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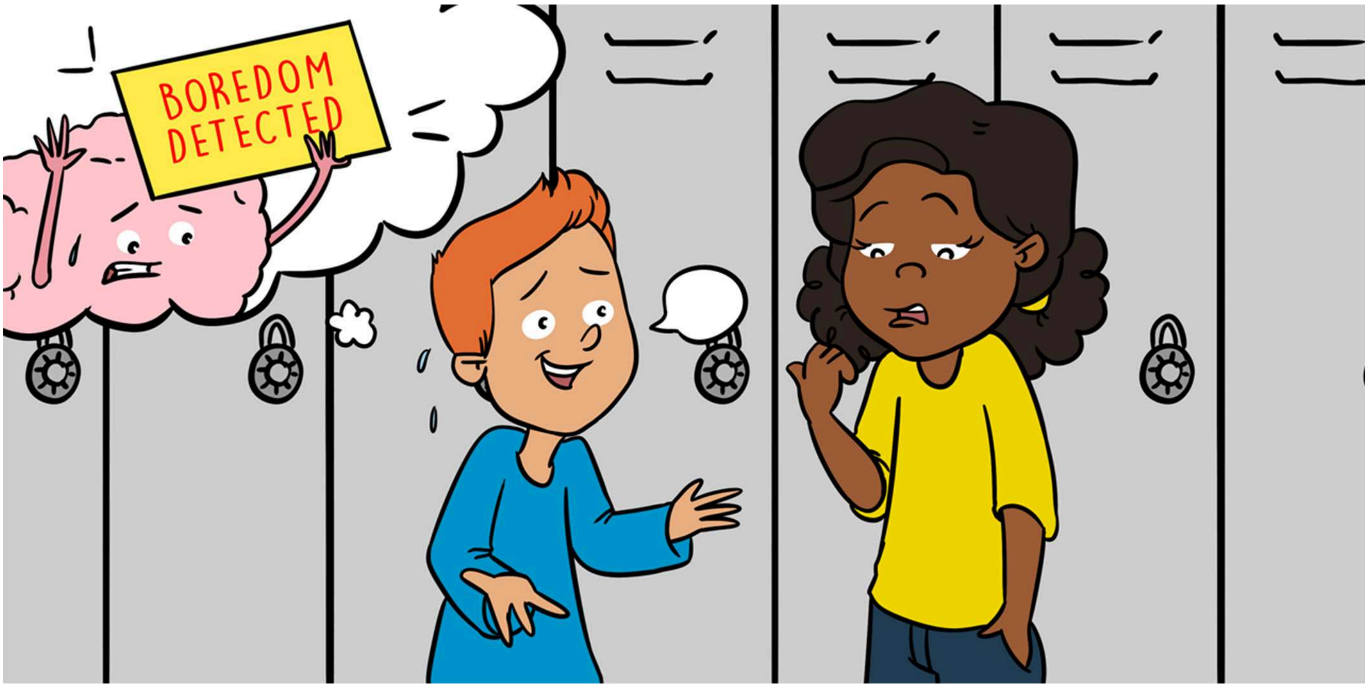

UNDERSTANDING OTHER MINDS: WHAT HAPPENS IN OUR BRAINS WHEN WE INTERACT WITH PEOPLE?

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YOUNG REVIEWERS:

EVERETT
AGE: 12

SARAH
AGE: 13

SOPHIE
AGE: 13

Think about a conversation you had recently. Could you tell whether it was going well or poorly? How did you know whether the other person was interested in what you had to say? The ability to imagine what someone might be thinking or feeling (known as mentalizing) probably plays a large part in what makes a social interaction successful. We know that certain brain regions are involved when we are asked what someone might be thinking, but do we engage these "mentalizing brain regions" whenever we interact with others, or just when something reminds us to think about thoughts? This question can only be answered by studies that make participants feel like they are in a real social interaction. Therefore, we designed an experiment in which children believed they were interacting with a partner while getting their brains scanned.

