STATE OF MICHIGAN
IN THE MICHIGAN SUPREME COURT

PEOPLE OF THE STATE OF MICHIGAN,
Plaintiff,

- VS -

ROBIN RICK MANNING
Defendant.

CIR. CT. NO. 84-000570-FC
C.O.A. NO. 345268
S.C. NO. 160034

BRIEF AMICUS CURIAE BRIEF IN SUPPORT OF

THE NATIONAL LIFERS OF AMERICA INC. CHAPTER 1016

* * * * * EXHIBITS * * * * *

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THE TRIAL COURT DID NOT ANSWER:	" "
THE COURT APPEALS DID NOT ANSWER:	" "
DEFENDANT APPELANT ANSWERS:	"YES"
(NLA) AMICUS CURIAE ANSWERS:	"YES"

INTRODUCTION AND STATEMENT OF INTEREST

Amicus curiae The National Lifers Of America Inc., Chapter 1016 [hereafter referred to as (NLA)], is a nation-wide organization, that seeks to introduce new legislation which will effect it's membership and prison population, which is comprised of Lifers, and Nonlifers. This is a major issue for this organization where a large percentage NLA, members were between 18 to 21 years old at the time of their offense.

There has been a shift in the treatment of adolescent over the last 15 years, starting with the United States Supreme Court ruling that Juveniles could not be executed. See, Roper v Simmons, 543 US 551, 567; 125 SCt. 1183 (2005).

Several years later came the current rulings, e.g. Miller v Alabama, 567 US 467, 132 SCt. 2455 (2012), Montgomery v Louisiana, ___ US ___; 136 SCt. 718, 734 (2016), these cases addressed defendant under 18 years of age. However this Amicus curiae, presents the rationale that is supported by the science of Dr. Steinberg, where he testified in relevant part: "Adolescence can be divided into three phases.

1). Early adolescents are age 10 through 13;

2). Middle adolescents are age 14 through 17, and

3). Late adolescents are 18 through 21.

Dr. Steinberg, further testified at a juvenile hearing to the following: "Generally, adolescents are:"

*more impulsive than adults,

*prone to engage in risky and reckless behavior,

*motivated less by punishment and more by reward,

*less oriented to the future and more oriented to the present, and

*susceptible to the influence of others.

The (NLA), finds that the aforementioned is a great case for this Honorable Court to address once and for all that the "Brain Science" supports not throwing children away, allowing them to languish in prison under the most harsh sentence which can be issued.

Although eighteen-to-twenty-one year olds are in some ways similar to individuals in their midtwenties, in other ways young adults are more like adolescents in their behavior, psychological functioning, and brain development. Where this is true, and scientifically established this matter should be addressed by this Court to correct, the draconian practice of discarding children, who have reached the age of 18 to 21 years old.

Thus, developmental science does not support the bright-line boundary that is observed in criminal law under which eighteen year olds are categorically deemed to be adults. This practice must be corrected, and the chance and time is now.

It is not our position that Science will always trump law, however the findings of these well respected Doctors, Elizabeth Scott, Richard Bonnie, and Laurence Steinberg, should be seriously considered when considering the entire future of an adolescent, facing the rest of their life in prison, for conduct which he or she more than likely "lacked the ability to extricate themselves from horrific crime-producing setting.

We ask that this Court consider the lack of development of the brain as partially addressed by the aforementioned doctors and has been partially excepted by the United States Supreme Court in previous decision see Miller, supra Montgomery, supra, [17 year olds], several cases admittedly not up to (21) twenty-one years of age however where the science supports this, defendant ask that this Court address defendants who are 18 through 21 years of age.

ARGUMENT I.

DID ANY LOWER COURT ERROR IN DENYING DEFENDANT'S REQUEST FOR RELIEF, WHERE THE DEFENDANT WAS OLDER THAN 17, WHEN THE CRIME WAS COMMITTED. WHERE THE "BRAIN SCIENCE" FINDS NO DIFFERENCE BETWEEN SOMEONE 17, AND SOMEONE 21. THE CONSTITUTIONAL PROTECTION TO THE 8TH AMENDMENT MUST APPLY TO THESE DEFENDANTS WHERE THE "BRAIN SCIENCE" COVERS EVERYONE IN THE AGE GROUPS OF 18-21. A DURATION OF 365 DAYS CAN NOT CHANGE WITH A BIRTHDAY, OR A FLIP OF A SWITCH.

STANDARD OF REVIEW

This is an issue of "First Impression" The National Lifers Of America, Inc., through its President Mark McCloud, ask that this issue be reviewed De Novo, see People v Skinner, 312 Mich App 14, 22-23 (2015), People v Williams, 483 Mich 226, 232 (2009).

It is well established that the Eight Amendment protects defendants under the age of 18 from receiving a "Death Sentence" or Life Without the Possibility of Parole" without assessing their "diminished culpability and heightened capacity for change." Miller, supra, as was determined by the United States Supreme Court. Finding it to be cruel and usual punishment, in vioaltion of the eight amendment.

It is noteworthy to mention that since the United States Supreme Court ruling in Roper v Simmons, 543 US 551; 125 SCt. 1183 (2005), (6) six states have abolished their death penalty[1], making a total of (19) nineteen states and the District of Columbia, without a death penalty statute.

Doctor Laurence Steinberg, and others have done extensive research on children, adolescent, and young adult brain development and has reached several conclusions, the ones which are germane to the instant case is (3) three-parts:

a). Mentally there is no difference between 17 year olds and 21 year olds developmentally;

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1). Connecticut (2012), Illinois (2011), Maryland (2013), New Jersey (2007), New Mexico (2009), and New York (2007).

b). All members of this group should be entitled to the ruling in Miller, "...sentencing courts consider a child's 'diminished culpability and heightened capacity for change..."

c). Further study of the brain development conducted in the past (10) years has shown that these key brain systems and structures actually continue to mature well into the mid-twenties this notion is now widely accepted among neuroscientists.

Amicus only uses the United States Supreme Court authorities for the court's considerations as it applies to the "Brain Science", information as provided by Dr. Steinberg and others. In, Graham v Florida, 560 US 48; 130 SCt. 2011 (2010). The United States Supreme Court also held in relevant parts:

> "As petitioner amici points out development in psychology and brain science continues to show fundamental differences between juvenile and adult minds."
>
> * * * *
>
> "Juveniles are more capable of change than are adults, and their actions are less likely to be evidence of 'irretrievably depraved character' than are the actions of adults." Id. 543 US at 570; 125 SCt. 1183.

Children have a lack of maturity and an underdeveloped sense of responsibility, leading to reckless, impulsivity, and heedless risk-taking. Second, children are more vulnerable to negative influences and outside pressures, including from their family and peers; they have limited control over their own environment and lack the ability to extricate themselves from horrific crime-producing settings. And third, a child's character is not as well formed as an adult's; his traits are less fixed and his actions less likely to be evidence of irretrievable depravity." Id. 132 SCt. at 2464.

Where Dr. Steinberg has testified about the similarities between 17 year olds and 21 years old, as it relates to the brain development, Amicus believes that the same rationale should apply. See Montgomery, supra quoting Miller, (quoting Graham, at 71. See (EXHIBIT A)

> "Miller recognized that the distinctive attributes of youth diminish the penological justifications for imposing life without

parole on juvenile offenders." Because retribution relates to an offender's blameworthiness, the case for retribution is not as strong with a minor as with an adult."

Recent psychological research indicates that individuals in their late teens and early twenties are less mature than their older counterparts in several important ways.[2] First, these individuals are more likely than adults to underestimate the number, seriousness, and likelihood of risks involved in a given situation.[3]

Second, they are more likely to engage in sensation-seeking, the pursuit of arousing, rewarding, exciting, or novel experiences. This tendency is especially pronounced among individuals between the ages of eighteen to twenty-one.[4]

Third, indivuals in their late teens and early twenties are less able than older individuals to control their impulses and consider the future consequences of their actions and decisions because gains in impulse control continue to occur during the early twenties.[5]

Fourth, basic cognitive abilities, such as memory and logical reasoning, mature before emotional abilities, including the ability to exercise self-control

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2]. For a recent review of this research, see LAURENCE STEINBERG, Age of Opportunity: Lessons From the New Science of Adolescence (2014).

3]. T. Grisso, et. al. Juveniles' Competence to Stand Trial: A Comparison of Adolescents and Adults Capacities as Trial Defendants, 27 Law & Hum. Behav. 333-363 (2003).

4]. E. Cauffman, et. al. Age Differences in Affective Decision Making as Indexed by Performance on the Iowa Gambling Task, 46 Dev. Psychol. 193-207 (2010); L. Stienberg, et. al., Around the World Adolescence is a time of Heightened Sensation Seeking and Immature Self-Regulation Dev. Sci. Advance online publication doi: 10.1111/desc.12532. (2017).

5]. L. Steinberg, et. al. Age Difference in Future Orientation and Delay Discounting, 80 CHILD DEV. 28-44 (2009); D. Albert, et. al., Age Difference in Sensation Seeking and Impulsivity as Indexed by Behavior and Self-Report Evidence for a Dual System Model, 44 DEV. PSYCHOL. 1764-1778 (2008).

to properly consider the risk and reward of alternative courses of action, and to resist coercive pressure from others.

Thus, one may be intellectually mature but also socially and emotionally immature. As a consequence of this gap between intellectual and emotion maturity, these differences are exacerbated when adolescents and young adults are making decisions in situations that are emotionally arousing, including those that generate negative emotions, such as fear, threat, anger, or anxiety.

