2004 WL 1633549 (U.S.) (Appellate Brief)
Supreme Court of the United States.

Donald P. ROPER, Superintendent, Potosi Correctional Center, Petitioner,
v.
Christopher SIMMONS, Respondent.

No. 03-633.
July 16, 2004.

On Writ of Certiorari to the Supreme Court of Missouri

Brief of the American Medical Association, American Psychiatric Association, American Society for Adolescent Psychiatry, American Academy of Child & Adolescent Psychiatry, American Academy of Psychiatry and the Law, National Association of Social Workers, Missouri Chapter of the National Association of Social Workers, and National Mental Health Association as Amici Curiae in Support of Respondent

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***i** QUESTION PRESENTED

Does the execution of an offender who committed the crime at the age of 16 or 17 constitute cruel and unusual punishment in violation of the Eighth Amendment?

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*1 INTERESTS OF *AMICI CURIAE* *

The American Medical Association, the American Psychiatric Association, the American Society for Adolescent Psychiatry, the American Academy of Child & Adolescent Psychiatry, the American Academy of Psychiatry and the Law, the National Association of Social Workers, the Missouri Chapter of the National Association of Social Workers, and the National Mental Health Association file this brief as *amici curiae* in support of respondent by written consent of both parties, pursuant to Rule 37.3(a) of the Rules of this Court.

With approximately 250,000 members, the American Medical Association is the nation's largest professional organization of physicians and medical students. Founded in 1847, its purpose is to promote the science and art of medicine and the betterment of public health. The American Psychiatric Association was founded in 1844 and today has more than 35,000 member physicians who specialize in psychiatry. The American Society for Adolescent Psychiatry was founded in 1967 and today has approximately 500 members. The American Academy of Child & Adolescent Psychiatry was founded in 1953 and today has approximately 6500 child and adolescent psychiatrists and other interested physicians. The American Academy of Psychiatry and the Law, with approximately 2000 physician members, is devoted to issues at the intersection of psychiatry and the law. Established in 1955, the National Association of Social Workers (NASW) is the largest association of professional social workers in the world with 153,000 members and chapters throughout the United States, in Puerto Rico, Guam, ***2** the Virgin Islands, and an International Chapter in Europe, with the purpose of developing and disseminating standards of social work practice while strengthening and unifying the social work profession as a whole. The Missouri Chapter of NASW has 2,700 members. The National Mental Health Association is the country's oldest and largest nonprofit organization addressing all aspects of mental health and mental illness since 1909. It has 340 affiliates in 43 states.

Each of the above-referenced *amici* is committed to the advancement of science. *Amici* submit this brief to describe the scientific findings of medical, psychiatric, and psychological research relevant to the legal issues under consideration.

SUMMARY OF ARGUMENT

The adolescent's mind works differently from ours. Parents know it. This Court has said it. Legislatures have presumed it for decades or more. And now, new scientific evidence sheds light on the differences.

Scientists have documented the differences along several dimensions. Adolescents as a group, even at the age of 16 or 17, are more impulsive than adults. They underestimate risks and overvalue short-term benefits. They are more susceptible to stress, more emotionally volatile, and less capable of controlling their emotions than adults.

In short, the average adolescent cannot be expected to act with the same control or foresight as a mature adult.

Behavioral scientists have observed these differences for some time. Only recently, however, have studies yielded evidence of concrete differences that are anatomically based. Cutting-edge brain imaging technology reveals that regions of the adolescent brain do not reach a fully mature state until after the age of 18. These regions are precisely those associated with impulse control, regulation of emotions, risk ***3** assessment, and moral reasoning. Critical developmental changes in these regions occur only after late adolescence.

Science cannot, of course, gauge moral culpability. Scientists can, however, shed light on certain measurable attributes that the law has long treated as highly relevant to culpability. This Court has concluded that both adolescents who are under age 16 and mentally retarded persons exhibit characteristics - "disabilities in areas of reasoning, judgment, and control of their impulses," *Atkins v. Virginia,* 536 U.S. 304, 306 (2002) - that categorically disqualify them from the death penalty. Offenders at age 16 and 17 exhibit those characteristics as well.

ARGUMENT

SCIENCE CONFIRMS THAT ADOLESCENT OFFENDERS AT THE AGES OF 16 AND 17 EXHIBIT DEFICIENCIES THIS COURT HAS IDENTIFIED AS WARRANTING EXCLUSION FROM THE DEATH PENALTY.

This Court has held that adolescents who commit capital crimes before the age of 16 and offenders who are mentally retarded are categorically exempt from the death penalty because they exhibit "disabilities in areas of reasoning, judgment, and control of their impulses." *Atkins*, 536 U.S. at 306; *Thompson v. Oklahoma,* 487 U.S. 815 (1988). Because of these pervasive deficiencies, this Court has concluded that members of these groups "do not act with the level of moral culpability that characterizes the most serious adult criminal conduct." *Atkins*, 536 U.S. at 306.

