

Brain Development Differences in autism

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Introduction to brain development differences in autism

Autism spectrum disorder is a neurodevelopmental condition that affects how an individual communicates and processes information. It is classified as a spectrum disorder, meaning that each individual can have their own unique way of expressing it and have different support needs. Although it is a spectrum, some neurogenetic factors have been consistently observed through scientific and technological research, such as early postnatal growth of the frontal cortex and other microcellular changes in brain tissue. Some key brain areas that are altered include the cerebellum, amygdala, and the frontal cortex.

An important finding in the research conducted on autism is that the trajectory of growth tends to change across an individual's lifetime. Studies show a period of accelerated growth in early childhood, especially during the first few years of life. This rapid growth is followed by a decrease in brain volume, and some studies show that there is a much greater loss during the adolescent and adult years of an individual. This shows that autism is not a simple fixed problem but rather evolves through a person's lifespan. Some specific differences have also been found in certain parts of the brain, including the cerebellum, temporal cortex, and amygdala.

In addition to the differences in brain size and regional development, studies have shown that there are changes at the microscopic and cellular levels. In autistic brains, there may be variations in the organization of brain structures, development of neuronal connections, and balance between excitatory and inhibitory signalling. Some differences in synapse formation also impact the way neurons communicate with each other. This indicates that autism can be a disorder at multiple levels, not just a single abnormality.

Early brain growth in autism disorder

An important factor that stands out about autistic brains is that the trajectory of brain development changes throughout the lifespan. Rather than simply being smaller or larger, it tends to grow and decrease during different stages of a person's life. Research conducted by Courchene et al. (2017) titled “*Mapping Early Brain Development in Autism*” indicates that abnormal brain enlargement is usually not present at birth but instead emerges during the first 2 years of an individual's life. This is around the same time when the earliest characteristics of autism may start to appear. The timings imply that there may be important biological differences before birth that continue to affect the individual's brain development.

This becomes evident first in toddlers. In the research conducted by Courche, they examined 586 cross-sectional longitudinal MRI scans of people with autism, especially those within the ages 2 - 50. This showed that autistic boys and girls definitely had a period of brain growth in their early childhood. Enlargement of the cerebrum has also been identified in this study. An important factor is that this brain enlargement does not occur evenly throughout one's brain. The research shows that there is more frontal and temporal cortex overgrowth and less occipital cortex overgrowth. The enlargement and development of these specific regions are relevant because they show that some regions play important roles in social behavior, communication, emotional processing, and higher-order thinking.

The accelerated brain growth is not consistent throughout childhood, as after a period of rapid overgrowth, the brain starts to decrease. Courchene referred to this as the “second developmental period” of arrested growth, and this is the period when autistic children's brains fall short of the brains of normal children. This difference was evident during Courchene's research, which also showed that in a normal child's brain, gray matter grew up to 20%, but that same gray matter only grew about 1% in the autism group, and on top of that, a 17% decrease in white matter was also seen at the same time in the autistic group.

During adolescence, the development pathway is altered again. The brain volume of autistic children shrinks at a much greater rate than that of non-autistic children, and by late adulthood, studies show that autistic males have a slightly smaller brain volume than average males.

Regional Brain Development in Autism

Changes in the brains of autistic individuals are not consistently or uniformly distributed across the group. Research conducted by Key autism services, called **“Unveiling the Distinct Architectures of the Autistic Brain”**

Shows several differences in some key regions, including the frontal cortex, amygdala, and cerebellum. Each part has its own unique way of development and shows more information than comparing brain volume.

Frontal Cortex

The frontal cortex of the brain is important in research related to brain development in ASD because it is mainly involved in higher-order thinking, which includes planning, decision-making, and communication. The frontal cortex is one of the clearest regions that show evidence of atypical growth in autism. Toddlers with ASD before the age of 12 show a 7–10% enlargement in the size of the frontal cortex. Research reviewed by Alex P. and M. Albert Basson shows postnatal frontal cortex growth as one of the most consistently reported neuroanatomical findings of ASD.

