

ORIGINAL ARTICLE

Adolescents: which risks for their life and health?

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Summary

This paper reviews emerging research findings related to the biological, behavioral, psychological and social processes that occur during adolescence. New research makes it possible to identify interactions among brain structures, hormonal production and

behavioral impulses, that underpin and explain the connections with serious problems emerging during adolescence: behavioral disorders, substance abuse, risky sexual conduct, violence and other social disorders.

Adolescence is defined as the period of life that starts with the biological, hormonal and physical changes of puberty and ends at the age at which an individual attains a stable, independent role in society. Adolescents' health and well-being is threatened by their inclination to engage in risky and reckless behavior. Factors affecting adolescence, including rapid developmental changes and physical growth, family and social contexts, mean that risk behavior at this stage is different in significant ways from adult behaviour [1]. Adolescents engage in more risky behavior than adults, although the magnitude of age differences in risk-taking varies; as a general rule, adolescents and young adults are more likely than adults to binge drink, smoke cigarettes, have casual sex partners, engage in violent and other criminal behavior, and have fatal or serious accidents.

Significant progress has occurred in the study of adolescent risk-taking, integrating findings across disciplines as neuroscience, psychology, sociology. The last decade has been one of sustained interests and technological advances that have created a lot of opportunities for researchers to learn more about the brain. Longitudinal MRI studies have revealed that a second surge of neuron growth peaks in the brain just before puberty [2, 3].

We know that changes that occur during adolescence are functionally linked to changes in brain structure. Adolescence is a period of "brain plasticity", when extraordinary brain changeability occurs [4].

Plasticity, the brain's ability to change in response to repeated stimulation, is important during adolescence because allows us to learn and adapt; it consists in an elaboration and stabilization of a synaptic architecture constructed as part of the process of learning, but also increases the vulnerability of adolescents toward making unhealthy decisions. Their brain circuitry is still being formed: re-wiring, neuron proliferation and pruning thus make it difficult to think critically before making choices. Neural connections can also be forged and refined or weakened and discarded during plasticity [2].

It was widely assumed that the vast majority of brain development takes place in the first few years of life, but the brain develops right throughout adolescence into the twenties and thirties [5]. This important discovery helped to increase understanding about adolescent brain development and provided support for many unexplained behaviors experienced in late adolescence and early adulthood.

This surge, exactly like the one that occurs during infancy, consists of a thickening of the brain's gray matter. Neurons grow and increase their ability to connect with other neurons. Following this period of proliferation, the brain "rewires" itself over the course of adolescence, especially in the prefrontal cortex. The rewiring is accomplished by two mechanisms: myelination (a process increasing the speed of conduction of nerve impulses) and neural pruning (a process to clean out the unused synapses).

Over the course of adolescence, connections between different areas and structures of the brain increase and strengthen, allowing for multi-tasking, better ability to solve problems and greater capacity to process increasingly complex information.

The processes of neuron proliferation and pruning occurring in the adolescent years result in a brain that is very malleable and adaptable in the face of challenges posed in the environment and highly subject to molding by experience. Experience and use the circuits of the brain are shaped through practice. This is how the brain consolidates learning. This implies that to some extent adolescents can influence the wiring of their own brains by the activities they engage in, the experiences they seek and the things they spend their time doing. Trauma, chronic stress, substance use, and even sedentary activities may have greater negative effects when experienced during this sensitive period of brain development.

Advances in brain research have shown that hormones are not the only explanation for erratic adolescent behaviour [6]. Researchers are still trying to establish the

exact nature of the interrelationships between pubertal processes and adolescent brain development. The timing of brain changes may underlie many aspects of adolescent behavior and risk taking. As for the brain changes that precede puberty, the brain itself initiates puberty by releasing hormones. Brain changes related to pubertal hormones appear to occur mainly in the structures of the brain most closely linked with emotion, arousal and motivation, and with appetite and sleep patterns (Limbic System). Brain changes independent of puberty, as indicated by adolescent brain research, are those related to the development of advanced cognitive functioning (Prefrontal Cortex). Pubertal-related hormones directly influence physical drives (such as appetite and sleep) motivations and emotions, whereas cognitive and regulative controls over behaviour are established in a more gradual and indirect manner.

