Brain and Behavior Differences in Autism

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Abstract

Autism Spectrum Disorder (ASD) is a developmental condition that affects how people perceive the world, communicate, and interact with others. Research shows that these differences are not caused by one single factor, but by a combination of changes in the brain and behavior. Studies on brain structure have found reduced gray matter and differences in connectivity in regions linked to memory, language, and social skills. Functional research shows that individuals with ASD often use their brains differently when processing language or faces, and these patterns can vary across age and gender. Other studies point to differences in neurochemicals such as oxytocin and vasopressin, which are important for social bonding and emotional responses. Finally, behavioral research highlights unique patterns in adaptation, sensory responses, and interaction styles. This review brings these findings together to show that ASD is best understood through multiple perspectives rather than one explanation.

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition that shapes how individuals perceive and respond to the world. Research shows differences between autistic and neurotypical individuals in areas such as language, social communication, and sensory processing. These differences are important to understand because they influence everyday behaviors like interpreting emotions, maintaining attention and adapting to new environments.

Much of literature has focused on single aspects of autism, such as brain imaging or sensory processing, which leaves a gap in understanding how these findings connect across methods. Recent studies however, have begun to address this by examining perception and social

processing from multiple perspectives. Brain imagining research has identified difficulties in coordinating networks for language and face perception, as well as structural differences in regions related to emotion and communication. Behavioral studies show that autistic individuals adapt differently to collaborative tasks, while neurochemical research suggests that oxytocin and vasopressin levels may influence social perception. Reviews of sensory processing further highlight unusual responses to complex stimuli and altered brain plasticity during development.

Altogether, these findings suggest that perceptual differences in autism arise from a combination of brain activity, structural differences, sensory imbalance, and neurochemical regulation. This literature review draws these findings together to better understand how autistic and neurotypical individuals differ in perception and social processing. The hypothesis is that these differences reflect a network of interacting brain changes, and not from single isolated causes.

Structural Brain Differences

Research on Autism Spectrum Disorder (ASD) has consistently pointed to differences in brain structure when compared to neurotypical peers. One approach frequently used to study those differences is voxel-based morphometry (VBM), a neuroimaging technique that measures changes in gray matter volume across the brain. Gray matter refers to the areas of the brain that are dense with neurons and are primarily involved in processing information, decision making, and regulating behavior.

A study by Ming-Xiang Xu and Xing Da Ju in 2023 found reduced gray matter volume in several key regions of the brain in children with ASD, specifically in the hippocampus and

temporal lobe. The hippocampus plays an essential role in memory formation and learning, while the temporal lobe supports language comprehension and social processing. These structural differences may help explain some of the challenges individuals with ASD experience with social communication and learning.

The same study also reported differences in brain connectivity, showing altered structural connections between regions that support language and social-emotional processing. Brain connectivity refers to the way different areas of the brain communicate with each other through networks of nerves. When these networks are disrupted, it can lead to difficulties in integrating information, which may contribute to the social and perceptual differences observed in ASD.

Collectively, findings from this study suggest that ASD is not associated with a single, localized brain abnormality, but rather with widespread changes across multiple regions that are important for memory, language, and social interaction. These patterns indicate that the challenges linked to ASD likely come from broader alterations in brain development and organization.

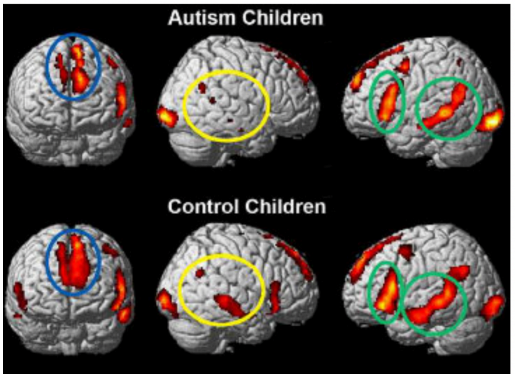
Functional Brain Differences

In addition to structural differences, research has shown that individuals with Autism Spectrum Disorder (ASD) also display differences in how their brains function during specific cognitive and social tasks. Functional differences are typically measured using neuroimaging tools such as electroencephalography (EEG), which records brain activity through electrical signals, and functional magnetic resonance imaging (fMRI), which detects

changes in blood flow that indicate activity in different brain regions. These tools allow researchers to see how people with ASD process language, faces, and social cues in real time.

