Acquired Brain Injury in Adolescents

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Adolescere

Latin: to grow into adulthood


When does it start?

• Generally thought to start with puberty
• Pre-21st century puberty started around age 13 years, now about 10 years

Why does the hypothalamic set point change?

• Genes: biological clock set genetically
• Signals indicating there are sexually mature mating partners in the environment
• Signals that the organism is healthy enough to support pregnancy (e.g., leptin protein levels in females) and whether individual is healthy and mature enough to reproduce
  – Stress, illness, nutritional deficiencies, excessive exercise, excessive thinness can delay onset of puberty
  – Onset of puberty earlier in obese girls and later in obese boys
Timecourse of Hormone Changes

Forbes (2010)

We all start life as girls

- Sex hormone effects on brain and behavior:
  - Organization
    - Circulating testosterone starting at around 8 weeks gestation "masculinizes" the brain in males and shapes some aspects of behavior that won't be evident until later in life (more on sex differences) gives the impression that these changes "start" at puberty
  - Activation
    - Triggering of some changes at puberty via changing hormone levels (e.g., change in HPG set point may lead to motivation to engage in sex)

Physical Manifestations of Puberty

(Marshall, 1978)

1. Rapid acceleration in growth => dramatic increases in height and weight
2. Development of primary sex characteristics including further development of gonads (sex-hormone-secreting glands – testes and ovaries)
3. Development of secondary sex characteristics (changes in genitals, breasts, body hair)
4. Changes in body composition: distribution of fat and muscle
5. Changes in circulatory and respiratory systems => increased strength and tolerance for exercise
- Part of a gradual process of endocrine and CNS changes that begins at conception (Susman & Rogol, 2004) – i.e., no new hormones are produced and no new bodily systems develop at puberty

Stages

- Early adolescence: Ages 10-13 years, middle/jr high school
- Middle adolescence: Ages 14-17 years, high school
- Late adolescence: Ages 18-21 years, college
- Emerging adulthood: Ages 18-25 years, when individuals make the transition from adolescence to adulthood

How do we know it’s over?

- Is adolescence terminable or interminable? (Arnett & Taber, 1994)
  - End is determined by a combination of cultural, cognitive, social, and biological attributes
  - In Western societies, might include living independently, employment, emotional self-sufficiency

Is sleep a biomarker for the end?

Roenneberg et al. (1994)
Other perspectives on the “end”...

<table>
<thead>
<tr>
<th>Perspective</th>
<th>When adolescence begins</th>
<th>When adolescence ends</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological</td>
<td>Onset of puberty</td>
<td>Becoming capable of sexual reproduction</td>
</tr>
<tr>
<td>Emotional</td>
<td>Beginning of detachment from parents</td>
<td>Attainment of separate sense of identity</td>
</tr>
<tr>
<td>Cognitive</td>
<td>Emergence of more advanced reasoning skills</td>
<td>Consolidations of advanced reasoning skills</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>Beginning of shift in interest from parental to peer relations</td>
<td>Development of capacity for intimacy with peers</td>
</tr>
<tr>
<td>Social</td>
<td>Beginning of training for adult work, family, and citizen roles</td>
<td>Full attainment of adult status and privileges</td>
</tr>
<tr>
<td>Educational</td>
<td>Entrance into Jr High</td>
<td>Completion of formal schooling</td>
</tr>
<tr>
<td>Legal</td>
<td>Attainment of juvenile status</td>
<td>Attainment of majority status</td>
</tr>
<tr>
<td>Chronological</td>
<td>Attainment of designated age of adolescence</td>
<td>Attainment of designated age of adulthood</td>
</tr>
<tr>
<td>Cultural</td>
<td>Entrance into period of training for ceremonial rite of passage</td>
<td>Completion of ceremonial rite of passage</td>
</tr>
</tbody>
</table>

Domains of Development in Adolescence

- **Identity**: self-conceptions, self-esteem, sense of self
- **Autonomy**: development and expression of identity
- **Intimacy**: formation, maintenance, and termination of close relationships
- **Sexuality**: development and expression of sexual feelings
- **Achievement**: behaviors and feelings in evaluative situations

