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Special Issue on the Adolescent Brain

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We are delighted to present this Special Issue on the Adolescent Brain. The impetus for this project came when the Neuroscience and Biobehavioral Reviews editorial staff contacted one of us (Linda Spear) about preparing an update of “The adolescent brain and age-related behavioral manifestations” published in the journal over a decade and a half ago (Spear, 2000). This review is still cited as frequently now as it was during the first couple of years after it was published (~2300 cites to date according to the Web of Science), despite the review being now considerably outdated by a marked escalation of research on the adolescent brain in studies conducted both using laboratory animals and with human adolescents (see Fig. 1). Factors contributing to the explosive, 10-fold increase in the number of publications on this topic from 2000 to present include marked advances in brain imaging and analysis, as well as the increasing recognition of the dramatic brain transformations occurring during adolescence and associated vulnerabilities and opportunities (see Dahl and Spear, 2004). This wealth of new information is transforming our understanding of the adolescent brain. A decade and a half ago, there was little consideration of the contribution of genetic and epigenetic factors to adolescent brain development, let alone assessment of critical gene \times environment \times age ($G \times E \times A$) interactions in influencing adolescent vulnerabilities and resiliencies that now form a major emphasis of research in the field. Much of the research on the adolescent brain at the beginning of this century used a region-focused approach, examining specific brain areas and their modifications during adolescence – a far cry from the increasing focus on brain connectivity and network analysis that has transformed studies of brain development. The evolution of molecular, cellular and neuro-physiological studies of adolescent rodents and technical advances in human imaging, permitting some comparable molecular assessments, has gradually escalated our understanding of the molecular and neural underpinnings of adolescent brain transformations. New areas of focus continue to emerge, including assessments of the role of the gut microbiome, microRNAs and neuroimmunology in adolescent brain development and function.

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The state of the field calls for an updated review on current knowledge about the adolescent brain. The sheer magnitude of exciting new research that has been generated, however, extends far beyond that which could be covered within the confines of a single review. Hence, for this project we came together, mentor and previous trainee, both passionate about the transdisciplinary approach to characterizing the adolescent brain, to recruit a broad variety of exceptional research groups, asking each to review a selected target area. The task of inviting research groups was a difficult one, given the exceptional quality and quantity of researchers currently engaged in many of the topic areas included in this special issue. We were excited by the enthusiastic responses of the invited participants, collectively representing 15 states in the US and 8 countries, with a nearly unanimous acceptance rate, resulting in a final author list reflecting a who's who of exceptional research groups dedicated to extending knowledge on the development of the adolescent brain. It should be noted, however, that the field contains a wealth of outstanding researchers, of which we were only able to invite a limited selection; the work of these other excellent research groups, however, is well represented in these pages, and many graciously agreed to serve as reviewers.

As summarized in Fig. 2, twelve topic areas were selected to represent the diversity of research being conducted in this area. These divisions, however, should not be interpreted as implying that these topics are completely separable. Each area is typically inextricably linked with one or more others, with many of the research groups invited to participate having research foci that intersect several areas. There is substantial overlap in networks of brain activity that influence behavioral, cognitive and emotional function, and these functions notably interact, sometimes in age-specific ways, during adolescence (e.g., see Dahl, 2004). For instance: emotional behavior and affect are bi-directionally influenced by social behavior, and are all likely impacted by pubertal development; consideration of the ontogeny of psychopathology interfaces with those areas, as well as with cognitive neuroscience, environment/stress and genetics/epigenetics; discussion of epigenetics inevitably leads to consideration of environmental factors influencing genetic regulation of diverse behavioral, cognitive and emotional outcomes; consequences of alcohol/drug exposure and stressors likewise can be expressed through potential alterations in these outcomes. Such intersections among topic areas lead to the emergence of some complementary themes across reviews, whereas in other cases, findings viewed through the lens of unique target functions may lead to different approaches, insights and interpretations.

