative IQ range (Golan, Baron-Cohen, & Hill, 2006). For this study, a set of 15 complex emotional stimuli was presented in a pseudo-randomized order. Emotions were presented

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once, and included exonerated, intimate, empathic, vibrant, insincere, resentful, stern, grave, subservient, appalled, confronted, mortified, distaste, lured and appealing. Each trial consisted of an initial 1s fixation cross, followed by a silent video clip (3 to 5 sec.) of a single actor expressing a complex emotion. Following each video clip, participants were asked to identify the displayed emotion from four options taken from previous work using the CAMs (Golan et al., 2006) using a keyboard.

Apparatus

Eye movements were recorded using a SensoMotoric Instruments Remote Eye Tracker Device (R.E.D; SensoMotoric Instruments, 2014). Stimulus presentation and behavioural data acquisition was controlled using E-Prime software (Psychology Software Tools, 2016) while eye movement data acquisition was controlled by SensoMotoric Instruments Eye View X software (SensoMotoric Instruments, 2014). The R.E.D was positioned in front of a 42inch screen on which the stimuli were presented. Participants were seated 70cm from the R.E.D on a height adjustable chair.

Procedure

Ethical approval (Curtin University HR52/2012) and written informed consent was obtained. This study was conducted as part of a larger experimental battery. Participants completed the WASI-2 and the TEA, before being familiarized with the eye tracker and FER task. A 9-point calibration procedure was then conducted. Upon adequate calibration, two practice items were shown, followed by the experimental trials of the FER task.

Data Preparation and Reduction

Fixation accuracy checks were conducted on all data with eye movement data excluded if the calibration accuracy was in excess of 1.5º of visual angle (VA). Fixations were defined

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as consecutive gaze samples held within 1° of VA for a minimum duration of 100ms. Areas of Interest (AOIs) were dynamically defined over the actor's eyes, nose and mouth region for each stimulus. The proportion of total fixation time to each of the eye, nose and mouth AOIs for each stimulus video was then calculated for correct and incorrect responses. Analysis of fixation time was subsequently conducted only for correct response trials.

Results

Emotion Recognition Accuracy

All participants received a total accuracy score (percentage). The proportions of correct responses were submitted to Mann-Whitney U tests as Kolmogorov Smirnov tests found the accuracy data to be not normally distributed. Analysis for FER accuracy revealed a near-significant trend indicating that autistic adults were less accurate in recognising complex emotions compared to NT adults (U=129, Z=-1.95, p=.056).

Fixation Time

Fixation time was subjected to a mixed factorial ANOVA, group (between subject factor; ASD, NT) x AOI (within subject factor; eyes, nose, and mouth).The results of the multivariate analysis are reported (Philai's trace) with partial eta square as the measure of effect size.

No main effect of group, $F(1,38)=2.79$, $p=.10$, $\eta^2p=.07$ was found. A main effect of AOI, $F(2,76)=58.41$, $p<.001$, $\eta^2p=.76$, was qualified by a group by AOI interaction, $F(2,76)=4.42$, $p=.02$, $\eta^2p=.19$. Bonferroni corrected pairwise comparisons indicated that autistic adults fixated longer on the mouth than did NT adults (p=.04) (Figure 1). There was no significant difference between groups for the eye AOI (p=.14) or the nose AOI (p=.74). These

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comparisons also revealed that both NT and autistic adults fixated significantly longer on the eyes (NT: $p<.01$, ASD: $p=.01$) and nose (NT: $p<.01$, ASD: $p=.01$) than the mouth.

[Insert Figure 1 Here]

Discussion

It was hypothesised that autistic adults would demonstrate poorer FER accuracy and altered gaze behaviour. A marginal effect was observed for accuracy, indicating that autistic adults tended towards reduced accuracy during the FER task. Findings are consistent with previous reports of impairments in basic (Uljarevic & Hamilton, 2013) and complex emotions (Golan, Baron-Cohen, & Hill, 2006; Golan, Baron-Cohen, Hill, & Golan, 2006) in autistic individuals.