Neither moral culpability, nor qualification for the death penalty is susceptible to scientific measurement. But the particular attributes this Court has recognized as critical to those legal judgments are scientifically identifiable. This brief focuses on what science can tell us about the neurological, ***4** physiological, psychological, and emotional development of older adolescents from the perspective of scientists and medical professionals. Although, for convenience, this brief refers to the oldest of minors as "teens" or "adolescents," all the scientific conclusions recounted are relevant to minors who are 16 and 17 years of age.

Contrary to what some laypersons may believe, *see Amicus* Br. of the State of Alabama, *et al.* at 3, the evidence reveals that these older adolescents do not have adult levels of judgment, impulse control, or ability to assess risks. Recent advances in brain-imaging technology confirm that the very regions of their brains involved in governing these behavior-control capacities are anatomically immature. *See* Point A, *infra.*

This evidence describes the characteristics of the normal, healthy adolescent. To the extent that adolescents who commit capital offenses suffer from serious psychological disturbances that substantially exacerbate the already existing vulnerabilities of youth, they can be expected to function at sub-standard levels. *See* Point B, *infra.*

If, as this Court has observed, executing adolescents under 16 and mentally retarded offenders does not serve the death penalty's legal purposes, the same must be true of 16- and 17-year-old offenders. *See* Point C, *infra.*

A. Older Adolescents Behave Differently Than Adults Because Their Minds Operate Differently, Their Emotions Are More Volatile, and Their Brains Are Anatomically Immature.

Anyone who remembers being a teenager, who has been the parent or caretaker of a teenager, or who has observed adolescent behavior, knows intuitively that adolescents do not think or behave like adults. These behavioral differences are pervasive and scientifically documented. ***5** Teens (including, again, the oldest of minors) are different. Their judgments, thought patterns, and emotions are different from adults', and their brains are physiologically underdeveloped in the areas that control impulses, foresee consequences, and temper emotions. They handle information processing and the management of emotions differently from adults.

1. Adolescents are inherently more prone to risk-taking behavior and less capable of resisting impulses because of cognitive and other deficiencies.

Adolescents, as a group, "are risk takers." [1] "Relative to individuals at other ages, ... adolescents ... exhibit a disproportionate amount of reckless behavior, sensation seeking and risk taking." [2] Risk taking of all sorts - whether drunk driving, unprotected sex, experimentation with drugs, or even criminal activity - is so pervasive that "it is statistically aberrant to refrain from such [risk-taking] behavior during adolescence." [3] In short, teenagers are prone to making bad judgments.

Cognitive experts have shown that the difference between teenage and adult behavior is not a function of the adolescent's inability to distinguish right from wrong. Nor is it a function, as early studies suggested, of an inability to conduct any cost-benefit analysis at all. [4] Rather, the difference ***6** lies in what scientists have characterized as "deficiencies in the way adolescents think," [5] an inability to perceive and weigh risks and benefits *accurately.* [6] "[B]ecause of developmental influences," teens "differ from adults in the subjective value[s] that they attach to various perceived consequences in the process of making choices." [7] They focus more on opportunities for gains and less on protection against losses. [8] They put greater emphasis on short-term consequences than adults and discount future consequences more than adults. [9] It is not that adolescents do not perform cost-benefit analyses; rather, they skew the balancing, resulting in poor judgments.

***7** Adolescents' cognitive deficiencies are compounded by "deficiencies in adolescents' social and emotional capability." [10] One group of psychosocial researchers gauging these factors, along with cognitive development, "maturity of judgment," or "psychological maturity," as compared to adults', has been able to draw conclusions about the adolescent in three respects: "responsibility" (including factors such as self-reliance and independence); "perspective" (which covers the capacity to "consider[] situations from different viewpoints"); and "temperance" (encompassing the ability "to limit impulsivity"). [11] Thus, "observed differences in risky decision-making between adolescents and adults" reflect "differences in capabilities, and not simply priorities." [12]

This study, based on a sample of more than 1,000 adolescents and adults, established that psychosocial maturity is incomplete until age 19, at which point it plateaus. [13] Adolescents "score lower on measures of self-reliance and other aspects of personal responsibility, they have more difficulty seeing things in long-term perspective, they are less likely to look at things from the perspective of others, and they have more difficulty restraining their aggressive impulses." [14] Perspective and temperance, in particular, do not mature until late in adolescence. [15]

Researchers have found that the deficiencies in the adolescent mind and emotional and social development are ***8** especially pronounced when other factors - such as stress, emotions, and peer pressure - enter the equation. These factors affect everyone's cognitive functioning, but they operate on the adolescent mind differently and with special force.