Theoretical Accounts of Adolescent Behavior and Development

- **Biosocial**: Period of sturm und drang via hormonal upheaval, nothing to do but manage (Hall)
- **Organismic**: Hormones and cognitive developments interact with experiences and others in the environment (Freud, Piaget, Erikson)
- **Learning**: Behavior modification and socialization into the culture of adulthood (Skinner, Bandura)
- **Sociological**: Young people have less power, are marginalized, leading to frustration and restlessness; influenced by family environment (Mannheim, Lewin)
- **Historical/Anthropological**: Social invention, reflection of political, social, and economic circumstances; culturally defined stage (Mead, Benedict)

Adolescent Brain Development

- **What do you believe?**

Theme of Adolescent Brain Development is Increasing Efficiency of Functional Networks

- **Structural changes**
  - Grey matter $\uparrow$, white matter and fractional anisotropy $\uparrow$, gyriﬁcation changes according to spatial and functional alignment of brain regions
- **Functional changes**
  - $\uparrow$ in cortical metabolic rate, delta and theta band amplitudes
  - Major changes in dopaminergic networks: $\uparrow$ PFC [Da] $\uparrow$
  - innervation of PFC by Da-ergic neurons

Caveats

- Extremes of Biological
- Extremes of Environmental

Steinberg (1999) Adolescence
**How about behavior?**

- Physical, cognitive, and social changes parallel changes in the brain
  - Big changes, individual variability, sex-based differences, related more or less to timing of puberty

**Behavioral Themes**

- The reward-seeking brain
  - Reward sensitivity
  - Social reward
  - Reward vs. risk
    - Dual-systems theory of adolescent risk-reward behavior (Steinberg)
  - Sexual dimorphism in behavior

**The Reward-Seeking Brain**

- Scores on sensation-seeking, risk preference, reward sensitivity all ↑ from age 10 until mid-adolescence, peak ~ 13-16 years, then ↓
- Why do adolescents do such stupid things?

**True or False?**

- Adolescents are irrational or deficient in their information processing, or reason about risk in fundamentally different ways than adults.

- Adolescents do not perceive risks where adults do, or are more likely to believe that they are invulnerable.

- Adolescents are less risk-averse than adults.

**Reward Sensitivity**

- Through either decreased buffering or increased concentrations of Da, PFC has more bioavailability of Da, the “reward” neurotransmitter
  - May underlie ↑ sensation seeking
  - Coincident with but not necessarily caused by puberty
Response to Social Rewards

- Elevation of gonadal steroids related to social bonding (e.g., oxytocin) = increases in social bonding and memory for social stimuli

Social Reward

Chein et al., 2011

Dual-Systems Account of Risk-Seeking in Adolescence

Steinberg, 2010

Sex-Based Differences

Sumter et al., 2009

These hormonal changes help explain why, relative to children and adults, adolescents show especially heightened activation of limbic, paralimbic, and medial prefrontal areas in response to emotional and social stimuli, including faces with varying emotional expressions and social feedback. They also explain why early adolescence is a time of heightened awareness of others’ opinions, so much so that adolescents often engage in “imaginary audience” behavior, which involves having such a strong sense of self-consciousness that the teenager imagines that his or her behavior is the focus of everyone else’s concern and attention. Feelings of self-consciousness increase during early adolescence, peak around age 15, and then decline (Ranking, Lane, Gisborne, & Gerrard, 2004). This rise and fall in self-consciousness has been attributed both to changes in hypothetical thinking (Elkind, 1967) and to fluctuations in social confidence (Ranking et al., 2004), and although these may in fact be contributors to the phenomenon, the arousal of the socio-emotional network as a result of increases in pubertal hormones probably plays a role as well.

Steinberg (2008), p. 90

What about and cognitive and social developments?
Cognitive Developments in Adolescence

- Main changes are in
  - Declarative knowledge (via school)
  - Executive functions
  - Speed of processing
  - Working memory

EF Developments

- Control: self-structure work, school, and free time; delay gratification; initiate complex behaviors with minimal cues
- Abstraction: understand strengths and limitations and generate strategies accordingly, create abstract plans to achieve long-range goals (e.g., study for passing grades), understand complex social situations, contribute to the community
- Sense of time: plan, sequence, estimate time required for, and recall temporal characteristics of complex behavioral events

Language Developments

- Related to cognitive changes, e.g.:
  - Vocabulary
    - Including peer-specific idiosyncratic vocabulary
  - Complex syntax
    - E.g., production and comprehension of complex clause and relational structures
  - Development of genres
  - Language flexibility and agility
- Pragmatics – more on that later…

Adolescent social skills: An oxymoron?

Development of Role Taking
Flavell (1968)
Let’s not forget the hormones…

How do these changes relate to developmental benchmarks?