In addition to this marginal effect for poorer FER abilities, autistic adults demonstrated increased gaze to the mouth compared to NT adults. Contrary to predictions however, no significant group difference in fixation time to the eye region was observed. In contrast to previous studies using static representations of emotions to examine FER, with atypical gaze most often observed to the eyes (Black et al., 2017; Harms et al., 2010), the present findings suggest that when complex, dynamic emotional concepts are considered, the primary difference observed in autistic individuals may pertain to the mouth region. Increased gaze to the mouth has been observed within the wider body of literature examining social attention in autistic individuals, however, similar to the FER literature, these findings are not consistently observed (Guillon et al., 2014). Taken together, the nature of the stimuli may likely play an integral role in the elicitation of gaze-based differences (Guillon et al., 2014).

Increased gaze to the mouth may indicate altered prioritisation of visual information, with this region arguably more physically salient and exhibiting a larger degree of movement than other facial features (Klin, Jones, Schultz, Volkmar, & Cohen, 2002). Previous research

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has found that rather than prioritising information based on social salience (i.e. eyes), autistic individuals may prioritise features based on other criteria, such as physical salience (i.e. motion) (Klin et al., 2002). This gaze behaviour during FER may have been elicited in the current study due to the movement inherent in the stimuli, with these effects being unobservable in previous investigations using static stimuli.

While these findings may provide insight into the mechanisms underlying FER difficulty in autistic individuals, limitations must be considered. Analysis was based on a relatively small sample and a modest selection of stimuli with an unequal number of positive, negative and neutral stimuli. Future research should seek to understand how gaze based differences to complex emotion may vary in accordance with emotional valence. Investigation of the functional role of core facial features during complex emotion processing via direct experimental manipulation or through combining eye tracking with neurophysiological measurement, such as electroencephalography would also be of interest.

Through this study, it is shown that the use of complex, dynamic stimuli elicited gaze behaviour less commonly documented in the current body of literature, namely increased gaze to the mouth. Inconsistency observed in gaze-based findings during FER may be due to differences in the stimuli and experimental paradigms, with future research required to confirm how gaze behaviour may differ in autistic adults when more ecologically FER valid stimuli are used. Findings based on such stimuli may be useful in ensuring findings have a direct practical relevance to the difficulties faced by autistic individuals.

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Notes

1. 'Autistic' is the terminology used to refer to individuals with a diagnosis of Autism Spectrum Disorder. This is one of the preferred terminologies of the Cooperative Research Centre for Living with Autism (Autism CRC), the world's first cooperative research centre focused on autism.