The interplay among stress, emotion, and cognition in teenagers is particularly complex - and different from adults. Stress affects cognitive abilities, including the ability to weigh costs and benefits and to override impulses with rational thought. [16] But adolescents are more susceptible to stress from daily events than adults, which translates into further distortion of the already skewed cost-benefit analysis. [17]

Emotion, like stress, also plays an important role in cognition, influencing decision-making and risk-taking behavior. [18] Because of both greater stress and more drastic hormonal fluctuations, adolescents are more emotionally volatile than adults - or children, for that matter. [19] They tend to experience emotional states that are more extreme and more variable than those experienced by adults. [20]

The typical adolescent is also more vulnerable to peer pressure than an adult. "Social interactions and affiliation with peers take on particular importance during ... adolescence." [21] Adolescents spend twice as much time with peers as with parents or other adults. [22] The pronounced ***9** importance of approval and acceptance by friends will make an already risk-prone or impulsive adolescent even more so. [23] Adolescents not only are more susceptible to peer pressure, but they gravitate toward peers who reinforce their own predilections. In other words, a risk-prone and impulsive teen will have a comparatively high propensity to gravitate toward others who reinforce that behavior. [24] Unsurprisingly, an adolescent who spends time with risk-prone friends is more likely to "engag[e] in risky behavior." [25]

In sum, the conclusion of the scientific research is that, for a variety of interrelated reasons, adolescents as a group are less able than adults to moderate risky behavior or control impulses.

2. Brain studies establish an anatomical basis for adolescent behavior.

Modern brain research technologies developed a body of data in the late 1990s - well after this Court decided *Stanford v. Kentucky,* 492 U.S. 361 (1989) - that provides a compelling picture of the inner workings of the adolescent brain. [26] ***10** Adolescents' behavioral immaturity mirrors the anatomical immaturity of their brains. [27] To a degree never before understood, scientists can now demonstrate that adolescents are immature not only to the observer's naked eye, but in the very fibers of their brains.

This insight emerges from sophisticated and non-invasive brain imaging techniques, performed by high-resolution structural and functional magnetic resonance imaging ("MRI") and other technologies. [28] These imaging techniques are a quantum leap beyond previous mechanisms for assessing brain development. Before the rise of neuroimaging, the understanding of brain development in the days of *Thompson and Stanford* was gleaned largely from post-mortem examinations, [29] which shed little light on how a live brain operates and how a particular brain develops over time, or "longitudinally." [30] Brain imaging, ***11** in contrast, allows researchers to study how a live brain progresses longitudinally.

Technological breakthroughs have not only enabled scientists to confirm some of what was previously known or believed, but they have provided new evidence that has changed the way scientists understand the development of the human brain as it progresses from childhood through adolescence and into adulthood. [31] "Structural brain imaging studies in normal children and adolescents have been helpful in relating the dramatic maturation of cognitive, emotional, and social functions with the brain structures that ultimately underlie them." [32]

In this regard, two complementary observations have been especially revealing. First, adolescents rely for certain tasks, more than adults, on the amygdala, the area of the brain associated with primitive impulses of aggression, anger, and fear. Adults, on the other hand, tend to process similar information through the frontal cortex, a cerebral area associated with impulse control and good judgment. Second, the regions of the brain associated with impulse control, risk assessment, and moral reasoning develop last, after late adolescence.

***12 a. Research shows that adolescent brains are more active in regions related to aggression, anger, and fear, and less active in regions related to impulse control, risk assessment, and moral reasoning than adult brains.**

The brain is a complex network of interrelated parts. Each part is associated with different functions and capabilities. The regions relevant to understanding the adolescent behaviors discussed in the previous section are the areas of the brain associated with (1) emotional impulses, particularly aggression; and (2) impulse control, risk assessment, and moral reasoning.

The emotional center of the brain is the limbic system. [33] Within the limbic system is the amygdala, which is associated with aggressive and impulsive behavior. [34] The amygdala is "a neural system that evolved to detect danger and produce ***13** rapid protective responses without conscious participation." [35] It dictates instinctive gut reactions, including fight or flight responses. [36]

When it comes to "response inhibition, emotional regulation, planning and organization," the so-called executive functions, the most important components of the brain are the frontal lobes. [37] In particular, "the neocortex at the top of the brain[] mediate[s] 'more complex' information-processing functions such as perception, thinking, and reasoning," [38] and the prefrontal cortex is associated with a variety of cognitive abilities, [39] including decision making, [40] risk assessment, [41] ability to judge future ***14** consequences, [42] evaluating reward and punishment, [43] behavioral inhibition, [44] impulse control, [45] deception, [46] responses to positive and negative feedback, [47] and making moral judgments. [48]

The frontal lobe modulates synaptic transmissions from the amygdala [49] to which it is strongly connected. [50] A still-***15** maturing frontal lobe exerts less control over the amygdala and has less influence over behavior and emotions than a fully mature frontal lobe. [51] In other words, if the frontal lobe is immature or underdeveloped, there is less of a check on the amygdala.

