Underlying Neural Causes of Autism Spectrum Disorder

Shelby Mills
smills@pugetsound.edu

Follow this and additional works at: http://soundideas.pugetsound.edu/soundneuroscience

Part of the Neuroscience and Neurobiology Commons

Recommended Citation
Available at: http://soundideas.pugetsound.edu/soundneuroscience/vol1/iss2/2
Underlying Neural Causes of Autism Spectrum Disorder
Shelby Mills

Abstract
Autism Spectrum Disorder (ASD) is an expansive disorder that affects aspects of behavior, social relations, communication skills, and more. What autism research lacks is a fundamental understanding of the underlying mechanisms that cause these symptoms. Autism is currently understood to be a behavioral disorder, and therefore it is important to establish the underlying brain functions that cause these deficits. A basic understanding of the neural underpinnings of ASD will allow for future research into more accessible and functional treatments for children with autism, specifically in their ability to functionally communicate. Further, this understanding may help to diagnose and treat ASD at an earlier age, which significantly increases a child’s chances of improving or recovering. The purpose of this paper is to collectively critique the research and treatments available in ASD in order to identify their important underlying neural causes.

Introduction
Autism Spectrum Disorder (ASD) affects 1 in 88 children, sparing no ethnic, racial, or socioeconomic groups [1]. Thrust into a school system that is often ill-prepared to accommodate this disorder, children with autism often find themselves drowning in a world that seems to make no sense to them, or that cannot seem to make sense of them.

As the name implies, patients with autism express a broad array of symptoms with significantly variable severities. According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV), patients with autism will express deficits in the realms of social functioning, behavioral deficits, and communicative difficulties. The DSM-IV recognizes a combination of some, but not necessarily all symptoms in determining autism as an appropriate diagnosis.

Autism Spectrum Disorder (ASD) manifests in such a wide variety of symptoms, which makes the understanding, diagnosing, and treating of autism-related speech disorders exceptionally difficult due to a constant and complex interaction between the social, behavioral, and communicative domains. Current research seeks to understand the symptoms of autism associated with each of these domains. However, what current research lacks is a strong, fundamental understanding of the underlying brain activity that causes these symptoms, or a way of applying this neural understanding to treatment plans for children with autism [2]. This paper collects and reviews the current neuroscience research in autism in order to highlight the weaknesses of current ASD treatment, and to develop a clinical intervention that has the potential to overcome these weaknesses. By studying communication deficits in autism with a broader lens that encompasses the fundamental neuroscientific underpinnings of ASD we can gain a better understanding of the disorder and develop more successful and accessible forms of treatment for all individuals living with ASD.

Speech and Language Deficits of ASD
Many of the same mechanisms and theories underlying the aforementioned social and behavioral impairments simultaneously contribute to the array of communication deficits experienced by children with autism. In order to understand exactly how autism affects communication abilities, it is imperative to understand the specific components of speech that are damaged.

Imitation plays a large role in the language development of typically developing children [3]. Throughout early language development children constantly take in and imitate the verbal input they receive while simultaneously “experimenting” with spontaneous vocalizations [3]. This allows children to develop socially acceptable speech that embodies the important components of speech such as prosody, pragmatics, and grammar. These are three crucial aspects of proper speech production that provide valuable insight into the language deficits experienced by children with high functioning autism (as will be addressed later, children with low functioning autism typically do not produce any speech at all).

Prosody functions at the sound level of speech. Prosodic qualities include such aspects as pitch, intonation, and stress [4]. More specifically, Shriberg et al. compartmentalize the functions of prosody into three distinct components: grammatical prosody, pragmatic prosody, and affective prosody [4]. Grammatical prosody functions to separate the meaning or tone of speech through sound. For example, the rising pitch at the end of a sentence helps to distinguish it as a question rather than a statement. Further, different stress patterns help to differentiate between the noun, address (a location), from the verb, add’ress (to call attention to). Pragmatic prosody refers to the more social aspect of conversation. Naturally when we speak, we tend to draw more attention to particular aspects of a conversation that are more important. Finally, affective prosody refers to the register changes and adjustments that are socially expected when addressing different speaking partners. A register simply refers to the person who is being addressed, such as a teacher, a peer, or a parent. Typically developing children learn very naturally to adjust their speech when addressing each of these titles to convey certain tones such as respect, formality, or comfort.

