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Atypical perception of affective prosody in Autism Spectrum Disorder

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ABSTRACT

Autism Spectrum Disorder (ASD) is characterized by impairments in language and social–emotional cognition. Yet, findings of emotion recognition from affective prosody in individuals with ASD are inconsistent. This study investigated emotion recognition and neural processing of affective prosody in high-functioning adults with ASD relative to neurotypical (NT) adults. Individuals with ASD showed mostly typical brain activation of the fronto-temporal and subcortical brain regions in response to affective prosody. Yet, the ASD group showed a trend towards increased activation of the right caudate during processing of affective prosody and rated the emotional intensity lower than NT individuals. This is likely associated with increased attentional task demands in this group, which might contribute to social–emotional impairments.

1. Introduction

To humans, voices bear a special significance (Blasi et al., 2011). Besides communicating verbal content, voices also communicate extra-verbal information, allowing for inferences about the intentions and emotional states of the speaker. Meanwhile, language impairments and difficulties with social and emotional communication are key characteristics of Autism Spectrum Disorders (ASD) (APA, 2000; Lord et al., 2000). Delayed language development is one of the earliest signs of ASD (De Giacomo and Fombonne, 1998; Wetherby et al., 2004), and language abnormalities, such as abnormal tone of voice or atypical stress patterns, ranging from monotonic, emotion-less speech to exaggerated intonation, pitch or volume affect large proportions of individuals with ASD throughout life (Ghaziuddin and Gerstein, 1996; Shriberg et al., 2001; Simmons and Baltaxe, 1975). Prosodic impairments are part of most clinical screening instruments for ASD (Lord et al., 2000; Lord et al., 1994; Sparrow et al., 1984), and there is a strong correlation between prosodic abnormalities and social and communicational difficulties in people with ASD (Paul et al., 2005). Thus, better knowledge of language processing and in particular processing of affective prosody in individuals with ASD is central for a better understanding of their impairments in social–emotional communication.

Emotions in speech are conveyed through affective prosody, which consists of variations in pitch, intensity, and duration (Fruhholz et al., 2012). In neurotypical (NT) individuals, language and specifically affective prosody are processed in fronto-temporal brain networks, including the temporal regions along the superior temporal gyrus/sulcus, and frontal regions in the inferior frontal gyrus and orbitofrontal gyrus (Buchanan et al., 2000a; Fruhholz and Grandjean, 2012; Kotz et al., 2013; Leitman et al., 2010; Schirmer and Kotz, 2006). In addition to this, affective prosody is associated with activity in subcortical brain structures, such as the amygdala and the basal ganglia (Fecteau et al., 2007; Grandjean et al., 2005; Wiethoff et al., 2009). While semantic content is typically processed more in the left brain-hemisphere, affective prosody seems to be processed more in the right hemisphere in NT individuals (Bulman-Fleming and Bryden, 1994).

Typically developing children are capable of perceiving and understanding affective prosody from a very early age, and seem to learn this automatically (Blasi et al., 2011). However, for individuals with ASD, this extra-verbal aspect of communication seems to pose a much greater challenge (McCann and Peppe, 2003). Meanwhile, findings from behavioral studies of affective prosody recognition in ASD individuals are mixed. In a large sample of high-functioning children with ASD, Peppe et al. (2007) described systematic deficits in both perception and production of affective prosody in single words. In addition, Philip et al. (2010) investigated emotion recognition in facial expressions, body movements, and speech in a group of adults with ASD, and found a core deficit in emotion recognition affecting all three stimulus-domains, suggesting that prosodic deficits are linked to a broader social–emotional impairment in individuals with ASD. Similar difficulties in recognizing affective prosody and decoding mental states from

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affective prosody are reported elsewhere (Golan et al., 2007; Heaton et al., 2012; Hobson, 1986; Lindner and Rosen, 2006; Mazefsky and Oswald, 2007). However, impairments in emotion recognition from affective prosody are often correlated with verbal intelligence (Golan et al., 2007; Lindner and Rosen, 2006; Mazefsky and Oswald, 2007), suggesting that impairments in affective prosody might be linked to language impairments rather than to ASD per se. Consistent with this, several studies have demonstrated intact emotion recognition from affective prosody particularly in groups matched on mental-age/verbal IQ (Boucher et al., 2000; Brennand et al., 2011; Chevallier et al., 2011; Grossman et al., 2010; Jones et al., 2011; Loveland et al., 1997; Ozonoff et al., 1990), and in high-functioning individuals with ASD (Doyle-Thomas et al., 2013; Heikkinen et al., 2010; O'Connor, 2007). However, there seem to be an effect of stimulus complexity on emotion recognition abilities in individuals with ASD. Both O'Connor (2007) and Doyle-Thomas et al. (2013) reported equivalent emotion recognition from voice stimuli in high-functioning individuals with ASD and NT participants when stimuli were presented in isolation, but impairments in the ASD group when the voice stimuli were presented alongside emotional faces. This points towards more subtle, but significant, emotion recognition difficulties in high-functioning individuals with ASD.

