# Teenage brain

British Neuroscience Association

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**Background**

The aim of this session is to introduce students (age 12-18) to concepts surrounding the teenage brain, including; ongoing development, sense of self and risk-taking/decision making. This information sheet should be used in conjunction with the 'Secondary– Teenage Brain PPT' PowerPoint presentation.

## The Developing Brain

**(Slide 1)** Title slide. Begin by asking the students to think of stereotypical behaviours of a teenager, compared to those of a younger child or adult e.g. moodiness, laziness. Explain that these stereotypes are often negative (particularly in the media), and people tend to think of teenagers as immature and underdeveloped adults. However, over the last couple of decades, research has begun to uncover that our teenage years are a distinct and incredibly formative part of our lives (which you will discuss today).

**(2)** Briefly outline the contents of the session.

**(3)** Title slide.

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**(4)** Starting with some basic neuroscience, ask the students what the image on slide 4 depicts. Most will know that this is a neuron or brain cell. Explain that neurons can be seen under a microscope (bottom of slide). Inform that there are approximately 86 billion neurons in our brain and the key to their function, and how the brain functions as a whole, is communication. Ask the students to suggest how neurons communicate, perhaps in terms of energy. Encourage the answer of electrical impulses. Using the neuron diagram, inform the students that the signal is received (as indicated), passed along the neuron and onto another neuron (as indicated). Show how this appears with 2 additional example neurons in place.

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**(5)** Explain that this is a schematic of a simple neuronal network. Neurons are connected to one another via very specialist structures - you may wish to ask the students whether they know what these are called. Inform the students that, in addition to connecting neurons, synapses are also important in other functions such as memory formation.

Pose the question that if synapses are so important to the brain, what do you expect would happen to their numbers as we grow up and develop. Take a poll of whether the students think they would decrease, stay the same or increase as we age.

**(6)** Explain what the graph shows with age on the x axis, and number of synapses on the y axis. Ask the students to focus on one of the coloured lines on the graph which broadly outlines synapse numbers. There is an initial rapid rise in the number of synapses, followed by a peak somewhere in early childhood before a gradual decline. Pose the question that if connections and synapses are so important to how the brain functions, why would there be a decline as we age.

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**(7)** Looking back at the neuronal network, the number of synapses is less important - it is actually how relevant they are. As we adjust to our environments, some synapses and connections will get stronger as they are being used (see neurons in middle of schematic). However, those connections and pathways that don't get used may weaken and be removed in a process known as synaptic pruning - a 'use it or lose it' principle. This can be seen as the brain becoming more efficient and refined. It can be useful to use examples here to aid understanding.

**(8)** Inform the students that this doesn't happen at the same rate throughout the brain. Brain regions associated with our senses (visual cortex - red line) may peak in synapse number and refine quickly relative to other regions. Regions associated with language (Broca's area, Wernicke's area, angular gyrus - green) take a little longer. If we look at regions associated with 'higher cognitive functions' (prefrontal cortex - blue line), such as decision-making, planning and problem-solving, these functions are still being refined, even throughout our teenage years. This continued and important development is likely to have an impact on how we develop through our teenage years and our associated behaviours.

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## Sense of Self

**(9)** Title slide. **(10)** Inform the students that during our teenage years, we devote much more of our thinking to our identity - our sense of self. This encompasses a large spectrum from our tastes in fashion and music to our moral and political principles, which may be heavily influenced by the social circles which we are in or aspire to be in.

**(11)** Additionally we begin to become aware of how we are viewed by others which may have an impact on how we behave - the concept of the 'looking-glass self'.

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In the following demonstration, pick a student at random to come up to the front of the class *(N.B. You may want to ask the teacher for selection advice)*. Ensure that the whole class can see the volunteer. Tell them that you are going to put music on and you would like them to begin dancing. This will be filmed and put on social media as well.

If the student has not already refused and sat down, just before putting the music on, ask them how they feel about dancing in front of the class. You should receive answers related to feeling uncomfortable, embarrassed and stressed. Inform the student that they don't have to dance, and it won't be filmed.

This is a good demonstration of the looking-glass effect. We imagine how we appear and are judged by others, leading to strong feelings such as embarrassment. This usually develops during our teenager years as younger children may not feel the same levels of embarrassment when carrying out that demonstration.

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Inform students that scientists have seen this in a research environment using brain scanning. When teenagers think they are being observed by their peers, they become self-conscious and show signs of embarrassment e.g. sweating and increased neural activity in parts of the brain associated with reflecting on oneself and other social aspects.

## Risk-taking

**(12)** Begin by asking the students whether they can think of risky behaviours that teenagers and adults carry out. Perhaps something that they know is bad for our health, may be dangerous or their parents tell them not to do. Take ideas and, if not already given, make suggestions such as smoking, taking drugs and dangerous driving.

