

**Brain Development Differences in Autism Spectrum Disorder: A Review of Longitudinal
MRI Findings**

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Abstract

Autism spectrum disorder is defined by differences in social communication, behavior, and sensory processing, and it is also a condition of brain development. Researchers get a clearer answer by asking how brain structure changes over time instead of searching for one region that is simply larger or smaller. This paper reviews longitudinal magnetic resonance imaging studies of autistic development from infancy through adolescence. The strongest early evidence suggests that some infants later diagnosed with autism show faster cortical surface-area expansion between 6 and 12 months, followed by increased total brain volume during the second year of life. White-matter pathways also appear to follow a different developmental course during this period. In toddlers and older children, the findings become more regional and variable. Differences have been reported in temporal, frontal, fusiform, callosal, and cerebellar regions, while cortical thickness changes depend on age, sex, intellectual ability, and the brain area examined. These studies do not support a single brain pattern shared by every autistic person. They show several developmental pathways that can produce overlapping behavioral characteristics. Longitudinal research is especially useful because a scan taken at one age may show a different pattern from a scan taken later. Overall, current MRI evidence supports a developmental and individual view of autism rather than a fixed structural explanation.

1. Introduction

Autism spectrum disorder is a neurodevelopmental condition associated with differences in social communication, restricted or repetitive behavior, focused interests, and sensory processing. Because these characteristics usually become clear during early childhood, researchers have long asked whether brain development also follows a different path before and during that period. Magnetic resonance imaging, or MRI, provides a way to study brain structure without surgery or radiation. It can measure total brain volume, the surface area and thickness of the cerebral cortex, the size of individual regions, and the organization of white-matter pathways.

Early MRI studies often compared autistic and nonautistic participants at only one age. Those studies were useful, but they sometimes produced opposite conclusions. A region could appear larger in young autistic children and smaller or unchanged in autistic adults. This does not automatically mean that one study was wrong. It can mean that the groups were examined at different points in development. Longitudinal studies reduce this problem by scanning the same participants more than once and measuring the direction and rate of change.

Therefore, this review asks: How does brain development differ in autism from infancy through adolescence, and what do those differences actually tell us? The focus is structural and diffusion MRI, especially studies that followed participants across time. The evidence suggests an early period of altered cortical and white-matter growth in some children, followed by more regional and individual differences later in development.

2. Background

2.1 Measures of brain development

Brain volume is affected by both cortical surface area and cortical thickness. Surface area describes how much cortex is spread across the folded outer layer, while thickness describes the distance between the outer cortical surface and the underlying white matter. These measures are biologically related but are not interchangeable. During typical development, brain volume and surface area increase rapidly in early life, while cortical thickness generally reaches an early peak and then gradually decreases as the cortex matures [9]. This thinning is not simply loss or damage. It reflects several processes, including changes in synapses, cell organization, and increasing myelination near the cortical boundary.

2.2 Why timing matters

A developmental difference can involve the starting size of a structure, its rate of growth, or the age at which growth changes direction. For example, two groups can have similar brain volume at 6 months but different rates of growth from 6 to 24 months. By age two, the groups may then differ even though the earlier scan looked similar. This is why a one-time MRI cannot describe the full developmental process. It is also why results from infants should not be generalized directly to teenagers or adults.

2.3 Autism is biologically diverse

Autism includes a wide range of language abilities, intellectual abilities, sensory profiles, medical conditions, and support needs. Genetic causes are also varied. As a result, a group average may describe a real trend without describing every person in the group. Sex is another major issue because autistic females have historically been underrepresented in imaging

research. A strong study must therefore consider age, sex, clinical characteristics, and repeated scans rather than treating autism as one uniform brain condition.

3. Review Method

This paper is a focused literature review rather than a systematic review or meta-analysis.

Primary MRI studies were selected if they examined brain development in autistic participants or in infants who were later diagnosed with autism. Longitudinal studies were given the greatest weight because they measured change within the same person. The review compared developmental age, imaging measure, sample size, and the direction of the main finding. Recent studies were included to address sex differences and the relationship between early brain structure and later language. The results were interpreted as group-level evidence and not as a diagnostic test for an individual person.