The "Brain Science" also points out that the presence of peers also amplifies these differences because this activates the brain's "Reward Center" in individuals in their late teens and early twenties. Importantly, the presence of peers has no such effect on adults.[6]]

In recent experimental studies, the peak age for risky decision-making was determined to be between nineteen and twenty-one.[7]]

There is a clear consensus among the scientific field as to the age of adulthood, which is clearly contrary to the current statutory authorities in most states in the country. However, this should not be a deterrent, for this Court and future legislature to move away from the erroneous "Norms", especially in light of what is at stake "adolescent/children", who have been discarded sentenced to die in prison for conduct which they lacked the mental maturity to understand.

The more the Supreme Court writes about this issue, the less it becomes about the age of the offender per se, and the more it becomes about recognizing

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6]. A. Cohen, et. al. When is an Adolescent an Adult? Assessing Cognitive Control in Emotional and Non-Emotional and Contexts, 4 PSYCHOLOGICAL SCIENCE 549-562 (2016); L. Steinberg, et. al., Are Adolescents Less Mature Than Adults? Minors' Access to Abortion, the Juvenile Death Penalty and the Alleged APA "Flip-Flop" 64 Am PYSCHOLOGIST 583-594 (2009).

7]. D. Albert, et. al., The Teenage Brain; Peer Influence on Adolescent Decision-Making, 22 CURRENT DIRECTIONS IN PSYCHOL. SCI. 114-120 (2013).

the hallmark characteristics of adolescence. It is clear after Montgomery that the Eighth Amendment requires more than mere consideration of the juvenile's age before the imposition of a sentence of life without parole.

Sentencing courts are required to decide whether the juvenile offender before it is an adolescent "whose crime reflects transient immaturity" or is one of those rare adolescent "whose crime reflect irreparable corruption" for whom a life without parole sentence may be appropriate.

There are states which offer greater protections to adolescent/youthful offenders into their early twenties,[8] including Michigan, see Holmes Youthful Trainee Act.

> MICHIGAN - The Holmes Youthful Trainee Act of 1927, which originally protected youths up to age twenty-one, in 2015 it was revised to allow for the expungement of the record of a youthful offender up to age twenty-four. See MCLA 762.11. For those over age twenty-one, the prosecutor consent is required, and it does not apply to any "felony for which the maximum penalty is imprisonment for life," or a "major controlled substance offense."

As of 2003 - two years before Roper thirty-five states had already extended dispositional jurisdiction beyond age eighteen. Young Adulthood, at 666, n. 156. By 2016, all fifty states, the District of Columbia, America Somoa, Guam, Northern Mariana, Puerto Rico and the Virgin Island had done so. See Angel Zang, US Age Boundaries of Delinquency 2016.

Amicus request that this Court include in it's decision, adolescents who were 18 to 21 this request is not without some precedent to support this request that adolescence is a "state of mind" (Brain Science), and not physical characteristic as has been discovered by Dr. L. Steinberg and the other professionals, in the field of Neuroscience, which with the advent of machines, e.g., Functional Magnetic Resonance (fMRI) which can actually allow non-intrusive

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8]. Alabama, California, Colorado, Florida, Georgia, Hawaii, Indiana, Michigan, New Jersey, North Carolina, New York, Oklahoma, South Carolina, Virginia, Vermont, and West Virginia.

examination of the brain. See (EXHIBIT B)

More recent Dr. Lebel and Beaulie (Lebel Study) used "Diffusion Tensor Imaging" (DTI) a technology more advance than MRI imaging to show that association tracts in the brain also continue to develop during late adolescence and early adulthood. These tracts are responsible for linking perceptual and memory centers of the brain and are needed for complex cognitive tasks such as inhibition, executive functioning and attention.

The National Center of Juvenile Justice. Geography, Policy, Practice & State Scan. This study shows a unanimous national consensus that late adolescents 18 to 21 requires extra protections from the criminal law. The Brain Science or research which speaks of the development of eighteen year old brains is not limited to eighteen year olds. The brain science encompasses 18,19,20, and 21 year olds as all being in the same group, late adolescence.

The Geography, Policy, Practice & State Scan, supports the contention that there is more consensus that turning eighteen does not magic away one's immaturity, than there is that seventeen is the proper jurisdictional age for juvenile court.

Perhaps one of the most germane studies to the opinion that 21 year olds are more like 16 or 17 year olds in a highly charged environment, see A. Cohen "When is an Adolescent an Adult? Assessing Cognitive Control in Emotional and Non-Emotional Contexts", 4 PSYCHOL. SCI. 549-562 (2016).

> "Under emotionally neutral conditions, individuls between eighteen and twenty-one were able to control their impulses just as well a those in their mid-twenties. However, under emotionally arousing conditions, eighteen to twenty-one year olds demonstrated levels of impulsive behavior and patterns of brain activity comparable to those in there mid-teens."

Put simply, under feelings of stress, anger, fear, threat, ect., the brain of a twenty year old functions similarly to a sixteen or seventeen year olds Amicus believes that were the brain functions the same, the parties 18 to 21, must be treated like their 17 year old counter-parts.

Where the "Brain Science" has lead, and guided the Courts of this country up to this point, [ruling that 17 year olds cannot be executed, or issued sentences of (LWOP) except in rare cases]. The same "Brain Science" applies to those who were 18,19,20, and 21 years of age at the time of their crimes.

Recent neurobiological research parallels the above psychological conclusions. This research has shown that the main cause for psychological immaturity during adolescence and the early twenties is the difference in timing of the maturation of two important brain systems.

The system that is responsible for the increase in sensation-seeking and reward-seeking sometimes referred to as the "socio-emotional system" undergoes dramatic changes around the time of puberty, and stays highly active through the late teen years and into the early twenties. However, the system that is responsible for self-control, regulating impulses, thinking ahead, evaluating the risk and reward of an action, and resisting peer pressure referred to as the "cognitive control system" is still undergoing significant development well into the mid-twenties. See, (EXHIBIT C)

The science shows that it pertains to 17,18,19,20, and 21 year olds, this Court has the duty to apply the science to all who are similarly situated. See, S-J Blakemore, Imaging Brain Development. There are considerable structural changes and improvements in connectivity across regions of the brain which allow for this development. These structural changes are mainly the result of two process:

> "Synaptic pruning [the elimination of unnecessary connections between neurons, allowing for more efficient transmission of information] and Myelination [insulation of neuronal, connections, allowing the brain to transmit information more quickly).

While synaptic pruning is mostly complete by age sixteen, Myelination continues through the twenties. Thus, while the development of the prefrontal cortex (logical reasoning, planning, personality) is largely finished by the late teens, the maturation of connections between the prefrontal cortex and regions which govern self-regulation and emotions continues in the mid-twenties.

This part of the science should be the essential part which shows the Court that the psychological science must lead this Court to conclude that even intellectual young adults may have trouble controlling impulses and emotions, especially in charged environments, this includes 18,19,20, and 21 years olds.

CONCLUSION

In conclusion The National Lifers Of America Inc. Chapter 1016 through it's Chapter President Mark McCloud, seeks to have this Court consider this Amicus Curaie Brief, which is based on the science of several doctors who specialize in neuroscience and Doctor Laurence Stienberg, who was excepted as an expert in Adolescent Development in the case of Commonwealth v Diaz, et. al. No. 15-CR-584.

Where the United States Supreme Court, and other Courts has excepted these scientific studies, reports and the testimony of Dr. Stienberg, and all of the science clearly indicates that under stressful situations a 21 year old is similar to someone in their mid-teens, these individuals should be treated the same. See, (EXHIBIT D).

Amicus does not believe that anyone would challenge that there is a distinct difference between Adolescents and adults. Dr. Steinberg, has since supplemented his initial testimony with a report further detailing the structural and functional changes responsible for the differences.

Now with (fMRI), and (DTI), which allows for the better views of the brain in real time, these advents will allow for better and more accurate examination and information of the adolescent brain and adult brain for comparison and study.

MITIGATING FACTORS

The interested parties (i.e., NLA Chapter 1016) Members Mark A. McCloud-El, DeMel A. Dukes, Gregory M. Allen, Quincy Howard, Tonya Snyder and NLA Chapter 1016 itself are among the parties who through various charged environments were forced into gangs and violent homes. Many of the interested parties were raised in the very conditions that make Dr. Steinberg and the other neuro-scientists' findings all the more conclusive.

Extreme poverty, low-employment, drug abuse, sexual abuse, illiteracy and the war on drugs, deeply affected most, if not all of the movants.

Statistics from the era in which most of the movants came of age (Mid-to-late-adolescence in and around the late eighties, up and through the early two-thousands,bare witness to the mitigating conditions that these late adolescence lived through.

Various drug gangs actively and vigorously recruited these teens and late adolescence, using intimidation and even the threat of murder to ensure continuous criminal activity. Many were coerced into becoming recruiters themselves. Some were even dispatched to carry out the orders of gang leaders. Leaving these gangs and groups were nearly impossible because the threat of death was ever present. Leaving a life that most had only known, was daunting as all were tethered to homes, families, and neighborhoods not to mention they were by all account not yet adults, but late adolescents, simply moving or getting out was in most cases, impossible.

To what extent should the consideration of developmental stages of youth extend itself and to whom? The Amici strongly pleads with this Honorable Court to extend it's consideration of Miller, so far as the mandatory aspect of late adolescence being sentenced to life without the possibility of parole. We ask that this Court recognize that maturity is not simply numerical, but that environmental factors can and does shape one's behavior. We also ask that the consideration of maturity shown through years of incarceration be reflected in this Honorable Court's holdings. As the Michigan Department of Corrections does when scoring for security classification. The MDOC Security Classification Screening Sheet, reflects the rewards of turning 26 years of age by removing and reducing points, thus lowering a person's security classification.