Pose the question that if we know these behaviours are risky and dangerous, why do people still do them. Encourage answers with questions such as, ‘Are we influenced by anyone?’. Take suggestions leading to peer pressure. Inform the students that peer pressure is a really important aspect of growing up, especially when we are teenagers. We are a social species and building networks of friends helps us find our independence from our parents and childhood as a whole. To maintain these friendships and groups, sometimes we will do things that are dangerous or bad for us - even if we know the risks of doing them.

**(13)** If we take the example of speeding, we know that we may get caught speeding, get a fine or even get hurt. However, we may be willing to take that risk as we attracted by the thrill of it or perhaps to maintain or elevate our status in a social group i.e. look cool in front of our friends.

Tell the students that taking risks are not always necessarily bad and help us to progress through our lives.

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**(14)** Inform the students that the question or hypothesis that teenagers are more likely to be influenced by peer pressure has been tested in a research environment.

In one study, a group of people were separated into 2 groups - teenagers and adults. They were asked to play a video game alone with a virtual car driving around a race track. The aim of the game was to get around the track in the fastest possible time. However, there were several traffic lights placed around the track.

**(15)** When they were driving up to an amber traffic light, they had to decide whether to go through the light. Was it worth the risk? Sometimes they got through ok and went faster around the track - the risk had paid off. Sometimes the light turned red and they crashed with another car, losing time - the risk hadn't paid off.

**(16)** Ask the teenagers and take a poll - when alone, do you think the teenagers would take fewer, the same or more risks than the adults? Inform the students that the scientists found that the teenagers and adults roughly drove through the lights the same number of times i.e. they took roughly the same number of risks when alone.

However, in the next experiment participants were asked to bring their friends to the lab. The driver was aware that their friends were watching in another room and making predictions on how well the participant would perform.

Ask the teenagers and take a poll - when they knew friends were watching, do you think the teenagers would take fewer, the same or more risks than adults in the same situation? Inform the students that in this situation teenagers took more risks (3X as many in some studies) than the same adults that were tested before, when they were watched by their adult friends. This suggests that teenagers are super sensitive to the influence of their peers, even if they just know they are being watched - relating back to development of sense of self.

## Activity - Balloon game

**(17)** In the following activity, the students will play a simple game of risk with balloons. **Note - check with the teacher beforehand for latex allergies.**

Begin by giving each student a balloon, ensuring they are the same size and specification. Explain that they have to blow up the balloons as much as possible and the winner will be the balloon with the largest circumference. However, the larger the balloon, the weaker it will become and the students will have to weigh up the risk of it popping. Note that the balloons must be tied off as well.

As the students start to complete the task, take the largest 3 balloons by eye and measure the circumferences using string and a tape measure. Reward the winner with a prize.

Summarise that this game of risk may be influenced by the peer pressure of the classroom i.e. you may take greater risks to impress your friends.

### *Alternative Egg game (slide 21 if needed)*

***Note - check with the teacher beforehand for egg allergies.***

*As an alternative to the Balloon game, you could play a risk game with eggs. In the set up, you have 2 boxes of 4 eggs. In the first box (Box A), 3 of the eggs are hard-boiled and one is raw. In the second box (Box B), 1 of the eggs is hard-boiled and 3 are raw.*

*Bring up volunteers to the front of the class. Inform them that the object of the game is to choose a hard-boiled egg. If they pick Box A and get a hard-boiled egg, they receive 50p. They have a 75% chance of winning. If they pick Box B and get a hard-boiled egg, they receive £2. They have a 25% chance of winning. They receive nothing if they pick a raw egg from either box.*

*Ask the class which box they think the volunteer should pick and once the egg is selected, ask the volunteer to slam the egg down onto the table. (N.B. prepare tissue and wipes to reduce mess on the table and clean up the volunteers hands). Replace the egg and repeat with other volunteers.*

## Risk-taking continued

**(18)** Following the Balloon or Egg game, settle the class and inform the students that scientists have looked into possible reasons why teenagers may be more sensitive to the influence of friends/peers.

Inform the students that in the driving video game study, where they saw that teenagers were more likely to take risks when with their friends, scientists also looked at brain activity of the teenagers. Brain regions involved in risk-taking are more activated in teenagers when they are with their friends, than alone. This effect is not seen in adults.

**(19)** Inform the students that one theory for why this occurs comes from looking at the development of different brain regions.

Inform the students that these videos show 2 views of the brain, from above and below. Orientate the students so they are aware of the front and back of the brain *(N.B. holding a model brain can assist with this).*

For your information, the 2 videos show grey matter volume changes during childhood and into early adulthood. To simplify for the students, inform them that the videos show how the brain develops over our childhood and teenage years. The majority of the brain is yellow/red showing less developed regions. As we age, the brain will develop and can be seen in the blue/purple colour.

Linking back to the development graph on slide 6, where you explained that brain regions associated with the senses develop relatively early on, highlight to the students that areas involved in vision are already seen as blue and therefore well developed early on in our lives.

