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Review

Auditory processing in autism spectrum disorder: A review

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ABSTRACT

For individuals with autism spectrum disorder or 'ASD' the ability to accurately process and interpret auditory information is often difficult. Here we review behavioural, neurophysiological and imaging literature pertaining to this field with the aim of providing a comprehensive account of auditory processing in ASD, and thus an effective tool to aid further research. Literature was sourced from peer-reviewed journals published over the last two decades which best represent research conducted in these areas. Findings show substantial evidence for atypical processing of auditory information in ASD at behavioural and neural levels. Abnormalities are diverse, ranging from atypical perception of various low-level perceptual features (i.e. pitch, loudness) to processing of more complex auditory information such as prosody. Trends across studies suggest auditory processing impairments in ASD are most likely to present during processing of complex auditory information and are more severe for speech than for non-speech stimuli. The interpretation of these findings with respect to various cognitive accounts of ASD is discussed and suggestions offered for further research.

Contents

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1. Introduction

For many of us, the ability to communicate and interact with others is an intuitive process and requires limited effort. However, for individuals with an autism spectrum disorder (ASD), communicating with and understanding others is often difficult.

Simply defined, ASD is a spectrum of neurodevelopmental disorders characterized by qualitative impairments in social interaction and communication, engagement in repetitive behaviours and reliance on routine. Standard diagnostic manuals such as the DSM-IV (APA, 1994) and ICD-10 (WHO, 1992) have divided ASDs into different subtypes of which Autistic Disorder (or autism) and Asperger's syndrome (AS) are the most commonly studied. The symptomatology of Autism and AS are similar, however in contrast to autism, individuals with AS typically function at the higher end of the spectrum (Wing, 1981). Furthermore, a diagnosis of AS is only given in the absence of significant language and/or cognitive delay (Attwood, 1998; Wing, 1981).

Several cognitive theories have been used to explain communication difficulties in ASD. These can be separated into a) those which propose a primary impairment in social cognition and b) those that view ASD as a more general difference affecting processing of both social and non-social information.

Social theories have centred on the idea that ASD is reflective of impaired understanding of emotions and the ability to attribute mental states (intentions, knowledge and beliefs) to others (Dawson et al., 2005; Klin et al., 2003; Schultz, 2005). Support for these theories is gained from numerous studies which have observed evidence for atypical processing of social stimuli in both the auditory and visual modalities (Baron-Cohen, 1989; Baron-Cohen et al., 2001; Dawson et al., 1998, 2004, 2005; Rutherford et al., 2002). Evidence ranges from impaired recognition of facial expressions to difficulties comprehending language. There are however several problems with this theory. For example, many research groups have observed impaired performance on both social and nonsocial tasks while others have failed to even observe evidence for a social processing impairment. Moreover, not all researchers have directly compared processing of social and non-social stimuli in the same study (see Mottron et al., 2006; O'Connor and Kirk, 2008 for reviews).

General theories are predominantly based on perceptual differences in ASD resulting from enhanced processing of local information or detail. The Weak Central Coherence theory originally described by Frith (1989) suggests ASD is the result of weak central coherence (WCC), a reduced tendency to integrate local information into a coherent or 'global' whole, coupled with increased attention to detail. Enhanced perception of detail would potentially result in reduced attention to global information and thus a decreased tendency to process information in context. This reasoning is consistent with several past studies which have suggested individuals with autism may have difficulty shifting attention from local to more global levels (Plaisted et al., 1999; Rinehart et al., 2001). The Enhanced Perceptual Functioning (EPF) theory suggests ASD results from enhanced perception of simple, low-level perceptual information in the absence of a global impairment (Mottron et al., 2006). A related theory, which has more specifically been used to describe auditory processing in ASD, is the Neural Complexity Hypothesis or NCH (Bertone et al., 2005; Samson et al., 2006). This hypothesis advocates for enhanced perception of simple, low-level auditory stimuli in ASD together with impaired perception of more complex auditory information. Together, these theories offer potential explanations as to why individuals with ASD tend to outperform typically developing subjects on tasks heavily dependent on local processing (see Happé and Frith, 2006; Mottron et al., 2006 for reviews).

Past research has found substantial evidence for atypical processing of auditory information in ASD, the specifics of which remain the focus for this review. Differences are diverse, affecting a wide range of auditory processing skills. Evidence for abnormal processing has been observed using a variety of experimental paradigms with both speech and non-speech stimuli. Studies range from investigations into the various physical properties of acoustic stimuli, (i.e. pitch and loudness) to perception of more complex auditory information such as prosody.

Surprisingly, given the volume of research in this field, there are currently no comprehensive reviews that have collectively examined the underlying behavioural, neuroimaging, neuroanatomical and neurophysiological correlates associated with auditory processing in ASD. The motivation behind this manuscript was to incorporate these aspects into a review with the purpose of producing a comprehensive account of auditory processing in ASD, with the aim to facilitate greater understanding amongst researchers and health professionals. Ultimately this will lead to further research and consequent development of therapies designed to improve processing of auditory information in ASD. Specific aims are (a) to provide an effective tool to aid future research in this field and (b) educate health and educational professionals on the current status of auditory processing in ASD, thus enabling them to work more effectively with this population.

In the following sections behavioural, neuroimaging and neurophysiological research pertaining to the most extensively researched areas of auditory processing in ASD are reviewed. We begin with examination of the psychoacoustic and behavioural literature in this field. Areas discussed include perception of basic stimulus characteristics (i.e. pitch, loudness) to processing of more complex auditory information such as orientation to speech and non-speech stimuli, prosody perception and processing speech in noise. Neuroanatomical evidence for structural abnormalities in brain regions implicated in auditory processing are reviewed, followed by examination of neuroimaging research. These sections are followed by discussion of electrophysiological responses to speech and non-speech stimuli in ASD at brainstem and cortical levels. Finally, the implications of these findings to our general understanding of ASD are explored with suggestions offered for future research.

Given the considerable volume and breadth of research on this topic, it is simply not feasible to discuss all publications pertaining to auditory processing in ASD here. To address this issue only literature published in peer-reviewed journals over the last two decades which best represent findings obtained from behavioural, neuroimaging and neurophysiological studies are examined. Participants in studies discussed in this review had normal peripheral hearing at the time of testing unless mentioned otherwise. All articles were sourced from the PubMed and PsycInfo online databases using a wide array of keywords pertaining to auditory processing (see Appendix A), in conjunction with the keywords 'autism' and/or 'Asperger's syndrome'.

2. Auditory processing in ASD: behavioural research

The behavioural literature pertaining to auditory processing in ASD is relatively extensive, ranging from psychoacoustic experiments investigating basic stimulus characteristics such as pitch to explicit recognition of complex auditory information pertaining to prosodic cues. The following sections focus on various aspects of auditory processing that differ between individuals with ASD and typically developing subjects. Sections are arranged hierarchically, commencing with examination of pitch and loudness to processing of more complex stimulus properties such as affective prosody and perception of speech in background noise.