For 11 of the 12 topic areas of the special issue, paired reviews were recruited for each topic: one clinical review focusing on the human literature, and the other a preclinical review focusing on research using laboratory animals (see Table 1). This atypical approach was chosen in recognition of the essential role that both types of research investigation play in the evolution of our understanding of adolescent neural, behavioral and cognitive function. With some rare exceptions where research groups have explored similar research questions across species (e.g., Casey et al., 2015; Silveri, 2014), the majority of research groups focus on either human studies or research using laboratory animals. Thus, to encourage a translational perspective of the adolescent brain, while ensuring inclusion across multiple research cohorts and associated study-related considerations, interpretations and limitations, reviews were encouraged to cross-reference each other. There has been substantial and

growing interest in modeling adolescence in laboratory animals (see Fig. 1) in large part because the transition from sexual immaturity and dependence on parental support to sexual maturity and relative independence is a developmental transition evident across species ranging from humans to rodents. Similar goals, as well as neural, hormonal, cognitive and behavioral transformations can be identified during this developmental transition across mammalian species, recognizing of course the important caveat that across-species comparisons need to be tempered by marked species variations in brain/cognitive/behavioral complexities, as well as duration of the life span and hence, timing and length of developmental transitions (see Spear, 2000). As can be seen in this Special Issue, some areas of consilience have emerged across species in instances where comparable data exist. In other instances, available techniques and levels of analysis have varied notably between research in adolescent humans and laboratory animals, resulting in assessments at differing levels of analysis and exploration of dissimilar, though sometimes complementary, research questions.

The last research topic in the Special Issue focuses on emerging areas, including three reviews that address promising new research areas where the quantity of available data is not yet commensurate with preparation of separate reviews of the clinical and pre-clinical literature. The special issue ends with invited commentaries by a number of distinguished researchers conducting human or laboratory animal studies across multiple areas relevant to advancing our knowledge of adolescent brain development and function. The collective result is an astounding group of state-of-the-art reviews of each of the adolescent research areas targeted, along with a series of insightful commentaries. The work summarized in these reviews provides an up-to-date multidisciplinary and translational perspective on the burgeoning area of adolescent brain research. The collection sets the stage for the next decade of research in this area, with the ultimate goal of helping adolescents, their caretakers, educators and clinical practitioners, optimize the opportunities and minimize the vulnerabilities afforded by this important developmental transition.

Acknowledgments

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References

- Casey BJ, Glatt CE, Lee FS. Treating the developing versus developed brain: translating preclinical mouse and human studies. *Neuron*. 2015; 86:1358–1368. [PubMed: 26087163]
- Dahl RE. Adolescent brain development: a period of vulnerabilities and opportunities. *Ann N Y Acad Sci*. 2004; 1021:1–26. [PubMed: 15251869]
- Dahl RE, Spear LP. Adolescent brain development: vulnerabilities and opportunities. *Ann N Y Acad Sci*. 2004; 1021
- Silveri MM. GABAergic contributions to alcohol responsivity during adolescence: insights from preclinical and clinical studies. *Pharmacol Ther*. 2014; 143:197–216. [PubMed: 24631274]
- Spear LP. The adolescent brain and age-related behavioral manifestations. *Neurosci Biobehav Rev*. 2000; 24:417–463. [PubMed: 10817843]