MENTALIZING: THINKING ABOUT THOUGHTS

Do you ever wish you had the power to read someone's mind? While literal mind-reading happens only in science fiction stories, in real life

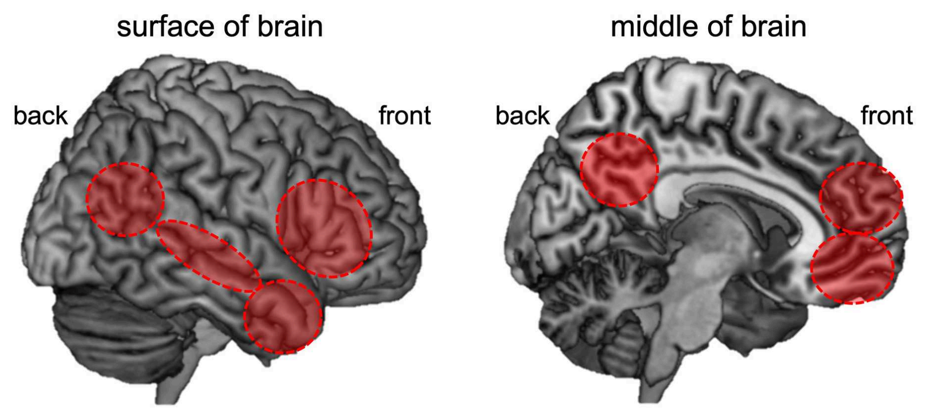

Figure 1

Figure 1

Mentalizing regions of the brain. The brain works slightly differently depending on what kind of mentalizing task is performed, but some or all of the regions colored red are usually activated in adults when they mentalize. Only one side of the brain is shown here (right side for the surface and left side for the middle), but the same regions are usually active on both sides.

MENTALIZING

Thinking about mental states. Mental states include beliefs, thoughts, knowledge, desires, and emotions.

ACTIVATED

When the MRI signal from a brain region is stronger (suggesting the neurons in that region are using more energy) during one condition compared with another.

MENTALIZING REGIONS

Brain regions that are often activated during tasks that require mentalizing.

SOCIAL INTERACTION

When two (or more) people each act in a way that affects the other person (or people), for example, having a conversation or playing a game together.

we have an ability that most of us take for granted: we can think about what others are *probably* thinking. We can often guess what is on someone's mind based on their facial expression or their actions. The ability to think about mental states like beliefs, desires, and emotions is called **mentalizing**. Mentalizing helps us predict and make sense of other people's behaviors. Without this ability, the social world would be very confusing!

Mentalizing is a complicated skill that requires several areas of the brain. Scientists who study the brain, called neuroscientists, have identified these brain regions using a special technique called magnetic resonance imaging (MRI; see Box 1). In a common experiment, participants get their brains scanned while they read stories and answer questions based on what the story characters know or believe [1]. Certain brain regions are **activated** by many different types of mentalizing tasks [2, 3], so we call them **mentalizing regions** (Figure 1).

Mentalizing is important not only when we are reading about or observing others, but also during **social interactions**. However, most MRI studies of mentalizing have used tasks that do not allow the participant to interact with anyone. Thus, it is not clear whether the brain works the same way when we mentalize about people we are interacting with as it does when we are not in a social interaction.

WHAT MIGHT HAPPEN IN CHILDREN'S BRAINS DURING SOCIAL INTERACTION?

Usually, only one person at a time can fit inside an MRI scanner. Thus, it might seem impossible to scan someone's brain during social interaction. But neuroscientists have figured out creative ways around this problem. For example, in one experiment, participants in the scanner were connected to someone in another room through a live

Box 1 | How do neuroscientists measure brain activity in humans?

The brain is made up of cells called neurons that communicate with each other using chemical and electrical signals. Because it is impossible to directly measure these signals in humans without removing the skull, neuroscientists use technologies that indirectly measure the signals. The technology we used in our study—magnetic resonance imaging (MRI)—takes advantage of a special property of the blood: it is more or less magnetic, depending on how much oxygen it contains. By measuring the strength of the magnetic signal, MRI can tell us how much oxygen is in the blood in different parts of the brain at different times.

But what does oxygen in the blood have to do with brain activity? The more signals a neuron sends, the more energy it uses. The more energy a group of neurons uses, the more oxygen those neurons need, so more oxygen is delivered by the blood to that region of the brain. It is kind of like what happens after you exercise a lot: you breathe faster and deeper to take in more oxygen from the air. Thus, with MRI, we are measuring which brain regions are using more or less oxygen, which indirectly tells us which regions have neurons that are more or less active.

Notice we said, "more or less active," not "active or inactive." This is because no part of the brain is ever "off." At any one time, your brain is doing many things that you are not even aware of! So to figure out which brain regions are involved in a certain type of thinking, we need to find the regions that are more active during that type of thinking than they are during other types of thinking. To do this, many studies have participants in the scanner do two or more very similar tasks (called "conditions") that only differ on the things the researchers are studying.

If you want to know more about how the MRI scanner works, see Boxes 1 and 2 from Parker [4].

video feed, and they played a simple game together [5]. This social interaction led to activation in similar brain regions as those activated in mentalizing studies.

