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Auditory processing and sensory behaviours in children with autism spectrum disorders as revealed by mismatch negativity

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ABSTRACT

Sensory dysfunctions may underlie key characteristics in children with Autism Spectrum Disorders (ASD). The current study aimed to investigate auditory change detection in children with ASD in order to determine event-related potentials to meaningless and meaningful speech stimuli. 11 high functioning boys with a diagnosis of autism spectrum disorders (mean age = 13.0; *SD* = 1.08) and 11 typically developing boys (mean age = 13.7; *SD* = 1.5) participated in a mismatch negativity (MMN) paradigm. Results revealed that compared to TD controls, the children with ASD showed significantly reduced MMN responses to both words and pseudowords in the frontal regions of the brain and also a significant reduction in their activation for words in the Central Parietal regions. In order to test the relationship between sensory processing and auditory processing, children completed the Adult and Adolescent Sensory Profile. As predicted, the children with ASD showed more extreme sensory behaviours and were significantly higher than their typically developing controls across three of the sensory quadrants (sensory sensitivity, low registration and sensory avoidance). Importantly, only auditory sensory sensitivity was able to account for the differences displayed for words in the frontal and central parietal regions when controlling for the effect of group, revealing an inverse relationship of the higher sensory sensitivity scores the less activation in response for words. We discuss how the expression of sensory behaviours in ASD may result in deficient neurophysiological mechanisms underlying automatic language processing.

1. Introduction

Abnormalities in auditory processing are one of the most commonly reported sensory processing impairments in children across the autism spectrum (Kellerman, Fan, & Gorman, 2005; Nieto Del Rincon, 2008; Samson et al., 2006). Children with an Autism Spectrum Disorder (ASD) consistently show atypical behaviours in response to auditory stimuli. Examples of these atypical behaviours include placing their hands over ears to attenuate sounds and/or a constant preoccupation with particular noises in the environment (Baranek, David, Poe, Stone, & Watson, 2006; Kern et al., 2006; Kientz & Dunn, 1997; Tomchek & Dunn, 2007).

Whilst the causes and consequences of atypical auditory sensory processing remain poorly understood, these difficulties do not reflect a general deficit in auditory processing. Previous research has consistently found that individuals with autism not only perceive music well but also outperform their peers in pitch discrimination (Heaton, 2003, 2005; Heaton, Hermelin, & Pring, 1998; Mottron, Peretz, & Menard, 2000; O'Riordan and Passetti, 2006) and in the perception of the detailed structure of segments of melodies (Bonnel et al., 2003). This high discrimination is in marked contrast to the deficits observed in their speech-like perception. For example, they have been shown to have particular difficulties processing speech in background noise, as demonstrated by high speech perception thresholds and poor temporal resolution and frequency selectivity (Alcántara, Weisblatt, Moore, & Bolton, 2004). Deficits in processing speech prosody have also been observed (Kujala, Lepistö, Nieminen-von Wendt, Näätänen, & Näätänen, 2005; McCann & Peppe, 2003).

One feature of ASD may be a speech-specific attentional deficit in orienting towards the features of sounds such as pitch, at the expense of the speech properties such as its meaning, leading to

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an attentional bias for non-speech information (Allen & Courchesne, 2003). Thus, one possible explanation for the pattern of behavioural findings that indicates co-occurring unimpaired musical and pitch perception, is that a general bias towards non-vocal information results in enhanced non-linguistic stimuli (Jarvinen-Päsley, Pasley, & Heaton, 2008).

Children with ASD appear to have particular difficulties when requiring automatic attention, showing an inability to automatically shift their attention to changes in sounds falling outside of their attention spotlight, unless they are specifically requested to do so (Dunn, Gomes, & Gravel, 2008). Consequently abnormal automatic processing can be related to many of the key characteristics observed in ASD, such as failing to notice important auditory information in the environment (Marco, Hinkley, Hill, & Nagarajan, 2011). Automatic processing has also been linked specifically to language development, mainly semantic organisation. If children with ASD are unable to automatically process information outside of their attention spotlight, likely results would be memorisation of isolated facts of schemas but poor organisation of semantic material, resulting in a weak understanding of the relationships among concepts. This idea is given further support by the many studies showing impairments in the understanding of language in context in individuals with ASD (e.g. Dunn & Bates, 2005; Toichi & Kamio, 2001).

Within the auditory modality, attentional switching has typically been tested using a mismatch negativity (MMN) component of the auditory event-related potential (ERP). The MMN is a response to a deviant within a sequence of otherwise regular stimuli and can occur in any sensory stem, but has most frequently studied for audition and vision. The auditory MNN can occur in response to deviance in pitch, intensity or duration. The MMN is elicited by any perceptible change in the auditory input even when the subject is not attending to sounds. Its amplitude and latency is related to how different the deviant stimulus is from the standard, but has also been shown to closely correlate with the individual's behavioural discrimination skills (Amenedo & Escera, 2001; Kujala, Kallio, Tervaniemi, & Näätänen, 2001; Novitski, Tervaniemi, Huotilainen, & Näätänen, 2004), making the MMN a feasible tool for evaluating sound-discrimination abilities.