**Pre-Adolescence**
- Defined by puberty
- Rapid physical growth
- Developing independent values and opinions but with inconsistent abstract reasoning
- Need for privacy
- Need to be an insider

**Early Adolescence**
- Typically begins with end of puberty
- Development of secondary sexual characteristics and sexual behavior
- Focus on physical appearance
- Need for self-reliance
- Shift to loose-knit, mixed sex social groups
- Increased intimacy of individual friendships
- Self-appraisal and consideration of the future

**Late Adolescence**
- Independent living skills
- Continued development of personal identity, morals, and values
- Continue to have inconsistent execution of ideals
- Community has high expectations for self-regulation, including self-directed learning

**Putting it all together…**

Elaborate and abstract self-knowledge
Sophistication in executive functions of the self
Separation from family and engagement with peers
Sophisticated interaction skills

Identity formation
A sense of belonging

Adapted from Worthington (1989)
What happens when this goes wrong?

Traumatic Brain Injury
(and acquired brain injury in general)

Effects of TBI on Pituitary Function
Rose & Auble (2011)

- Up to 30% of children with TBI have hypopituitarism at 5 years post injury
- Most common problems are growth hormone deficiency and disturbances in puberty
- Other problems include ACTH deficiency, diabetes insipidus, central hypothyroidism, and elevated prolactin
- Every hormonal axis can be affected after TBI in children
- Need serial assessment of hormone function

Effects of TBI on Brain Structures and Functions
Ciccia, Meulenbroek & Turkstra (2009)

1. Damage to and associated atrophy of the frontal and temporal lobes
2. Diffuse axonal injury and related ex-vacuo dilation of the ventricles
3. Decreased volume of the corpus callosum
4. Generalized cerebral atrophy in the chronic phase, even in the absence of structural findings at the time of the injury

Particularly after Moderate-Severe TBI:

- Reduced growth of corpus callosum up to 3 years post-injury (Levin et al., 2000)
- Reduced hippocampal volume (di Stefano et al., 2000)
- If TBI was complicated by ↑ ICP, disproportionate hippocampal growth reduction 5 years postinjury, most notable on ipsilateral side to the site of impact (Tasker et al., 2006)

Impairment of social and moral behavior related to early damage in the human prefrontal cortex

Subject A: Run over by a motor vehicle at age 15 months
Subject B: Right frontal tumor at age 3 months
Cognitive Effects

- Impairments in cognitive functions dependent on PFC function and network development
  - EFs, working memory, speed of processing
  - Metacognitive impairments are the hallmark of injury at this age
- Phase mismatch between physical and cognitive recovery (Boyer & Edwards, 1991)
- Potential cognitive “stall” later in development (Gamino et al., 2009)

Two different types of long-term memory

- Explicit (aka declarative)
  - Dependent on conscious experience to encode and recall
  - Stored by semantic associations
  - Role of errors is dependent on factors such as consequences and meaning
  - May generalize with conscious effort
  - May be learned with a single trial
- Implicit
  - Often not accessible to conscious recall
  - Stored by surface features
  - Highly context-specific
  - Learning is probabilistic
  - Requires multiple repetitions but durable over time

Self-Perception

<table>
<thead>
<tr>
<th>LCQ Tool</th>
<th>Self (n = 19)</th>
<th>Self (n = 19)</th>
<th>Control (n = 19)</th>
<th>Control (n = 19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alexea</td>
<td>3.12</td>
<td>6.84</td>
<td>3.12</td>
<td>6.84</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>46.77</td>
<td>38.47</td>
<td>46.77</td>
<td>38.47</td>
</tr>
<tr>
<td>Range</td>
<td>34 - 72</td>
<td>34 - 72</td>
<td>34 - 72</td>
<td>34 - 72</td>
</tr>
</tbody>
</table>

Douglas, 2010

Memory

- Explicit: Semantic, Episodic, Lexical
- Implicit: Habits, Skills, Emotional Associations

Social Perception

Sociability may depend upon brain cells generated in adolescence

Also become profoundly anti-social when the creation of new brain cells is interrupted in adolescence, a surprising finding that may help researchers understand schizophrenia and other mental disorders, Yale researchers report.

When the same process is interrupted in adults, no such behavioral changes were noted, according to research published in the Oct. 4 issue of the journal Neuron.

“[This has important implications in understanding social development at the molecular level],” said Ken Kallman, assistant professor of psychiatry and senior author of the study.