This result could mean that we automatically mentalize whenever we interact with others. However, because the game did not require the players to think about mental states, we cannot be sure that the regions activated during the game were exactly the same regions that the participants use when they mentalize. To clarify this, we designed a new game, in which the players interacted with another person *and* had to think about mental states.

MIDDLE CHILDHOOD

The time between the preschool years and the teenage years. Our study includes children ages 8–12.

Most of what we know about mentalizing and the brain during social interaction comes from studies of adults. We know that our minds and brains change as we grow from children to adults, but few studies have looked at whether children use the same brain regions as adults when mentalizing or interacting with others. During **middle childhood**, children start to interact in more complex ways. They spend more time with friends and classmates and can think about more complicated mental states. Therefore, we decided to focus on middle childhood for our study of how the brain works during mentalizing and social interaction.

HOW DID WE TEST OUR QUESTIONS?

Our study aimed to answer three questions about the brain during middle childhood:

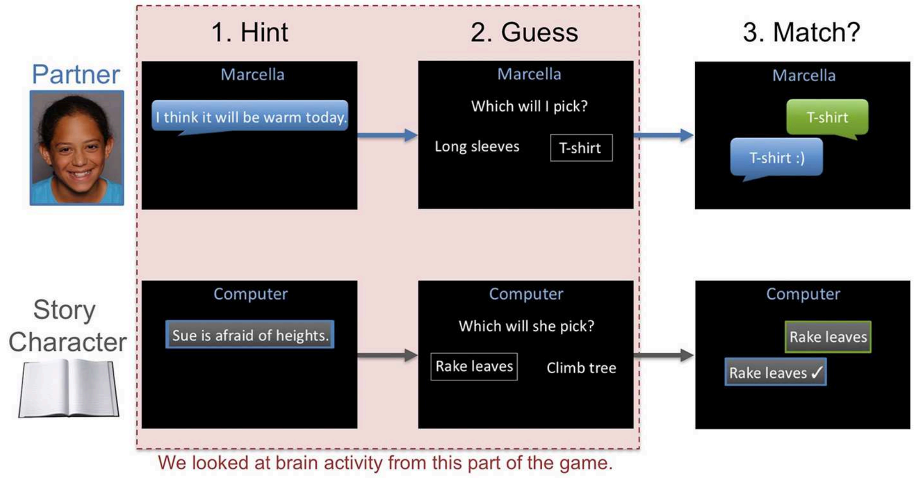

Figure 2

Figure 2

Children played a guessing game inside the MRI scanner. Each black rectangle shows what the children saw at different times throughout the game. The game had three parts: (1) Hint: children received a hint from their partner or from the computer about a story character. (2) Guess: children used the hint to guess between two choices. (3) Match: children learned whether their guess matched what the partner or computer chose. The hints shown here are both Mental, but the game worked the same way when the hints were Non-Mental. The children saw a total of 96 hints.

1. Which brain regions are involved in mentalizing?
2. Which brain regions are involved in social interaction?
3. Are mentalizing regions activated automatically during social interaction?

To answer these questions, we invited healthy children aged 8–12 to get their brains scanned using MRI. We ended up with good-quality scans from 28 children.

While in the scanner, the children believed they were playing a guessing game over the internet with another child. Really, they were just playing with a computer—that way, we could make sure the responses from the "partner" were always the same. For half of the game, our participants got hints from their "partner." Each hint was one sentence, like, "I have a kite." Then, our participants used these hints to guess what their partner would pick between two answer choices. For the example hint above, the answer choices were "rainy day" or "windy day." To make their guesses, the children pressed one of two buttons they were holding (one in each hand). After each guess, the children learned whether their guess matched the partner's choice. The other half of the game was the same, except instead of getting hints from a supposedly real partner, children got hints from the computer about a character in a story (Figure 2).

For both the partner and story character, half of the hints were about mental states, like something the partner or character knew, wanted, or felt. For example, a Mental hint from the partner might read, "I want to get a good grade." The other half of the hints were about the partner or character but did not include a mental state. For example, a Non-Mental hint from the partner might be, "I live far away from school."

To figure out which brain regions are involved in mentalizing (Question 1), we looked for regions that were more activated when children guessed using Mental compared with Non-Mental hints. To figure out which regions are involved in social interaction (Question 2), we looked for regions that were more activated when children guessed about their partners compared to when they guessed about story characters.

Finally, we wanted to know whether mentalizing regions are activated automatically during social interaction (Question 3). In other words, when children guessed about their partners, would mentalizing regions be activated even when nothing in the game reminded the children to think about mental states? To answer this question, we compared activation during Partner vs. Character conditions when children guessed using Non-Mental hints.

WHAT DID WE FIND?

Question 1: Which Brain Regions Are Involved in Mentalizing?