RELIEF SOUGHT

Based on what is, undisputed scientific research and evidence concerning adolescence brain development, which categories 18, 19, 20 and 21 years old as late adolescence, Amicus ask this Court expand it's review of 18 years old defendants, to include all those persons in late adolescence who were 18, 19, 20, and 21 years of age at the time of their offenses, and provide the Miller protections to these person.

Date: February 18, 2020

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EXHIBIT A

UNITED STATES V C.R., 792 F. Supp2d 343 (ED NY. 2011).

TESTIMONY OF DR. LAURENCE STEINBERG

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2. Testimony

Expert testimony presented at the sentencing hearing strongly supports application of general scientific principles of adolescent brain development to C.R.'s situation.

Dr. Laurence Steinberg was the "the lead scientist for the American Psychological Association in assisting the Association's counsel in preparing the amicus brief in [*Roper v. Simmons*, and *Graham v. Florida*]". His testimony summarizes the scientific studies discussed, in subsection 1, *supra*, which find that the bright line cut-off of age eighteen does not accurately reflect the realities of adolescent brain development:

> Q Dr. Steinberg, what is the difference between chronological age and developmental age?
>
> A Chronological age is simply a count of the number of years that somebody has been alive. But developmental age can be measured by looking at the person's [**424] intellectual functioning or social functioning or emotional functioning, and within any given chronological age there will be a range in terms of individual's developmental functioning.
>
> Q So, one's chronological age and one's developmental age don't necessarily match up?
>
> A Correct.
>
> Q And at what age does a person's brain fully develop?
>
> A It really depends on what aspects of the brain and what brain systems one is talking about. But I think the consensus among developmental neuroscientists scientists now would be some time during the mid-20s probably.
>
> Q And what kind of research is that conclusion based on?
>
> A It's based on both structural and functional MRI. Structural MRI would be exams that would look at the brain's anatomy whereas functional MRI would be exams that look at the brain's functioning.
>
> Q And those tools, when given to large groups of people over time, show development continues until the mid-20s in most people?
>
> A Correct.
>
> Q Now, is there any developmental significance from a brain development perspective as to whether chronologically someone is 17 and 364 days or 18 years old?
>
> A No, there isn't.
>
> Q There's no shift in the brain because one turns 18?
>
> A No.
>
> Q And from a developmental [**425] perspective, how do you define adolescence?
>
> A Well, that's hard to do because it really depends on what aspects of development you're speaking about. If you were doing it in terms of brain development, I would say probably from about 10 to 24 or so in the sense that we can see that there is still brain development going on during that time period. If you were talking about psychological development, I would say maybe from 10 to 20, 10 to 21, around there.
>
> Q And does the term adolescence itself indicate that a person is still developing?
>
> A Yes. I think that we use it commonly to refer to somebody who is not yet an adult.

Q And I know you were present for the testimony of Dr. Barr and you heard **[*503]** him say that the cutoff is 18 for adolescence. Do you agree with that from a brain development point of view?

A Certainly not.

Q Do you agree with that from a psychosocial point of view?

A No.

Q And why do you disagree with the idea that adolescence cuts off at 18 from a brain development point of view?

A Well, we know that there's structural brain change after the age of 18 both in gray matter and in white matter, and we also know that there's function in the brain after 18 in terms of differences in [**426] patterns of brain activity that you see among people of different ages.

Q And from a psychosocial point of view, why do you disagree with the idea that adolescence is cut off at 18?

A Well, on certain measures, we, in our own research and others, find that there's continued maturation of certain psychosocial capabilities after 18.

. . . .

Q When you're saying that, grossly speaking, people's brains continue to develop until age 25 you're talking about normal or typical persons, not a developmentally delayed group?

A Yes.

Q So, a normal 19-year-old's brain is not fully developed?

A On average, right.

Q On average.

Hr'g Tr. 63-67, Jan. 25, 2011..

Dr. Steinberg also testified about the import of the continued adolescent brain development on "executive functions" such as decision-making, impulse control, balancing risk and reward in young adulthood. He explained:

Q Are there neurobiological changes occurring at age 19 that might influence of a person's decision-making processes?

A Yes, because regions of the brain that are important for things like thinking ahead and planning and impulse control and weighing risks and rewards, those regions and systems of the brain are still developing after age 19. [**427] And to the extent that those capacities affect judgment and decision making, we can link the two together and argue that what we know about adolescent brain development would suggest that some aspects of judgment and decision making are probably still immature at that age.

Q And, again, you're saying this as to the typical person not as to someone outside the norm?

A That's correct.

Q I think you also heard Dr. Barr testify that C.R., our defendant here, as an average, based on his tests, has an average executive function for his age group. Do you recall that testimony?

A Yes, I do.

Q Now, based on your research, am I correct, that this age group is still developing in its executive functioning?

A Yes.

Q So, to say that C.R. falls within that average group also says that his executive function is still developing?

A Probably, yes.

Q Now, what are the characteristics of executive function that, from your research and your knowledge of this field, are still developing in this group? And I'm talking now specifically say from age 17 to 21.

A Impulse control as I mentioned. Planning and thinking ahead probably although there's less research on this. The way that people balance risk and **[*504]** reward when [**428] they make decisions about engaging in a potentially risky behavior.

Q When you say "impulse control," can you tell us more about what you mean by that?

A Well, the ability to stop yourself from acting by thinking through the potential consequences, let's say, of the action.

Q And how does that differ for the normal, the cognitively normal 19-year-old from a fully-matured adult?

A Well, a cognitively normal 19-year-old would be more apt to behave impulsively than a typical 25-year-old, let's say, as a point of comparison.

Id. at 67-69.

Professor Steinberg went on to explain the scientific evidence regarding anatomical brain development that supports the conclusions about executive functions. His testimony fully corroborated the research and studies relied upon by the Supreme Court in *Roper v. Simmons*, and *Graham v. Florida* previously discussed. *Id.* at 69-71. Also discussed was the relationship between adolescent "sensation-seeking" behavior and brain development. His testimony was as follows:

Q You talked about this processing of emotions and social information. Is that connected with what's called "sensation-seeking behavior"?

A A little bit. Sensation seeking is regulated by parts of the [**429] brain that are also important in processing emotion and social information but I wouldn't say that they're the same thing.

Q Okay. And when do individuals develop sensation-seeking behavior?

A Well, sensation seeking which is also sometimes discussed under the heading of novelty seeking or reward seeking. Sensation seeking is known to increase fairly dramatically between preadolescence and mid-adolescence and then starts to decline, let's say, after age 16 or 17 gradually as people mature into adulthood and that's what we now understand a little bit about the biological underpinnings of that change.

Q And is there a part of the brain that regulates this sensation-seeking behavior so that it decreases as one matures?

A Well, sensation seeking decreases for two different reasons. The first is that the part of the brain may lead to an event striatum which is part of the limbic system which is that part of the brain that part impels us to seek rewards. It's the part that's responsible for our experience of pleasure and for reward. That part of the brain becomes very much more aroused during the first part of adolescence and that arousal is particularly high during the mid-adolescent years, [**430] 16 or so. That declines as individuals move into adulthood, so one reason that sensation seeking declines is that that reward system, if you will, becomes less easily aroused. But a second reason is that the part of the system that puts the brakes on things which is the prefrontal cortex is, as I've discussed, continuing to mature during late adolescence and into early adulthood.

And if we think of middle adolescence as the metaphor is the accelerator is pressed down to the floor but the braking system is still not mature; and as the accelerator becomes lifted a little bit, and as the braking system matures, sensation seeking declines.

Q And at what age does the braking system or what we might call the regulatory mechanisms, at what age are those fully developed?

A Probably, again, in the mid-20s or so.

[*505] Q And is that also data that's available from these two forms of MRIs or from other types of research?

A Well, if we're talking about — yes, yes. Because particularly, I mentioned before the third type of structural change that's going on, the connectivity that psychiatrists believe that plays a very important role in emotion regulation because it's the —it refers to the connection between [**431] the part of the brain that is processing emotions and the part of the brain that is important in self-regulation. And because that connection becomes stronger and more well-developed during late adolescence and early adulthood, the capacity to regulate one's emotions also becomes more mature.

Q And to put it in a concrete context such as the one we face here, can you give an example of how the same choice such as whether to commit what might be pleasurable but still be criminal conduct might be handled differently by a still developing 19-year-old versus a fully-developed adult?

A Let me put this in context because I think it's important to know that psychologists and sociologists refer to that as what's called the Age Crime Curve. . . . [The] Age Crime Curve, which shows that misbehavior of almost every sort increases from age 10 or so on and peaks around 17 or 18 and then declines. And it's likely to be the case that that decline is related to improvements in self-regulation and in the maturation of self-control. So, to go back to your question, I think that a 19-year-old would be less likely than a fully-mature individual to stop and think about a misdeed before engaging in it.

Q And, [**432] to your knowledge, is that Age Crime Curve similar for sexual offenses versus nonsexual offenses?

A It pretty much applies to all kinds of offenses.

Q Now, again, with all this, you're talking about normal development, not abnormal; is that correct?

A Correct.

Q Now, turning now to the psychosocial context which we've touched on a little bit. From your research and the data available in your field, are normal adolescent psychosocial capacities comparable to those of adults?

A No.