New research suggests that the limbic system is more active in adolescent brains than adult brains, particularly in the region of the amygdala [52] and that the frontal lobes of the adolescent brain are less active. [53] More generally, as teenagers grow into adults, they increasingly shift the overall focus of brain activity to the frontal lobes. [54]

***16 b. Adolescent brains are not fully developed in regions related to reasoning, risk taking, and impulse control.**

Even more groundbreaking than the evidence of brain activity is the recent revelation, confirmed through brain imaging studies, that the brain's frontal lobes are still structurally immature well into late adolescence. [55] The prefrontal cortex (which, as noted above, is most associated with impulse control, risk assessment, and moral reasoning) is "one of the last brain regions to mature." [56] This, in turn, means that "response inhibition, emotional regulation, planning and organization … continue to develop between adolescence and young adulthood." [57] As one prominent neurophysiologist put it, "[s]tructural maturation of individual brain regions and their connecting pathways is a condition *sine qua non* for the successful development of cognitive … functions." [58]

***17** The adolescent's frontal lobes are underdeveloped in two distinct ways, each of which directly affects brain functioning. First, myelination is incomplete. Second, pruning is incomplete. We discuss each in turn.

Myelination. An important measure of brain maturity is myelination. [59] Myelination is the process by which the brain's axons are coated with a fatty white substance called myelin. Myelin surrounds the axons, which are neural fibers that use electrical impulses to carry information across long distances, and insulates the pathway, speeding the neural signal along the pathway. [60] "The presence of myelin makes communication between different parts of the brain faster and more reliable." [61] Myelination of "white matter" [62] continues through adolescence and into adulthood. [63]

***18** As measured by myelination, different parts of the brain mature at different rates. [64] The new brain imaging data, supported by data gathered through the older autopsy technique, [65] provides credible evidence that the frontal lobes, which are still developing well into adolescence and beyond, are among the last portions of the brain to mature. [66] In other words, the region of the brain associated with impulse control, risk assessment, and moral reasoning is the last to form, and is not complete until late adolescence or beyond.

Pruning. Gray matter, which comprises the outer surfaces, or cortices, of the brain, is composed of the brain cells (or neurons) [67] that perform the brain's tasks, such as the cognition and higher functions that are carried out in the frontal lobes. [68] Like myelination, changes in gray matter are important indications of brain maturity. As the brain matures, gray matter *decreases* [69] through a process called pruning. Just as the pruning of a rose bush strengthens the remaining branches, the pruning of gray matter improves the functioning of the brain's reasoning centers. [70] Brain cells that are not used shrivel off, [71] thereby increasing the efficiency of the ***19** neural system. [72] Thus, pruning establishes some pathways and extinguishes others, enhancing brain functioning.

Scientists have known about pruning for over 20 years, [73] but modern brain imaging technology has provided insights into the process of pruning. [74] Until MRI technology emerged, the common wisdom was that the volume of gray matter spurted only once, shortly after birth, and then declined gradually over time. Brain scans have revealed a more complicated reality: In particular regions of the brain, gray matter blossoms once again later in childhood. [75] The frontal ***20** lobe is one of the places where gray matter increases - before adolescence - and then gets pruned over time, beyond adolescence. [76] As is true of myelination, the frontal lobes are the last regions where pruning is complete. [77] That means pruning is occurring last in the areas related to impulse control, risk-taking, and self-control. One of the last areas of the brain to reach full maturity, as measured by pruning, is the part associated with regulating behavior, stifling impulses, assessing risks, and moral reasoning. [78]

B. To the Extent That Adolescents Who Commit Capital Offenses Suffer From Serious Psychological Disturbances That Substantially Exacerbate the Already Existing Vulnerabilities of Youth, They Can Be Expected to Function at Sub-Standard Levels.

The evidence summarized to this point, based upon studies of normal adolescents, leads to the conclusion that normal adolescents cannot be expected to operate with the level of maturity, judgment, risk aversion, or impulse control of an adult. Adolescents cannot be expected to transcend their own psychological or biological capacities. However, an adolescent who has suffered brain trauma, a dysfunctional family life, violence, or abuse cannot be presumed to operate even at standard levels for adolescents.

***21** There is good reason to believe that the population of adolescents who end up on death row are more likely to have suffered any or all of these disturbances. [79] To the extent that this is true, the population of adolescent offenders on death row is likely to be exceptionally immature as a matter of cognitive development, psychosocial development, anatomical development, or all three.

C. Executing Adolescents Does Not Serve the Recognized Purposes of the Death Penalty.

This Court has never required mountains of data to appreciate that "youth is more than a chronological fact.... It is a time and condition of life when a person may be most susceptible to influence and to psychological damage." *Eddings v. Oklahoma,* 455 U.S. 104, 115-16 (1982) (quoting *Bellotti v. Baird,* 443 U.S. 622, 635 (1979)). The foregoing data do, however, show that older adolescents are not simply miniature adults, with less experience or wisdom. They are also not as equipped as adults to engage in moral reasoning and adjust their conduct accordingly.

These neurological, physiological, and psychological deficits are exactly the characteristics that this Court has identified as warranting a categorical exemption from the death penalty.