Other regions of the brain involved in emotions, impulsivity and reward-seeking (subcortical - seen in middle of 'from below' view) also develop early. Crucially this is in contrast to regions involved in decision making and controlling those impulsive behaviours - the prefrontal cortex. Therefore, this difference in development may be one reason why we are more likely to be guided by our impulses, reward-seeking and peers in our teenage years, without the control and restraint provided by a fully developed prefrontal cortex.

Inform the students that we still don't completely know if this is the case as there are different ways of measuring brain development and thus many questions remain in the research field of the teenage brain.

## Take-home messages

**(20)** Bring the session together by summarising what the students have learned in the whole session, as outlined in the final slide.

The key point to emphasise is that, despite these discoveries informing us of overall trends in teenagers, the results do vary from person to person. There is no average teenager - we are all individuals. Our brains develop at different rates and many factors are likely to play a role in this.

Additionally, highlight the importance of our teenage years that impact on the adults we become. We are a sponge to information and have so much exciting potential.

# Further information and references

Content for this module was guided by Professor Sarah-Jayne Blakemore's book:

**Inventing Ourselves: The Secret Life of the Teenage Brain (ISBN-13: 978-0857523709)**

We would like to thank Sarah-Jayne and members of her group, including Jack Andrews and Saz Ahmed, for their help in putting this material together.

## Materials needed

- Balloons (as many as there are students - bring spares just in case)
- Tape measure (flexible is better)
- String
- Speaker (*optional*) for music demonstration
- Brain model (*optional*)

## Definition of Adolescence

The term 'teenager' has been used throughout the module in order to simplify content. However, many of the studies cited investigate changes throughout adolescence. This in itself is not a well defined term, although it appears to refer to an age range between 10-24 years. You may wish to keep this in mind during the Q&A or choose to address this at the start of the module. Further information can be found here:
Sawyer, S.M., Azzopardi, P.S., Wickremarathne, D. and Patton, G.C., 2018. The age of adolescence. The Lancet Child & Adolescent Health, 2(3), pp.223-228.

## Grey and White Matter

For simplification, the session refers to changes in the number of synapses (Slide 6) and general brain development (Slide 19).

For students in the upper age groups you may wish to additionally explain that the brain is made up grey and white matter (grey matter changes shown in the videos on slide 19). One component of grey matter is synapses - the number of synapses increases during childhood and declines during adolescence, as previously discussed. White matter is myelinated axons (which helps strengthen the connections) and this increases across adolescence.

Figure 3 in the following reference shows these changes in more detail:
Mills, K.L., Goddings, A.L., Clasen, L.S., Giedd, J.N. and Blakemore, S.J., 2014. The developmental mismatch in structural brain maturation during adolescence. Developmental neuroscience, 36(3-4), pp.147-160.

**For detail on changes in synapse number, see the work of paediatric neurologist and neuroscientist Dr. Peter Huttenlocher:**

Huttenlocher, P.R., 1979. Synaptic density in human frontal cortex-developmental changes and effects of aging. Brain Res, 163(2), pp.195-205.

**and**

Nelson, C. National Research Council, 2000. From neurons to neighborhoods: The science of early childhood development.

**Sense of self and the 'looking-glass self':**

Cooley, C.H., 1902. Looking-glass self. The production of reality: Essays and readings on social interaction, 6.

Vartanian, L.R., 2000. Revisiting the imaginary audience and personal fable constructs of adolescent egocentrism: A conceptual review. Adolescence, 35 (140), p.639.

Somerville, L.H., 2013. The teenage brain: Sensitivity to social evaluation. Current directions in psychological science, 22(2), pp.121-127.

**Stoplight Task and Risk-taking:**

N.B. One group 19-22 was omitted from discussion in this module for simplification

Gardner, M. and Steinberg, L., 2005. Peer influence on risk taking, risk preference, and risky decision making in adolescence and adulthood: an experimental study. Developmental psychology, 41 (4), p.625.

Chein, J., Albert, D., O'Brien, L., Uckert, K. and Steinberg, L., 2011. Peers increase adolescent risk taking by enhancing activity in the brain's reward circuitry. Developmental science, 14(2), pp.F1-F10.

**Balloon game:**

Lejuez, C.W., Read, J.P., Kahler, C.W., Richards, J.B., Ramsey, S.E., Stuart, G.L., Strong, D.R. and Brown, R.A., 2002. Evaluation of a behavioral measure of risk taking: the Balloon Analogue Risk Task (BART). Journal of Experimental Psychology: Applied, 8(2), p.75.

**Grey matter changes in development:**

Gogtay, N., Giedd, J.N., Lusk, L., Hayashi, K.M., Greenstein, D., Vaituzis, A.C., et al. (2004). Dynamic mapping of human cortical development during childhood through early adulthood. Proceedings of the National Academy of Sciences USA, 101, 8174– 8179.


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