UNIVERSITY OF OXFORD

DEPARTMENT OF COMPUTER SCIENCE

Policy brief

Fetal Brain Atlas

The first digital atlas using advanced AI to show how the human brain develops in the womb captured patterns of brain growth from as early as 14 weeks' gestation, filling a significant gap in our understanding of early fetal brain maturation.

Summary

- The digital atlas of fetal brain maturation was constructed from healthy pregnant women in eight geographically and culturally diverse populations.
- Advanced artificial intelligence (AI) and image processing tools were used to construct the map from analysis of an international dataset of 3D ultrasound scans.
- Asymmetric regions were detected from as early as 14 weeks, peaking between 20-26 weeks in regions associated with language development and functional lateralisation.
- The study provides the earliest week-by-week evidence of the asymmetrical organisation and differential growth rates of specific regions of the fetal brain.
- It lays the foundation for future research into the relationship between the early development of specific brain regions and later impaired function.
- The results are consistent with previous structural MRI and postmortem findings, demonstrating the value of ultrasound imaging to assess fetal brain maturation.

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A normative digital atlas of fetal brain maturation was constructed from a prospective international cohort of healthy pregnant women in eight geographically and culturally diverse populations.

The women had reliable menstrual dates and gestational age was confirmed by ultrasound in the first trimester of pregnancy. All enrolled women met the WHO's strict prescriptive criteria for selecting subjects to construct international growth standards and their children had satisfactory growth and neurodevelopmental outcomes at 2 years of age.

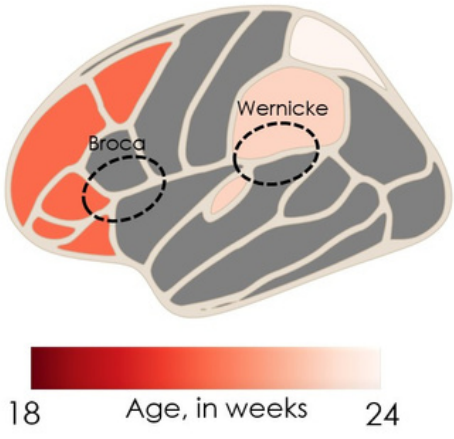
Asymmetric regions between the brain hemispheres were detected from as early as 14 weeks' gestation. The asymmetries peaked between 20-26 weeks' gestation in regions associated with language development and functional laterialisation.

Across cortical regions, the earliest asymmetries were detected at the following gestational ages:

- At 21 weeks: middle frontal and inferior frontal gyri
- At 23 weeks: supramarginal and transverse temporal gyri (i.e., Heschl's gyrus)
- At 24 weeks: paracentral and superior parietal gyri

In the context of the brain areas associated with speech and language processing:

- From 20 to 31 weeks' gestation, the most notable morphological changes were consistently observed in the insular cortex (INS) and peri-Sylvian regions.
- Between 20 and 22 weeks' gestation, the gyri within the INS, temporal lobe (middle temporal gyrus), Broca's (pars opercularis) and Wernicke's (superior temporal gyrus, Heschl's gyrus, supramarginal gyrus and bank of the superior temporal sulcus) areas progressively expanded.
- Three of the above regions will eventually form Broca's area (inferior frontal gyrus) and Wernicke's areas (supramarginal and Heschl's gyri), which constitute the primary auditory cortex and the brain's language centre.



Brain surface with emergent asymmetric regions shown from 18 to 24 weeks' gestation. Dashed lines indicate Broca's and Wernicke's areas.

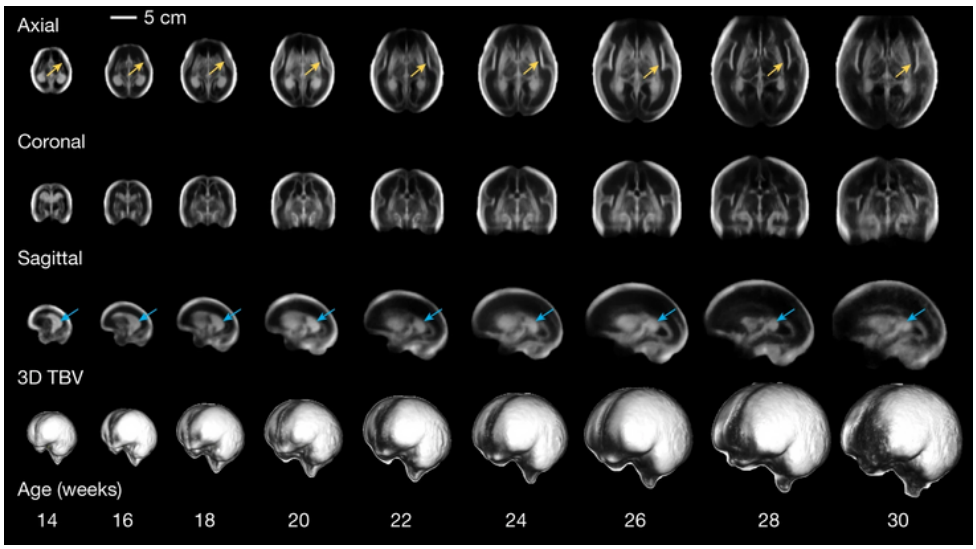
The study provides the earliest week-by-week evidence of the asymmetrical organisation and differential growth rates of specific regions of the fetal brain. Reflecting the healthy and well-nourished status of their mothers, these infants grew adequately from birth to 2 years of age, and their development in cognitive, visual, language, auditory and fine motor domains met international standards.

There were no sex differences in the type of asymmetries detected, nor the gestational ages at which they were detected. However, the mean total brain volume of boys was larger than girls in keeping with many other body structures.

The foundation has been laid for future research into the relationship between the early development of specific brain regions and later impaired function, e.g. deficits in speech and language acquisition.

The results are consistent with previous structural MRI and postmortem findings, and clearly demonstrate the value of ultrasound imaging to assess fetal brain maturation, especially as it allows large cohorts of pregnant women to be studied.

The between-study site variability represented less than 8.0% of the total variance of all brain measures, supporting: (i) pooling data from the eight study sites to produce patterns of normative maturation and (ii) the previous findings of similarities in fetal skeletal growth, infant growth and child neurodevelopment across international low-risk populations whose health, nutritional and socio-environmental needs during early life are met.



3D + time atlas templates depicting the fetal brain at even gestational weeks for the axial (top), coronal (middle) and sagittal (bottom) views.
Image credit: Nature

View the full paper and references:
https://www.nature.com/articles/s41586-023-06630-3