The limbic system, sometimes referred to as the “emotional brain,” is involved in the expression of emotions (fear, anger) and motivation, particularly those related to survival. The limbic system is also involved in feelings of pleasure that reward behaviors related to species survival, such as eating and sex. In addition, limbic system structures have functions related to memory storage and retrieval, particularly memories related to events that invoked a strong emotional response.

Different studies [7] involving brain scans revealed that when interacting with others, and making decisions, adolescents are more likely than adults to be influenced by their emotions. In addition, adolescents often “read” others’ emotions incorrectly. Studies involved comparing a teen brain to an adult brain determined that adolescents’ prefrontal cortex (where “logical” thinking occurs) is used less often during interpersonal interactions and decision making than their adult counterparts’. Instead, teens relied more on the emotional region of their brains when reading other’s emotions, which is more impulsive [8].

An understanding of what is going on in the limbic system during adolescence helps provide a partial explanation for some characteristic and familiar adolescent behaviors such as: quickness to anger, intense mood swings and making decisions on the basis of feelings. Adolescents’ brains are still rooted in the “emotional brain” making it challenging to make what adults consider to be logical and appropriate decisions.

Brain-wise, the most dramatic happens to the prefrontal cortex, the area of the brain involved in high level cognitive functions such as decision-making, planning, social interaction and self-awareness. MRI studies show that this region undergoes quite dramatic change during adolescence. In fact, there’s a significant decline in the prefrontal cortex in adolescence because the brain is finetuning itself.

As adolescents progress toward adulthood, the self-regulatory parts of their brains are still evolving. An earlier onset of puberty increases the vulnerability for today’s teens, making them more susceptible to take risks that effect their health and development over a longer period of time. Self-regulation is broadly described among psy-

chologists as the management of emotions and motivation. It also involves directing and controlling behavior to meet the challenges of the environment and to work toward a conscious purpose. Self-regulation also encompasses affect regulation, which entails controlling the expression of intense emotions, impulse control, and delaying gratification.

Such behavioral control requires a higher level of cognitive and executive functions. These functions reside in the prefrontal cortex, which matures independent of puberty and is still evolving and developing well into an individual’s mid twenties. During this period of development, adolescents should not be over-protected, but allowed to make mistakes and learn from their experiences and practice self-regulation.

The prefrontal cortex is responsible for cognitive analysis and abstract thought, and the moderation of “correct” behavior in social situations. The prefrontal cortex takes in information from all of the senses and programs thoughts and actions to achieve specific goals [9].

The prefrontal cortex is one of the last regions of the brain to reach maturation. This delay may help to explain why some adolescents act the way they do. This region is involved in functions like attention, problem solving, evaluating consequences of behaviour, making predictions, planning, balancing short-term rewards with long term goals, impulse control and delaying gratification, emotions.

This brain region gives an individual the capacity to exercise “good judgment” when presented with difficult life situations

MRI studies of the brain show that developmental processes tend to occur in the brain in a back to front pattern, explaining why the prefrontal cortex develops last. These studies indicate that brain development is not complete until near the age of 25, referring specifically to the development of the prefrontal cortex.

The better flow of informations between brain regions is allowed by a process of myelinisation of connections [10]. This body of brain research data has led to the idea of a progressive growth of the prefrontal cortex that gradually becomes able to oversee and regulate the behavioral responses initiated by the more primitive limbic structures [11]. The brain area is more active in adolescents when they make decisions than it is in adults – which suggests that adolescents really do use a different mental approach to make social decisions. The ability to account for someone else’s perspective is still developing even in relatively late-stage adolescence.

During adolescence, white matter increases in the corpus callosum, the bundle of nerve fibers connecting the right and left hemispheres of the brain. This allows for enhanced communication between the hemispheres and enables a full array of analytic and creative strategies to be brought to respond to the complex problems that may arise in a young person’s life. The role of experience is critical in developing the neural connectivity that allows for conscious cognitive control of the emotions and passions of adolescence. Teens who take risks in relatively safe situations exercise the circuitry and de-

velop the skills to control themselves in more dangerous situations.

