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Drama in the teenage brain

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Reviewed by:

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The lives of teenagers are different from the lives of children. This period of life – **adolescence** – is a time of both social and biological changes. Social life becomes more complex during adolescence, and the teenage years are the period when we hone our skills for navigating the social world. These abilities are reflected in the changes occurring in the brain. We know that the areas of the brain involved in understanding other people and predicting their actions are undergoing changes during adolescence. As a result, this might be a period when we are more sensitive to signals from the people around us and the events in our social lives.

WHAT IS ADOLESCENCE?

Adolescence, which comes from the Latin word *adolescere*, meaning "to grow up," is used to describe the period of life between childhood and adulthood. It is commonly defined as starting around **puberty** and ending when an individual has developed an independent, stable role in society. Adolescence is not a new phenomenon. Ancient humans experienced adolescence and Aristotle (384–322 BCE) was one of the first to record and comment on the changes in the way people think and behave during this period. Characteristic behaviors of adolescence, such as heightened **self-consciousness**, **novelty seeking**, risk taking, and spending more time with friends, are all fundamental to the successful transition into adulthood.

WE ARE PARTICULARLY SENSITIVE TO WHAT OTHERS THINK ABOUT US DURING ADOLESCENCE

Social influences, like what other people think of us, play a big role in the way we feel and act. Scientists from around the world have shown that adolescents are particularly sensitive to their social environment. This can mean many things. For example, many adolescents care about the opinions (both good and bad!) of their peers or friends, sometimes even more than about those of family members. One way to measure how sensitive we are to the opinions and actions of others is by measuring how bad we feel after being excluded from a multiplayer game. One such game, called "cyberball," involves participants playing a game of "catch" with two other players. The participant can be included in the game of catch

or excluded by the other players. Figure 1 shows an example animation of what it would look like to be excluded in the cyberball game. When adolescents are excluded by other players in this game, they report feeling worse and more anxious than adults (although adults do not like being excluded either) [1].

FIGURE 1 - "Cyberball" game.
This animation shows what it would look like to be excluded in the game of cyberball. If you were the participant playing the game, your hand would be shown at the bottom center of the screen, and the other two players are shown above.

Knowing that adolescents can feel differently to adults in social situations can help us understand how teenagers make decisions. Our actions, and the ways in which we choose to behave, are the result of a constant stream of decisions we are making. To make these decisions, we have to take all the information we have that is relevant and weigh up whether it is a good idea to act or not. This decision making process can be viewed as a kind of seesaw (see Figure 2). All of the reasons in favor of doing an action – the positive outcomes – are placed on the "Yes" side of the seesaw, while the negative outcomes are placed on the "No" side. Older children and adolescents can perceive just as well as adults whether something good or bad is likely to happen as a result of an action, a process called **risk perception**. This decides which side of the seesaw the outcome goes on. One thing that may differ between adolescents and adults is how much value they place on the good and bad outcomes, or how "heavy" each of the outcomes is on the seesaw. Adolescents tend to rate potential rewards as very high, which may make the perceived benefits (good outcomes) outweigh the perceived risk (bad outcomes).

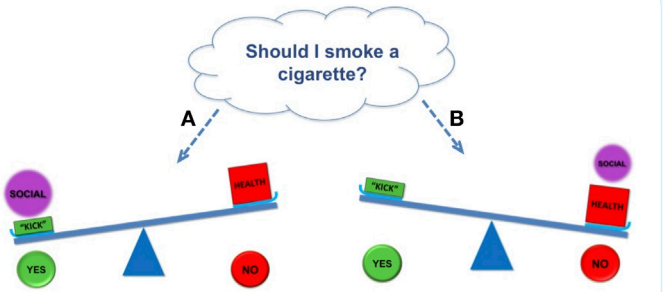

FIGURE 2 - The seesaw of decision making.
Every time we make a decision, we weigh up the good and bad outcomes. For example, when thinking "Should I smoke a cigarette?" we consider bad outcomes like health risks, but might also think that smoking gives us a positive feeling ("kick"). We also consider the social outcomes of our decisions. In this example, our friends and family might be upset or disapprove of our smoking, so that becomes a negative outcome, and we choose "No" (Option B). Alternatively, we might think that smoking will make us popular, a positive outcome, and we choose "Yes" (Option A).