Q How do they differ?

A Well, compared to adults, adolescents are more susceptible to peer pressure. They are more impulsive, they are less likely to plan ahead, and they are more reward sensitive, meaning, that in evaluating a situation in which there are both risks and rewards present, they're going to pay relatively more attention than an adult would to the potential rewards and relatively less attention to the potential risks or costs.

Q And is that true for someone at the age of 18 and 19?

A It's true for most of that . Not so much reward

sensitivity because that pretty much sort of hits an asymptote for a while around the age 16, 17, but the ones having to do around regulation. So, impulse control, susceptibility [**433] to influence, thinking ahead, considering the future consequences of one's actions, those are all still immature at age 18.

Q You've spoken about this a little bit, but are there biological rationales or evidence that support these psychosocial observations?

A Yes, they would have to do with maturation of the prefrontal lobe both in **[*506]** synaptic pruning and myelination and the development of stronger connections between cortical and subcortical regions.

Id. at 71-75.

Discussed by Professor Steinberg was the adverse impact of incarceration on adolescent development. He explained, "I don't think there's enough research, you know, on that to draw conclusions. What we do know is that individuals coming out of correctional environments are much less likely to become reintegrated into the community, be gainfully employed, and so forth than other what we might call at-risk groups." *Id.* at 83-84. In a colloquy with the court Professor Steinberg confirmed that these conclusions are controlled for a variety of factors such as education, race, and parents' occupation. *Id.* at 84. Protective factors that would reduce the likelihood of sexual re-offending were also examined. The professor explained,

> [B]eing [**434] in school is a protective factor against future offending. Having parents who monitor your whereabouts and provide structure and guidance is a protective factor against offending. Being gainfully employed is a protective factor against future offending. And not associating with antisocial peers a protective factor against future offending. Being in — successfully completing an evidence-based intervention or treatment is a protective factor against future offending. Yes, it's always in individual cases it's very hard to make predictions; but on average, we can say that young people who are, you know, in school and/or working and have a good home environment and are treated for a mental problem, if present, are going to be less likely to re-offend than individuals who, you know, are not attending school, who don't have good parents, who hang out with deviant peers, and who have a problem like a substance abuse problem that's untreated.

Id. at 86-87.

EXHIBIT B

TEENS IMPULSIVELY REACT RATHER THAN RETREAT FROM THREAT

DEVELOPMENTAL NEUROSCIENCE

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Teens Impulsively React rather than Retreat from Threat

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Key Words

Adolescence · Fear · Impulsivity · Limbic circuitry · Orbitofrontal cortex · Medial prefrontal cortex

Abstract

There is a significant inflection in risk taking and criminal behavior during adolescence, but the basis for this increase remains largely unknown. An increased sensitivity to rewards has been suggested to explain these behaviors, yet juvenile offences often occur in emotionally charged situations of negative valence. How behavior is altered by changes in negative emotional processes during adolescence has received less attention than changes in positive emotional processes. The current study uses a measure of impulsivity in combination with cues that signal threat or safety to assess developmental changes in emotional responses to threat cues. We show that adolescents, especially males, impulsively react to threat cues relative to neutral ones more than adults or children, even when instructed not to respond. This adolescent-specific behavioral pattern is paralleled by enhanced activity in limbic cortical regions implicated in the detection and assignment of emotional value to inputs and in the subsequent regulation of responses to them when successfully suppressing impulsive responses to threat cues. In contrast, prefrontal control regions implicated in detecting and resolving competing responses show an adolescent-emergent pattern (i.e. greater activity in adolescents and adults relative to children) during successful suppression of a response regardless of emotion. Our findings suggest that adolescence is a period of heightened sensitivity to social and emotional cues that results in diminished regulation of behavior in their presence.

Introduction

Adolescents commit more crimes per capita than children or adults in the USA [1] and in nearly all industrialized cultures [2]. Their proclivity toward incentives [3, 4] and risk taking [5–8] has been suggested to underlie the inflection in criminal activity observed during this time. Yet heightened sensitivity to incentives and risk taking are only part of the equation, as criminal behaviors often occur in emotionally charged situations of negative valence. Does negative emotional information impact self-

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control differently across development? Previous work has shown that positive emotional cues lead to poorer self-control in adolescents relative to children and adults [3], but do negative emotional cues also lead to poor impulse control? The current study tests whether adolescents are more impulsive relative to adults or children when there is a signal of potential threat, using a measure of impulsivity in combination with cues that signal threat (e.g. a frightened face) relative to neutral ones (calm face) and examines potential mechanisms for developmental differences in behavior.

The fight-or-flight response is a physiological reaction to perceived threat [9]. Fearful faces are a reliable indicator of threat in the immediate environment [10], evoking a well-defined neural response [11, 12]. Negatively valenced stimuli such as fearful faces generally inhibit behavior, slowing response times and inhibiting motor responses in various tasks [13–15]. Adolescents, however, show difficulty suppressing attention and actions toward emotional stimuli even when irrelevant to the task at hand [16, 17]. This relative lack of cognitive control in the presence of emotional and motivational cues may underlie the behavioral risks that are characteristic of adolescence [18].

Prior work suggests that diminished self-control during adolescence may result from competition between limbic and control circuitry [17–20]. A combination of evidence from human imaging [3, 21–25], postmortem [26] and animal [27, 28] studies of regional brain changes over the course of development indicate that limbic and prefrontal circuitry interact differentially across development [29]. Specifically, limbic circuitry is thought to develop earlier than control circuitry as a result of evolutionary pressure and changes in gonad hormone levels that impact limbic structures. This developmental imbalance is suggested to result in a greater influence of limbic than prefrontal regions on behavior during adolescence. This pattern is in contrast to that observed in adulthood when these circuits have matured or in childhood when they are still developing.

The current study uses a A go/no-go paradigm to measure impulsivity in combination with cues that signal threat or safety (fearful or calm facial expressions) to assess developmental changes in emotional responses to such cues, their influence on behavior and their neurobiological correlates. In previous work using the same task and overlapping sample, we have shown a heightened sensitivity to emotional cues during adolescence. In the first study [30] we showed longer response latencies to negative (fear faces) relative to positive (happy faces) emotional cues across ages but adolescent-specific increases in amygdala activity when having to respond (go) to fear faces. In a second study [3], we focused on the ability to withhold a response to positive cues, focusing solely on happy no-go trials and showed that adolescents made more false alarms to happy cues than to neutral cues compared to children and adults. This pattern was paralleled by greater ventral striatal activity in adolescents relative to children and adults. Finally, recent reports by other laboratories have noted decrements in behavioral performance on cognitive control tasks in the presence of negatively valenced stimuli versus neutral stimuli in adolescents relative to children or adults [15, 16].

In the current study, expanding on these previous adolescent-specific findings toward emotionally valenced stimuli, we test for developmental differences in brain and behavior when required to suppress responses to cues of potential threat. Second, we explore individual differences in brain activity associated with overall behavioral performance. Finally, we explore possible sex differences in behavior and brain responses to cues of potential threat.

Methods

Subjects

A total of 80 participants between the ages of 6 and 27 years were scanned using functional magnetic resonance imaging (fMRI). Data from 23 participants were excluded due to poor overall accuracy (mean no-go accuracy <70%, n = 9), too much head motion (>2 mm translational or 2° rotational motion within a run, n = 12) or technical problems (n = 2), resulting in data from 57 usable subjects (27 females) in all reported analyses. Participants were grouped into child (aged 6–12 years, n = 18, 10 male), adolescent (aged 13–17 years, n = 19, 10 male) and adult (18 years or older, n = 20, 10 male) age groups. Data from this sample have been published previously on a different subset of the data [3, 30]. All participants provided informed written consent (parental consent and subject assent for children and adolescents) approved by the Institutional Review Board of Weill Cornell Medical College.

Behavioral Paradigm

Participants completed six runs of a go/no-go task [3, 30] using fearful, happy and calm facial expressions as target (go) and nontarget (no-go) stimuli (fig. 1a). Within each run, two types of facial emotions were presented, one serving as the target (go) stimulus, to which they were instructed to press a button, and the other serving as a nontarget (no-go) stimulus, for which they were instructed to withhold a button press. Facial expressions were pseudorandomized across the run to control for presentation order, and all combinations of expression were used as both targets and nontargets, resulting in a 2 (response: go, no-go) ×3 (emotion: fear, calm, happy) factorial design. Prior to each run, participants were instructed as to which expression served as the target (go) stimulus and that they should respond with a button press only to that ex-

