Sarah-Jayne Blakemore: The mysterious workings of the adolescent brain

Fifteen years ago, it was widely assumed that the vast majority of brain development takes place in the first few years of life. Back then, 15 years ago, we didn't have the ability to look inside the living human brain and track development across the lifespan. In the past decade or so, mainly due to advances in brain imaging technology such as magnetic resonance imaging, or MRI, neuroscientists have started to look inside the living human brain of all ages, and to track changes in brain structure and brain function, so we use structural MRI if you'd like to take a snapshot, a photograph, at really high resolution of the inside of the living human brain, and we can ask questions like, how much gray matter does the brain contain, and how does that change with age? And we also use functional MRI, called fMRI, to take a video, a movie, of brain activity when participants are taking part in some kind of task like thinking or feeling or perceiving something.

So many labs around the world are involved in this kind of research, and we now have a really rich and detailed picture of how the living human brain develops, and this picture has radically changed the way we think about human brain development by revealing that it's not all over in early childhood, and instead, the brain continues to develop right throughout adolescence and into the '20s and '30s.

So adolescence is defined as the period of life that starts with the biological, hormonal, physical changes of puberty and ends at the age at which an individual attains a stable, independent role in society. (Laughter) It can go on a long time. (Laughter) One of the brain regions that changes most dramatically during adolescence is called prefrontal cortex. So this is a model of the human brain, and this is prefrontal cortex, right at the front. Prefrontal cortex is an interesting brain area. It's proportionally much bigger in humans than in any other species, and it's involved in a whole range of high level cognitive functions, things like decision-making, planning, planning what you're going to do tomorrow or next week or next year, inhibiting inappropriate behavior, so stopping yourself saying something really rude or doing something really stupid. It's also involved in social interaction, understanding other people, and self-awareness.

So MRI studies looking at the development of this region have shown that it really undergoes dramatic development during the period of adolescence. So if you look at gray matter volume, for example, gray matter volume across age, from age four to 22 years, increases during childhood, which is what you can see on this graph. It peaks in early adolescence. The arrows indicate peak gray matter volume in prefrontal cortex. You can see that that peak happens a couple of years later in boys relative to girls, and that's probably because boys go through puberty a couple of years later than girls on average, and then during adolescence, there's a significant decline in gray matter volume in prefrontal cortex. Now that might sound bad, but actually this is a really important developmental process, because gray matter contains cell bodies and connections between cells, the synapses, and this decline in gray matter volume during prefrontal cortex is thought to correspond to synaptic pruning, the elimination of unwanted synapses. This is a really important process. It's partly dependent on the environment that the animal or the human is in, and the synapses that are being used are strengthened, and synapses that aren't being used in that particular environment are pruned away. You can think of it a bit like pruning a rosebush. You prune away the weaker branches so that the remaining, important branches, can grow stronger, and this process, which effectively fine-tunes brain tissue according to the species-specific environment, is happening in prefrontal cortex and in other brain regions during the period of human adolescence.

So a second line of inquiry that we use to track changes in the adolescent brain is using functional MRI to look at changes in brain activity across age. So I'll just give you an example from my lab. So in my lab, we're interested in the social brain, that is the network of brain regions that we use to understand other people and to interact with other people. So I like to show a photograph of a soccer game to illustrate two aspects of how your social brains work. So this is a soccer game. (Laughter) Michael Owen has just missed a goal, and he's lying on the ground, and the first aspect of the social brain that this picture really nicely illustrates is how automatic and instinctive social emotional responses are, so within a split second of Michael Owen missing this goal, everyone is doing the same thing with their arms and the same thing with their face, even Michael Owen as he slides along the grass, is doing the same thing with his arms, and presumably has a similar facial expression, and the only people who don't are the guys in yellow at the back — (Laughs) —and I think they're on the wrong end of the stadium, and they're doing another social emotional response that we all instantly recognize, and that's the second aspect of the social brain that this picture really nicely illustrates, how good we are at reading other people's behavior, their actions, their gestures, their facial expressions, in terms of their underlying emotions and mental states. So you don't have to ask any of these guys. You have a pretty good idea of what they're feeling and thinking at this precise moment in time.

So that's what we're interested in looking at in my lab. So in my lab, we bring adolescents and adults into the lab to have a brain scan, we give them some kind of task that involves thinking about other people, their minds, their mental states, their emotions, and one of the findings that we've found several times now, as have other labs around the world, is part of the prefrontal cortex called medial prefrontal cortex, which is shown in blue on the slide, and it's right in the middle of prefrontal cortex in the midline of your head. This region is more active in adolescents when they make these social decisions and think about other people than it is in adults, and this is actually a meta-analysis of nine different studies in this area from labs around the world, and they all show the same thing, that activity in this medial prefrontal cortex area decreases during the period of adolescence. And we think that might be because adolescents and adults use a different mental approach, a different cognitive strategy, to make social decisions, and one way of looking at that is to do behavioral studies whereby we bring people into the lab and we give them some kind of behavioral task, and I'll just give you another example of the kind of task that we use in my lab.

