The Adolescent Brain: A Unique Vulnerability to Substances

This briefing paper is **part of a series** produced by Mentor-ADEPIS to support the delivery of effective alcohol and drug education and prevention in schools and other settings.

About Mentor

Mentor promotes best practice around building young people's resilience in order to prevent alcohol and drug misuse.

About ADEPIS

The Alcohol and Drug Education and Prevention Information Service (ADEPIS) is a platform for sharing information and resources aimed at schools and other professionals working in drug and alcohol prevention. In 2017, ADEPIS was recognised by UNESCO, UNODC and WHO as a 'prime example' of best practice in alcohol and drug education.

For more information, please contact:

Mentor-ADEPIS
CAN-Mezzanine
49-51 East Road
London N1 6AH

T: 020 7553 9920
E: adepis@mentoruk.org

mentor-adepis.org

This extended briefing paper forms part of a mini-series on the 'Brain under Construction'. It is intended to be read alongside the other papers in the series (available on the Mentor UK website).

Adolescence is a period of discovery and experimentation during which many young people start to explore what they perceive as adult behaviours, such as drinking alcohol and experimenting with drugs (Wheeler and Frankland, 2015). It is also a vulnerable time, and pictures of the brain in action show that adolescents' brains not only function differently than those of adults, but they also respond differently to substance use. This briefing paper explores what happens in the brain and the consequences of consuming substances during the teenage years.

Mentor
Protecting children from alcohol and drugs

mentor-ADEPIS.org
Alcohol and Drug Education and Prevention Information Service

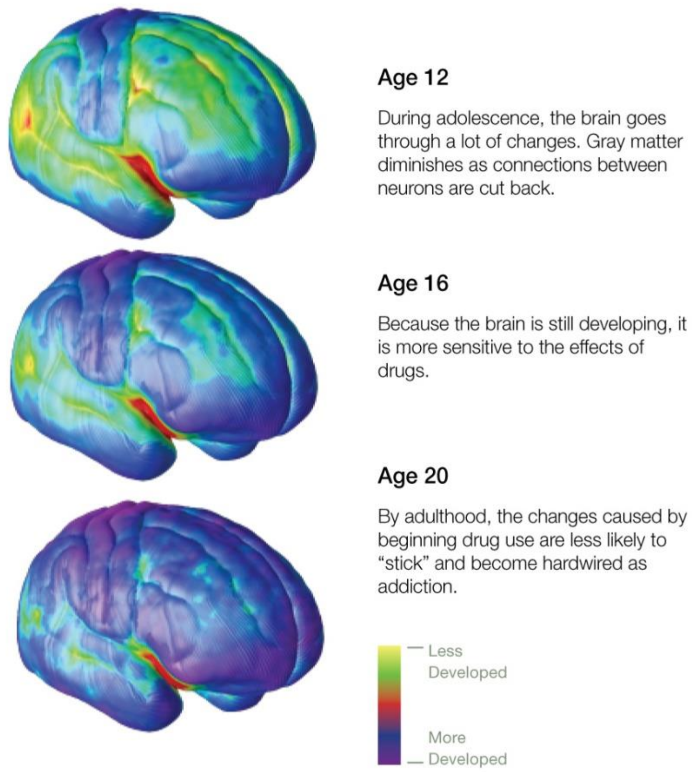
CAYT
Centre for Analysis of Youth Transitions

Firstly, this paper considers what is unique about the adolescent brain that makes it more vulnerable to physical and environmental factors, such as stress and peer pressure – factors that can lead to substance use. It highlights how the use of substances during adolescence can impact on both the structure and function of the brain. Finally, it comments on Harvard research findings, which conclude that neuroscience education is a promising supplemental strategy for adolescent substance use prevention (Harris et al., 2013).

