Behavioural Brain Research 338 (2018) 118–127

Contents lists available at ScienceDirect

Behavioural Brain Research

journal homepage: www.elsevier.com/locate/bbr

Research report

Speech perception in autism spectrum disorder: An activation likelihood estimation meta-analysis

Ana Tryfon[a,b,*], Nicholas E.V. Foster[a], Megha Sharda[a], Krista L. Hyde[a,b]

[a] International Laboratory for Brain, Music, and Sound Research (BRAMS), Pavillon 1420 Mont-Royal, Department of Psychology, University of Montreal, C.P. 6128, Succ. Centre-Ville, Montreal, Quebec, H3C 3J7, Canada

[b] Faculty of Medicine, McIntyre Medical Building, McGill University, 3655 Sir William Osler, Montreal, Quebec H3G 1Y6, Canada

ARTICLE INFO

Keywords:
Autism spectrum disorder
Activation likelihood estimation
Speech perception
Functional magnetic resonance imaging (fMRI)

ABSTRACT

Autism spectrum disorder (ASD) is often characterized by atypical language profiles and auditory and speech processing. These can contribute to aberrant language and social communication skills in ASD. The study of the neural basis of speech perception in ASD can serve as a potential neurobiological marker of ASD early on, but mixed results across studies renders it difficult to find a reliable neural characterization of speech processing in ASD. To this aim, the present study examined the functional neural basis of speech perception in ASD versus typical development (TD) using an activation likelihood estimation (ALE) meta-analysis of 18 qualifying studies. The present study included separate analyses for TD and ASD, which allowed us to examine patterns of within-group brain activation as well as both common and distinct patterns of brain activation across the ASD and TD groups. Overall, ASD and TD showed mostly common brain activation of speech processing in bilateral superior temporal gyrus (STG) and left inferior frontal gyrus (IFG). However, the results revealed trends for some distinct activation in the TD group showing additional activation in higher-order brain areas including left superior frontal gyrus (SFG), left medial frontal gyrus (MFG), and right IFG. These results provide a more reliable neural characterization of speech processing in ASD relative to previous single neuroimaging studies and motivate future work to investigate how these brain signatures relate to behavioral measures of speech processing in ASD.

1. Introduction

Autism spectrum disorder (ASD) is a complex neurodevelopmental disorder characterized by atypical social communication and restrictive and repetitive behaviors [1]. Moreover, individuals with ASD often present atypical language profiles and auditory and speech processing [2]. For example, while typically-developing (TD) individuals are naturally attracted to the human voice, individuals with ASD have shown decreased attention and salience for voices [3–5]. Such atypical speech perception can lead to aberrant development of language and social-communication skills in ASD and thus serves as a potential biomarker to identify ASD in early childhood (for a review, see [6]). From this perspective, studying the neural mechanisms underlying speech perception in ASD can help to refine ASD phenotypes and has important implications for education and clinical intervention.

While various studies have examined the neural correlates of language processing in general in ASD versus TD, few studies have specifically examined auditory speech processing in particular. Moreover, the finding of mixed results across studies renders it difficult to find a reliable neural characterization of speech processing in ASD. The overall goal of the present study was to perform a quantitative meta-analysis of the functional neural basis of speech perception in TD and ASD by examining both common and distinct patterns of brain activation within and across these groups.

1.1. Neural correlates of speech perception in TD

The neural correlates of speech perception in TD have been summarized in the context of Hickok and Poeppel's [7] two-stream model for speech perception. They proposed that when speech is perceived, it first undergoes spectrotemporal processing in primary auditory cortices (e.g., Heschl's gyrus) before diverging from secondary auditory cortex in the superior temporal sulcus (STS) into a ventral and dorsal pathway. The ventral pathway maps sound onto lexical and semantic meanings and includes middle and inferior temporal gyri. The dorsal pathway maps sound onto articulatory representations, and includes predominantly left hemispheric areas such as posterior inferior frontal gyrus (IFG) and premotor cortex. Importantly, Hickok and Poeppel's

* Corresponding author at: International Laboratory for Brain, Music, and Sound Research (BRAMS), Pavillon 1420 Mont Royal, Department of Psychology, University of Montreal, C.P. 6128, Succ. Centre-Ville Montreal, Quebec, H3C 3J7, Canada.
E-mail address: ana.tryfon@mail.mcgill.ca (A. Tryfon).

http://dx.doi.org/10.1016/j.bbr.2017.10.025
Received 26 June 2017; Received in revised form 13 October 2017; Accepted 20 October 2017
Available online 23 October 2017
0166-4328/

model [7] notes bilateral but left dominant activation in speech perception. In line with Hickok and Poeppel's model, neuroimaging studies have found that speech perception in TD implicates a network of frontal and temporal brain regions including STS, superior temporal gyrus (STG), middle temporal gyrus (MTG), and IFG [8,9].

Recently, Turkeltaub & Coslett [10] conducted an activation likelihood estimation (ALE) meta-analysis of neuroimaging findings to quantify common and consistent patterns of neural activity for speech perception in TD. The ALE method is an algorithm for coordinate-based meta-analyses of neuroimaging data that is useful for converging results across multiple studies [11–13]. A common limitation of neuroimaging studies is their small sample size and therefore reduced reliability [14]. The ALE meta-analysis offers the advantage of pooling neuroimaging results across studies, thereby increasing the sample size and the ability to localize consistent patterns of activation of a particular paradigm [12,15]. Turkeltaub & Coslett [10] found clusters of brain activation in bilateral STG and STS, right MTG and left middle frontal gyrus for speech versus nonspeech stimuli in TD. In a subsequent ALE meta-analysis, LaCroix et al. [16] investigated differences and commonalities of brain activation between speech and music in TD. Compared to music tasks, speech significantly activated brain regions associated with lexical semantic processing such as posterior STS regions and IFG (pars triangularis). Taken together, studies in TD have shown that speech processing implicates a network of frontal and temporal brain regions including STG, IFG and MTG.