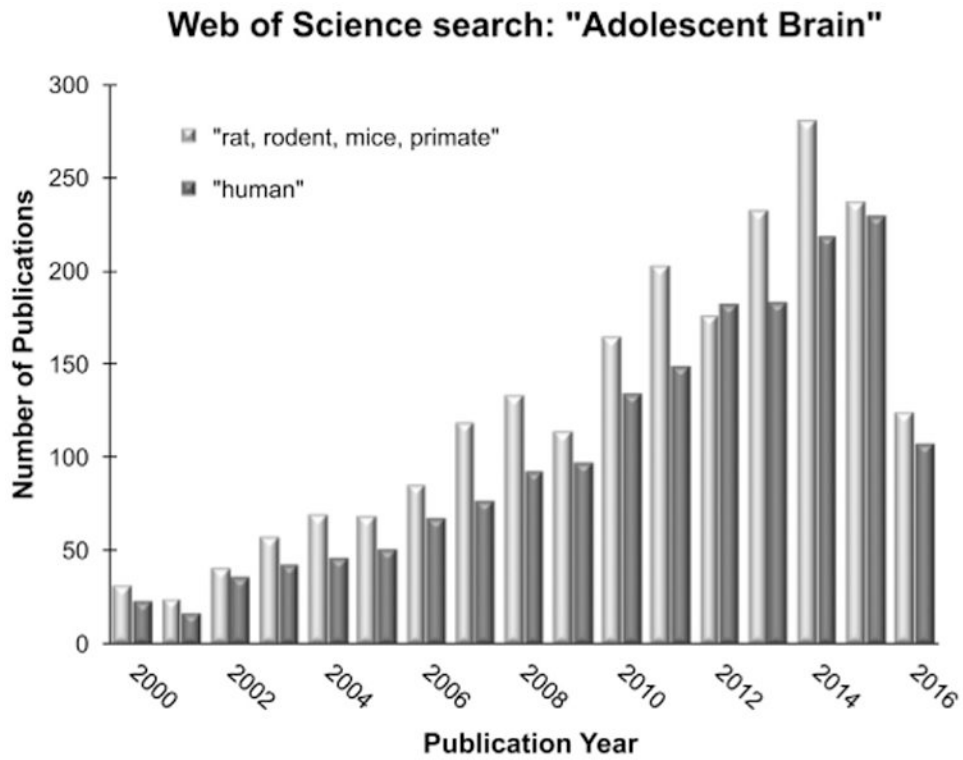


Fig. 1. Estimated number of publications in each year from 2000 to 2016, for Web of Science searches: Adolescent brain – rat, rodent, mice, primate (left panel); Adolescent brain – human (right panel). 2016 data are through June, 2016.

**Special Issue: ADOLESCENT BRAIN
Updates from Preclinical & Clinical Models**

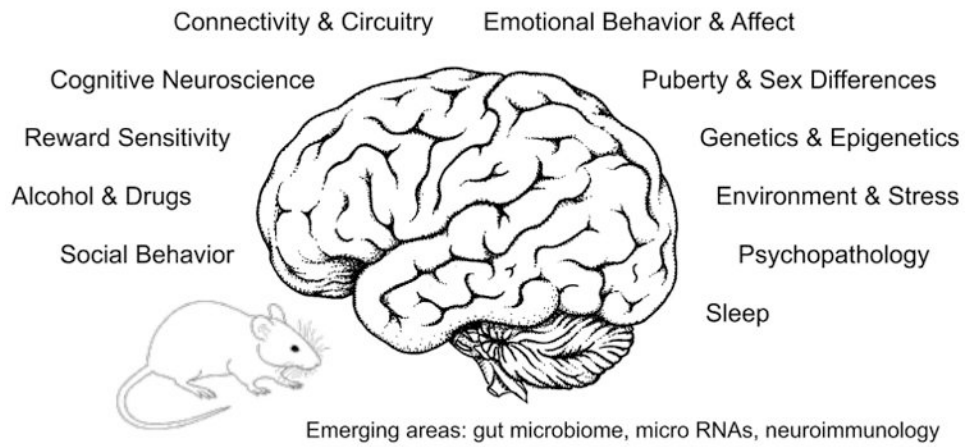


Fig. 2.
Illustration of content areas represented in the Adolescent Brain Special Issue.

Table 1

Adolescent Brain: Special Issue Table of Contents.