The Developing Adolescent

G.S. Hall (1904) described adolescence as a period of heightened 'storm and stress.' He described it as a time when there is conflict with parents, mood disruption, and risky behaviour. Hall acknowledged that not all adolescents experience storm and stress, but argued that it is more likely during adolescence than at other ages. Adolescence is a vulnerable time when young people are particularly susceptible to a variety of issues - including the negative impact of substance use on the adolescent brain.

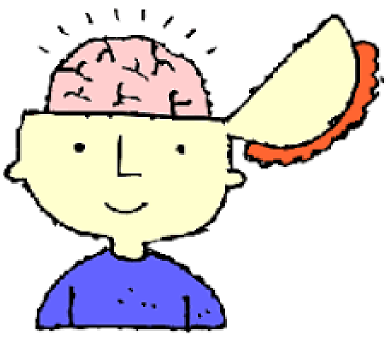
When we think of adolescence, we think of a period somewhere between requiring adult supervision and having full self-responsibility for his or her behaviour. Researchers often refer to it as the developmental interval encompassing the body and changes in the brain before adulthood. Adolescence is a period of profound brain growth, and change and advancements in neurology and brain imaging have shown that the adolescent brain differs significantly to that of an adult in both anatomy, biochemistry, and physiology.



Sleep

One example of positive adolescent brain development is sleep. As we have discussed in previous papers, during adolescence, the brain is still developing, and a good night's sleep is essential to healthy structure and function of the brain. Lack of sleep can make adolescents irritable and impulsive and can play a role in erratic behaviour problems. The development of the pre-frontal cortex (PFC) area of the brain is especially sensitive to the effects of sleep deprivation during adolescence. Too often, adolescents do not get enough sleep. Lack of sleep leads to a range of cognitive, behaviour, social, emotional and academic/ performance issues. Adolescents, with lack of sleep, are at risk of a wide range of intellectual, social, emotional and behavioural problems. Insufficient sleep in teenagers correlates with (among other things) poor judgment and decision-making, poor academic performance, higher risk of depression and anxiety and a higher risk of engaging in risky behaviours - including smoking, drinking, and drug use.

Uniqueness



When trying to understand the role of brain development in substance prevention, we must ask what is unique about the adolescent brain that promotes experience and excessive consumption of substances. Although this series of briefing papers primarily considers the role of the developing brain, it is essential to consider all dimensions of functioning in seeking to completely understand youth development and the heightened risk of substance misuse. Taking a holistic approach is critical because the inter-related cognitive, biological, social, and active changes that occur not only affect each other but also influence an individual's risk of problem drinking.

In the 'Window on the developing brain' paper, we discussed the slow development of the pre-frontal cortex (PFC) during adolescence. The PFC is the 'Chief Executive' or 'main control centre' of the brain, which controls reasoning and modulating mood. As the PFC matures, teenagers can reason better, develop more control over impulses and make better judgments. We also outlined the much faster development of the limbic system - the interconnected areas of the brain used for emotions and response to incentives - during adolescence. This imbalance may drive young people's behaviour over rational decision-making, which contributes to the prevalence of risk-taking in adolescents (Casey et al., 2008).

Environment and Vulnerability

Some researchers have argued that the continued development of the adolescent brain makes it more vulnerable to environmental factors, such as drug exposure. It is clear that teenagers engage in risky behaviours much more than adults, especially when they are with their peers. The adolescent brain craves stimulation and reward, and as Johnson et al. (2009) suggest, require higher doses of risk to feel the same 'rush' as adults do. Consequently, they spend more time on computers and mobile phones and this 'rush', in turn, alters the brain's neural pathways.

During adolescence, the social environment can have a profound influence on risky behaviours, such as substance use (Sharma and Morrow, 2016). As already mentioned, the limbic system (which controls emotions) develops faster in adolescents and this region is activated by social cues more than adults is.