However, it is not simply that the frontal cortex is permanently larger. The increase in grey matter volume in toddlers appears to be more related to increased surface area rather than increased cortical thickness. The findings show evidence that ASD does not simply involve the size of the brain but also the architecture in the way it is made.

Amygdala

The amygdala, which is located in the medial temporal lobe, is involved in emotional processing and functions as an important social factor. Since autism can affect social interactions and emotional processing, scientists have researched the amygdala in children with ASD. Research in young children shows a larger amygdala, and a longitudinal study conducted by Cynthia Schumann and colleagues showed the right amygdala was larger than the left and that the right amygdala volume is associated with worse social and communication skills.

The enlargement is age-dependent, where enlargement is followed by different patterns in adolescence and adulthood, also illustrating autism-related brain differences that are more accurately understood as developmental patterns and not permanent defects. The same structure may have various features depending on age.

Cerebellum.

The cerebellum is historically associated with movement and coordination; however, in a review, scientists Samuel H. Wang and colleagues recently discovered that it also plays a role in language and cognitive processing. Studies have found evidence of reduced volumes of the cerebellum in people with ASD, especially specific parts such as the vermis and some lobules. Another consistent finding is the significant decrease in the size and number of Purkinje cells, which are neurons that play a role in cerebellar signaling. This disruption of cerebellar development influences cortical regions and explains why differences in cerebellar relate to characteristics involving cognition, language, and social behavior.

Overall, all three brain parts show how autism and other related brain differences occur in several stages. The frontal cortex may have early overgrowth and altered cortical organization, while the amygdala may have age-dependent changes in volume, and the cerebellum may have structural and cellular differences with considerable variation between studies.

Neural Connectivity and Brain Networks

The human brain is made of a bunch of individual structures that work together and communicate through neural networks. Researchers have studied whether Autism involves differences in the ways the brain communicates with itself. This has led to the discovery of the “connectivity paradox” where autistic brains often exhibit a mix of overconnectivity and underconnectivity.

Structural and functional connectivity.

Structural connectivity usually refers to the physical pathways that connect different brain regions. It is partially reflected in white matter fiber tracts. Functional connectivity, on the other hand, refers to the statistical relationships between brain regions and activities over time. Since different connectivities produce different findings, research studies both for evidence for autism

An important idea about autistic brains is that they show long-range connectivity alongside increased or atypical local connectivity. Long-range connections are between distant parts, whereas local connections are for nearby parts. Research conducted by Mohammed-Rezazadeh et al. reviewed studies on brain connectivity in autism and found results that show that increased local connectivity, particularly within sensory and attention-related networks, contributes to differences in sensory processing.

The evidence shows that decreased white-matter integrity and long-range neural coherence were reported in autism in a review of MRI studies, most frequently identified in the corpus callosum. Although this might not always be the case, as Mohammad-Rezazadeh et al. suggest,

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connectivity results can differ depending on participants' age, the brain region studied, the measurement method, the time window, and the frequency band.

White matter

White matter is important in this research as it contains long-distance axonal pathways that help independent brain regions communicate with each other. A study titled “Structure-function coupling in white matter” used diffusion MRI (dMRI) to reveal an atypical organization of white matter fiber tracts. Abnormalities in axonal development can hinder effective communication between brain regions. In the study “Structure-function coupling in white matter uncovers the hypoconnectivity in autism spectrum disorder which examined individuals with autism, the results showed that structural-functional coupling was reduced in the autism group in the majority of regions of white matter, especially in the corpus callosum, association tracts, and projection tracts.

These findings connect the two sides of brain development: physical and functional growth and connections mutually affect each other. Researchers use these to study how they work together to create functional neural networks. The strongest conclusion is that neural communication is altered in autism, but in some cases, the exact nature of these alterations depends on the developmental stage and the method used to measure it.

There is a biological process that causes the changes observed in brain size, regional development, and connectivity. Brain development relies on many cellular functions, such as synapse formation, neuron signaling, and gene expression. Studies have shown that abnormalities in these processes play a role in the formation of abnormal circuits in the brain.