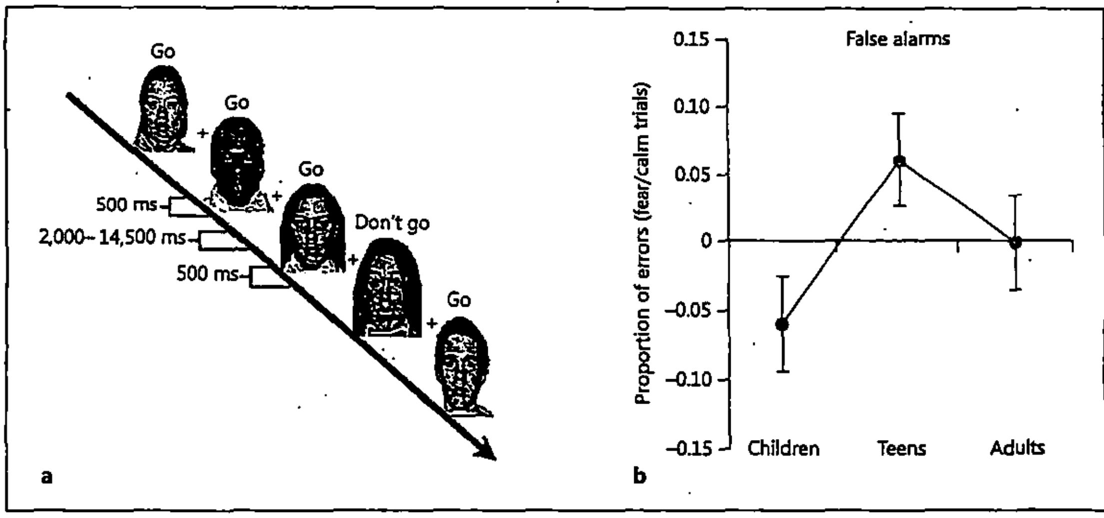

Fig. 1. Development of impulse control to threat cues. **a** The emotional go/no-go task illustrating 5 trials with calm faces as the target stimuli, for which participants should go by pressing a button. Fearful faces are the nontarget (no-go) stimuli, to which participants should withhold a button press. Each face was displayed for 500 ms followed by a variable intertrial interval. **b** False alarms (dark gray line) to fear relative to calm no-go trials show an adolescent-specific pattern of more commission errors for adolescents than either children ($t_{35} = 2.79$, $p < 0.009$) or adults ($t_{37} = 2.30$, $p < 0.03$).

pression. Participants were also instructed to respond as fast as possible but to try to avoid making errors. The present report focuses specifically on the analysis of fear no-go trials relative to calm no-go trials. Previously published work on this task focused on no-go trials to happy facial expressions [3] and go trials to fearful facial expressions [30].

Stimuli and Apparatus

The stimuli consisted of fearful, happy and calm faces from the NimStim set of facial expressions [31]. We used calm faces (mildly pleasant neutral faces) because we [32] and others [33, 34] have shown that developmental populations may perceive neutral faces as negative. The task was programmed using E-Prime software and presented to subjects on an overhead liquid crystal display panel integrated with the IFIS-SA system (fMRI Devices Corporation, Waukesha, Wisc., USA). Button responses and reaction times were logged using E-Prime software integrated with the IFIS system.

Task Parameters

The data were acquired in six functional imaging runs that combined each emotion (happy, calm and fear) and response (go and no-go; fig. 1) using a rapid event-related design. On each trial, a face appeared for 500 ms followed by a jittered intertrial interval of between 2 and 14.5 s (mean 5.2 s) during which participants were presented with a fixation crosshair. A total of 48 trials were presented per run in pseudorandomized order (36 go and 12 no-go). A total of 24 no-go trials and 72 go trials were acquired for each expression type.

Image Acquisition

Participants were scanned with a General Electric Signa 3.0-T fMRI scanner (General Electric Medical Systems, Milwaukee, Wisc., USA) and quadrature head coil. A high-resolution, T1-weighted anatomical scan (256 × 256 in-plane resolution, 240-mm field of view, 124 1.5-mm slices) was acquired for each subject for transformation and localization of data to Talairach grid space. A spiral in and out sequence [35] was used to acquire functional imaging data (repetition time = 2,500 ms, echo time = 30 ms, field of view = 200 mm, flip angle = 90, skip 0, 64 × 64 matrix). In all, 34 4-mm-thick coronal slices (3.125 × 3.125 mm resolution) covering the entire brain except for the posterior portion of the occipital lobe were acquired per repetition time.

Behavioral Analysis

Behavioral data from the emotional go/no-go task were analyzed for false alarms (incorrect presses to a 'no-go' stimulus) to fear and calm cues. Errors were calculated as a difference score between errors to fear nontargets relative to calm nontargets to isolate the effects of negative valence from the overall error rate. Error rates were compared between age groups (children, adolescents and adults). A positive value represents a greater proportion of errors to nontarget fear faces than calm faces, while a negative value represents the inverse. Mean reaction times and hit rates have been reported elsewhere [30]. A two-way ANOVA was performed with age group and sex as the between-subject variables and a difference score between errors to fear nontargets and errors to calm nontargets as the dependent variable of interest.

Imaging Analysis

Imaging data processing and analyses were performed using AFNI (analysis of functional neuroimages) software [36]. Functional imaging data were slice-time corrected, realigned within and across runs to correct for head movement, coregistered with each participant's high-resolution anatomical scan, scaled to percent signal change units, and smoothed with a 6-mm FWHM gaussian kernel. A general linear model (GLM) analysis was performed on each subject to characterize task effects with task regressors (calm/go, calm/no-go, happy/go, happy/no-go, fear/go, fear/no-go, errors), convolved with a gamma-variate hemodynamic response function. Separate regressors were created for correct go and no-go trials, broken down by emotion (errors were grouped and modeled separately with insufficient numbers to analyze separately). Only correct fear and calm trials were considered of interest and included in the second-level analysis.

We modeled the effects of response (go vs. no-go), age group (child, adolescent or adult) and emotion (fear or calm) on brain activity using a linear mixed-effects model [37]. Parameter estimate (β) maps representing task effects were then transformed into the standard coordinate space of Talairach and Tournoux [38] (1988) by applying the warping parameters obtained from the transformation of each subject's high-resolution anatomical scan. Talairach-transformed parameter estimate maps were resampled to a resolution of 3 × 3 × 3 mm. A group linear mixed-effects model was performed to identify functional regions of interest (ROIs) implicated in the interaction of response, age group and emotion. Imaging findings considered statistically significant exceeded whole-brain correction for multiple comparisons to preserve an alpha <0.05 by using a p value/cluster size combination stipulated by Monte Carlo simulations run in the AlphaSim program within AFNI. Off-line analyses were conducted in SPSS Statistics 17.0 software (SPSS, Chicago, Ill., USA). Beta values were extracted from whole-brain-corrected ROIs (drawing a 5-mm sphere around the peak voxel in each region) and submitted to offline post hoc analyses with SPSS.

Control Analyses

All imaging analyses were based on correct no-go trials. As task performance was significantly different between age groups, a second analysis was conducted to verify that the observed developmental effects were not due to less power in one age group relative to another. First-level GLMs were estimated in which number of correct trials were equated for all participants across conditions (fear/go, fear/no-go, calm/go, calm/no-go), using the lowest mean number of correct trials of all age groups (calm no-go trials in children; mean = 17 out of 24 possible, or 70% mean accuracy). New regressors were generated by randomly selecting 17 (of 24) trials per condition for inclusion. All other trials were modeled as separate regressors that were not further examined. Beta values were extracted from the 17-trial regressors using the previously defined ROIs, tested for replication, and reported in Results.

Results

Behavioral Results

The 2-way ANOVA showed a main effect of age group on false alarm rates to fear relative to calm nontargets ($F_{2,59} = 8.58$, $p < 0.001$), but no main effect of sex ($F_{1,51} = 0.05$, $p > 0.85$) or interaction with sex ($F_{2,51} = 0.27$, $p > 0.77$). Post hoc t tests showed that adolescents made more false alarms to fear nontargets in comparison to calm nontargets than either children ($t_{35} = 2.79$, $p < 0.009$) or adults ($t_{37} = 2.30$, $p < 0.03$; fig. 1b).

Imaging Results

The whole-brain age group (3) × response (go/no-go) × emotion (fear, calm) linear mixed-effects model revealed 7 ROIs (see table 1). Given the behavioral results we performed post hoc tests on beta values extracted from each whole-brain-corrected ROI to determine if teens differed from adults and from children in these regions. When we tested each region to determine whether significant variance could be attributed to adolescent-specific differences in response to fear relative to calm nontargets, two patterns emerged (see fig. 2): (1) *adolescent-specific* effects were of greater activity in adolescents compared to children or adults on correct threat no-go trials relative to calm no-go trials and (2) *adolescent-emergent* effects of adolescents and adults activated this region more than children on correct threat no-go trials. The left orbitofrontal cortex (LOFC) and medial prefrontal cortex (mPFC) showed adolescent-specific effects. Although the striatum showed a similar developmental pattern post hoc tests did not reach significance between age groups (adolescents vs. children: $p = 0.09$ and adolescents vs. adults: $p = 0.11$). The right inferior frontal gyrus (RIFG), right anterior cingulate cortex (RACC) and left premotor cortex showed adolescent-emergent effects. Our control analysis, equating power across age groups and conditions, revealed similar patterns of activity, but to a lesser degree given less overall power of the analysis. However, the LOFC maintained a robust pattern of activity across analyses (adolescents vs. children: $t_{35} = 2.74$, $p < 0.01$ and adolescents vs. adults: $t_{37} = 2.27$, $p < 0.03$).

Sex Differences

We performed exploratory analyses to test for sex differences within the three adolescent-specific findings (i.e. false alarm rates and OFC and mPFC activity to threat nontargets relative to calm nontargets). These exploratory analyses revealed that males rather than females appeared to be driving the inflection in false alarms to threat nontargets during adolescence (fig. 3a). Independent t tests revealed that in males, adolescents made more false alarms than children ($t_{18} = 2.28$, $p < 0.04$) or adults ($t_{18} = 2.96$, $p < 0.009$) and showed a similar pattern in the activation of the OFC, a region implicated in the regulation of approach-related behavior (adolescents vs. children: $t_{18} = 2.31$, $p < 0.04$; adolescents vs. adults: $t_{18} = 2.39$, $p < 0.03$; fig. 3b).