Peer Pressure

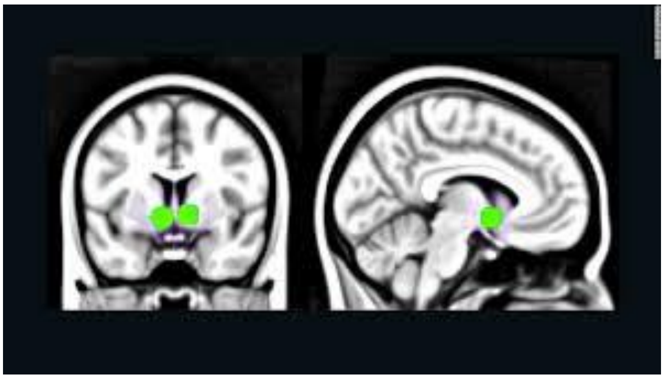
During this stage of life, young people spend the most time with their friends and peers than any other time in their lives. They begin to place importance on friendship. It is well documented that these peer relationships play an important role, not only in risk-taking behaviour but particularly in substance (Dick et al.., 2007; Steinberg, 2008; Gardner and Steinberg, 2005).

Chein et al.. (2005) report that, when performing a task in front of peers, adolescents display an increase in the ventral striatum (a significant portion of the basal ganglia functioning as part of the brain's reward system) and the orbital frontal cortex (OFC). The OFC region (located in the *frontal* lobes of the brain) is responsible for the cognitive processing of decision-making) of the brain, which correlates with risky behaviour. As Chein notes, this does not mean that the presence of peers has a direct influence on neurobiology, as their presence could be influencing cognition and behaviour, which in turn could explain the changes seen in neuroimaging. The findings are consistent with the concept that peer influence can enhance rewards and researchers conclude that this consequently increases the likelihood of high-risk substance use (ibid.).

Stress

It is evident that stress is a risk factor for initiation of substance use. For various reasons, including school exams and study problems, adolescence is a time of increased stress. In addition to young people having increased exposure to stress, it is a period of increased vulnerability to it. Studies have shown that as age and puberty increase, physiological responses to stress also increase. At this stage of development, changes in hormones can have complex interactions with stress and substance use. For example, a particular steroid (THP) increases the effect on the GABA A receptor, which consequently reduces stress and halts anxiety.However, as adolescents have high levels of GABA A, which is inhibited by THP, stress responses are increased and prolonged rather than reducing them. Alcohol and some other substances activate GABA A receptors, making them easy-to-access antidotes for this additional stress (Sharma and Morrow, 2016).

Pleasure and Reward

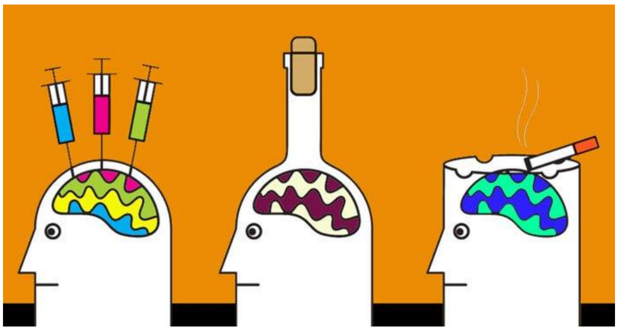


The nucleus accumbens (NA) region of the brain can cause substance use (and misuse). The brain views all pleasures in the same way and makes no difference between a prize of money or a psychoactive substance. However, pleasure leaves a unique mark in the brain. Dopamine, a neurotransmitter, is released in the NA area of the brain and is so consistently linked with pleasure that neuroscientists call this are of the brain ‘the pleasure centre’ or the ‘reward centre.’ All substances cause a powerful surge of dopamine in the NA and so, in sum, activation of this circuitry leads to pleasure, and pleasure increases the probability that the rewarded behaviour repeats itself (White, 2009).