Synapse formation and pruning

The formation and elimination of synapses, which are communication factors for neurons, is an important developmental process. The brain initially creates more synapses than are needed and then slowly eliminates the unnecessary ones in a process called synaptic pruning. This altered synaptic pruning has been observed to be a mechanism in ASD. Research shows that reduced pruning in autistic brains leads to excessive synaptic connections during childhood. Although their relationship is more complicated, this can be a good explanation for increased local connectivity.

Excitatory and Inhibitory Signaling

Another proposed theory involves the balance between excitatory and inhibitory signaling. Neurons require both inhibitory and excitatory signaling, which either increases the likelihood that neurons will fire or decreases the activity of some neurons.

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An important aspect of this is the brain's primary inhibitory neurotransmitter. It is called GABA, and research shows that changes in GABA and altered inhibitory signaling contribute to excessive neuronal activity in people with ASD. Because balance matters a lot, this disruption can lead to changes in activity in neural circuits that alter how the entire brain works and develops.

Gene regulation and development

Genetic factors also play an important role in the connection between the brain and other cellular processes in the body. Rather than having a single gene that is completely responsible for autism, it works as a complex genetic structure with multiple genes and regions.

There are several pathways that play a role in this mechanism, especially in the organization of the cortex. These include WNT, Notch, and Reelin. There is also another PTEN pathway where mutations are linked to larger brain seizures and altered development of autistic brains. This explains why small genetic differences alter entire brain structures. These gene variants affect each other and eventually accumulate across all developmental stages and can be detected using modern technology.

Neural stem and early brain growth

Neural stem cells produce new cells during development, and an abnormal amount of growth and expansion of these neural cells during development is a reason why there is increased brain growth in some particular regions in autistic brains.

In the study *Excitatory/Inhibitory balance in autism spectrum disorders: Integrating genetic, neurotransmitter and computational perspectives*

Researchers used models of the brains of mice, as these models allow researchers to observe some specific genetic changes in the brains that help influence autism and other problems. Human-induced pluripotent stem cells allow researchers to model early fetal development and observe whether it is shifting to produce more inhibitory or excitatory signals.

Even though the mouse brain does not develop exactly like a human brain, these models can still provide some evidence and biological mechanisms.

The molecular changes outlined in this section offer a potential link between the molecular and imaging levels of large-scale brain differences. Genetic variation may affect the growth, maturation, and pruning of neurons, as well as neurotransmitter systems and pathways. Changes in cells can then impact the organization and function of neural circuits, which could be a part of the differences in brain structure and connectivity seen in ASD.

Variation and limits in autism brain research

Although research has helped to provide many theories and explanations of questions about autism and brain growth in autistic brains, it is quite difficult to find a single difference or pattern with autism. This is one of the reasons why autism research can be difficult, as brain growth and individual structures vary for each person; thus, there is not always a single pattern among everyone with autism.

Research on connectivity with hyper- and hypoconnectivity shows different results for different individuals depending on an individual's age, type of autism, and many other factors. Age is also an important factor because studies have found many exceptional and interesting cases, such as a study conducted by „, who found increased frontal activity at only 14 months old in autistic brains.

Genetic factors also provide an explanation for why it is unique to individuals, and overall, it shows how autism comes from different neural networks and biological factors working together and affecting brain development.

Conclusion

Studies of autism have all found brain differences to be complex and unique. Rather than having a consistent developmental pattern, autistic brains exhibit different behaviors and patterns at various ages. These differences can occur from early childhood to late adulthood. The results show that knowing when neural differences occur in the brain is important for understanding the development of brains with autism.

Variations have been found in several areas, such as the frontal cortex, amygdala, and cerebellum. The different parts have been shown to have cellular and structural variations, implying that autism is not due to a single affected region in the brain.

The cellular and molecular differences that underlie some of the larger-scale differences seen from brain imaging include differences in the development and pruning of synapses, differences in neurotransmitter systems, differences in gene expression, and differences in neural stem-cell activity. There are a lot of genetic factors that affect developmental outcomes.

Overall, what was consistent is the fact that autism is very complex and would need many different processes working together, and the timing and organization matter as well. The different types and degrees of variation seen in individuals also show that there is no one neurological trait that unites autism. Ongoing research using brain imaging, genetic analysis, cellular models, and developmental research could help to shed light on the various biological pathways linked to autism.

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