In contrast, the female age groups did not differ from one another in performance (children vs. adolescents: $p = 0.44$ and adolescents vs. adults: $p = 0.07$) or in OFC activity (children vs. adolescents: $p = 0.19$ and adolescents vs.

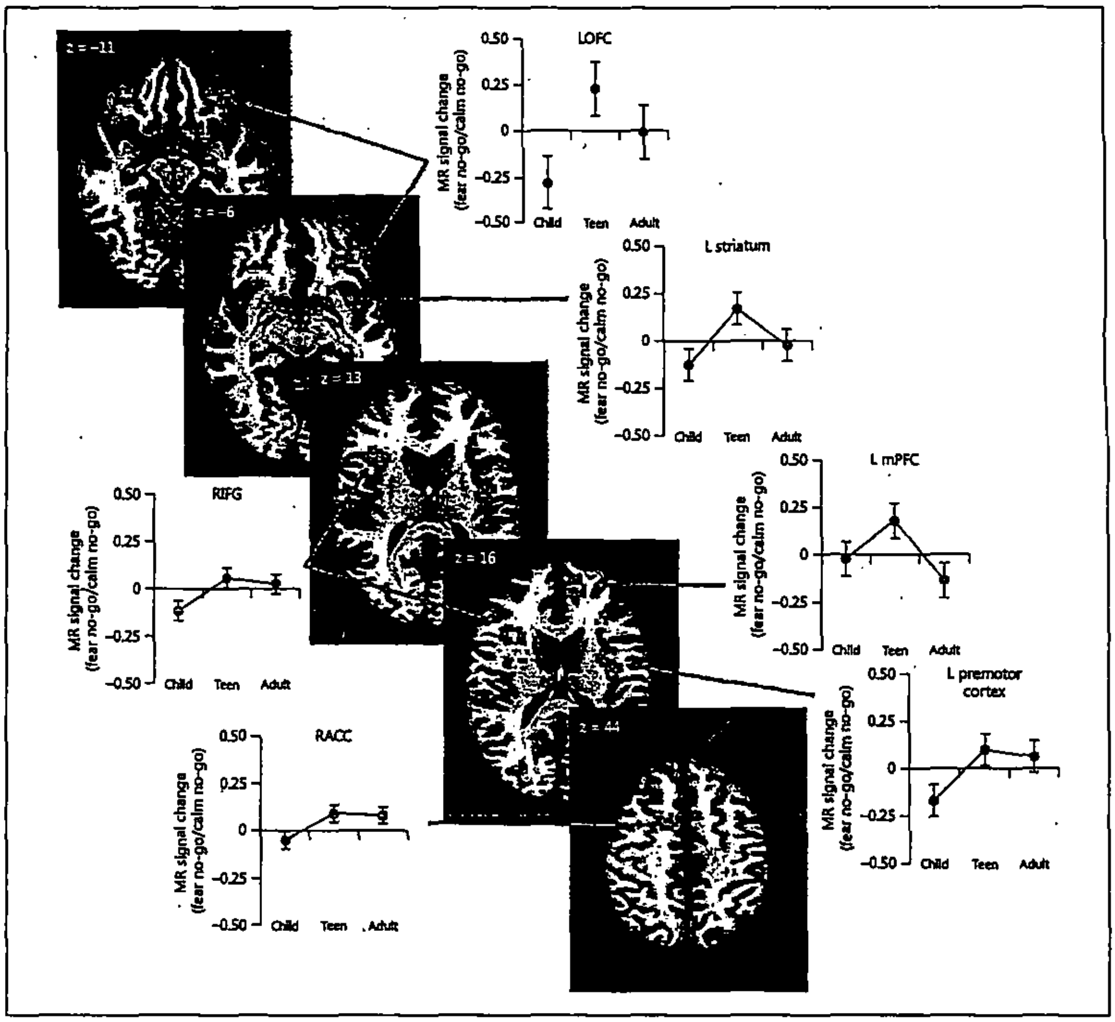

Fig. 2. Adolescent-specific and adolescent-emergent brain regions. Representative axial images and beta weights for those regions showing an age effect on correct fear no-go trials relative to calm ones from the whole-brain-corrected age (3) × response (2) × emotion (2) interaction. L = Left. Adolescent-specific effects on correct fear relative to calm no-go trials were found in contrasts between adolescents relative to children and adults together in the LOFC ($t_{55} = 2.612$, $p < 0.012$) and left mPFC ($t_{55} = 2.832$, $p < 0.006$) Adolescent-emergent effects were found in activation contrasts in children relative to adolescents and adults together on correct fear relative to calm no-go trials in the RIFG ($t_{55} = 2.503$, $p < 0.02$), RACC ($t_{55} = 2.44$, $p < 0.02$) and left premotor cortex ($t_{55} = 3.658$, $p < 0.001$).

Table 1. ROIs (Talairach) for the interaction of age group × emotion × response type

Voxels, n	Region	Brodmann's area	Coordinates (peak)	F value
193	RIFG	45	32, 17, 18	8.41
104	LOFC	11	−38, 41, −7	8.86
78	L mPFC	9	−8, 53, 24	7.95
72	L premotor	6	−41, 2, 7	8.68
58	L striatum		−20, 8, −10	6.59
56	L motor/premotor	4, 6	−14, −8, 63	7.74
51	RACC	32	11, 2, 45	6.86

Results are whole-brain corrected (alpha = 0.05, 47 voxels). L = Left.

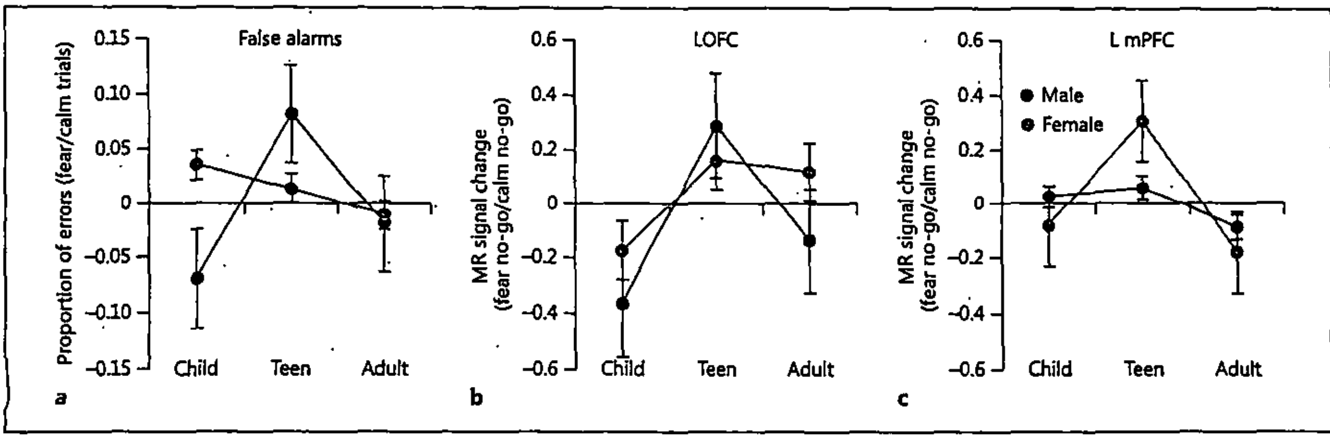

Fig. 3. Sex Differences in behavior and limbic activity by age group. **a** Difference score in number of false alarms to fear no-go trials relative to calm no-go trials by age group and sex. **b** Beta weights for OFC to correct fear no-go trials relative to calm no-go trials by age group and sex. **c** Beta weights for mPFC to correct fear no-go trials relative to calm no-go trials by age group and sex. L = Left.

adults: $p = 0.76$). Rather, adolescent females showed greater activity in the mPFC, a region implicated in the regulation of avoidance-related behavior (fig. 3c; children vs. adolescents $t_{15} = 2.53$, $p < 0.03$ and adolescents vs. adults $t_{17} = 2.65$, $p < 0.02$). Males did not differ across age groups in this region (children vs. adolescents: $p = 0.79$ and adolescents vs. adults: $p = 0.26$).

Discussion

Prior research has focused almost exclusively on how incentives and positive social cues lead to impulsive decisions during adolescence to help explain inflections in risk taking and criminal behavior during this period [3, 8, 25, 39]. The current study examined the effect of threat cues on impulse control and the underlying neural circuitry in adolescents. We found that just as positive cues can lead to more impulsive responses by adolescents relative to children and adults [3], so too can threat cues. This adolescent-specific inflection in false alarms to threat cues was paralleled by marked increases in limbic prefrontal (orbitofrontal and medial prefrontal) regions, implicated in regulating emotional and behavioral responses, particularly in the case of threat-related stimuli.

In contrast to the adolescent-specific effects in limbic prefrontal regions, prefrontal control circuitry implicated in detecting and resolving conflict between two competing responses showed an adolescent-emergent pattern [40–42]. Specifically, activity in RIFG and RACC increased from childhood to adolescence and then plateaued. These findings are consistent with developmental studies showing that the ability to ignore irrelevant information on cognitive tests like the flanker and go/no-go tasks reaches maturity levels roughly by adolescence [16, 41, 43–45].

The difficulty of adolescents in suppressing attention and actions specifically toward negatively valenced information in the current study is a pattern that is emerging in the developmental literature [15, 16]. This diminished performance in adolescents is not observed in tasks demanding suppression of attention or actions toward neutral information [3, 16]. One explanation for the results reported here may be a failure of adolescents to withhold responses to any emotional stimuli [41]. However, recent work suggests that the actions of adolescents may be disrupted more easily by negative than positive emotional information [15] and differential patterns of activity have been shown for positive and negative emotional stimuli [3, 30]. Together these findings suggest that changes in behavior and limbic circuitry during adolescence coincide with a heightened sensitivity to emotional cues that may cause them to impulsively react rather than retreat from cues of potential threat.