In humans, the brain is the only organ that shapes itself through its experience of the world, and during adolescence, the pleasure or reward centre of the brain plays a central role in learning. When activated, the behaviours leading to its activation are reinforced and are more likely to reoccur in the future. In general, researchers concur that the primary purpose of the reward centre is to reinforce behaviours that the brain assumes are good for the adolescent's behaviour and survival. The functional and structural changes in the brain that occur during adolescence, alongside a strong motivation to fire-up the pleasure centre of the brain, can quickly lead to the development of bad habits that can become embedded in the brain's circuitry. Some researchers have suggested that this can lead to addiction and dependency in later life.

It is evident that the use of substances has effects on both brain structure and brain function. As the adolescent brain is still forming, substance use can impact brain development. Imaging studies suggest that cocaine dependence correlates with abnormalities in brain structure in humans. However, it is unclear whether these differences predispose an individual to drug use or are a result of cocaine's action on the brain. In a study using mice, researchers found that cocaine use brought about changes in brain structure and these were most pronounced in mice exposed to cocaine during adolescence.

Potential of Addiction



There are various ways in which adolescents are more sensitive to substance-induced neuronal dysfunction (Sharma and Morrow, 2016). One team of researchers found significant memory impairment in adolescents than in adults (White and Swartzwelder (2004). Another piece of research found that in adolescents with adolescent-onset alcohol use disorder, the volume of the hippocampus was considerably smaller (De Bellis et al., 2000). Sharma and Morrow (2016) suggest that this could be because adolescents are more sensitive to the neurotoxic effects of alcohol. They report that many of the regions of the brain that are more sensitive to alcohol-induced neurodegeneration are the areas that exert inhibitory control over urges to abuse substances (ibid..).

Many professionals agree that experimentation can turn into excessive rates of substance use. Initiation of substance use occurs during adolescence (a vulnerable time), and some researchers have argued that substance use as an adolescent can lead to an increase in users becoming dependent in later life. Some researchers have proposed the argument that adolescents require less alcohol to experience drunkenness. They argue that they may not understand the limits of safe alcohol consumption. In a contrary study of adolescent boys by Behar et al. (1983) findings show that 'little gross behavioural change occurred in the children after a dose of alcohol which had been intoxicating in an adult population'. Behar's team concluded that the implication of this is that adolescents experience fewer subjective cues to limit intake, potentially resulting in the use of higher quantities, and consequently higher risk for dependence (Sharma and Morrow, 2016).

Some research has concluded that prolonged use of a substances leads the brain to stop producing as much dopamine as it would naturally, which in turn creates further withdrawal, leading to dependency - the user needs more of a substance to feel normal, creating a vicious cycle, which is hard to break. Some researchers suggest that due to this learning process and eventual physical dependence, the user becomes an abuser and loses control. While it seems sensible that substances can hijack the brain's natural reward centre and produce an easily accessed feeling of pleasure, it is misleading to think that every young person who experiments with substances becomes addicted.

Neuroscience Education

The neurological changes that happen during adolescence provide incredible opportunities for personal growth but also enhanced vulnerabilities to consequences (Smith et al., 2013).

The unique aspects of brain development during adolescence should inform the design of prevention programmes for young people. Interest in the brain has risen dramatically in recent decades, suggesting that neuroscience-based information about substance-use risks could be a valuable addition to prevention efforts. A high school curriculum, developed in the USA and focusing on neurobiology, was evaluated by a team of Harvard researchers. Findings from the research showed that, compared to a control group, those following the curriculum had lower rates of smoking cigarettes (7% against 21%) and marijuana use (5% against 35%) in the past 30 days and lower alcohol initiation (3% against 20%). The researchers concluded that neuroscience education is a promising supplemental strategy for adolescent substance use prevention, although highlighted the need for further research in the area (Harris et al., 2013). Understanding the adolescent brain helps us understand their behaviours and responses. It helps to explain why they behave in risk-taking behaviour, and with that knowledge, we can begin to teach adolescents coping strategies.