When the children guessed using Mental hints, we saw activation in many of the same regions that are often activated when adults think about mental states (Figure 3A). It is still possible that mentalizing regions change in some way between middle childhood and adulthood. However, we did not have adults do our task, so we cannot answer that question based on this study alone.

Question 2: Which Brain Regions Are Involved in Social Interaction?

As expected, mentalizing regions were more activated when children guessed about their partners than when they guessed about story characters. We saw activation in not only the regions we found in Question 1, but even more regions that are often found in mentalizing studies (Figure 3B).

In addition to mentalizing regions, we found activation in **reward regions** and areas involved in memory when children believed they were involved in a social interaction.

REWARD REGIONS

Brain regions that are often activated when people receive—or expect to receive—a reward, such as money or food. These regions are also often activated during social interaction.

Question 3: Are Mentalizing Regions Activated Automatically During Social Interaction?

To answer this question, we looked for brain regions that were activated when children guessed about a story character using Mental compared with Non-Mental hints—that is, when the children were mentalizing. Then we looked at whether these regions were the same as the ones activated when children guessed about their partners using Non-Mental hints (Figure 3C).

Several regions (colored yellow in Figure 3C) were activated both when children mentalized about a story character and when they guessed about their partners using Non-Mental hints. At the same

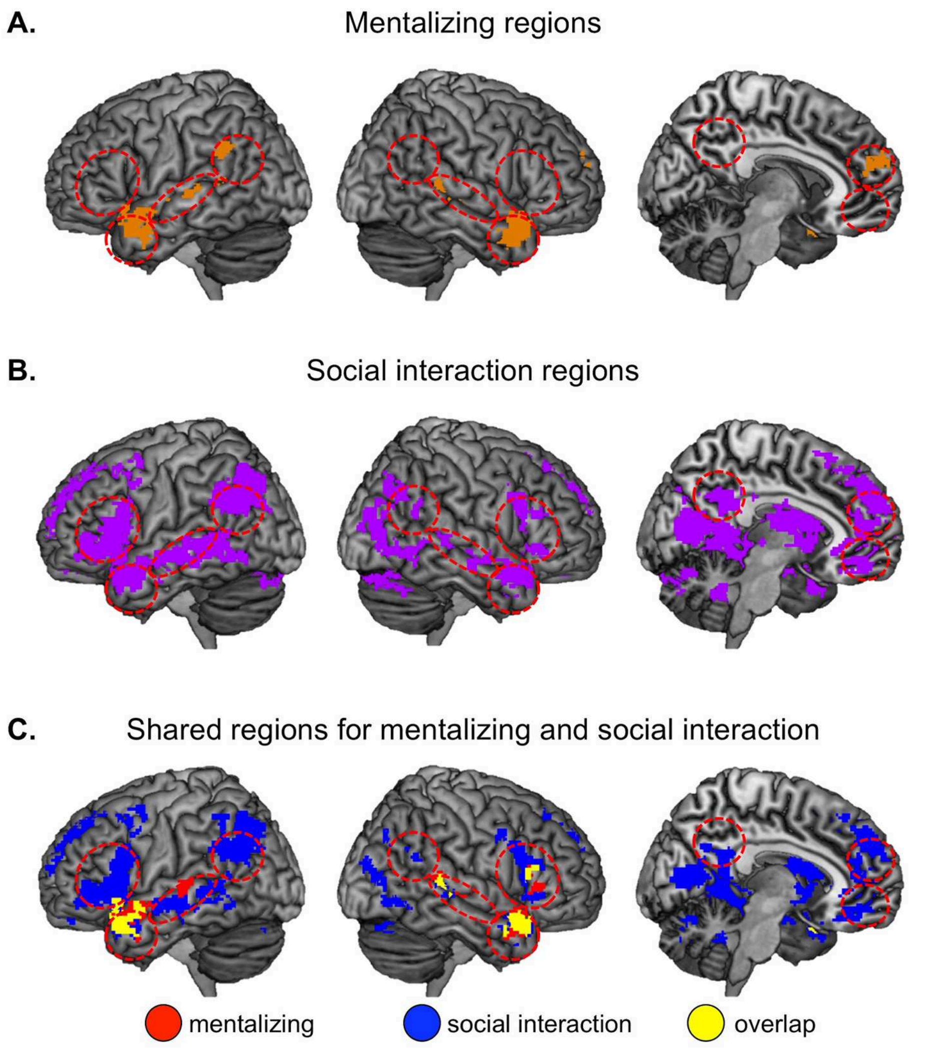

Figure 3

Figure 3

Results from our study. The red circles in this figure show regions that are often activated when adults mentalize (see Figure 1). **(A)** Orange regions were activated more when children guessed using Mental hints than when they used Non-Mental hints (Question 1). **(B)** Purple regions were activated more when children guessed about their partners than when they guessed about the story character (Question 2). **(C)** Yellow regions were activated when children mentalized about a story character and when they guessed about their partners using Non-Mental hints. This suggests that some mentalizing regions are automatically activated during social interaction (Question 3).

