Biological Differences between Adolescent and Adult Brains that Contribute to Problem-Solving, Critical Thinking and Emotions

November 2006

B L A M

- In decision-making, adolescents engage less efficient brain networks than adults. When confronted with a judgment task regarding a dangerous situation, adults recruit the visual association cortex (to construct mental images of all the possible outcomes) and the insular cortex (involved in eliciting somatic reactions to the situation) to arrive at a solution. Adolescents, conversely, engage the dorsolateral prefrontal cortex, which is involved in effortful reasoning in the absence of imagery and autonomic arousal.
- Emotional stimuli or events activate the anterior cingulate cortex, the orbital frontal cortex and the amygdala more strongly in adolescents than adults, suggesting that their decisions are largely products of affective systems outside conscious awareness. Alternatively, the adults' capacity to maintain goal-oriented attention prevents emotional content from biasing their cognitive processes, allowing a narrow focus on concrete aspects of a situation that help establish a more rational decision.
- Prefrontal cortex of adolescents has fewer pathways to other cortical regions, is less synaptically pruned and has undermyelinated nerve fibers. These biological patterns contribute to more deficient higher-level self-regulatory capabilities leading to manifestation of impulsive behaviour, inability to perceive consequences of particular actions, lack of planning, and heightened risk-taking.
- Adolescents show less activity in the frontal eye field, superior conicullus, and cerebellum during tasks that require attenuation of automatic behavioural responses. Decreased engagement of the superior conicullus and frontal eye field (involved in suppression of reflexes) and cerebellum (which projects to prefrontal and premotor cortices) implicates that their top down modulation of reflexes is underdeveloped causing them to engage in more impulsive acts than adults.
- Greater myelination of nerve fibers in adulthood accounts for bigger hippocampi sizes, greater white matter volume and smaller grey-matter density than in adolescence. These structural discrepancies are also reflective of more intra-cortical links within the limbic system and inter-cortical connections with various other regions of the adult neocortex that form ascending and descending pathways. Integration of emotional and cognitive areas of the brain in adulthood, further enhances problem-solving strategies due to a dynamic interplay between bottom-up and top-down mechanisms.
- In comparison to adults, adolescents show increased left temporoparietal cortex activation in cognitive tasks requiring application of navigational knowledge to a new spatial representation. Their inability to engage in such abstract thinking might be caused by a greater recruitment of immature left-hemisphere task-relevant systems, which inhibit memory retrieval. Smaller activation of the left temporoparietal cortex in adults implicates that they already developed more efficient mechanisms for extraction of constant allocentric spatial maps.

Keeping the classroom environment positive to optimize learning…

- To facilitate synaptic strengthening in the prefrontal cortex, sensorimotor experiences, such as music or touch, are an effective tool for capturing students' attention
- Competitive strategies should be minimized so that girls aren't discouraged from learning
- Mistakes and risks should be accepted and teachers should not judge students on their mistakes, but their successes
- Some effective classroom activities to optimize learning involve: using simulations to communicate complex issues; involving students in real-life apprenticeships; encouraging peer collaboration; posing physical and mental challenges to solve problems; having students reiterate their learning material daily; teaching students that there are various ways to solve a problem

BOTTOM LINE ACTIONABLE MESSAGE

The articles used to prepare this BLAM are referred to below.

Recommended Reading:

Abigail A. Baird, Jonathan A. Fugelsang and Craig M. Bennett's paper, What were you thinking: An fMRI study of adolescent decision making, used fMRI to investigate neural mechanisms that differentiate adult and adolescent decision making. Participants were presented with hypothetical scenarios and asked to indicate whether they perceived it to be a "good idea" or "not a good idea". Adults' better judgment strategies are a product of increased activity in the right and left insular cortices as well as the right and left fusiform face areas. The decrements in adolescents reasoning result from exclusive reliance on the right dorsolateral prefrontal cortex. This paper was retrieved in November 2006 from the following link:
http://www.theteenbrain.com/research/presentations/pdfs/CNS_05_ab.pdf