Theoretical and empirical accounts for this diminished performance during adolescence fall along two lines of evidence. The first is evidence of regional brain development with lateral PFC continuing to reach structural and functional maturity throughout the adolescent years [3, 23] and the connections between subcortical and cortical structures continuing to strengthen [46, 47]. Given the role of the lateral PFC in the regulation of behavior, immature connections between it and limbic structures might reduce the capacity to exert cognitive control, particularly in emotionally salient contexts [15, 16]. The second line of evidence comes from neuroendocrinology studies, showing an influx of hormones during puberty thought to sensitize functional properties of certain brain circuits [19, 48, 49], potentially resulting in adolescent-specific enhanced signaling in limbic regions that are especially sensitive to hormonal changes. Thus the heightened recruitment of regulatory prefrontal circuitry when successfully suppressing attention to emotional cues may suggest an adolescent-specific hyper-responsiveness to emotional cues that requires greater recruitment of regulatory regions. Together, these observations suggest that diminished regulation of sensitized limbic circuits may heighten the detection of, and response to, salient social cues during adolescence, even when irrelevant for goal-directed behavior.

An elevated sensitivity or reaction to threat cues during adolescence may have important implications for understanding risky or criminal-related behaviors under a heightened sense of threat. These behaviors have been reported to be higher in males than females [50–52]. So how might the adolescent-specific behavioral and imaging findings relate to sex differences observed in real world behavior? Although there was no main effect of, or interaction with, sex in the 2-factor ANOVA, exploratory independent t tests revealed that males rather than females appeared to be driving the inflection in false alarms to threat cues during adolescence. Specifically, male adolescents made more false alarms than either male children or adults and showed a parallel increased activation pattern in the OFC when successfully inhibiting a response, a region implicated in the regulation of approach-related behavior. In contrast, female adolescents did not significantly differ from female children or adults in their performance or in activity in this region. Rather, they showed greater activity in the mPFC, a region implicated in regulation of avoidance-related behavior. Adolescent males did not significantly differ from children or adults in this region. These exploratory results suggest a possible double dissociation between adolescent males and females in cortical limbic activity related to impulsively reacting and retreating from cues of potential threat, respectively, that warrants further investigation in a larger sample. In addition, a number of other factors, not specifically measured in this study, may have contributed to the observed age and sex differences such as discrepancies between the sexes in pubertal onset, pubertal stage and quality and/or lack of sleep.

The present study demonstrates that impulsive behavior during adolescence is as likely to occur in the presence of threat as reward cues. We show that rather than retreating or withholding a response to threat cues, adolescents are more likely than children or adults to impulsively react to them, even when instructed not to respond. This developmental pattern is mirrored by adolescent-specific changes in limbic cortical circuitry implicated in the detection and assignment of emotional value to inputs and in the subsequent regulation of responses to them [53–56]. Clearly more research will be required to specify the impact of threat cues on adolescent behavior. Nonetheless, these findings may have significant implications for conditions in which adolescents impulsively react and put themselves and others in harm's way.

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EXHIBIT C

SUMMARY OF ADOLESCENT DEVELOPMENTAL SCIENCE IN JUVENILE

LIFE WITHOUT PAROLE

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PAGES 6

Summary of Adolescent Developmental Science in re Juvenile Life Without Parole

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In a series of US Supreme Court decisions, evidence from the developmental science of adolescence, including developmental neuroscience, has been cited in support of decisions eliminating capital punishment for juveniles and restricting the use of mandatory sentencing to life without parole for juveniles. This summary is intended to provide a brief descriptive overview of the developmental science cited in those decisions, and of the continuing scientific progress in the relevant fields of research.[1] The overview covers six topics: immaturity of the prefrontal cortex and executive functions; the elevation of socioemotional and incentive systems; the developmental maturity mismatch between those two brain systems; the implications of current research for the prospects of rehabilitation among juvenile offenders; the issue of age cutoffs; and a note on scientific methodology.

- **Immaturity of Prefrontal Cortex (PFC) and Executive Function (EF)**
  - *Executive Function, judgment, and decision making.* The prefrontal cortex of the brain (the PFC) has long been understood to have the principal function of carrying out what are known as the "executive functions" (EF). These included basic functions such as working memory and planning, as well as the direction of cognitive resources (known as "effortful control") and, especially relevant here, impulse control (also known as the "inhibition of prepotent responses") and

[1] A recent summary of the developmental science used in *Thompson v. Oklahoma* (1988), *Roper v. Simmons* (2005), *Graham v. Florida* (2010), and *Miller v. Alabama* (2012) can be found in L. D. Steinberg, (2013): *The influence of neuroscience on US Supreme Court decisions about adolescents' criminal culpability, Nature/Neuroscience, 14*, pp. 513-518. This summary draws on that and its citations, along with other publications, including: Keating, D. P. (2012). *Cognitive and brain development, Enfance, 3*, 267-279; Keating, D. P. (2014). Adolescent thinking in action: Minds in the making. In J. Brooks-Gunn, R. M. Lerner, A. C. Petersen, & R. K. Silbereisen (Eds.), *The developmental science of adolescence: History through autobiography*. NY: Psychology Press. (Pp. 257-266).

decision-making in complex situations. The PFC is known to begin developing in early childhood and to continue that development through the childhood, adolescent, and early adult years, showing full adult maturity in the early to mid-20s.[2] It is the functioning, and especially its immaturity, that is referenced in discussions of suboptimal adolescent judgment, especially in complex decision-making contexts that include competing demands. Another key aspect of the PFC is that it has limited capacity. When fully engaged in one task involving effortful control, it has limited or no capacity to undertake additional tasks that require judgment. This has two implications: (1) having embarked on a plan to undertake a risky behavior, the execution of that plan may use up available PFC resources, compromising the individual's ability to adjust behavior when circumstances warrant; (2) engagement with other activities that demand PFC resources, such as maintaining status among peers, may make the limited PFC resource unavailable.

  - *Governance of other brain systems.* In addition to the EF developments just described, the PFC shows development in a related function, the governance of other brain systems. This is also a gradual series of developments, as peripheral systems are brought more fully under the direction of the PFC. (This is the basis of the colloquial designation of the PFC and its projections to other brain regions as the "top brain.") It is not until the early to mid-20s that the ability to delegate tasks efficiently to other brain systems, relieving the PFC of its role to maintain effortful control and freeing up PFC space for other demands.

- **Elevation of Socioemotional and Incentive Systems**
  - *Incentive systems*: Beginning in early to mid-adolescence, there is a sharp increase in what are termed "incentive systems" that entail complex neural circuitry, including emotional arousal (associated most strongly with the amygdala), sensation seeking (mediated by activity in the ventral striatum), and the heightened experience of rewards (mediated by a sharp increase in dopamine

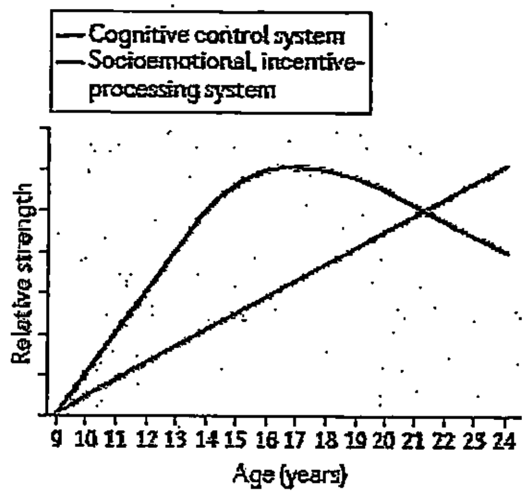
[2] This is found in research on the structure of neural circuitry, in neuroimaging in active performance situations, and in cognitive and behavioral evidence. The last section of this overview provides a brief description of the scientific methods used in the research described here and throughout the summary.

receptors) – a coordinated limbic system often referred to colloquially as the "bottom brain". These developments also coincides with (and may be partially explained by) significant changes in the hormonal balance associated with pubertal shifts, principally as an activation of the HPG-axis (hypothalamic-pituitary-gonadal) whose endpoint is the production of the steroids testosterone and estrogen (among others). These developments are observed behaviorally and cognitively as a significant increase in exploratory and sensation seeking behaviors during this same period of development when the governing capabilities of the PFC are limited (a mismatch described further below).

- *Benefits over risks.* There is substantial evidence that the factors above lead adolescents to focus more heavily on the benefits of risky behavior than on the possible negative consequences of their actions. This is not because adolescents are incapable of understanding or evaluating possible consequences of risky behavior, which under conditions of "cold cognition" (where nothing arousing or incentivizing is activated) is roughly the same as adults. Rather, they value the potential benefits of the behavior more highly than adults, altering the risk/benefit ratio in favor of undertaking unwise risks.
- *Peer susceptibility.* Among the most incentivizing and arousing contexts for adolescent risk behavior is the susceptibility to peers, sometimes in response to pressure (to maintain social status) but also because of the rewards (both behavioral and brain-activated) associated with peer influence. Under experimental conditions of peer presence, different neural circuits are activated than when performing a judgment task on one's own. In combination with the limited PFC capabilities noted above, the impact of peers is substantially higher for adolescents than for adults.

