

Early signatures of social brain: Children as young as 3 have brain network devoted to interpreting thoughts of others

March 12 2018



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Humans use an ability known as theory of mind every time they make inferences about someone else's mental state—what the other person

believes, what they want, or why they are feeling happy, angry, or scared.

Behavioral studies have suggested that children begin succeeding at a key measure of this ability, known as the false-belief task, around age 4. However, a new study from MIT has found that the brain network that controls theory of [mind](#) has already formed in children as young as 3.

The MIT study is the first to use [functional magnetic resonance](#) imaging (fMRI) to scan the brains of children as young as age 3 as they perform a task requiring theory of mind—in this case, watching a short animated movie involving social interactions between two characters.

"The brain regions involved in theory-of-mind reasoning are behaving like a cohesive network, with similar responses to the movie, by age 3, which is before kids tend to pass explicit false-belief tasks," says Hilary Richardson, an MIT graduate student and the lead author of the study.

Rebecca Saxe, an MIT professor of brain and cognitive sciences and an associate member of MIT's McGovern Institute for Brain Research, is the senior author of the paper, which appears in the March 12 issue of *Nature Communications*. Other authors are Indiana University graduate student Grace Lisandrelli and Wellesley College undergraduate Alexa Riobueno-Naylor.

Thinking about others

In 2003, Saxe first showed that theory of mind is seated in a brain region known as the right temporo-parietal junction (TPJ). The TPJ coordinates with other regions, including several parts of the prefrontal cortex, to form a network that is active when people think about the [mental states](#) of others.

The most commonly used test of theory of mind is the false-belief test, which probes whether the subject understands that other people may have beliefs that are not true. A classic example is the Sally-Anne test, in which a child is asked where Sally will look for a marble that she believes is in her own basket, but that Anne has moved to a different spot while Sally wasn't looking. To pass, the subject must reply that Sally will look where she thinks the marble is (in her basket), not where it actually is.

Until now, neuroscientists had assumed that theory-of-mind studies involving fMRI brain scans could only be done with children at least 5 years of age, because the children need to be able to lie still in a scanner for about 20 minutes, listen to a series of stories, and answer questions about them.

Richardson wanted to study children younger than that, so that she could delve into what happens in the brain's theory-of-mind network before the age of 5. To do that, she and Saxe came up with a new experimental protocol, which calls for scanning children while they watch a short movie that includes simple social interactions between two characters.

The animated movie they chose, called "Partly Cloudy," has a plot that lends itself well to the experiment. It features Gus, a cloud who produces baby animals, and Peck, a stork whose job is to deliver the babies. Gus and Peck have some tense moments in their friendship because Gus produces baby alligators and porcupines, which are difficult to deliver, while other clouds create kittens and puppies. Peck is attacked by some of the fierce baby animals, and he isn't sure if he wants to keep working for Gus.

"It has events that make you think about the characters' mental states and events that make you think about their bodily states," Richardson says.

The researchers spent about four years gathering data from 122 children ranging in age from 3 to 12 years. They scanned the entire brain, focusing on two distinct networks that have been well-characterized in adults: the theory-of-mind network and another network known as the pain matrix, which is active when thinking about another person's physical state.

They also scanned 33 adults as they watched the movie so that they could identify scenes that provoke responses in either of those two networks. These scenes were dubbed theory-of-mind events and pain events. Scans of children revealed that even in 3-year-olds, the theory-of-mind and pain networks responded preferentially to the same events that the adult brains did.

"We see early signatures of this theory-of-mind [network](#) being wired up, so the theory-of-mind brain regions which we studied in adults are already really highly correlated with one another in 3-year-olds," Richardson says.

The researchers also found that the responses in 3-year-olds were not as strong as in adults but gradually became stronger in the older children they scanned.

Patterns of development

The findings offer support for an existing hypothesis that says children develop theory of mind even before they can pass explicit false-belief tests, and that it continues to develop as they get older. Theory of mind encompasses many abilities, including more difficult skills such as understanding irony and assigning blame, which tend to develop later.

Another hypothesis is that children undergo a fairly sudden development of theory of mind around the age of 4 or 5, reflected by their success in

the false-belief test. The MIT data, which do not show any dramatic changes in [brain](#) activity when children begin to succeed at the false-belief test, do not support that theory.

"Scientists have focused really intensely on the changes in children's theory of mind that happen around age 4, when children get a better understanding of how people can have wrong or biased or misinformed beliefs," Saxe says. "But really important changes in how we think about other minds happen long before, and long after, this famous landmark. Even 2-year-olds try to figure out why different people like different things—this might be why they get so interested in talking about everybody's favorite colors. And even 9-year-olds are still learning about irony and negligence. Theory of mind seems to undergo a very long continuous developmental process, both in kids' behaviors and in their brains."

Now that the researchers have data on the typical trajectory of theory of mind development, they hope to scan the brains of autistic children to see whether there are any differences in how their theory-of-mind networks develop. Saxe's lab is also studying [children](#) whose first exposure to language was delayed, to test the effects of early language on the development of [theory](#) of mind.

Provided by Massachusetts Institute of Technology

Citation: Early signatures of social brain: Children as young as 3 have brain network devoted to interpreting thoughts of others (2018, March 12) retrieved 16 July 2023 from <https://medicalxpress.com/news/2018-03-early-signatures-social-brain-children.html>

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