Brain control in infancy linked to cognitive ability in toddlers

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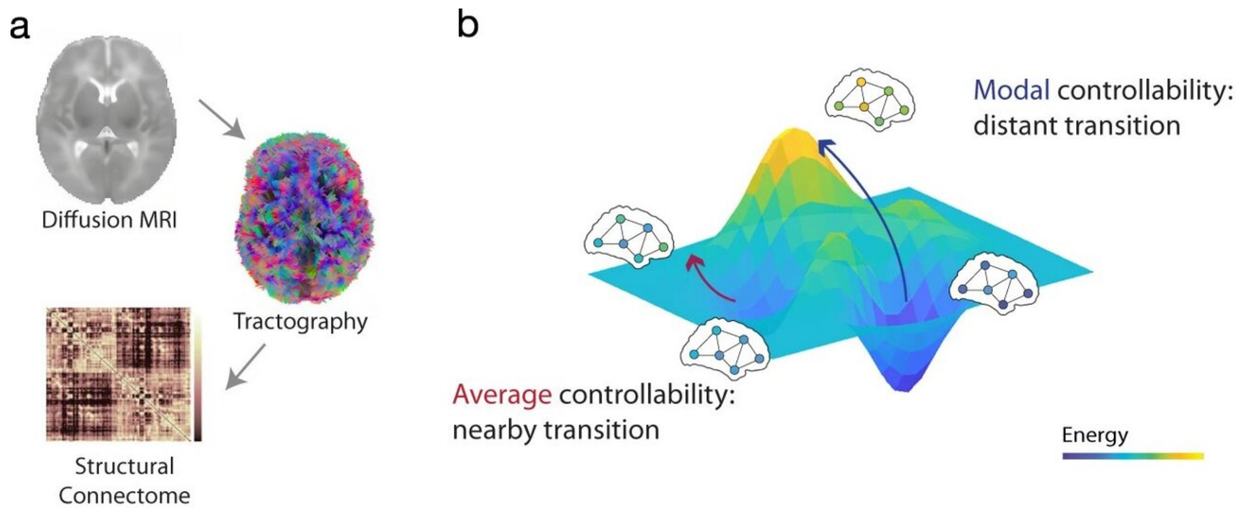

Network control theory. **a** Using diffusion-weighted imaging (DWI), structural connectomes were created from automatic fiber tracking for 521 infants. From these connectomes, average and modal controllability were calculated. **b** Controllability represents the ease of switching between different dynamic brain states. Average controllability measures a regional capability to support nearby state transitions. Modal controllability measures a regional capability to support distant state transitions. Credit: *Nature Communications* (2023). DOI: 10.1038/s41467-023-41499-w

In a new study, Yale researchers offer a look into how infants' brains work and change over time, and how these processes can be disrupted by preterm birth. The findings, the researchers say, could point to treatments that correct developmental trajectories that go awry in neurodevelopmental disorders.

The study was published in *Nature Communications*.

For the study, the researchers were interested in exploring how well infant brains can control networks of brain regions and whether that early-in-life control might be linked to cognitive ability as they age.

But unlike adolescents or adults, whose brain function can be studied by having them perform some sort of cognitive task, infants pose a particular challenge.

"With infants, we couldn't ask them to do something like math, for instance," said Huili Sun, lead author of the study and a Ph.D. candidate in the lab of senior author Dustin Scheinost, associate professor of radiology and biomedical imaging at Yale School of Medicine. "So we had to get more creative."

Sun and her colleagues used data collected by the Developing Human Connectome Project, a large UK-based study of infant brain development. They included MRI brain scans from 448 term infants and 73 preterm infants. From those scans, the researchers constructed structural connectomes—or maps of brain regions and the connections between them—and simulated the activation of brain networks based on the infants' brain structure. They then calculated the control energy required for those network activations.

"You can think of each brain region as a power station and the connections between regions as the wires that connect power stations," said Sun. "Brain control is essentially the regulation of energy flow between power stations."

The researchers assessed two types of control. The first, average controllability, describes the ability to switch between similar brain states: for example, transitioning from a motor behavior like grasping to a sensory behavior like listening, which use similar brain circuits. The other, modal controllability, encompasses the ability of the brain to navigate more distinct brain states, such as between complex cognitive functions: for instance, decision making and attention.

Across term and preterm infants, average controllability developed earlier than modal controllability—as early as the third trimester of pregnancy, according to the study.

This fits with what is known about newborn development, said the researchers. At this early age, infants typically learn sensory and motor behaviors, which rely on similar brain circuits and make prioritizing average controllability, or switching between similar states, beneficial. Brain networks that support complex cognitive function are not yet developed in newborns, so there's less need for high modal controllability.

While term and preterm infants had similar patterns of controllability, the extent of controllability within individual brain regions differed between the two groups. Many of the brain regions with the greatest differences in controllability were areas that underlie known deficits observed in children born preterm, including brain regions linked to language development and social processing.

However, the researchers also found that preterm infants were able to "catch up" to their term-born peers, showing more rapid development of regional controllability in the first months of life.

"Maybe most interestingly, across all infants, the higher the controllability of a brain region at birth, the faster it developed over time," said Sun. "And infants with stronger controllability at birth tended to have stronger cognitive ability at 18 months old."

Ultimately, the findings give new insight into how the brain functions very early in life and could point to treatment options for correcting developmental trajectories affected by neurodevelopmental disorders, researchers said.

"In adults, deep brain stimulation and transcranial magnetic stimulation has been used to activate or deactivate particular brain regions," said Sun. "That kind of approach is very far off for infants but it's a potential future direction."

More information: Huili Sun et al, Network controllability of structural connectomes in the neonatal brain, *Nature Communications* (2023). DOI: 10.1038/s41467-023-41499-w

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