There are many outcomes of a decision. While some outcomes of risky decisions are clearly positive or negative and remain relatively stable (e.g., serious health risks from smoking), the value of other outcomes of a decision might vary depending on the social environment. For example, even though we understand the extensive health risks of smoking, the *social outcomes* of smoking are variable. Socially, smoking can lead to peer acceptance and popularity, but can also lead to social stigma and disapproval, depending on the attitudes and opinions of your group of friends and your family (see Figure 2). Social outcomes vary between individuals and can be the reason that the decision-making seesaw tips one way or another, changing the decisions we make and the way we act in different socials contexts.

The seesaw model can help explain why different people make different choices by highlighting the value of social outcomes in decision making. These social outcomes are thought to be particularly important in adolescence [2]. Using this model might make it easier to understand why teenagers (and children and adults!) make risky decisions.

HOW DOES THE BRAIN CHANGE IN ADOLESCENCE?

Scientists have begun to link these changes in thinking and behavior to changes occurring in the adolescent brain. We know that the brain is changing both in its function (how it processes information) and its physical structure (or anatomy). A number of studies have explored what is happening in the brain when we try to understand the thoughts, feelings, and intentions of others. These studies use a technology called **Magnetic Resonance Imaging (MRI)**, which allows us to see what is happening in the living human brain. One MRI technique, functional MRI, uses powerful magnetic fields to detect the level of blood flow in the different regions of the brain. Areas activated during an activity need more oxygen to help them work, and this oxygen is transported around the body in red blood cells. Functional MRI measures how much blood is being sent to an area of the brain to determine whether that area is activated during an activity. The signal it measures is call the **BOLD signal**.

In our lab, we compared BOLD signal when people were reading emotional sentences [3]. Some emotions make you think about someone else's opinion, e.g., embarrassment and guilt (see Figure 3). For example, you only feel guilty or embarrassed when you understand how someone else might be thinking about you; guilt and embarrassment are therefore *social* emotions. Other emotions do not involve thinking about someone else's opinion, e.g., disgust and fear.

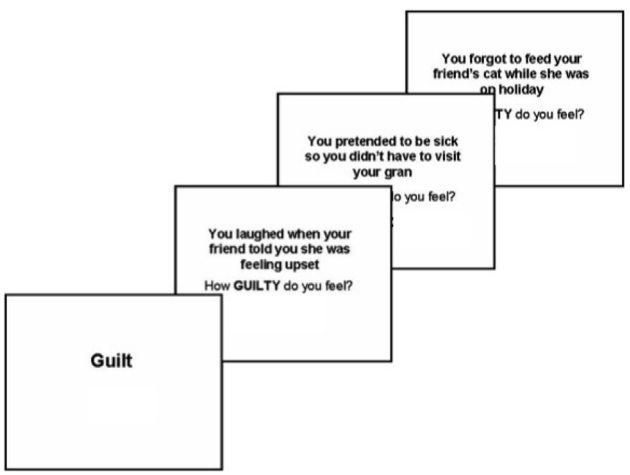

FIGURE 3 - Social emotion task.
An example of sentences designed to make a participant feel a little bit guilty, which is a social emotion.

Studies like this have found that specific brain areas are involved in the social part of feeling emotions, and that this changes during adolescence. While adolescents and adults can feel and describe these emotions equally well, there is a different pattern of brain activity when they do so. Some areas generate more activity in adolescents and others generate more activity in adults. And within adolescence, some of the brain changes associated with social emotions relate to other developmental processes like puberty. We do not know why this changing pattern of brain activity occurs during adolescence, but these studies provide clear evidence that the brain is still developing.