These three prosodic qualities are found to be frequently impaired in children with high functioning autism, and often show little improvement over time [4]. The speech of children with autism is often described as being excessively monotone, or overly exaggerated in stress and intonation, and there is a decreased amount of social understanding in the speech of children with autism [4]. These speech characteristics and difficulties are consistent with children with high functioning autism, but an even more difficult challenge is the general lack of speech production that is characteristic of children with low functioning autism. Children with low functioning autism suffer more exaggerated symptoms due to an inability to communicate through speech. This lack of verbal language permeates their social relationships and their school environment, leading them to a more isolated standard of living that can be as damaging as it is frustrating.

According to McGonigle-Chalmers et al., children with low functioning autism fall into three distinct categories of “nonverbal” that inevitably helps to identify the underlying neural mechanisms behind their severely impaired speech [3]. Children can be classified as nonverbal due to their inability to produce varied and expressive language, while still maintaining one or two-word phrases that are constantly repeated.
Other children attempt to produce speech, but their verbal outputs are incomprehensible to those around them. Finally, there are children that are incapable of producing original expressive speech, but constantly mimic and repeat the auditory input they receive, a stereotyped behavior known as "echolalia."

This lack of fluency in children with low functioning autism is often attributed to, along with many other interacting factors, a lack of coordinated motor function [3]. The neural mechanisms underlying this assertion can be observed in brain areas commonly believed to specifically control language production. Research into the speech production abilities of children with autism consistently returns to Brodmann areas 44 and 45 in the brain, more commonly referred to as Broca’s area [5]. Broca’s area, residing in the left hemisphere, is most commonly associated with language production. Lesion studies of this area show patients with exceptional difficulty in producing fluent speech, though their comprehension typically remains intact. For example, Paul Broca’s original patient, nicknamed “Tan,” was incapable of producing any word other than “tan,” although he was capable of understanding everything that was said to him [6]. Upon his death, an autopsy of Tan’s brain showed a distinct lesion in the area that thereafter was known as Broca’s area, lending support to the idea that this area of the brain is in large part responsible for fluent speech production, while also suggesting that speech comprehension occurs in a different area of the brain [6]. Further investigations show that the same area in the right hemisphere of the brain show activations during such activities as prosodic processing and response inhibition [5]. These abnormalities in Broca’s area underlie many of the communication disorders experienced by children with autism.

Further investigation of Broca’s area reveals a distinct deficiency in the pyramidal neurons, compared with the pyramidal neurons of typically developing children. Pyramidal neurons in Broca’s area, which function to help create connections throughout the prefrontal cortex, are consistently smaller in children with autism compared with control subjects [5], which would suggest a basic explanation for the communication deficits experienced by children with autism. Further fundamental differences in the neuronal architecture of the autistic brain can be observed. Along with a decrease in pyramidal neurons, ASD patients show an increase in the density of glial cells, or supportive cells with no neuronal function, as indicated by a microscopic examination of the cytoarchitecture of autistic brains [7]. The dysfunction observed in Broca’s area of children with autism leads to a very prominent theory of the overall communication deficits experienced, called the Disconnection Theory [2].

The disconnection theory holds that the frontal lobe of children with autism is generally disconnected with the rest of the brain [2]. The underlying problem, according to research, is that the frontal lobe is actually over-connected with itself and under-connected with other key areas of the brain. This theory is upheld by the finding that children with ASD tend to have enlarged brains, seemingly due to the excessive formation of connections that are never pruned in early development [8]. The disconnection theory is significant in its ability to explain the wide range of deficits occurring in the realm of speech, motor, and many other deficits [9].