If offenders with mental retardation are less culpable because their underdeveloped brains leave them with "diminished capacities to understand and process information, to communicate, to abstract from mistakes and learn from experience, to engage in logical reasoning, to ***22** control impulses, and to understand the reactions of others," *Atkins*, 536 U.S. at 318, then the same must also be true of older adolescents. So too, if younger adolescents are less culpable because of their inexperience, emotionality, susceptibility to peer pressure, and impulsivity, *Thompson*, 487 U.S. at 834, the same must again be true of older adolescents. They, too, are limited by the capacities of their "equipment" as are mentally retarded offenders. The greater predilection for high-risk behavior, the emotional volatility that clouds judgment, and the underdeveloped impulse control are pervasive among adolescents, just as they are among mentally retarded individuals.

The difference is that youth is temporary. Adolescents, with immature brains, emergent coping skills, and diminished judgment capacity, eventually become adults who can and should be held fully accountable for their actions. In the meantime, however, to execute 16- and 17-year-old offenders is to presume full adult responsibility and to hold them accountable not just for their acts, but also for the immaturity of their neural anatomy and psychological development.

This Court has held that executing a mentally retarded offender is unlikely to "affect the 'cold calculus that precedes the decision' of other potential murderers." *Atkins*, 536 U.S. at 319 (quoting *Gregg v. Georgia,* 428 U.S. 153, 186 (1976)). The same is true of older adolescents whose "calculus" weighs inputs - particularly, future consequences - differently from adults, and far differently from the cold-blooded adult murderer for whom the death penalty is reserved. *Id.* at 320; *see id.* at 319.

As long as this Court adheres to the view that an underdeveloped brain combined with heightened emotionality, an immature ability to anticipate long-term consequences, and susceptibility to peer pressure, justifies categorically excluding younger adolescents and mentally ***23** retarded offenders from the death penalty, the medical evidence should lead the Court to accord the same treatment to adolescents at the age of 16 or 17.

CONCLUSION

Sixteen- and 17-year-old offenders possess the same characteristics that warranted excluding offenders under 16 and mentally retarded persons from the reach of the death penalty, and on that basis they should also be excluded.

Footnotes

* No counsel for a party authored this brief in whole or in part and no person or entity other than the *amici curiae* or their counsel made any monetary contribution to the preparation or submission of this brief. The parties have consented to the filing of the brief of the *amici curiae*, and their letters of consent have been filed with the Clerk of the Court.

1 L.P. Spear, *The Adolescent Brain and Age-Related Behavioral Manifestations*, 24 Neuroscience & Biobehav. Revs. 417, 421 (2000); *see also* William Gardner & Janna Herman, *Adolescents' AIDS Risk Taking: A Rational Choice Perspective*, 50 Adolescents in The AIDS Epidemic 17 (1990).

2 Spear, *supra* note 1, at 421.

3 *Id.*

4 *See* Lita Furby & Ruth Beyth-Marom, *Risk Taking in Adolescence: A Decision-Making Perspective*, 12 Developmental Rev. 1, 9-11 (1992); *see also* William Gardner, *A Life-Span Rational-Choice Theory of Risk Taking*, Adolescent and Adult Risk Taking: The Eighth Texas Tech Symposium on Interfaces in Psychology at 66, 69 (N. Bell & R. Bell eds., 1993).

5 Elizabeth Cauffman & Laurence Steinberg, *(Im) Maturity of Judgment in Adolescence: Why Adolescents May Be Less Culpable Than Adults*, 18 Behav. Sci. & L. 741,742 (2000); *see also* Gardner (1993), *supra* note 4, at 67.

6 *See* Furby, *supra* note 4, at 17; *see also* Laurence Steinberg & Elizabeth S. Scott, *Less Guilty by Reason of Adolescence: Developmental Immaturity, Diminished Responsibility, and the Juvenile Death Penalty*, 58 Am. Psychologist 1009, 1012 (2003). For this reason, Missouri's contention that Christopher Simmons was able to perform some kind of cost-benefit analysis when he committed his crime, Petitioner's Br. at 35, may be technically correct, but it fails to acknowledge that neither Simmons, nor adolescents generally, can be expected to perform such an analysis the *way* adults do.

7 *See* Elizabeth S. Scott *et al., Evaluating Adolescent Decision Making in Legal Contexts*, 19 Law & Hum. Behav. 221, 233 (1995).

8 *See id.* at 231.

9 *See id.*

10 Cauffman, *supra* note 5, at 743.

11 *Id.* at 745.

12 *Id.* at 744.

13 *See id.* at 756.

14 *Id.* at 759.

15 *See id.* at 756.

16 *See* Spear, *supra* note 1, at 423; Furby, *supra* note 4, at 22.

17 *See* Spear, *supra* note 1, at 423; Furby, *supra* note 4, at 22.

18 *See* Steinberg, *supra* note 6, at 1011-13.

19 *See* Spear, *supra* note 1, at 429.

20 *See id.* at 429; Cauffman, *supra* note 5, at 757.