Scientists have known for quite some time that new brain cells are continually generated in specific brain regions at birth. This process, called neurogenesis, occurs at a significantly greater rate during childhood and adolescence than in adulthood, yet most research has focused upon the function of these neurons in older brains.

The Yale team decided to explore the function of these new brain cells in mice of different ages. Normal adult mice tend to spend 2 to 3 h of time exploring and interacting with unfamiliar mice. However, adult mice that had neurogenesis blocked during adolescence showed no interest in exploring other adult mice and even evaded attempts made by other mice to engage in social behavior.
### Social Effects of TBI

- In high-achieving teens with TBI, significantly lower scores on standardized pragmatic language tests (Turkstra, Williams, Tonks & Frampton, 2008)
- In teens with poor social perception, less frequent use of mental state terms in conversation (Stronach & Turkstra, 2008)
- No significant differences in proceduralized interpersonal behaviors in extemporaneous conversations (Turkstra, Brehm, & Montgomery, 2006)

### Similarities in Social Beliefs

**Turkstra, Dixon, & Baker (2004)**

- Cliques and crowds
- Did not acknowledge clique membership
- Positive and negative social attributes in others
- Personal endorsement of qualities they rated highly in others
- Social activities
- Actions that would make a person feel accepted or rejected in social contexts
- Range of scores on self-ratings of social behavior
- Feelings of belonging

### Differences

- Adolescents with TBI cited communication skills as important skills and as personal challenges, comparison peers did not
- Adolescents with TBI did not identify good listening as a skill, comparison peers frequently did
- Adolescents with TBI rated themselves as less skilled in social perception than their peers

### Effects on Outcome

- Major changes in career plans (Balaban et al., 2009)
- Protracted involvement of parents in everyday social life (Bedell et al., 2005)
- Social isolation

### Summary

- Impaired social perception combined with self-image and self-perception as more or less “normal”

### Summary of TBI Effects

- Injury in adolescence disrupts ongoing brain development, “frontal lobe” functions are particularly vulnerable
- Injury before adolescence may significantly delay or even prevent these functions from developing
- As in typical development, trajectories of development differ across those of the same age and the “endpoint” is not known
- Many adolescents with TBI do not perceive social and emotional cues accurately
  - This has been associated with impairments in the expression of some social behaviors, but typically not behaviors that are overlearned
- Nevertheless, for the most part they view themselves as “typical”
How about intervention?

Not always…

Principles of Intervention

How about cognitive rehabilitation?

• Maybe
  – Good evidence in adults, but almost no evidence in adolescents or children (Laatsch et al., 2007)

• Some things might not be amenable to treatment
  – PFC less plastic than other parts of the brain (Kolb, Muhammad & Gibb, 2011)

Principles of Intervention

• Just do it
  – Adolescence is a critical period for social and cognitive development - a window of opportunity for intervention

• Use peer mentoring to make it socially rewarding
  – Adolescents with ABI may not affiliate with injured peers - e.g., in support groups or rehabilitation - particularly at younger ages
  – Pairing with older individuals with ABI who have experienced social isolation may have negative emotional consequences

Principles of Intervention

• Make it immediately rewarding
  – “If you don’t show you can help them in the first 10 minutes, you’ve lost them.”

• Stop talking
  – Consistent evidence that didactic programs (e.g., DARE, abstinence programs) are ineffective at changing behavior in typical adolescents – why would they work for adolescents with impaired executive functions?

Principles of Intervention

• It’s a chronic disease
  – Social isolation may be perceived less when social life is more structured
  – Feelings of alienation may evolve as demand for self-organized social life increases
  – Impairments in social cognition may become more apparent as brain fails to develop typically

• Adolescents may require the most social support long after injury
  – Are we prepared to assess and treat chronic problems?
A Framework for Intervention

Sohlberg & Turkstra (2011)

Diagnosis: __________________________

Social Participation

Social Activities

Social Functions

Environmental factors

Personal factors

PLAN:________________________________________________________

PROGNOSIS: _________________________________________________

Figure 9.3. ICF worksheet.

Health Condition Traumatic Brain Injury

Social Functions

Disinhibition, impaired metacognition

Social Activities

Inappropriate comments, tangential and verbose in conversation

Participation in Social Roles

Loss of pre-injury friends, limited employment, withdrew from school

Environmental factors

Good access to social activities, lives with a roommate who has no training in social supports

Personal factors

Strong motivation to engage socially, highly charismatic

References