Topic	Animal Studies	Human Studies
1 Neurocircuitry/Connectivity	Caballero & Tseng: <i>Mechanisms contributing to prefrontal cortex maturation during adolescence</i>	Stevens: <i>The contributions of resting state and task-based functional connectivity studies to our understanding of adolescent brain network maturation</i>
2 Cognitive Neuroscience	Hunt, Burk & Barnet: <i>Adolescent transitions in reflexive and non-reflexive behavior: Review of fear conditioning and impulse control in rodent models</i>	Murty, Calabro & Luna: <i>The role of experience in adolescent cognitive development: Integration of executive, memory, and mesolimbic systems</i>
3 Emotion	Baker, Bisby & Richardson: <i>Impaired fear extinction in adolescent rodents: Behavioural and neural analyses</i>	Guyer, Silk & Nelson: <i>The neurobiology of the emotional adolescent: From the inside out</i>
4 Social	Vanderschuren, Achterberg & Trezza: <i>The neurobiology of social play reward in rats</i>	Kilford, Garrett & Blakemore: <i>The development of social cognition in adolescence: An integrated perspective</i>
5 Reward	Doremus-Fitzwater & Spear: <i>Reward-centricity and attenuated aversions: An adolescent phenotype emerging from studies in laboratory animals</i>	van Duijvenvoorde, Peters, Braams & Crone: <i>What motivates adolescents? Neural responses to rewards and their influence on adolescents' risk taking, learning, and cognitive control</i>
6 Puberty/Sex	Schulz & Sisk: <i>Organizing actions of adolescent gonadal steroid hormones on brain and behavioral development</i>	Gur & Gur: <i>Sex differences in brain and behavior in adolescence: Findings from the Philadelphia Neurodevelopmental Cohort</i>
7 Sleep	Hummer & Lee: <i>Daily timing of the adolescent sleep phase: Insights from a cross-species comparison</i>	Tarokh, Saletin & Carskadon: <i>Sleep in adolescence: Physiology, cognition and mental health</i>
8 Genetics/Epigenetics	Mychasiuk & Metz: <i>Epigenetic and gene expression changes in the adolescent brain: What have we learned from animal models?</i>	Dick, Adkins & Kuo: <i>Genetic influences on adolescent behavior</i>
9 Stress	Romeo, Patel, Pham & So: <i>Adolescence and the ontogeny of the hormonal stress response in male and female rats and mice</i>	Tottenham & Galvan: <i>Stress and the adolescent brain: Amygdala-prefrontal cortex circuitry and ventral striatum as developmental targets</i>
10 Alcohol/Drugs	Spear: <i>Consequences of adolescent use of alcohol and other drugs: Studies using rodent models</i>	Silveri, Dager, Cohen-Gilbert & Sneider: <i>Neurobiological signatures associated with alcohol and drug use in the human adolescent brain</i>
11 Psychopathology	Gomes, Rincon-Cortes & Grace: <i>Adolescence as a period of vulnerability and intervention in schizophrenia: Insights from the MAM model</i>	Lichenstein, Verstynen & Forbes: <i>Adolescent brain development and depression: A case for the importance of connectivity of the anterior cingulate cortex</i>
12 Emerging Areas	Brenhouse & Schwarz: <i>Immunoadolescence: Neuroimmune development and adolescent behavior</i> Neufeld, Luczynski, Oriach, Dinan & Cryan: <i>What's bugging your teen? – The microbiota and adolescent mental health</i> Rao & Pak: <i>microRNAs and the adolescent brain: Filling the knowledge gap</i>	
Commentaries on the Special Issue	Adriani & Laviola: <i>How can we run operant paradigms in a preclinical adolescent model? Technical tips and future perspectives.</i> Andersen: <i>Adolescence, trajectories and the importance of prevention</i> Ernst: <i>A tribute to the adolescent brain</i> Luciana: <i>Incentive-based striving and the adolescent brain</i> Steinberg: <i>Redefining adolescence</i>	