21 Spear, *supra* note 1, at 420.

22 *See id.*

23 *See* Steinberg, *supra* note 6, at 1012; *see also* Laurence Steinberg & Susan Silverberg, *The Vicissitudes of Autonomy in Early Adolescence*, 57 Child Dev. 841, 845 (1986).

24 *See generally* Jeffrey Jensen Arnett, *Reckless Behavior in Adolescence: A Developmental Perspective*, 12 Developmental Rev. 339, 354-55 (1992).

25 Denise B. Kandel & Kenneth Andrews, *Processes of Adolescent Socialization by Parents and Peers*, 22 Int'l J. Addictions 319, 334-335 (1987); *see also* Jeffrey Jensen Arnett, *Adolescent Storm and Stress, Reconsidered*, 54 Am. Psychologist 317, 321 (1999) ("Unlike conflict with parents or mood disruptions, rates of risk behavior peak in late adolescence/emerging adulthood rather than early or middle adolescence.")

26 *See* Sarah Durston *et al., Anatomical MRI of the Developing Human Brain: What Have We Learned?*, 40 J. Am. Acad. Child & Adolescent Psychiatry 1012, 1012 (2001) (reviewing results of MRI studies of brain development in childhood and adolescence); Michael S. Gazzaniga *et al.*, Cognitive Neuroscience: The Biology of the Mind at 20-21, 138 (2d ed. 2002).

27 *See* Nitin Gogtay *et al., Dynamic Mapping of Human Cortical Development During Childhood Through Early Adulthood*, 101 Proceedings Nat'l Acad. Sci. 8174, 8177 (2004).

28 "MRI measures the response of atoms in different tissues when they are pulsed with radio waves that are under the influence of magnetic fields thousands of times the strength of the earth's. Each type of tissue responds differently, emitting characteristic signals from the nuclei of its cells. The signals are fed into a computer, the position of those atoms is recorded, and a composite picture of the body area being examined is generated and studied in depth." Florence Antoine, *Cooperative Group Evaluating Diagnostic Imaging Techniques*, 81 J. Nat'l Cancer Inst. 1347, 1348 (1989).

29 *See* Gazzaniga, *supra* note 26, at 63.

30 *See generally* Elizabeth R. Sowell *et al., Development of Cortical and Subcortical Brain Structures in Childhood and Adolescence: A Structural MRI Study*, 44 Developmental Med. & Child Neurology 4 (2002); Elizabeth R. Sowell *et al., Mapping Continued Brain Growth and Gray Matter Density Reduction in Dorsal Frontal Cortex: Inverse Relationships During Postadolescent Brain Maturation*, 21 J. Neuroscience 8819 (2001).

31 *See* Elizabeth R. Sowell *et al., In Vivo Evidence for Post-Adolescent Brain Maturation in Frontal and Striatal Regions*, 2 Nature Neuroscience 859 (1999); *see also* Jay N. Giedd *et al., Brain Development During Childhood and Adolescence: A Longitudinal MRI Study*, 2 Nature Neuroscience 861 (1999).

32 Elizabeth R. Sowell *et al., Mapping Cortical Change Across the Human Life Span*, 6 Nature Neuroscience 309 (2003); *see also* Gogtay, *supra* note 27, at 8177.

33 *See generally* Daniel J. Siegel, The Developing Mind: Toward a Neurobiology of Interpersonal Experience at 10-11 (Guilford Press 1999).

34 *See generally* Jan Gläscher & Ralph Adolphs, *Processing of the Arousal of Subliminal and Supraliminal Emotional Stimuli by the Human Amygdala*, 23 J. Neuroscience 10274 (2003); Ralph Adolphs, *Neural Systems for Recognizing Emotion*, 12 Current Opinion in Neurobiology 169 (2002); Gazzaniga, *supra* note 26, at 553-572; K. Luan Phan *et al., Functional Neuroanatomy of Emotion: A Meta-Analysis of Emotion Activation Studies in PET and fMRI*, 16 NeuroImage 331, 336 (2002); Elkhonon Goldberg, The Executive Brain: Frontal Lobes & the Civilized Mind at 31 (2001); Kevin S. LaBar *et al., Human Amygdala Activation During Conditioned Fear Acquisition and Extinction: A Mixed-Trial fMRI Study*, 20 Neuron 937 (1998); Richard D. Lane, *et al., Neuroanatomical Correlates of Pleasant and Unpleasant Emotion*, 35 Neuropsychologia 1437, 1441 (1997); Hans C. Breiter *et al., Response and Habituation of the Human Amygdala During Visual Processing of Facial Expression*, 17 Neuron 875 (1996); Ralph Adolphs *et al., Fear and the Human Amygdala*, 15 J. Neuroscience 5879, 5889 (1995).