Table 1. Main longitudinal MRI studies used in this review

Study	Age range	MRI data	Main finding
Hazlett et al. [1]	6 months	98 high-risk and 36 low-risk infants	No clear group difference in total brain volume at 6 months.
Hazlett et al. [2]	6-24 months	106 high-risk and 42 low-risk infants	Faster surface-area expansion from 6-12 months preceded greater volume growth in infants later diagnosed.
Wolff et al. [3]	6-24 months	92 high-risk infants	White-matter fiber measures followed different trajectories in infants later diagnosed.
Schumann et al. [4]	1.5-5 years	Repeated structural MRI in autistic and typical children	Early enlargement was strongest in frontal, temporal, and cingulate

			tissue and changed with age.
Andrews et al. [7]	2-13 years	918 scans from 429 children	Cortical thickness and thinning patterns differed by sex and developmental stage.
Duan et al. [8]	Toddler years	372 scans from 275 toddlers	Regional structure added information about later language outcomes.

4. Findings

4.1 Infancy and early brain growth

The clearest finding from infancy is that the timing of growth matters more than brain size at a single point. In one study, 6-month-old infants with a high family likelihood of autism did not show significant differences in total brain volume compared with low-risk infants [1]. A later longitudinal study followed 106 high-risk and 42 low-risk infants at 6, 12, and 24 months.

Among the 15 high-risk infants later diagnosed with autism, cortical surface area expanded more rapidly from 6 to 12 months. Increased total brain volume then appeared from 12 to 24 months [2]. Cortical thickness did not show the same group trajectory, which indicates that the early volume difference was mainly connected to surface-area growth.

White matter also developed differently during the first two years. Wolff and colleagues followed 92 high-risk infants and found altered trajectories in major fiber tracts among the infants later diagnosed with autism [3]. The direction changed with age: measurements were relatively higher at 6 months but developed more slowly, leading to lower values by 24 months in several tracts. This pattern is another example of why one scan cannot be treated as a permanent marker.

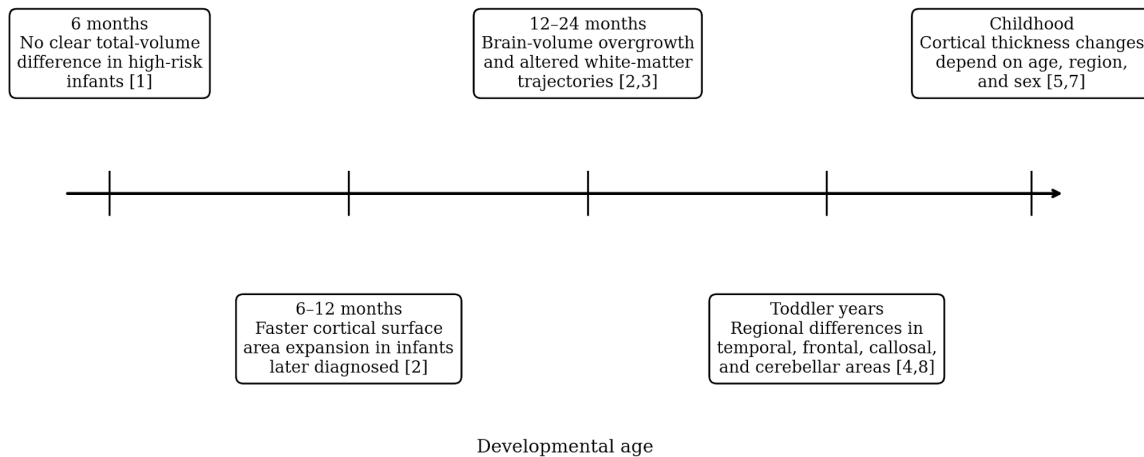


Figure 1. Developmental timing of MRI differences reported across major longitudinal studies.

This is a summary diagram of published findings and not a pooled quantitative dataset.