With an immature prefrontal cortex, even if teens understand that something is dangerous, they may still go ahead and engage in the risky behavior. Recognizing the asynchrony of development of the regions of the brain helps us to see adolescent risk-taking in a new light [12]. The most prevalent risks adolescents are sexual risk-taking, substance use, injury and violence being the leading causes of death in age 10-24 years of age, (motor vehicle crashes: 30%; homicides: 15%, and suicide: 12%). Alcohol and drug use have a key-role in approximately 41% of deaths related to motor vehicle crashes. Risky sexual behaviors are the cause of almost half of the 19 million new sexually transmitted infections diagnosed each year in the U.S. adolescents 15-24 years old [13]. Adolescents take risks to test and define themselves. Especially among males, risk-taking makes good evolutionary sense: it can lead to situations where new skills are learned and new experiences can prepare them for future challenges. Risk-taking serves as a mean for discovery about oneself, others and the larger world. The natural and normative proclivity for risk-taking plays a central role in adolescent development, making it a time of both great potential and great vulnerability.

It is important to understand how the changes that occur in the brain influence adolescent risk-taking behaviour. Developmental psychologists have measured and documented a jump in cognitive capabilities in early adolescence. Beginning around the age of 12, adolescents decrease their reliance on concrete thinking and begin to show the capacity for abstract thinking, visualization of potential outcomes, and understanding of cause and effect. Teens begin looking at situations and deciding whether it is safe, risky, or dangerous [14].

These aspects of development correlate with the maturation of the frontal lobe, a shift from expanding neural connections to pruning and an increase in hormones released; all of which drive an adolescent's mood and impulsive behavior. By age 15, studies show there is little difference in decision-making about hypothetical situations between adults and adolescents [14].

Teens were found capable of reasoning about the possible harm or benefits of different courses of action. However, in the real world, adolescents still engaged in dangerous behaviors, despite understanding the risks involved. Both the role of emotions and the connection between feeling and thinking need to be considered: thinking under conditions of intense emotions and high arousal leads teens to make poorer decisions. When circumstances are less intense teens can make better decisions. With the addition of all the complex feelings, such as fear of rejection, wanting to look "smart", the excitement of the risk, or anxiety, it is even more difficult for teens to think through potential outcomes, understand consequences of their decisions, or even use common sense.

The immaturity of the connections between the limbic system and the prefrontal cortex, and the research around the amygdala, provide support to this theory. The

nucleus accumbens, a part of the brain's reward system located in the limbic system, is the area that processes information related to motivation and reward. Brain imaging studies have shown that the nucleus accumbens is highly sensitized in adolescents, sending out strong impulses to act when faced with the opportunity to obtain something desirable [15]. These regions have been implicated in diverse aspects of social processing, including the recognition of socially relevant stimuli (expressions, social judgments, appraisal of others, judging attractiveness, assessing other's intentions, social reasoning, and many other aspects of social processing). Interestingly, among adolescents the regions that are activated during exposure to social stimuli overlap considerably with regions also shown to be sensitive to variations in reward magnitude. Because these same regions have been implicated in many processes of reward-related affect it is suggested that, at least in adolescence, social acceptance by peers may be processed in ways similar to other sorts of rewards, including nonsocial rewards [16].

When teens are alone they make safer decisions, but in the presence of friends the teens make riskier decisions. This helps to explain why so much adolescent risk-taking occurs in the context of the peer group. Peer influence is an important component of adolescence development and drives to both positive and negative outcomes [12]. In adolescence, teens begin to develop friendships that are more intimate and longer lasting and at the same time have multiple groups of friends that are similar in demographics or interests. These friendships allow teens to develop their identities and define themselves independently of their parents, feel accepted, and practice social skills.

Healthy friendships provide support for challenges teens encounter in adolescence and provide positive experiences during these years of intense change. However, when teens find themselves in emotionally arousing situations and with their immature prefrontal cortex, cognition thinking may be impaired, and they may be more likely to take reckless actions and make impulsive decisions [12].

Mass media, community norms, and adult role models also influence adolescent risk-taking behaviors. Teens are constantly bombarded with emotionally arousing, and often dangerous messages through multi-media: unprotected sex, substance abuse, and alcohol use, which even adults have trouble resisting to.

During puberty, the increases in estrogen and testosterone bind receptors in the limbic system, which not only stimulates their sex drive, but also increases teens' emotional impulsivity. Changes in the brain's reward sensitivity that occur during puberty have also been discovered. These are related to changes in dopaminergic neurons, circuits that produce feelings of pleasure (among other functions). The increase in risk-taking between childhood and adolescence is due primarily to increases in sensation seeking that are linked to changes in patterns of dopaminergic activity around the time of puberty [17].