35 Abigail A. Baird *et al., Functional Magnetic Resonance Imaging of Facial Affect Recognition in Children and Adolescents*, 38 J. Am. Acad. Child & Adolescent Psychiatry 1, 1 (1999) (study found that adolescents 12-17 years old showed significant amygdala activation in response to a task that required the judgment of fearful facial affect); *see also* William D.S. Killgore & Deborah Yurgelun-Todd, *Activation of the Amygdala and Anterior Cingulate During Nonconscious Processing of Sad Versus Happy Faces*, 21 NeuroImage 1215 (2004); Phan, *supra* note 34, at 336.

36 *See* Goldberg, *supra* note 34, at 31; Phan, *supra* note 34, at 336.

37 Sowell (1999), *supra* note 31, at 860; *see also* Gazzaniga, *supra* note 26, at 75, 547.

38 Siegel, *supra* note 33, at 10.

39 *See* B.J. Casey *et al., Structural and Functional Brain Development and Its Relation to Cognitive Development*, 54 Biological Psychology 241, 244 (2000).

40 *See* Antoine Bechara *et al., Dissociation of Working Memory From Decision Making Within the Human Prefrontal Cortex*, 18 J. Neuroscience 428 (1998).

41 *See* Facundo Manes *et al., Decision-Making Processes Following Damage to the Prefrontal Cortex*, 125 Brain 624 (2002).

42 *See* Antoine Bechara *et al., Characterization of the Decision-Making Deficit of Patients with Ventromedial Prefrontal Cortex Lesions*, 123 Brains 2189 (2000).

43 *See* J. O'Doherty *et al., Abstract Reward and Punishment Representations in the Human Orbitofrontal Cortex*, 4 Nature Neuroscience 95 (2001); Robert D. Rogers *et al., Choosing Between Small, Likely Rewards and Large, Unlikely Rewards Activates Inferior and Orbital Prefrontal Cortex*, 20 J. Neuroscience 9029 (1999).

44 *See* R. Dias *et al., Dissociable Forms of Inhibitory Control Within Prefrontal Cortex with an Analog of the Wisconsin Card Sort Test: Restriction to Novel Situations and Independence From "On-Line" Processing*, 17 J. Neuroscience 9285 (1997); Durston, *supra* note 26, at 1016.

45 *See* Bechara (2000), *supra* note 42, at 2198-99.

46 *See* D.D. Langleben *et al., Brain Activity During Simulated Deception: An Event-Related Functional Magnetic Resonance Study*, 15 NeuroImage 727 (2002).

47 *See* R. Elliott *et al., Differential Neural Response to Positive and Negative Feedback in Planning and Guessing Tasks*, 35 Neuropsychologia 1395 (1997).

48 *See* Jorge Moll *et al., Frontopolar and Anterior Temporal Cortex Activation in a Moral Judgment Task: Preliminary Functional MRI Results in Normal Subjects*, 59 Arq Neuropsiquiatr 657 (2001); Steve W. Anderson *et al., Impairment of Social and Moral Behavior Related to Early Damage in Human Prefrontal Cortex*, 2 Nature Neuroscience 1032 (1999).

49 *See* Mario Beauregard, *et al., Neural Correlates of Conscious Self-Regulation of Emotion*, 21 J. Neuroscience 165RC (2001); Ahmad Hariri, *et al., Modulating Emotional Responses: Effects of a Neocortical Network on the Limbic System*, 11 NeuroReport 43 (2000).

50 Ralph Adolphs, *The Human Amygdala and Emotion*, 5 Neuroscientist 125, 125-26 (1999); *see also* Joseph LeDoux, The Emotional Brain: The Mysterious Underpinnings of Emotional Life at 303 (1996).

51 *See* Gargi Talukder, *Decision-Making Is Still a Work in Progress for Teenagers*, Report dated July 2000 at www.brainconnection.com; *see also* Spear, *supra* note 1, at 440 (reporting Dr. Yurgelun-Todd's research); *see also* Adolphs (1995), *supra* note 34, at 5889.

52 *See* Deborah Yurgelun-Todd, *Inside the Teen Brain*, Frontline (2002) (interview); *see also* K. Rubia, *et al., Functional Frontalisation with Age: Mapping Neurodevelopmental Trajectories with fMRI*, 24 Neuroscience & Biobehav. Revs. 13 (2000).

53 *See* Yurgelun-Todd, *supra* note 52; *See also* Rubia, *supra* note 52, at 18.

54 *See* K. Rubia, *supra* note 52, at 18; *see also* Spear, *supra* note 1, at 440; Yurgelun-Todd (2002), *supra* note 52.

55 *See* Gogtay, *supra* note 27, at 8174 (subjects of study aged 4 to 21 years); Giedd, *supra* note 31, at 861 (subjects of study aged 4.2 to 21.6 years); Sowell (1999), *supra* note 31, at 860-61 (subjects of study aged 12 to 16 and 23 to 30 years); *see also* Sowell (2001), *supra* note 30, at 8026 (noting pronounced brain maturational processes continuing into post-adolescence; subjects of study aged 7 to 30 years); Sowell (2003), *supra* note 32, at 309 (subjects of study aged 7 to 87 years).