However, this disconnection theory neglects to explain why music abilities tend to be preserved in children with autism, which creates an interesting paradox. Research shows that neural networks involved in both music and language production tend to
overlap significantly [10]. For example, in typically developing children, the left inferior frontal gyrus, which includes Broca’s area, is activated both during speech stimulation as well as music stimulation. However, during speech stimulation in children with autism, functional magnetic resonance imaging (fMRI) showed decreased activity in the left inferior frontal gyrus, but increased activation during music stimulation [10]. This shows that the neural system is still intact, just suffering from decreased activation.

Moving away from the more common disconnection theory, and outside of the cerebrum altogether, other theories of language dysfunction in ASD focus on activity in the cerebellum. Commonly understood to activate primarily during tasks of sensorimotor function, as well as balance, the cerebellum (specifically the posterior cerebellum) has recently been implicated in language processing due to its far-reaching connections with the cerebral cortex [11]. MRI studies of subjects with partial cerebellar agenesis (or atypical development) have demonstrated autism-like behaviors that include language deficits such as expressive language delay and dysfunctional prosody [11]. These results were replicated through the further study of patients with Tuberous Sclerosis (TS), a disease that causes lesions throughout vital organs including the brain. Researchers identified very specific autism-like behavioral outputs of the cerebellum when damaged [12]. Further studies show a decrease in the number of Purkinje cells (cerebellar communicator cells) in the cerebellum of patients with ASD [13].

With so many theories of underlying neuropathology in autism, very recently a more genetically based explanation for the speech deficits experienced in ASD has been developed. Located on chromosome 7q are three genes associated with language dysfunction in autism: the FOXP2 gene, the CNTNAP2 gene, and the WNT2 gene [14]. The FOXP2 gene is associated with deficits in oro-facial musculature, which is implicated in dyspraxia, or difficulty in articulating words due to decreased muscle function. The FOXP2 gene regulates the CNTNAP2 gene, which is implicated in nonsense word repetition. And finally, a deletion of the WNT2gene leads to specific language impairments. This evidence suggests that children with autism have very specific genetic indicators that account for the various symptoms experienced.

The speech and language deficits associated with ASD are perhaps the largest contributors to the overall difficulties in communication experienced by children with autism. Underlying deficiencies in cortical areas, such as Broca’s area, and connectivity within the frontal lobe, as well as the possible genetic markers identified by Lin et al., lead to daunting challenges in speech production and prosody [14]. The communication disorders associated with ASD are challenging both to research and to the success of the patient. In order to target these deficits, it is imperative to develop stronger diagnostic strategies that help to construct a full and complete profile of the child’s deficits (behavioral, social, speech, etc.) in order for the ASD child to receive and fully benefit from an accurate intervention strategy.

Speech/Language Therapy

Speech-language therapy is crucial to a child’s ability to communicate in a way that others can interpret and understand. This can be achieved through either verbal communication or through alternative forms of communication.
Speech-language therapy is designed specifically to target the specific speech deficits that may arise, including prosody, articulation, and fluency. This is extremely relevant to children with autism, as the National Research Council noted that one third to one half of children with autism are not capable of producing functional or fluent speech [15]. This statistic shows the need for alternative forms of communication in circumstances where verbal communication is beyond the grasp of the child with autism.

Alternative communication can take the form of gestural compensation, similar to the way that sign language functions for deaf children. A further alternative intervention called the Picture Exchange Communication System (PECS) helps to improve communication for the non-verbal child [15]. PECS functions to help children learn to communicate successfully through a system of pictures, but what research has shown is that PECS actually increases the length of communication elicited by children with autism, indicating not just a compensatory process of communication, but an improvement [15].

Speech-language therapy represents yet another aspect of autism that has yet to benefit from a neuroscience perspective. More so than behavioral outputs in autism, speech-language disorders can be more definitively tracked within the brain, specifically in Broca’s area and the cerebellum. Future research should target these areas, specifically to aid in supplementing the deficient neurons at work.

Conclusion
Current research in autism is expansive, revolving around many different treatments and interventions, all operating on different mechanisms. In order for treatment to improve, it is important to investigate how these interventions operate at the neural level. Having this fundamental understanding of ASD symptoms will help to develop more accurate and useful treatment strategies, in order to give children with autism the best chance at improving. Further, this neural understanding has the potential to give rise to earlier identification and earlier intervention.

References