Neural processing of speech and vocal sound, but not tonal and environmental sounds, has consistently been shown to be abnormal in individuals with autism relative to typically developing controls using the MMN paradigm (Gervais et al., 2004; Čeponienė et al., 2003). It is often reported that a reduced MMN is observed in ASD when requiring passive responses. For example, Dunn et al. (2008) carried out a study looking at automatic and active processing of simple stimuli using the MMN paradigm and found that amplitudes of MMN in children with autism was significantly smaller than in children with typical development (Kuhl, Conboy, Padden, Nelson, & Pruitt, 2005; Seri, Cerquiglini, Pisani, & Curatolo, 1999).

The present study aimed to test whether high functioning children with a diagnosis of ASD were impaired in auditory discrimination of speech sounds using an MMN paradigm with two types of deviants, words and pseudowords. This paradigm allows the recording of cortical responses to words and pseduowords in a constantly varying auditory environment, and is thus more similar to the discrimination challenges posed by natural speech. More specifically, this study aimed to assess whether a relationship existed between sensory behaviours and underlying brain activity for processing speech properties of acoustically matched stimuli.

Although other studies have considered differences between speech and non-speech stimuli, few studies have addressed the influence of semantic content of the stimuli using a MMN task. When considering that many children with ASD have difficulties processing language, one could assume that this would be reflected in a reduction of MMN using real, meaningful words compared to pseudowords. Previous studies have suggested that there exists a greater focus towards perceptual aspects of speech sounds in autism (Lepistö et al., 2008; Samson et al., 2011), which may contribute to difficulties in processing meaningful speech sounds. Importantly, it was anticipated that atypical auditory sensory processing in ASD would predict deviants across an MMN paradigm more strongly for meaningful words compared to pseudowords.

2. Method

2.1. Participants

Children with Autism Spectrum Disorders (ASD) and typically developing control participants (TD) were recruited through local mainstream schools. Twelve children with a diagnosis of autism spectrum disorders were recruited and took part in the study and were paid for their participation. However one child was female and was not included in the final analysis in order to match for gender. Eleven boys aged 11–16 years with a diagnosis of Autism Spectrum Disorder—9 subjects with diagnosis "High Functioning Autism" and 2 with Asperger's Syndrome—and 11 typically developing boys were included in the final analysis. Their ages ranged from 11 years 1 month to 16 years (mean age = 13 years; SD = 1.08) in the ASD group and ages ranged from 11 years 11 months to 15 years 8 months (mean age = 13.7 year; SD = 1.5) in the control group. All children were native monolingual speakers of English. Their parents confirmed that partaking children did not suffer from any hearing problems or any other psychopathological or neurological disorders, and had not suffered from such a disease in the past. Children were matched for verbal and nonverbal IQ as well as for handedness (Oldfield, 1971). Details of participant characteristics are displayed in Table 1.

The Autism Diagnostic Observation Schedule Generic (ADOS-G; Lord et al., 2000) was carried out on the clinical group to confirm their diagnosis of autism and to gain additional information about their social and language patterns of behaviour. The ADOS-G was carried out by researchers trained to use it for research purposes. The protocol consists of a series of structured and semi-structured tasks that involve social interaction between the examiner and the participant. All ASD participants had an unambiguous clinical diagnosis of autistic disorder or Asperger's syndrome according to DSM-IV criteria, and scored above threshold for ASD on the ADOS-G diagnostic algorithm. Mean and standard deviations for the three factors on the ADOS with cut-off scores: Communication = 6.54 (1.96); Reciprocal Social Interaction = 9.09 (3.48); Communication and Social Interaction total = 15.63 (5.33). None of the children had identifiable medical conditions underlying their ASD.

2.2. Materials

Clinical and behavioural data were collected from all children (ASD and TD groups) including the following measures: The Adolescent/Adult Sensory Profile Questionnaire (Brown & Dunn,

Table 1
Psychometric data for ASD and TD children with differences between groups.

	Group		Difference	p Value
	ASD(N = 11)	TD (N = 11)	t (20)	
Age in years	13.0 (1.08)	13.7 (1.5)	1.37	.65
Verbal IQ	100.9 (10.4)	99.7 (18.2)	.75	.87
Non-verbal IQ	97.4 (12.7)	93.4 (12.8)	.19	.21
Laterality quotient	73.25 (13.6)	90.0 (6.32)	3.69	<.001

Note: Standard deviations are in parenthesis.