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Figure Captions

Figure 1. Proportion of fixation time to areas of interest

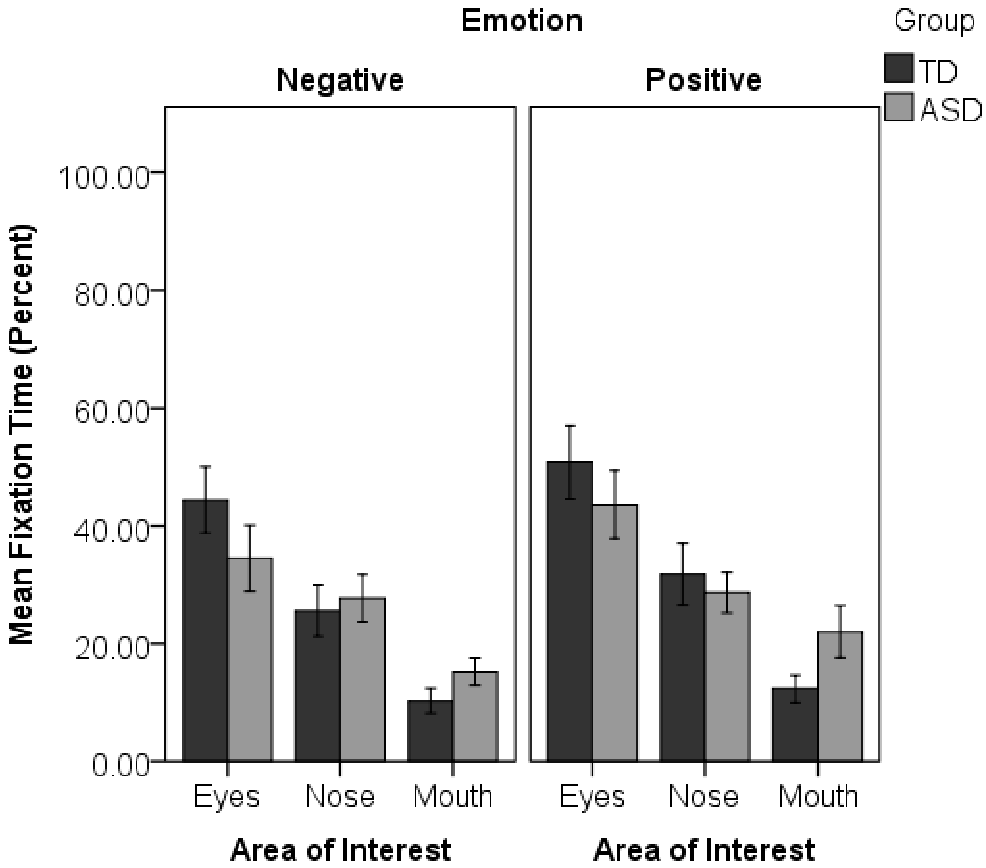

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Table 1.Participant Demographics

	NT[a] (n=20)	ASD[b] (n=20)	Test of significance
Age years (SD[c])	28.2 (9.5)	24.3 (7.9)	U=120.500, Z=-2.151, *p*=.030
Gender (Male: Female)	16:4	17:3	χ2 (1) =.173, p=0.677
WASI-2[d]			
VCI[f]	103.8 (12.0)	101.3 (12.6)	*t*(38)=.655, *p*=.516
PRI[g]	113.5 (14.6)	109.5 (18.4)	*t*(38)=.761, *p*=.451
FSIQ[h]	109.4 (11.4)	105.7 (12.9)	*t*(38)=.949, *p*=.349
TEA[e]			
Map Search 1 minute	11.1 (2.6)	7.6 (3.7)	t(38)=.3.479, p=.001
Map Search 2 minute	9.9 (2.7)	6.2 (4.2)	U=81, Z=-3.254, *p*=.001
Visual Elevator	12.4 (2.3)	10.6 (3.0)	U=128.500, Z=-2.032, *p*=.052
Timed Visual Elevator	10.8 (3.6)	9.2 (4.8)	U=158, Z=-1.142, *p*=.265
SRS-2[i]	35.1 (16.25)	81.5 (24.5)	*t*(37)=-6.874, *p*<.001
Tscore 59 and below (normal range)		5	
Tscore 60 – 65 (mild range)		5	
Tscore 66 – 75 (moderate range)		7	
Tscore 76 and above (severe range)		2	

[a]Neurotypical, [b]Autism Spectrum Disorder, [c]Standard Deviation, [d]Wechsler Abbreviated Scale of Intelligence -2, [e]Test of Everyday Attention, [f]Verbal Comprehension Index (composite score) from WASI-2, [g]Perceptual Reasoning Index (composite score) from

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WASI-2 , [h]Full Scale Intelligence Quotient (composite score) from WASI-2, [i]Social Responsiveness Scale-2

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Supplementary Information

Given that autistic and Neurotypical (NT) groups were found to differ on age and the Test of Everyday Attention (TEA) (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994), follow up analyses were conducted to assess whether age or TEA performance may have influenced FER or gaze variables, independent of group differences. Partial correlations examining the effect of age and TEA performance on accuracy and gaze variables were calculated while controlling for group. No significant correlations were found between age and accuracy or fixation time to any Area of Interest (AOI) $r(37)<.14$, $p>.41$ (supplementary table 1). Further, no significant correlations emerged between fixation time or accuracy and TEA scores $r(37)<.23$, $p>.16$ (supplementary table 1). Results suggest that neither age nor TEA scores were likely to influence the present findings.

Supplementary table 1. Partial correlations between accuracy, fixation time, age and Test of Everyday Attention (TEA) sub-tests.

	Age		TEA[a] Map Search 1 minute		TEA Map Search 2 minute		TEA Visual Elevator		TEA Visual Elevator timed	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Accuracy (%)	-.01	.97	-.07	.67	.06	.72	.11	.52	-.11	.5
Eyes (fixation time)	.14	.41	07	.66	.17	.31	.23	.16	-.16	.45
Nose (fixation time)	-.10	.53	<.01	.98	-.13	.44	-.14	.4	.13	.42
Mouth (fixation time)	-.09	.58	-.05	.65	-.01	.96	-.05	.74	.18	.26

[a]Test of everyday attention. Scores are based on Standard Score Equivalent (SSE).

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