56 Casey, *supra* note 39, at 243; *see also* Gogtay, *supra* note 27, at 8175.

57 Sowell (1999), *supra* note 31, at 860; *see also* Kenneth E. Towbin & John E. Schowalter, *Adolescent Development*, Psychiatry at 145, 151-52 (Allan Tasman ed., 2d ed. 2003). This paper recognizes the link between "improvement during adolescence in specific cognitive skills such as organizing information, conceptualization, perspective taking, and social perception, to structural changes in frontal cortical and sub-cortical structures." *Id.* at 152.

58 Tomas Paus *et al., Structural Maturation of Neural Pathways in Children and Adolescents: In Vivo Study*, 283 Sci. 1908 (1999) (subjects of study aged 4 to 17 years).

59 *See* Goldberg, *supra* note 34, at 144; *see also* Sowell (2001), *supra* note 30, at 8819; Sowell (2003), *supra* note 32, at 311.

60 *See* Gazzaniga, *supra* note 26, at 31, 48-49; Eric R. Kandel, *et al.*, Principles of Neural Sci. at 22, 85 (4th ed. 2000).

61 Goldberg, *supra* note 34, at 144.

62 White matter is the tissue that composes the pathways between brain regions that permits communication and interaction within the brain and between the brain and the body. *See* Gazzaniga, *supra* note 26, at 70, 72. For example, the corpus callosum, a critical white matter structure, bridges the two halves of the frontal lobes, permitting and regulating communication between the two halves of the brain. *See* Paus, *supra* note 58, at 1908.

63 *See* Durston, *supra* note 26, at 1014; Sowell (1999), *supra* note 31, at 860; Adolf Pfefferbaum *et al., A Quantitative Magnetic Resonance Imaging Study of Changes in Brain Morphology from Infancy to Late Adulthood*, 51 Archives of Neurology 874, 885 (1994) (after age 20 white matter volume did not fluctuate until about age 70; subjects of study aged 3 months to 70 years).

64 *See* Sowell (2003), *supra* note 32, at 311; Sowell (2002), *supra* note 30, at 4; Towbin & Schowalter, *supra* note 57, at 151.

65 *See* Paus, *supra* note 58, at 1908.

66 *See* Sowell (1999), *supra* note 31, at 859; Rubia, *supra* note 52, at 13 (subjects of study aged 12 to 19 and 22 to 40 years).

67 *See* Gazzaniga, *supra* note 26, at 64-65.

68 *See* E. Kandel, *supra* note 60, at 9.

69 *See* Durston, *supra* note 26, at 1014.

70 *See* Robert F. McGivern *et al., Cognitive Efficiency on a Match to Sample Task Decreases at the Onset of Puberty in ChiMren*, 50 Brain & Cognition 73 (2002) (subjects of study aged 10 to 22 years).

71 *See* Siegel, *supra* note 33, at 13-14.

72 *See* Casey, *supra* note 39, at 241 ("findings are consistent with the view that increasing cognitive capacity during childhood coincides with a gradual loss rather than formation of new synapses and presumably a strengthening of remaining synaptic connections.").

73 *See generally* Peter R. Huttenlocher, *Synaptic Density in Human Frontal Cortex: Developmental Changes and Effects of Aging*, 163 Brain Research 195 (1979).

74 *See, e.g.*, Sowell (2002), *supra* note 30, at 4.

75 *See* McGivern, *supra* note 70, at 85; *see also* David N. Kennedy *et al., Basic Principles of MRI and Morphometry Studies of Human Brain Development*, 5 Developmental Sci. 268, 274 (2002)

Studies showed linear increases in white matter in the age range of 4-20 years. They were also able to demonstrate nonlinear changes in cortical gray matter, summarized as a preadolescent increase followed by a postadolescent decrease. Further localization of these changes indicated that the frontal and parietal lobe peaked at about age 12, the temporal lobe at about age 16, and the occipital lobe continued its increase through age 20, although the confidence intervals on these observations are large.

Giedd, *supra* note 31, at 861.

76 *See* Giedd, *supra* note 31, at 861; McGivern, *supra* note 70, at 85.

77 A very recent article published by the National Academy of Sciences measured gray matter density in individuals longitudinally from childhood to early adulthood and concluded that "the [gray matter] maturation ultimately involves the dorsolateral prefrontal cortex, which loses [gray matter] only at the end of adolescence." Gogtay, *supra* note 27, at 8175.

78 *See id.* at 8177 ("Later to mature were areas involved in executive function, attention, and motor coordination (frontal lobes).").

79 *See, e.g.*, Chris Mallet, *Socio-Historical Analysis of Juvenile Offenders on Death Row*, 39 Crim. L. Bull. 445, 457-60 (2003); *Thompson*, 487 U.S. at 835 note 42 (plurality) (citing Dorothy Otnow Lewis, *et al., Neuropsychiatric, Psychoeducational and Family Characteristics of 14 Juveniles Condemned to Death in the United States*, 145 Am. J. Psychiatry 584 (1988)).

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