So imagine that you're the participant in one of our experiments. You come into the lab, you see this computerized task. In this task, you see a set of shelves. Now, there are objects on these shelves, on some of them, and you'll notice there's a guy standing behind the setof shelves, and there are some objects that he can't see. They're occluded, from his point of view, with a kind of gray piece of wood. This is the same set of shelves from his point of view. Notice that there are only some objects that he can see, whereas there are many more objects that you can see. Now your task is to move objects around. The director,

standing behind the set of shelves, is going to direct you to move objects around, but remember, he's not going to ask you to move objects that he can't see. This introduces a really interesting condition whereby there's a kind of conflict between your perspective and the director's perspective. So imagine he tells you to move the top truck left. There are three trucks there. You're going to instinctively go for the white truck, because that's the top truck from your perspective, but then you have to remember, "Oh, he can't see that truck, so he must mean me to move the blue truck," which is the top truck from his perspective. Now believe it or not, normal, healthy, intelligent adults like you make errors about 50 percent of the time on that kind of trial. They move the white truck instead of the blue truck. So we give this kind of task to adolescents and adults, and we also have a control condition where there's no director and instead we give people a rule. We tell them, okay, we're going to do exactly the same thing but this time there's no director. Instead you've got to ignore objects with the dark gray background. You'll see that this is exactly the same condition, only in the no-director condition they just have to remember to apply this somewhat arbitrary rule, whereas in the director condition, they have to remember to take into account the director's perspective in order to guide their ongoing behavior.

Okay, so if I just show you the percentage errors in a large developmental study we did, this is in a study ranging from age seven to adulthood, and what you're going to see is the percentage errors in the adult group in both conditions, so the gray is the director condition, and you see that our intelligent adults are making errors about 50 percent of the time, whereas they make far fewer errors when there's no director present, when they just have to remember that rule of ignoring the gray background. Developmentally, these two conditions develop in exactly the same way. Between late childhood and mid-adolescence, there's an improvement, in other words a reduction of errors, in both of these trials, in both of these conditions. But it's when you compare the last two groups, the mid-adolescent group and the adult group where things get really interesting, because there, there is no continued improvement in the no-director condition. In other words, everything you need to do in order to remember the rule and apply it seems to be fully developed by mid-adolescence, whereas in contrast, if you look at the last two gray bars, there's still a significant improvement in the director condition between mid-adolescence and adulthood, and what this means is that the ability to take into account someone else's perspective in order to guide ongoing behavior, which is something, by the way, that we do in everyday life all the time, is still developing in mid-to-late adolescence. So if you have a teenage son or a daughter and you sometimes think they have problems taking other people's perspectives, you're right. They do. And this is why.

So we sometimes laugh about teenagers. They're parodied, sometimes even demonized in the media for their kind of typical teenage behavior. They take risks, they're sometimes moody, they're very self-conscious. I have a really nice anecdote from a friend of mine who said that the thing he noticed most about his teenage daughters before and after puberty was their level of embarrassment in front of him. So, he said, "Before puberty, if my two daughters were messing around in a shop, I'd say, 'Hey, stop messing around and I'll sing your favorite song,' and instantly they'd stop messing around and he'd sing their favorite song. After puberty, that became the threat. (Laughter) The very notion of their dad singing in public was enough to make them behave.

So people often ask, "Well, is adolescence a kind of recent phenomenon? Is it something we've invented recently in the West?" And actually, the answer is probably not. There are lots of descriptions of adolescence in history that sound very similar to the descriptions we use today.

So there's a famous quote by Shakespeare from "The Winter's Tale" where he describes adolescence as follows: "I would there were no age between ten and three-and-twenty, or that youth would sleep out the rest; for there is nothing in the between but getting wenches with child, wronging the ancientry, stealing, fighting." (Laughter) He then goes on to say, "Having said that, would any but these boiled brains of nineteen and two-and-twenty hunt in this weather?" (Laughter) So almost 400 years ago, Shakespeare was portraying adolescents in a very similar light to the light that we portray them in today, but today we try to understand their behavior in terms of the underlying changes that are going on in their brain.

So for example, take risk-taking. We know that adolescents have a tendency to take risks. They do. They take more risks than children or adults, and they are particularly prone to taking risks when they're with their friends. There's an important drive to become independent from one's parents and to impress one's friends in adolescence. But now we try to understand that in terms of the development of a part of their brain called the limbic system, so I'm going to show you the limbic system in red in the slide behind me, and also on this brain. So the limbic system is right deep inside the brain, and it's involved in things like emotion processing and reward processing. It gives you the rewarding feeling out of doing fun things, including taking risks. It gives you the kick out of taking risks. And this region, the regions within the limbic system, have been found to be hypersensitive to the rewarding feeling of risk-taking in adolescents compared with adults, and at the very same time, the prefrontal cortex, which you can see in blue in the slide here, which stops us taking excessive risks, is still very much in development in adolescents.

So brain research has shown that the adolescent brain undergoes really quite profound development, and this has implications for education, for rehabilitation, and intervention. The environment, including teaching, can and does shape the developing adolescent brain, and yet it's only relatively recently that we have been routinely educating teenagers in the West.All four of my grandparents, for example, left school in their early adolescence. They had no choice. And that's still the case for many, many teenagers around the world today. Forty percent of teenagers don't have access to secondary school education. And yet, this is a period of life where the brain is particularly adaptable and malleable. It's a fantastic opportunity for learning and creativity.

So what's sometimes seen as the problem with adolescents — heightened risk-taking, poor impulse control, self-consciousness — shouldn't be stigmatized. It actually reflects changes in the brain that provide an excellent opportunity for education and social development. Thank you. (Applause) (Applause)

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