

Should the Science of Adolescent Brain Development Inform Public Policy?

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American Psychologist, in press.

Laurence Steinberg received the Award for Distinguished Contributions to Research in Public Policy. Award winners are invited to deliver an award address at the APA's annual convention. A version of this award address was delivered at the 117th annual meeting, held August 6–9, 2009, in Toronto, Ontario.

Author Note: The research program described in this article was supported by the John D. and Catherine T. MacArthur Foundation. I thank Dustin Albert, Elizabeth Cauffman, Sandra Graham, Ellen Greenberger, Thomas Grisso, Peter Marshall, Charles Nelson, Howard Sercombe, and Elizabeth Shulman for their helpful comments on a previous draft of this paper.

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Abstract

One factor that has contributed to confusion in discussions of the use of adolescent neuroscience in the development of public policies affecting young people is a blurring of three very different issues that need to be separated: (1) what science does and does not say about brain development in adolescence; (2) what neuroscience does and does not imply for our understanding of adolescent behavior; and (3) what these implications suggest for public policy. In this paper, I argue that we know a good deal about adolescent brain development, that this knowledge has in fact been useful in shaping our understanding of adolescent behavior, and that neuroscience, like behavioral science, can usefully inform policy discussions. I caution, however, that non-experts may be unduly swayed by neuroscience evidence and thus that such evidence should be presented with special care.

Should the Science of Adolescent Brain Development Inform Public Policy?

The oddest question I have ever been asked during the 35 years that I have been studying adolescent development is this: “Do you believe that someone would need to be capable of formal operational thinking in order to build an IED?” For readers unfamiliar with the study of adolescent development, formal operational thinking is, according to Piaget’s theory, the highest level of cognitive development, which is not attained until early adolescence, and even then, not consistently displayed by everyone (Kuhn, 2009). And for those who might not immediately recognize the acronym, an IED is an Improvised Explosive Device, a homemade bomb often planted along the roadside in an effort to attack the enemy.

This unusual question was posed to me during a pre-trial investigation held at Guantánamo Bay, where I was serving as an expert witness in a case involving a detainee who had been accused of building and setting IEDs in Eastern Afghanistan, as an assistant to Al Qaeda and Taliban operatives, and throwing a hand grenade that killed an American soldier. Omar Khadr, the detainee, was 15 at the time he was captured by American soldiers (Glaberson, 2007). Khadr’s defense team, which had retained me, was planning to argue in court that a 15-year-old, by virtue of his developmental immaturity, warranted special consideration under the law, consideration he had not been afforded by the interrogators who questioned him after his capture and that he would not likely be afforded by those prosecuting him for his alleged actions.

My purpose in this article is to examine the relation between developmental science, and neuroscience in particular, and public policy involving adolescents. I begin with the Khadr case to illustrate just how far-reaching the application of developmental science has grown. For if we can find developmental science in as unlikely a place as Guantánamo Bay, we can probably find

it just about everywhere.

Discussions of adolescent brain research in the popular media and in debates about public policy are frequently hyperbolic and misinformed. Many who advocate on behalf of young people take issue with those who suggest that new knowledge about brain development should influence our view of adolescence. While it is undoubtedly true that the neuroscience evidence has sometimes been embraced too uncritically, explained too glibly, or extended too broadly, it is also true that the very same evidence frequently has been dismissed too readily, described as less conclusive than it actually is, and banished from the discussion prematurely, almost on principle. As I shall argue, we know a good deal about brain development during adolescence that usefully informs policy discussions, even if the image of young people that sometimes emerges from developmental neuroscience clashes with the “strength-based” vision of youth promoted by youth advocates and adherents of the Positive Youth Development movement, an ideological partiality that has dominated youth policy discussions for the past two decades (e.g., Damon, 2004).

One factor that has contributed to the hyperbole noted above is a blurring of three very different issues that really need to be kept distinct: (1) what science does and does not say about brain development in adolescence; (2) what neuroscience does and does not imply for our understanding of adolescent behavior; and (3) what these implications do or do not suggest for public policy. In this paper, I explore each of these questions.

The paper is divided into four parts. I begin with a discussion of the Omar Khadr case, illustrating how and in what ways developmental science might inform how this Guantánamo Bay detainee should be treated. Next, I discuss of the current state of our knowledge about adolescent brain development. In the third section of the paper, I examine whether and in what

ways this knowledge contributes to our understanding of adolescent behavior and development. I conclude by asking how brain and behavioral evidence should, and should not, inform policy discussions.

The U.S. versus Omar Khadr

The person questioning me at Guantánamo Bay about formal operations and IEDs was Marine Major Jeff Groharing, the attorney prosecuting the case against Khadr for the U.S. government. Major Groharing was looking for evidence that Khadr, by virtue of his bomb-building ability, demonstrated adult-like cognitive maturity, which argued in favor of treating him as an adult and viewing his responses during the interrogation as no different than those an adult would have provided. He was hoping I would say that in order to do what he did, Khadr would have had to be functioning at an adult level of logical ability.