Due to these changes, teens may require higher levels of stimulation to achieve the same levels of pleasure or reward, leading them to seek out new experiences, and driving them to make riskier decisions. The early reorganization of dopaminergic neurons in the motivational system, due to the secretion of sex hormones (mostly estrogens, testosterone and oxytocin) at the beginning of puberty, impels adolescents toward thrill seeking. On the other hand, the slow maturation of the cognitive control system, mostly exerted by the prefrontal cortex, implies that these impulses cannot be appropriately regulated [18].

“Adolescents are more vulnerable than any other age group to developing nicotine, alcohol, and other drug additions because of the regions of the brain that govern impulse and motivation are not yet fully formed” [19].

Parents can help adolescents through this period by listening, offering support, and guidance.

Teens need to be surrounded by caring adults and institutions that help them learn specific skills and appropriate adult behavior. Suggestions should answer more challenging and specific questions about specific systems and practices, that will best help them grow and mature in appropriate ways and opportunities that will be most effective in helping them develop the skills of judgment, planning and impulse control.

Having knowledge of adolescent brain development can help to understand why teens take risks and that risk-taking behavior is a normal and necessary part of adolescence. This knowledge can assist in developing effective interventions that focus on reducing the harm associated with risk-taking behaviour, to establish a safer, healthier, more teen friendly environment.

References

- [1] Taylor SJ, Barker LA, Heavey L, et al. *The typical developmental trajectory of social and executive functions in late adolescence and early adulthood*. Dev Psychol 2013;49:1253-65.
- [2] Giedd JN, Blumenthal J, Jeffries NO, et al. *Brain development during childhood and adolescence: a longitudinal MRI study*. Nature Neuroscience 1999;2:861-3.
- [3] Dosenbach NUF, Nardos B, Cohen AL, et al. *Prediction of individual Brain Maturity Using fMRI*. Science 2010;329:1358.
- [4] Lebel C, Beaulieu C. *Longitudinal development of human brain wiring continues from childhood into adulthood*. J Neurosci 2011;31:10937-47.
- [5] Stiles J, Jernigan TL. *The basics of brain development*. Neuropsychol Rev 2010;20:327-34.
- [6] Sisk CL, Foster DL. *The neural basis of puberty and adolescence*. Nature Neuroscience 2004;7:1040-478.
- [7] Guyer AE, McClure-Tone EB, Shiffrin ND, et al. *Probing the neural correlates of anticipated peer evaluation in adolescence*. Child Dev 2009;80:1000-15.
- [8] Cohen Kadosh K, Johnson MH, Dick F, et al. *Effects of age, task performance, and structural brain development on face processing*. Cerebral Cortex 2013;23:1630-42.
- [9] Casey BJ, Jones RM, Hare TA. *The adolescent brain*. Ann NY Acad Sci 2008;1124:111-26.
- [10] Giedd JN. *Structural magnetic resonance imaging of the adolescent brain*. Ann NY Acad Sci 2004;1021:77-85.
- [11] Steinberg L. *A social neuroscience perspective on adolescent risk-taking*. Dev Rev 2008;28:78-106.
- [12] Steinberg L. *Risk taking in adolescence: what changes and why?* Ann N Y Acad Sci 2004;1021:51-8.
- [13] <http://www.cdc.gov/mmwr/pdf/ss/ss6104.pdf>- Accessed March 2013
- [14] Steinberg L. *Cognitive and affective development in adolescence*. Trends Cogn Sci 2005;9:69-76.
- [15] Gardner M, Steinberg L. *Peer Influence on risk taking, risk preference and risky decision-making in adolescence and adulthood*. Dev Psych 2005;41:625-35.
- [16] Van Leijenhorst L, Zanolie K, Van Meel CS, et al. *What motivates the adolescent? Brain regions mediating reward sensitivity across adolescence*. Cereb Cortex 2010;20:61-9.
- [17] Lopez, Schwartz SJ, Prado G, et al. *Adolescent neurological development and its implications for adolescent substance abuse prevention*. J Prim Prev 2008;29:5-35.
- [18] Barbalat G, Domenech P, Vernet M, et al. *Risk-taking in adolescence: A neuroeconomics approach*. Encephale 2010;36:147-54.
- [19] Carls J. *New research on adolescent brain development*. Center for Substance Abuse Prevention. 2004 November. Issue #1.

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