- **Developmental Maturity Mismatch (DMM) (dual process models)**
  - *Divergent developmental pathways*: The developmental pathways of the "top" and "bottom" brain diverge, with the limbic system advancing rapidly from early adolescence while the prefrontal system continues to grow, but at a slower pace, not reaching adult levels until the mid-20s. The term used to describe this is a "developmental maturity mismatch" (DMM), with significant consequences for

the levels of all kinds of risk behaviors during the adolescent period. A schematic figure illustrates this[3]



The behavioral and cognitive evidence converges with the developmental neuroscience evidence here, with highly similar age-risk behavior profiles for a number of areas, including crime (the age-crime curve), accidental injuries, serious driving mishaps, and so on. All show peaks by mid-adolescence, with gradual drop-offs until an asymptote in the mid-20s or so.

- *Dual process models*: The DMM is one version of a more general finding, known as dual process models. The research here is that when performing a complex decision making task, there are two systems functioning. One is a rational, judgment based system that takes considerable cognitive effort. The second is a more automatic, "intuitive", non-analyzed system that is accessed more often (because it requires less time and energy). This occurs for automated tasks (especially in domains where expertise is high) but also for "hot" cognition where there are competing demands – for example, from arousal and incentive systems.

- **Rehabilitative Prospects**

In addition to mitigation of sanctions owing to diminished culpability by reason of developmental immaturity, another implication of the developmental neuroscience evidence is that there are increased prospects for change among juveniles. This is supported by the evidence above that major changes continue during this period. In

[3] This version is from Steinberg (2013, see fn 1), although it has appeared in several publications.

addition, there is very substantial evidence for neural plasticity by way of "synaptic pruning." Simply put, neural circuitry is shaped by the individual's experiences, such that the resulting mature circuitry is not settled until the mid-20s. (Some plasticity continues throughout life, but never again as strongly as in adolescence.) This potential for positive change was noted as a significant factor in recent Supreme Court decisions.

- **Age Cutoffs**

The evidence above, and additional developmental science evidence, point to the difficulty of identifying strict age cutoffs for various levels of maturity or for resolution of the DMM. The evidence does support the view that full maturity on average is likely to occur by the mid-20s. Clearly, the bright line of 18-years of age is a necessary legal definition, as it jibes more readily with common sense views of maturity and resulting culpability. But it does not suggest a line of argument that 17 is nearly 18, so the evidence does not really apply.

- **Note on Scientific Methodology**

The evidence above is an integration of several kinds of research methodologies, and it is useful to understand the sources of evidence.

  - *Structural neuroscience*: This refers to evidence on the changing structure of the "static" brain, that is, when it is not performing a task. There are several methods for this, but the most prominent currently is diffusion tensor imaging (DTI), collected during a session of magnetic resonance imaging (MRI). This allows the characterization of the size of various parts of the brain, how they differ with age, and how they are connected with each other.
  - *Functional neuroscience*: This assesses how the brain is working while it is engaged in a task, most prominently in functional MRI (fMRI) and various forms of electrical encephology (EEG), such as evoked response potential (ERP). These use different physical methods (blood flow in fMRI, electrical signals in ERP), but they have the same goal, to elucidate the time and location of brain activity.
  - *Cognitive and behavioral evidence*: In addition to the brain imaging evidence above, there are large amounts of behavioral and cognitive evidence that are relevant to the DMM, including self-reports of sensation seeking, impulsivity,

and risk judgments, among others, as well as performance on cognitive tasks that assess EF, risk-reward trade-offs, and others.

- *Convergence of findings*: With respect to the confidence that is warranted with respect to the findings described above, one of the most important criteria (used in this summary) is to focus on findings where there is a convergence of methods across methods and content. Specifically, where the same developmental pattern emerges from structural brain imaging, functional brain imaging, cognitive and behavioral evidence, and the epidemiology of risk behavior, we can have strong confidence in the major findings.

EXHIBIT D

WHEN DOES A JUVENILE BECOME AN ADULT?

IMPLICATION FOR LAW AND POLICY

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produced mixed results. [73] For example, while young adults over eighteen show little impact of peers on their decision making on a driving task, [74] they show less delay of gratification (i.e., choose immediate smaller rewards over delayed larger rewards) when they believe a peer is observing them. [75] Yet, they show better overall performance on gambling tasks in the presence of peers. [76] Thus, sensitivity to peers in young adulthood may share both overlapping and distinct effects to those observed in teens. This work highlights the importance of contextual influences, such as social and emotional arousal, on the development of behavior and brain function that may be particularly relevant for evaluating appropriate age cutoffs.

In an effort to address aspects of these questions, members of the MacArthur Research Network on Law and Neuroscience examined cognitive capacity in emotionally charged and emotionally benign situations in young adults. [77] We focused specially on eighteen-to twenty-one-year-olds relative to younger (thirteen to seventeen) and older (twenty-two to twenty-five) ages. To discern specific emotional contexts that may impact cognitive control differently across development, we examined the impact of both brief and prolonged emotional states and of both positive and negative valence on cognitive control. Our premise was that these emotional contexts may relate more to emotionally charged situations relevant for legal policy judgments, such as those related to **[*786]** criminal responsibility, accountability, and public safety, than to emotionally benign situations.

We tested whether young adults would behave more similarly to adolescents (thirteen to seventeen) or adults (over twenty-one) in these emotionally laden contexts. Second, we tested whether prefrontal activity would differentiate performance levels between young adults from adults. In contrast, we predicted few differences in cognitive capacity between young adults and teens or adults in nonemotional situations. We used social cues of emotional expressions (smiling, fearful, neutral) as cues to assess the effects of brief emotional triggers on cognitive control. To assess prolonged emotional states on cognitive control, participants performed the cognitive control task while anticipating a negative event (loud aversive noise), positive event (winning up to $ 100), or no event. These emotional events were unpredictable in an attempt to elicit sustained states of anticipation and did not relate to the individual's performance.

Our findings show that, relative to adults over twenty-one, young adults show diminished cognitive capacity, similar to that of adolescents, under brief and prolonged negative emotional arousal [78] (see Figure 5). This behavioral pattern was paralleled by less adultlike recruitment of prefrontal circuitry in teens and young adults, consistent with relatively protracted development of the prefrontal cortex into the early twenties. [79] In contrast, young adults' performance did not differ significantly from either teens or adults in nonemotional situations. Positive emotional arousal impacted teens more than either young adults or adults, underscoring the point that developmentally informed age lines may differ from one context to another.

Figure 5. Young Adults, Like Teens, Have Poorer Cognitive Control and Less Prefrontal Activity to Threat Cues than Adults. (Cohen et al. in press)

[*787] Taken together, the findings suggest that young adulthood is a developmental period when cognitive capacity is still vulnerable to negative emotional influences. This diminished capacity is paralleled by immature engagement of prefrontal regions that are important for overriding emotionally triggered actions. The results are consistent with prior research implicating the importance of prefrontal control circuitry in regulating emotions. [80] Although these findings may be relevant for evaluating appropriate age cutoffs relevant to policy judgments relating to risk-taking, accountability, and punishment, they are presumably less relevant for setting minimum ages for voting or making medical decisions.

Conclusions: How Can Developmental Science Inform Policy?

We began by asking whether social practices and expectations about "adulthood" had informed laws and policies that define the rights and responsibilities of adulthood, and whether age boundaries drawn by these policies and laws reflect emerging scientific understanding of human development. If we focus solely on state policies governing the minimum age for adult prosecution of young people in the United States, we would have to reply "no" to both questions. Nearly half the states have no minimum age for trying a child as an adult and, among those that do, fourteen is the most common age. Moreover, many jurisdictions automatically transfer children to the adult system even though prosecuting teenagers in criminal courts does not deter offending [81] but rather increases recidivism. [82] These findings have spurred reforms to keep more adolescents in juvenile courts by raising the age for transfer and by repealing mandatory transfers in favor of individualized decisions by juvenile court judges. More recently, reformers are also making the case for a rehabilitative, developmentally informed approach to young adult offenders eighteen to twenty-one, recognizing that there is no developmentally informed magical line of demarcation at eighteen. What should the age of eligibility be under young offender sentencing statutes? When should a "youth discount" be exhausted? These remain open questions.

[*788] The developmental science referenced in U.S. Supreme Court decisions regarding treatment of juvenile versus adult offenders over the past decade acknowledges immature cognitive capacity in juveniles as a mitigating factor in judgments of criminal culpability. 83 Scientific research has demonstrated that adolescents show heightened sensitivity to peer influences, rewards, and threats, potentially rendering them more vulnerable to making poor decisions in these situations. 84 Minimum legal ages have been imposed largely to protect young people from these vulnerabilities. Recent findings on young adults suggest that these same vulnerabilities affect young adults. Studies that fail to focus on emotional influences on cognitive capacity are likely underestimating developmental similarities between adolescents and young adults that have the most bearing on social and legal policies relating to risk-taking and accountability.

These findings of diminished cognitive capacity in negative emotional contexts in young adults reinforce and extend the developmental logic of reforms of the juvenile justice system already underway. Previous research on the diminished capacities of adolescents in self-control in emotionally laden contexts has supported arguments for raising the minimum age of criminal court jurisdiction to sixteen, keeping youth under eighteen in the juvenile court, and mitigating their punishment in criminal court. These new findings provide empirical support for extending the juvenile court's dispositional age to twenty-one or older and for reconsideration of sentencing statutes for young adult offenders. This work does not suggest that young people should not be held accountable for their actions, but rather that the boundaries of juvenile court jurisdiction and criminal court sentencing and punishment should be informed by developmental considerations.

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