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The Brains behind Autism Spectrum Disorder: Exploring Emerging Elements of Potential Neurological Phenotypes

Eric Shyman*

St. Joseph's College, USA

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***Corresponding author:** Eric Shyman, St. Joseph's College, USA, Email: eshyman@sjcny.edu

Abstract

The identification and diagnosis of Autism Spectrum Disorder (ASD) has become an international educational and medical priority over the last two to three decades, resulting in a surge of research from a variety of perspectives. This brief, selective review of extant literature attempts to identify some major themes in the neurological study of ASD in order to help organize further research endeavors as well as inform educational and interventional decision making. The main areas addressed in this paper are sensory processing, social-emotional processing, and connectivity.

Introduction

With the identification of Autism Spectrum Disorder (ASD) creating an educational and medical exigencyglobally over the last two to three decades [1], there has been a surge in research from a variety of perspectives. While elements of epidemiological and etiological findings are highly debated, the field of neuroscience has contributed significantly to potential understanding of brain differences, as well as potential neurological phenotypes for individuals with ASD. Indeed, these findings are, and likely always will be, increasing works in progress. However, there have been some emerging categorical trends gaining evidence in the extant literature.

Neuroscience, particularly in the area of neurological imaging, has undergone significant advancements over the past two decades, allowing for considerable progress in understanding the potential neurology of ASD. While the specificity of each study varies, it appears to be quite clear that the brains of individuals with ASD consistently appear to be both structurally and functionally different from brains of non-autistic individuals, but also similar to one another [2-4]. Trends in the neuroscience research appear to point to at least three areas of consistency:

A. Issues with sensory processing.

B. Issues with social-emotional processing.

C. Issues with neural connectivity.

Sensory Processing, Social-Emotional Processing and Neural Connectivity

The first category in which there appears to be emerging neurological evidence of functional and structural difference for individuals with ASD is sensory processing. Overall, sensory processing allows individuals to receive and utilize information from the environment in a meaningful way. Individuals with ASD appear to be able to engage in this process, however do so in a vastly different manner and with vastly different outcomes than those without ASD. Sensory processing can involve the induction and use of any information related to one of the five senses. One study suggested that, among a sample of 281 children with ASD, 95 percent showed some level of dysfunction on the Short Sensory Profile overall score, and 92 percent on the subtests including under-responsivity of sensation seeking, auditory filtering, and tactile sensitivity [5].

A common area of research involving sensory processing in ASD is that of visual processing. More specifically, it appears that individuals with ASD process facial stimuli distinctly differently than individuals without ASD. Differences in facial recognition and visual processing are likely to result in a number of atypical behavioral and experiential patterns in areas such as social interaction, social and emotional memory, and certain types of skill retention [6,7]. One study that directly addressed the role that facial recognition may play in social modulation for individuals with ASD investigated 16 individuals with ASD matched with 16 control participants. Results indicated that while the non-social object (houses) were modulated by attention for both groups, the social object (face) was only modulated by attention for the control group. These results demonstrate a clear difference in both processing and social stimulation for individuals with ASD, possibly resulting from neurological differences [8].

Another study approaching sensory processing in a broader context investigated the specific patterns of sensory processing among 54 children with autism as it was associated with their display of adaptive behavior. Using a cluster analysis statistical process, the authors were able to determine three distinct sensory processing subtypes among the participants. Additionally, the researchers suggested that the evidence suggested sensory processing subtypes were predictors of both communicative competence and the occurrence of maladaptive behavior. This study lends credence to the idea that sensory processing is not an isolated issue, but, rather, is likely directly related to behavioral outplays of individuals [9].

Individuals with ASD also appear to show structural and functional neurological differences is social-emotional processing. Because it is common for individuals with ASD to demonstrate hyper-emotional or hypo-emotional responses to banal situations, advancement in the area of neural processing of the social emotional centers of the brain is of utmost importance.

As is the case with most neurological theories, there are a number of potential explanations for the difference in social-emotional processing. One common theory that is gaining evidence regards the centrality of dysfunction in the orbitofrontal-amygdala circuit, an area which is largely attributed to emotional regulation [10,11].