One study, “Brain Function Differences in Language Processing in Children and Adults with Autism,” examined neural activity during language tasks. The researchers found that participants with ASD showed less activation in areas of the brain typically involved in understanding and producing language, such as the left temporal lobe and Broca’s area. Broca’s area, located in the frontal lobe, is responsible for speed production and language processing. Reduced activation in these regions suggests that individuals with ASD may rely on other neural pathways to process language, rather than the traditional way, which could explain some of the communication difficulties observed in both children and adults with the condition.

The same study contains a brain activation map, shown below, which compares children with ASD to control, or normal children. It demonstrates reduced activation in specific regions during language processing tasks. The temporal lobe and certain areas of the prefrontal cortex (highlighted in yellow and green circles) show noticeably less activity in children with ASD. This suggests that these regions, which are critical for language comprehension, social processing, and executive function, may be less engaged during cognitive tasks in ASD, potentially contributing to challenges in communication and social interaction.



Another study, “Sex Differences in Social Brain Neural Responses in Autism: Temporal Profiles of Configural Face-Processing within Data-Driven Time Windows,” focused on how autistic males and females respond to faces. Using EEG, the researchers measured brain responses while participants viewed facial features. They found that males and females with ASD showed different timing and patterns of activation in regions associated with face processing, such as the fusiform gyrus, which plays an important role in recognizing faces and interpreting expressions. These findings suggest that individuals with ASD process faces differently than neurotypical peers, and that males and females with ASD may also use distinct patterns of brain activity when interpreting faces.

Together, these studies suggest that functional brain differences in ASD go beyond a single region and instead involve multiple systems responsible for language, social interaction, and perception. Most importantly however, they indicate that the functional differences are not uniform across all individuals with ASD, with factors such as age and sex influencing how the brain responds to language and social information.

Neurochemical Factors

Beyond structural and functional brain differences, researchers have also examined the role of neurochemicals in Autism Spectrum Disorder. Neurochemicals are naturally occurring substances in the brain that help transmit signals between neurons, influencing emotions, behavior and social interaction. Two neurochemicals that have strongly been linked to ASD are oxytocin and vasopressin, both of which play an important role in regulating social bonding and emotional responses.

The study “Differences in Oxytocin and Vasopressin Levels in Individuals Suffering from Autism Spectrum Disorder vs General Population,” compared levels of these neurochemicals in people with ASD and in neurotypical individuals. The researchers found that individuals with ASD often have altered levels of oxytocin and vasopressin. Oxytocin is sometimes referred to as the “social bonding hormone” because it supports trust, empathy, and connection in relationships. Vasopressin, which is better known for regulating water balance in the body, is also linked to social communication and pair bonding. Abnormal activity in these systems may contribute to the social difficulties frequently observed in ASD.

The chart below summarizes the data used in this study for examining oxytocin levels in individuals with ASD. It illustrates that oxytocin levels vary significantly across the studies that were used, with many showing noticeable differences compared to neurotypical individuals. These findings highlight oxytocin as a key neurochemical potentially involved in the social and behavioral characteristics associated with ASD.

Table 1 Review of publications finally included in the full-text analysis

Publication	n	n studied group (girls)	n g. control (girls)	Diagnosis	Participants' age M (SD)	Conclusion	Materials and methods	Publication's evaluation[d]
Taurines et al, 2014[12]	36	19	17	DSM; ADI-R; ADOS	10.7 (3.8) years	OXT in the ASD group (p=0.132)[b]	Plasma RIA	8
Modahl et al, 1998[31]	59	29	30	DSM	8.08 (1.6) years	OXT in the ASD group[c]	Plasma RIA	6.5
Alabdali et al, 2014[32]	80	50	30	DSM	7.0 (2.34) years	OXT in the ASD group[c]	Plasma ELISA	6
Green et al, 2001[33]	59	28	31	DSM	8.08 (1.6) years 5.8–11.58 years	OXT in the ASD group[c]	Plasma RIA	5.5
Al-Ayadhi 2005[19]	154	77 (6)	77 (6)	DSM	3.5–14 years	OXT in the ASD group[c] AVP in the ASD group[c]	Plasma ELISA	4
Abdulamir et al, 2016[34]	86	60	26	DSM	7.28 (2.89) years	OXT in the ASD group[c]	Plasma ELISA	6
Althaus et al, 2016[15]	61	31	30	DSM	22.67 (422) years 18–34 years	OXT in the ASD group (p=0.05)[b]	Plasma RIA	7.5
Boso et al, 2007[20]	39	18 (2)	21 (3)	DSM	27.5 (7.2) years 15–42 years	AVP in the ASD group[a]	Plasma ELISA	5
Zhang et al, 2016[17]	169	84 (13)	85 (14)	DSM	3.95 (1.26) years 2–7 years	OXT in the ASD group[c] AVP in the ASD group (p=0.477)[b]	Plasma ELISA	7.5
Carson et al, 2015[21]	112	57 (9)	55 (19)	DSM; ADI-R; ADOS	8.58 (0.45) years	No differences between the groups (AVP; p>0.05)	Plasma ELISA	6
Miller et al, 2013[11]	75	40 (19)	35 (16)	DSM; ADI-R; ADOS	8–18 years	No differences between the groups (OXT; p>0.05) No differences between the groups (AVP; p>0.05)	Plasma ELISA	7.5
Jacobson et al, 2014[16]	78	37 (12)	41 (17)	DSM; ADI-R; ADOS	4.73 (0.61) years	OXT in the ASD group[a]	Plasma ELISA	8