1.2. Neural correlates of speech perception in ASD

Previous work has shown that speech processing in ASD and TD relies on both common and distinct neural mechanisms, particularly in fronto-temporal brain areas. For example, ASD participants who passively listened to speech stimuli have shown reduced activation in left IFG [17,18] and bilateral superior temporal regions [19,20] relative to TD. In an active task context, adults with ASD have shown decreased activation in left STG and left precentral gyrus/rolandic operculum when asked to rate the emotion felt by the speaker [21]. Adolescents with ASD have also shown atypical activation in response to angry statements and questions, where increases in activation were found in more distributed areas such as right STG and middle frontal gyrus [22]. Just et al. [23] found that participants with ASD had greater brain activity in the left STG and less activity in left IFG compared to TD participants on a sentence comprehension task. Wang et al. [5] found that children with ASD showed greater activity in prefrontal and temporal regions compared to TD individuals on a speech task in which participants had to identify whether speech stimuli were ironic or sincere based on either contextual cues or prosodic cues.

Recently, Herringshaw et al. [24] conducted an ALE meta-analysis of neuroimaging findings to quantify common and consistent patterns of neural activity differences associated with language processing in ASD versus TD. Tasks included in this study examined semantic processing, sentence comprehension, processing figurative language, and speech production in both the auditory and visual domains. Overall, results showed largely overlapping patterns of language-related activation in ASD and TD groups particularly in bilateral STG and IFG. However, the ASD group also showed some atypical brain activation and this was related to task performance. For example, the ASD group exhibited increased activation in right STG and IFG on tasks where they had poorer performance, and increased left lingual gyrus activation where performance was equivalent to TD. These results are important because they suggest that language processing in ASD is dependent on the complexity of the task demands. In addition, and of particular interest for our present study, the Herringshaw et al. [24] meta-analysis also included a supplementary analysis of only auditory-based language studies ($n = 8$). Again, the results showed largely overlapping patterns of language-related brain activation in ASD and TD, with some differences in bilateral STG, left transverse temporal gyrus (TTG), insula, right MTG, and cerebellum. However, these results should be interpreted with caution given that only 8 studies were included in this sub-analysis.

Taken together, previous work has shown that individuals with ASD show mostly common but also some distinct brain activation compared to TD in response to speech stimuli. However, mixed results and differences in the speech tasks used across these studies render it challenging to determine a consistent pattern of brain activation for speech tasks in ASD.

1.3. Objectives and hypotheses

To complement previous work that has examined broader aspects of language (e.g., [24]), the main goal of the current study was to conduct a more focused ALE-analysis of the neural correlates of speech perception in ASD versus TD. Moreover, previous work has mainly focused on between-group contrasts of brain activation, highlighting particular brain regions with atypical activation in ASD versus TD. The present study included separate analyses for TD and ASD, which allowed us to examine patterns of within-group brain activation as well as both common and distinct patterns of brain activation across the ASD and TD groups. Specific aims were to identify patterns of functional brain activation of speech perception that were: 1) common within the TD group alone, 2) common within the ASD group alone, 3) common across the ASD and TD groups and 4) different between the ASD versus TD groups. Both TD and ASD participants were expected to show converging brain activation in speech-related areas such as STG, and IFG regions. However, distinct brain activation was also expected between groups for example with TD showing additional brain activation in higher-order frontal brain areas.

2. Methods

2.1. Criteria for study inclusion in ALE meta-analysis

In order to identify and include studies in this meta-analysis, we used Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement guidelines [25] to aid in standardizing systematic reviews. Studies included in this meta-analysis used functional magnetic resonance imaging (fMRI) or positron emission tomography (PET) neuroimaging methods to specifically examine the neural correlates of speech perception in ASD and TD individuals. In contrast to previous meta-analyses, the aim of the present study was to examine the neural bases of speech perception and thus visual and expressive language tasks were not considered. Using a computerized literature search through PubMed, and Scopus, peer-reviewed and published scientific papers were identified using following keyword combinations to identify neuroimaging studies that investigated speech perception: 1) “autism OR autism spectrum OR PDD (pervasive developmental disorder) OR Asperger”, AND 2) “fMRI OR PET OR neuroimaging”, AND 3) “speech OR voice OR prosody OR sentence comprehension OR pragmatic processing OR semantic processing”. We reviewed all functional neuroimaging papers published in English between years 1998 and August 2016. IRB approval was not necessary because analyses in this study did not involve collecting empirical data. All but one study (e.g., [26]) stated that they followed the IRB guidelines at their respective home institution. In order to meet inclusion criteria for the present meta-analysis, all studies: 1) used fMRI or PET data; 2) included both ASD and TD participant groups; 3) used whole-brain level analysis to obtain activation results; 4) reported results in standard stereotactic coordinates (i.e., Montreal Neurological Institute [MNI] or Talairach space); 5) included only contrasts that involved listening to speech sounds minus a baseline or rest so as to be able to isolate brain regions specifically involved in speech perception; and 6) were published in English. Initially, 109 articles were selected for full text review, 18 of which met the above inclusion criteria and were included in the present