Christopher C. Monk et al.'s paper, Adolescent immaturity in attention-related brain engagement to emotional facial expressions, used fMRI to determine distinctions in brain activity between adolescents and adults during viewing of emotionally engaging face stimuli. Participants were presented with neutral and emotional faces (angry, fearful, and happy) and asked to attend to either 1) the subjective emotional reactions of the faces (i.e. attention to emotions), 2) focus on a physical feature on the face (i.e. attention to neutral features) or 3) passively view the face (i.e. no attention demands). Goal-directed attention towards emotional or neutral features activated the orbital frontal cortex more in adults. Selective attention to neutral stimuli or passive viewing activated the anterior cingulated cortex, the orbital frontal cortex and the amygdala more in adolescents. These results suggest that adults modulate activity in relevant brain structures based on attentional dimensions whereas adolescents regulate activity to a greater degree on the basis of emotional content of the stimuli.

Laurence Steinberg's paper, Cognitive and affective development in adolescence, offers an extensive review of biological, behavioural and cognitive maturational changes that occour in adolescence. It further comments on the way in which interaction of these factors, the affective system and social variables influences decision-making, risk-taking and self-regulation. This paper was retrieved in November 2006 from the following link:
http://scholarsportal.info.libaccess.lib.mcmaster.ca/pdflinks/06102416372224028.pdf

Beatriz Luna et al.'s paper, Maturation of Widely Distributed Brain Function Subserves Cognitive Development, investigated differences in the pattern and extent of brain activation in children, adolescents and adults during suppression of automatic behaviours. In prosaccade vs. antisaccade tasks, subjects were required to orient their eyes towards a target that followed a green fixation stimulus (a prosaccade response) and away from a target that followed a red fixation stimulus (an antisaccade response). Compared to adults, adolescents showed less activity in the frontal eye field, intraparietal sulcus, thalamus, cerebellum and superior conicullus, which subserve antisaccade responses. These findings suggest that adolescents have a diminished capability to suppress reflexive behaviours, offering a plausible insight into their impulsiveness.

Michio Suzuki et al.'s paper, Male-specific Volume Expansion of the Human Hippocampus during Adolescence, compared brain morphology of younger and elder adolescent males using voxel-based morphometry (VBM) and volumetric region-of-interest analyses. Older adolescents had consistently larger hippocampi size, greater white matter volume and smaller gray matter density than younger adolescents. These differences might reflect increased myelination of hippocampal nerve fibers, which form links within the limbic system and various other extrastriatal regions of the neocortex. Such connections, in turn, reflect a more effective interplay between cognitive and emotional processes that result in better decision-making.

Daniel S. Pine et al.'s paper, Neurodevelopmental Aspects of Spatial Navigation: A Virtual Reality fMRI study used a navigation paradigm to map brain regions activated in adolescents and adults during memory retrieval. Following training in a virtual city, brain regions engaged during navigation were delineated using fMRI as subjects either used memory for city locations or arrows appearing in the virtual city to reach a destination. Subsequent to the navigation tasks, “allocentric” memory for town goal-locations was tested by showing subjects a novel aerial-view display of the virtual reality environment and asking them to label the town locations. Although comparable navigation skills were displayed by adolescents and adults, adults showed superior ability to transpose their knowledge of the virtual reality environment to new spatial representations of the town. In terms of brain mapping, adolescents showed greater left tempropariеtal cortical activity than adults during memory retrieval. These results suggest that adolescent left-hemisphere task relevant systems are less mature for abstract processing than those of adults.

Lucinda M. Wilson and Hadley Wilson Horch’s overview, Implications of Brain Research on Teaching Young Adolescents, offers various teaching strategies to enhance attention and memory span of adolescents as well as keep the school environments positive to maximize learning. On the basis of existing knowledge on adolescent brain maturation, these authors provide a list of effective activities that prune the important synaptic connections in the maturing brain, while eliminating the distracters. Furthermore, they emphasize the importance of providing students with diverse learning experiences to enhance their knowledge. This paper was retrieved on November 2006 from the following link:
http://www.nmsa.org/Publications/MiddleSchoolJournal/September2002/Article10/tabid/418/Default.aspx