Notes: [a]Increased level; [b]Increased level but statistically insignificant result; [c]Decreased level. [d]According to the Newcastle–Ottawa Quality Assessment Scale for Case Control Studies – max 9 pkt.
Abbreviations: DSM, diagnostic and statistical manual of mental disorders IV-TR; ADI-R, autism diagnostic interview – reviewed; ADOS, autism diagnostic and observation schedule; OXT, oxytocin; ASD, autism spectrum disorde; ELISA, enzyme-linked immunorbent assay; AVP, arginine-vasopressin.

These findings connect with brain imaging research, as both oxytocin and vasopressin are known to influence the activity of brain regions involved in emotional and social processing, such as the amygdala. The amygdala is responsible for detecting emotional significance in facial expressions and social cues. When neurochemical signaling is disrupted, the brain's ability to respond effectively to social information may also be affected.

Overall, studies of oxytocin and vasopressin suggest that the challenges individuals with ASD experience in social communication may not come simply from structural or functional brain differences, but also form altered chemical signaling that shapes how the brain processes social information.

Behavioral/Processing Implications

Research on Autism Spectrum Disorder (ASD) not only highlights differences in the brain, but also shows how these differences affect real-world behavior and processing. One study, "Behavioral Patterns in Robotic Collaborative Assembly: Comparing Neurotypical and Autism Spectrum Disorder Participants", investigated how individuals with and without ASD performed in a collaborative task with a robot. The study followed participants over multiple days to observe patterns in task adaptation, communication, and interaction styles.

The researchers found that participants with ASD displayed distinct behavioral patterns compared to the neurotypical peers. For example, they often relied on consistent routines when approaching the task, adapted more slowly to changes, and showed unique communication strategies when working alongside the robot. These findings suggest that individuals with ASD may process information and adapt to new contexts differently, showing the underlying structural, functional and neurochemical differences in other areas of research.

In addition to differences observed in collaborative tasks, broader reviews such as "Sensory Perception in Autism: What Can We Learn?" emphasize that atypical sensory processing is an important part of ASD. Many individuals with ASD experience either heightened or reduced sensitivity to stimuli such as sound, light, or touch. For example, loud noises may feel overwhelming, while subtle visual details may capture more attention than they do for neurotypical individuals. These sensory differences can significantly shape how individuals with ASD interact with their environment, contributing to unique behavioural patterns and responses in social and learning contexts.

Together, these observations show how differences in brain development and sensory processing directly influence how individuals with ASD engage with technology learning environments, and everyday social settings.

Conclusion

Research on Autism Spectrum Disorder shows that it is shaped by a combination of biological and behavioral factors. Structural imaging studies reveal changes in gray matter volume and brain connectivity, specifically in areas involved with memory, language and social communication. Functional studies show that individuals with ASD use their brains differently during language and face-processing tasks, with patterns that vary across age and gender. Neurochemical findings show another perspective, suggesting that differences in oxytocin and vasopressin levels may affect how social and emotional information is processed. Behavioral studies demonstrate how these brian-level differences translate into everyday patterns of interaction and problem solving among those with ASD.

Overall, this literature shows that ASD cannot be attributed to a single cause of deficit. It arises from a combination of structural, functional, and chemical differences that influence how individuals experience and respond to the world. Understanding this complexity is important for deepening scientific understanding and also for developing interventions that aid individuals on the autism spectrum.

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