4.2 Toddler and early-childhood development

Longitudinal MRI of children from about 1.5 to 5 years showed that cerebral gray and white matter were enlarged in the autistic group by roughly 2.5 years, with strong differences in frontal, temporal, and cingulate regions [4]. However, the study did not find one simple pattern that continued at the same rate across early childhood. The results instead suggested that much of the enlargement developed before or near the time of diagnosis and that later growth rates varied by tissue and region.

A 2024 study connected regional structure with developmental outcomes. Using 372 scans from 166 autistic and 109 nonautistic toddlers, Duan and colleagues reported larger or thicker temporal and fusiform regions, smaller or thinner inferior frontal and midline regions, a larger part of the corpus callosum, and a smaller cerebellum in the autistic group [8]. Many findings were tested in a second cohort. Brain measures also improved short-term prediction of language outcome beyond the clinical and demographic information collected at intake. This does not

mean MRI can predict one child's future with certainty. It shows that early language development may be related to several brain systems rather than one isolated language center.

4.3 Childhood and adolescence

After the toddler years, differences in cortical thickness become more dependent on age and brain region. Zielinski and colleagues reported that autistic development could be described by periods of faster early expansion, faster thinning during later childhood and adolescence, and slower thinning in early adulthood [5]. Their results also changed after accounting for IQ, showing that cognitive differences can affect group comparisons. A 16-year longitudinal study of autistic males similarly found that brain-volume differences were dynamic across development rather than stable at every age [6].

The largest recent longitudinal study in this review included 290 autistic and 139 nonautistic children, with up to four scans per participant between about 2 and 13 years [7]. Autistic females showed more widespread cortical differences than autistic males when each group was compared with same-sex nonautistic peers. At about age three, autistic females more often had thicker cortex in several regions and then faster thinning across childhood. Autistic males showed a smaller and different set of changes. By later childhood, many of the sex-specific differences covered less of the cortex. Therefore, studies with mostly male participants may miss developmental patterns that are more visible in autistic females.

5. Discussion

5.1 A developmental explanation

Taken together, the evidence supports a developmental explanation of autism-related brain differences. Some children later diagnosed with autism show altered cortical surface growth and

white-matter organization during the first two years. In early childhood, differences are found across several regions connected with language, attention, face processing, and coordination. Later, cortical thickness changes continue, but the pattern depends strongly on age, sex, region, and individual ability. No single structure explains the full condition.

This conclusion also explains why MRI studies can disagree. A thicker cortex at age three can be followed by faster thinning, producing a smaller difference several years later. A study that combines young children, adolescents, and adults into one group may average these stages together and hide the real trajectory. Longitudinal designs are stronger because they separate a difference in size from a difference in the rate of development.

5.2 Limits of the evidence

Several limits should be kept in mind. Infant studies often recruit younger siblings of autistic children, so the results may not represent every autistic child. The number of infants who later receive a diagnosis can be small; in the major surface-area study, that subgroup included 15 infants [2]. MRI studies also tend to underrepresent autistic people with high support needs, significant movement during scanning, or co-occurring medical conditions. Different scanners, processing programs, and statistical methods can create additional variation. Finally, an association between a brain measurement and a behavior does not prove that the measurement caused the behavior.

5.3 Meaning for diagnosis and future research

At present, structural MRI should not be described as a stand-alone diagnostic test for autism. Group differences overlap, and a measurement that is useful in a research sample may not classify an individual child accurately. A useful goal is to understand developmental subgroups

and identify which combinations of age, brain trajectory, genetics, and behavior are connected with different outcomes. Future studies should follow larger and more diverse groups, include more autistic females and people with different support needs, and use repeated measurements collected with consistent methods.

6. Conclusion

Brain development in autism is different in timing and trajectory, but there is no single autistic brain pattern. The strongest longitudinal evidence shows faster cortical surface-area growth in some infants during the first year, followed by greater brain volume and altered white-matter development during the second year. During childhood, regional structure and cortical thinning continue to differ, while sex, age, intellectual ability, and language outcome affect the pattern that is observed. These findings are most useful when they are treated as developmental group trends rather than fixed biological labels. Future MRI studies should measure how different brain systems grow over time in different autistic people.

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