time, many regions (colored blue in Figure 3C) were activated when children guessed about their partners but not when they mentalized about a character. Altogether, we think this is good evidence that mentalizing regions are automatically activated during social interaction—but there are also differences in how the brain works during social interaction vs. mentalizing when we are not in a social interaction.

WHAT DO OUR FINDINGS MEAN?

When our participants interacted with what they thought was a real person, mentalizing regions were activated even when the game did not require thinking about mental states. There is still a lot we do not understand about all the different things each brain region might be doing, so we cannot be sure that our participants were thinking certain things. Still, our results are what we would expect to find if interacting with a partner led to more automatic mentalizing than did thinking about a story character.

Our study shows that the brain responds differently when we engage with a supposedly real person than when we think about a story character. Therefore, to really understand how the brain works during real-life social exchanges, neuroscientists should try to make their experiments feel as much as possible like real social interactions.

We also recognize that our game, in which children communicated using pre-programmed text messages, is just one example of a social interaction. In the real world, social interactions are often face-to-face, and mentalizing in these situations probably involves understanding facial expressions, body movements, and tone of voice. Future studies using different types of tasks can help us figure out what is similar and what is different about how the brain works during various forms of social interaction.

WHY IS THIS RESEARCH IMPORTANT?

Social interactions are a key part of the human experience. They affect how we learn and think, our happiness, and even our physical health. This means that people who have trouble with social interactions, such as those with **autism spectrum disorder** or **social anxiety**, may struggle with many parts of daily life. Understanding what goes on in typical children's brains when they interact with others can help neuroscientists figure out what might be different in the brains of children with social difficulties—and eventually, how to help those children overcome these differences and lead happier lives.

AUTISM SPECTRUM DISORDER

People with this condition have trouble with social interactions and communication. They also might show unusual interest in a small number of topics or activities, and they might have differences in their sensory experiences (e.g., hearing, seeing, or touch) compared with other people.

SOCIAL ANXIETY

Fear of being negatively judged by other people. People with social anxiety often feel worried before, during, and after social interactions.

ORIGINAL SOURCE ARTICLE

Alkire, D., Levitas, D., Warnell, K. R., and Redcay, E. 2018. Social interaction recruits mentalizing and reward systems in middle childhood. *Hum. Brain Mapp.* 39:3928–42. doi: 10.1002/hbm.24221

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CONFLICT OF INTEREST STATEMENT: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

EVERETT, AGE: 12
Everett enjoys playing Magic: the Gathering, Dungeons and Dragons, Gloomhaven, and spending time with his dog.

SARAH, AGE: 13
Science has always been a topic that I found interesting to study. Even outside of school. For instance, in baking. Baking has shown me a whole new side to the chemistry that I cannot wait to dive deeper into. I am always baking or coming up with something new. I also like to spend a lot of time in the mountains, when I am not in the kitchen. While there, I am usually hiking, skiing, or camping with my family.

SOPHIE, AGE: 13
Sophie is a seventh grader at Synapse School. Outside of school, she does a lot of gymnastics training because her goal is to make the USA National Team. Her hobbies include art, reading a variety of books and spending time with family and friends. Sophie has two younger sisters and a 4-years-old yellow labrador retriever named Qpid. She hopes you enjoy reading this awesome article on brains!

AUTHORS

DIANA ALKIRE

I am a graduate student in the Neuroscience and Cognitive Science program at the University of Maryland. I also went to the University of Maryland for college, where I studied psychology and philosophy. I now research how the mind and brain work when we interact with other people, and specifically how we are able to think about others' thoughts and feelings. I am also interested in how these abilities differ among people with and without autism spectrum disorder, and across different ages. When I am not researching, I work on science outreach—that is, making science accessible to non-scientific audiences of all ages. *diana@umd.edu

ELIZABETH REDCAY

I am a Professor at the University of Maryland where I teach classes on how children develop and how our brains work. I lead a lab where we do research to understand how our brains support social interactions and why these can be fun and easy for some but difficult for others. When I am not teaching or researching, I can be found spending time with my partner and son—going on long walks, trying new restaurants or breweries, or listening to music. When I find time to myself, I like to do yoga, crossword puzzles, or read.