Despite the large number of behavioral studies investigating affective prosody in ASD, relatively few have looked at neural processing of basic emotions from affective prosody in individuals with ASD compared to NT individuals. Eigsti et al. (2012) investigated angry prosody in a group of high-functioning adolescents with ASD using functional magnetic resonance imaging (fMRI) during an implicit task where no emotion identification was required. They found that NT individuals showed stronger activation in the left inferior frontal gyrus, while the ASD group showed more widespread brain activation, which Eigsti et al. (2012) suggest reflect a less automatic processing of angry prosody, and a higher reliance on cognitive control in the ASD group. The study by Eigsti et al. (2012) is the only fMRI study which directly investigates neural processing of basic emotions in individuals with ASD. However, they only looked at angry prosody. Thus, the brain regions involved in the processing of affective prosody other than anger remain to be investigated in individuals with ASD. Clearer knowledge in this area is essential for understanding ASD individuals' impairments in language and social–emotional processing. Thus, the aim of the present study was to compare the neural activity to happy, sad and neutral prosody in high-functioning adults with ASD and NT adults, matched on age, gender, full-scale IQ and verbal IQ.

2. Methods

2.1. Participants

A total of 43 participants were included in the study, and 23 of these had a formal diagnosis of ASD. Participants with ASD were recruited through the National Autism and Asperger's Association, assisted living services for young people with ASD, and specialized educational facilities. The structural MRI of three participants with ASD showed abnormal ventricular enlargement (this is not an uncommon finding see Gillberg and Coleman, 1996) and were excluded before data analysis was begun. One ASD participant was unable to relax in the scanner and thus did not complete the testing. Consequently, a total of 19 high-functioning adults with ASD (2 females, 17 males) and 20 NT adults (2 females, 18 males) were included in the data analysis.

All participants were right-handed and native speakers of Danish, with normal hearing. Groups were matched on gender, age, IQ, and verbal IQ (Table 1). All participants were IQ-tested using Wechsler's Adult Intelligence Scale (WAIS-III; Wechsler, 1997), and filled out the adult version of the Autism Spectrum Quotient (AQ) (Baron-Cohen et al., 2001). The AQ provides a measure of autistic traits from 0 to 50, and from 0 to 10 on five subscales (social impairments, attention to detail, attention switching, impaired imagination and communication) in high-functioning individuals with ASD as well as in NT individuals. None of the NT participants had any history of neurological or psychiatric illness. All participants with ASD carried a previous formal diagnosis of ASD, which were supported by the Autism Diagnostic Observation Schedule (ADOS-G (Lord et al., 2000)) at the time of the study. All participants with ASD were invited in for the ADOS testing after the brain scanning session, but unfortunately five participants were unable to come back for testing due to long transportation, or because they needed special assistance. Thus a total of 14 participants with ASD completed ADOS testing (Table 2), of these 14 individuals two did not meet the cut-off criteria of 7 (1 female, ADOS score = 5; 1 male, ADOS score = 3). Nonetheless, all participants with ASD were previously diagnosed by specialized psychiatrists and we were given access to their medical records to confirm diagnoses. All ASD participants were medication naive and did not have any comorbid psychiatric disorders. All participants gave written informed consent and were compensated for their time and transportation expenses. The study was approved by the local ethics committee and was in accordance with the Helsinki Declaration.

2.2. Stimuli

The stimuli used during scanning were semantically non-emotional sentences (e.g. "if you go grocery shopping later will you please buy me 1 liter of milk and 10 eggs, I feel like baking a cake today — maybe Ill make muffins") in Danish. Stimuli were vocal recordings of 12 s duration. Each sentence was recorded with happy, sad, and neutral prosody. Stimuli consisted of both male and female voices recorded from students at the Acting Academy in Aarhus, Denmark. To validate the stimuli they were piloted on a group of NT adults (N = 12) before the fMRI-study. Stimuli were selected from a sample of 90 stimuli, comprised of a sample of 30 sentences recorded with happy, sad and neutral prosody.

Table 1
Subject characteristics

	ASD N = 19 (2♀)	NT N = 20 (2♀)	t-value p-value
Age in years (SD/range)	26.16 (5.6/20–36)	24.45 (4.6/19–41)	0.92 *ns*
Full-scale IQ[a] (SD/range)	108.32 (14.56/78–135)	114.50 (12.4/92–137)	−1.58 *ns*
Verbal IQ[b] (SD/range)	112.68 (23.7/74–186)	118.30 (13.8/90-143)	−1.05 *ns*
AQ[c] total mean (SD)	28.84 (7.43)	16.05 (5.93)	5.96 <.001

SD = standard deviation. *ns* = not significant at $p < 0.05$.
[a] WAIS-III full-scale (Wechsler, 1997).
[b] Verbal IQ from WAIS-III.
[c] The autism spectrum quotient (Lord et al., 2000).