To understand more about the development of these "social brain" areas, we can also look at how their physical structure changes in adolescence. We can do this using another kind of MRI called structural MRI, which visualizes the structures that make up the brain. Different parts of the brain contain different amounts of water, which is made up of hydrogen atoms and oxygen atoms. When these atoms are put in a large magnetic field like the one produced by the MRI scanner, they emit characteristic energy patterns, depending on which structure they are a part of. The scanner detects these differences, and uses them to construct a 3D image of the scanned area of the body. A study from our lab looked at the brains of a large group of children, adolescents, and adults aged 7–30 [4]. The physical structure that we measured is called **cortical gray matter** volume, which is an approximate measure of the brain cells and their connections, as well as supporting cells found on the outer-most layer of your brain (the cortex). We found that these social brain areas continue to develop structurally throughout adolescence, before relatively stabilizing

in the early twenties (see Figure 4). In other words, the structure of these social brain areas is still changing between childhood and adulthood.

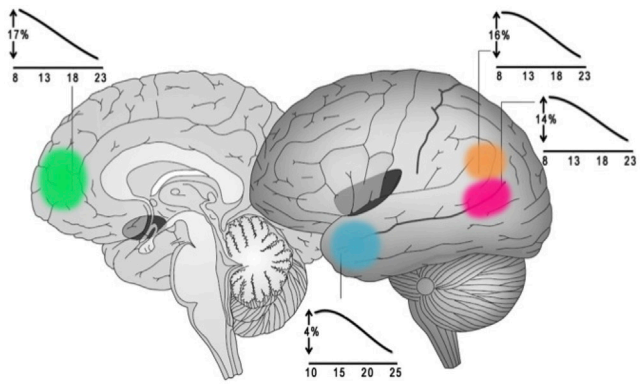

FIGURE 4 - Social brain structural changes.
These four areas of the brain (highlighted in different colors) are involved in understanding the thoughts, feelings, and intentions of others. The structure of these areas changes throughout adolescence. The graphs show how gray matter volume is changing across age (x-axis) in percentages (y-axis).

IS ADOLESCENCE A SENSITIVE PERIOD?

Adolescence is a time of opportunity for learning new skills and forging an adult identity. We now have a body of scientific evidence demonstrating that the adolescent brain is continuing to develop. This ongoing change, particularly in areas of the brain involved in understanding other people, might indicate that adolescence is a time when our brains are especially sensitive to social learning and experiences. Perhaps the abilities that emerge during adolescence enhance social signals or allow them to be more easily integrated into other processes. If this is the case, then the complexities of the adolescent environment, and the opportunities available to young people, may have a significant impact on how young people's brains are shaped.

GLOSSARY

Adolescence the period of life between childhood and adulthood.

BOLD signal a measurement of how much blood is being sent to a brain area, used to determine brain activity by functional MRI.

Cortical gray matter a type of brain tissue found on the outer-most layer of your brain.

Magnetic Resonance Imaging (MRI) a technology that allows us to safely image body parts (like the brain) in living creatures (like humans). MRI can help us study both the structure of different body parts and the way they work (function).

Novelty seeking trying out new or unfamiliar actions.

Puberty the biological developmental process causing a child's body to mature into an adult body capable of producing children.

Risk perception the ability to know whether something good or bad is likely to happen as a result of an action.

Self-consciousness the awareness of oneself, and how other people might think about you.

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Gen, 9 years old

My name is Gen, and I enjoy drawing, gaming, piano, and reading. I love my Dad and he is a biologist. I like science, literacy, and history at school.

AUTHORS

Kathryn L. Mills

I study the human brain and how it develops between childhood, adolescence, and adulthood. I am particularly interested in how we navigate the social environment during the teenage years. Outside of the lab, you will likely find me playing ping pong or walking around London.

Anne-Lise Goddings

I am a children's doctor and became fascinated by how the teenage brain develops after spending lots of time speaking to young people who I met in hospital. I am particularly interested in knowing how hormone levels in our bodies affect brain development in adolescence, and in trying to work out what makes all of our brains develop differently. I have always wanted to learn to play the piano, and this year have finally had my first lesson. It is definitely challenging my brain!

Sarah-Jayne Blakemore

Professor of Cognitive Neuroscience at University College London. My research focuses on the development of how we understand other people. I am also interested in how the brain matures to enable cognitive control – a collection of brain processes that guide thought and behavior to achieve our goals or plans.