In one study, eight men with high-functioning autism were compared to eight control participants while engaging in an emotion recognition task involving facial emotional stimuli. The stimuli involved voice modulation as well as gender recognition. Positron Emission Tomography (PET) scans revealed marked differences in brain functioning in emotional regulatory areas; specifically, the frontal and fusiform areas as well as the temporal lobe, anterior cingulate, and thalamus [12].

An additional study compared 54 males with ASD, aged 8-25 years with a control group of 26 age and sex-matched participants. The researchers analyzed the participants' amygdala volume, judgement of facial expression, and eye tracking patterns. Results demonstrated that the size of the amygdala was connected to emotional processing. More specifically, participants with smaller amygadalae were slowest and least accurate in recognizing emotional facial expressions [13].

While some researchers are embracing location-based theories involving brain differences, others are furthering the notion of overall connectivity theories, suggesting that ASD is likely a result of hyper-connectivity in some regions and hypo-connectivity in others. Overall, this strain of theory posits that connections between particular neural systems and circuits are the most likely explanation for the behavioral and experiential differences of individuals with ASD. By focusing on the greater idea of connectivity, neurological discoveries can have a greater effect on both basic understanding and therapeutic interventions [14,15].

One common connectivity theory suggests the centrality of localized issues in connectivity at the mini column organizational level causing atypical brain function and neuronal communication patterns. These issues may result from atypical neuronal migration and excess neurogenesis, causing disorganized, poorly synchronized and hypo-selective connectivity [16,17].

Some neural connectivity studies also suggest the role of communication between sensory and emotional regions of the brain. A 2011 study of 20 males, 10 with ASD and 10 without, suggested that the connectivity between the fusiform face area, which is associated with facial recognition, and the amygdala, which is associated with emotion, along with certain areas of the temporal lobe was impaired in individuals with ASD. This study is important in that it connects two of the areas cited for functional and structural differences, but which are often studied separately [18].

Implications for Education and Therapy

While the fields of neuroscience research and educational research have long been seen as two distinct fields with little connection, research emerging over the last decade increasingly connects the two fields, demonstrating not only its compatibility, but also its reciprocal benefit. As eloquently stated: Neuro-education is a nascent discipline that seeks to blend the collective fields of neuroscience, psychology, cognitive science, and education to create a better understanding of how we learn and how this information can be used to create more effective teaching methods, curricula, and educational policy. Though still in its infancy as a research discipline, this initiative is already opening critical new dialogs between teachers, administrators, parents, and brain scientists [19].

Additionally, advances in neuroscience, as connected to education, offers a viable and, likely, a more legitimate means of assessment and progress monitoring than high-stakes testing and cognitive assessments which are often plagued with issues of validity, reliability, and cultural or linguistic bias [20]. In the area of ASD, increasing understanding in both neural functioning and the meaning of neural changes can also extend the means by which behavioral data are currently taken, allowing those therapies that have difficulty operationalizing its components or therapeutic goals, such as developmental, emotional, or sensory-based approaches another potential means to determine and display effectiveness. Incorporating the advances in neuroscience with advances in educational and interventional methodology in

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ASD can provide a synergistic improvement, resulting in increased quality of life for individuals with ASD.

These goals, however, can only be achieved with increased and earnest attention on connecting the field of neuroscience and education in a spirit intended to foster reciprocal and mutually beneficial advancements that are free from paradigmatic allegiances, ulterior motives, and efforts to pit one approach against another. In effect: The interdisciplinary field of neuro education is built on the connections among neuroscience, cognitive science, psychology, and education in an effort to create a new science of learning that may transform educational practices. The future advancement of neuro education, however, is facilitated through clarifying its disciplinary boundaries as a field of study...[which can be defined as] a broad interdisciplinary and multidimensional field concerning matters pertaining to mind, brain and education drawing on theories from a range of disciplines. The main goal of the field is to investigate scientific and pedagogic bases of learning and education utilizing a variety of research methods that are currently used with all the contributing fields [21].

Conclusion

Because advances in neurosciences, especially in the area of neuroimaging, are increasing the current understanding of ASD, it is important to organize the research in a way that is meaningful. The current paper sought to highlight three promising categories among individuals with ASD: sensory processing, social-emotional processing, and connectivity. Additionally, it is argued that these advances can specifically be used to enhance the field of educational and interventional methodology for individuals with ASD, which is often beleaguered with paradigmatic combativeness as well as limited by behavioral and cognitive assessment methodologies.

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