In summing up, the great irony of the adolescent brain is that it is designed to learn from experimentation and risk, but it is not yet fully able to account for the long-term consequences of these risks. It is easier to permanently damage the developing adolescent brain by certain risky behaviours such as substance use than it is to damage an adult brain (Quinn, 2017). The brain is what makes us, but as Patricia Daniels (2017) points out, 'it is a paradox that the organ that lets us understand the world understands so little about itself. However, while much more research is needed, particularly about the effects of substance use on the adolescent brain, 'science is peeling away the layers of mystery to reveal how three pounds of flesh create an entire universe inside our heads (ibid..).

References

Behar, D.; Berg, C.J.; Rapoport, J.L. (1983) Behavioural and physiological effects of ethanol in high risk and control children: a pilot study. Alcohol Clinicians Experience of Research 7 (4) 404-10

Casey, B.J.; Getz, S.; Galvan, A. (2008) The adolescent brain. Developmental Review, 28 (1), 62-77

Chein, J.; Albert, D.; O'Brien, L. (2011) Peers increase adolescent risk-taking by enhancing activity in the brain's reward circuitry. Developmental Science 14 (2): F1-10

Daniels, P. (2017) Your brain: A User's Guide – 100 things you never knew. Washington DC: National Geographic

De Bellis, M.D.; Clark, D.B.; Beers, S.R. (2000) Hippocampal volume in adolescent-onset alcohol use disorders. American Journal of Psychology 157 (5): 737-44

Dick, D.M.; Pagan, J.L.; Holliday, C. (2007) Gender differences in friends' influence on adolescent drinking: a genetic epidemiological study. Alcohol Clinical Experience Research 31 (12) 2012-9

Gardener, M. & Steinberg, L.A. (2005) Peer influence on risk-taking, risk preference, and risky decision making in adolescence and adulthood: an experimental study. Developmental Psychology 41 (4), 625-35

Hall, G. S. (1904). Adolescence: Its psychology and its relations to physiology, anthropology, sociology, sex, crime, religion, and education (Vols. I & II). New York: D. Appleton & Co.

Harris, S.K.; Doyle, S.; Sherritt, L.; Van Hook, S.; Knight, J.R. (2013) "This is your brain on drugs": Adolescent substance use prevention through neuroscience education. Addiction Science and Clinical Practice 8 (Suppl. 1): A32

Johnson, S.B.; Blum, R.W.; Giedd, J.N. (2009) Adolescent maturity, and the brain: the promise and pitfalls of neuroscience research in adolescent health policy. Journal of Adolescent Health 45 (3), 216-21

Quinn, A. (The adolescent brain – potential and vulnerabilities. Retrieved from http://slideplayer.com/slide/7526474 on 13.04.18

Sharma, A. & Morrow, J.D. (2016) Neurobiology of Adolescent Substance Use Disorders. Child and Adolescent Psychiatric Clinics of North America, 25 (3), pp. 367-375.

Smith, S.S. (2013) The influence of stress at puberty on mood and learning: the role of the GABA A receptor. Neuroscience 249: 192-213

Steinberg, L. (2008) A social neuroscience perspective on adolescent risk-taking. Developmental Review 28 (1) 78-106

White, A.M. (2009) Understanding adolescent brain development and its implications for the clinician. Adolescent Medicine (20) 73-90

Images

https://adolescentbrain-coltoncook.weebly.com/see-whats-happening-inside-of-the-teenage-brain.html

http://rhea.kehsblogs.net/2014/02/06/teen-sleeping-patterns/

http://barton.mpls.k12.mn.us/guide_to_the_adolescent_brain

https://e27.co/event/the-power-of-peer-pressure-how-to-build-a-successful-influencer-marketing-program/

https://en.wikipedia.org/wiki/Addiction

https://edition.cnn.com/2016/07/12/health/social-media-brain/index.html

http://raysac.org/2017/04/19/helping-your-teen-manage-stress/

https://upliftconnect.com/what-causes-addiction/

http://scienceandsociety.columbia.edu/cssevent/neuroscience-and-education-seminars-in-society-and-neuroscience/