As far as I know, Piaget never created any tasks designed to test the hypothesis that abstract reasoning was required for bomb-making, so my answer to the prosecutor's question would have to extrapolate from the broader literature on cognitive development in childhood and adolescence. I replied that I thought it likely that concrete operational thinking – the stage of cognitive development that emerges between 5 and 7, and that characterizes most of the elementary school years – would suffice for building an IED. After all, it does not require abstract reasoning to be able to follow instructions to connect one wire to another, or to hook a series of parts together in a predetermined sequence. Even young children can do this, I pointed out, as evidenced by their ability to assemble Legos or Tinker Toys according to plans included in the box.

The Khadr case has received worldwide attention for a number of reasons. Omar Khadr had been interrogated repeatedly between August and October of 2002 at the U.S. detention

center housed at Bagram Air Base, in Afghanistan, where he was taken after his capture, and for several years after his transfer to Guantánamo, where he continues to be detained while plans to dismantle the prison camp are developed and implemented. He is the youngest person to have been detained at Guantánamo, and is the first child soldier ever tried by the United States for war crimes. Many human rights and juvenile advocacy organizations have argued that the United States' treatment of Khadr has been in violation of the United Nations' "Optional Protocol" to the Convention on the Rights of the Child on the Involvement of Children in Armed Conflict (which requires the rehabilitation of child soldiers), as well as international juvenile justice standards, which require treating children held in custody in accordance with their age (Juvenile Law Center, 2008).

I was asked to weigh in on two issues in the Khadr case that are potentially informed by the scientific study of adolescent development. The first concerns the reliability of statements he made during the many hours of his interrogations. At least some of the government's case against Khadr derives from statements that he made while being interrogated, and there is considerable evidence that, as a result of developmental immaturity, juveniles are more prone to giving false confessions (see Kassin, 2008, for a review), although this research has not, of course, examined juveniles' behavior under interrogations carried out using techniques even remotely similar to those that have been alleged to have been used at Bagram and Guantánamo. Given his age and the circumstances of his interrogations, I concluded that there was reason to worry about the reliability of Khadr's statements.

The second issue concerns Khadr's degree of criminal culpability. Even if it were proven that he had participated in the manufacture and planting of IEDs, one could argue that a 15-year-old working under the supervision and authority of adults is not fully responsible for criminal

behavior in which he might have been encouraged to engage. As my colleagues and I have argued, an offender who, by virtue of developmental immaturity, is impulsive, short-sighted, and easily influenced by others should be punished less harshly than one who is better able to control himself, anticipate the future consequences of his behavior, and resist the antisocial urgings of those around him (Scott & Steinberg, 2008; Steinberg, 2009a; Steinberg & Scott, 2003). Indeed, our work on the subject, which I discuss later in this paper, was cited multiple times in the 2005 U.S. Supreme Court decision to abolish the juvenile death penalty, in which Justice Anthony Kennedy, writing for the majority, specifically identified youthful impetuosity and susceptibility to outside pressures as grounds for barring the imposition of capital punishment for crimes committed by individuals younger than 18 (*Roper v. Simmons*, 2005). On this score, it seemed to me that a reasonable case for mitigation, and lesser punishment, could be made on Omar Khadr's behalf, should he be found guilty.

Interest in whether adolescents are as mature as adults, whether pertaining to debates about the juvenile death penalty, how we should treat Omar Khadr, or other, more mundane matters, such as whether the driving age ought to be raised, has been greatly stimulated during the past decade by the rapid expansion of knowledge about adolescent brain development. Articles in the popular press describe the teenage brain as a "work in progress," often leading the public to wonder whether the rights and responsibilities we grant young people are correctly synched with their neurobiological maturity. Newsmagazine cover stories on the prolonged maturation of the prefrontal cortex (e.g., Wallis, 2004) have generated considerable interest, and public awareness of this phenomenon is widespread. A recent cartoon in *The New Yorker* depicts parents disciplining their teenage son, ordering him to go to his room "until his cerebral cortex matures" (Smaller, 2006).

Explicit reference to the neuroscience of adolescence is slowly creeping into policy discussions as well as popular culture. Although the Supreme Court's opinion in *Roper* did not specifically cite any developmental neuroscience, several of the amicus curiae briefs submitted in the case, including that of the American Psychological Association, drew the justices' attention to that body of research:

Why do adolescents show differences from adults with respect to risk-taking, planning, inhibiting impulses, and generating alternatives? Recent research suggests a biological dimension to adolescent behavioral immaturity: the human brain does not settle into its mature, adult form until after the adolescent years have passed and a person has entered young adulthood. . . . Of particular interest with regard to decision-making and criminal culpability is the development of the frontal lobes of the brain. The frontal lobes, especially the prefrontal cortex, play a critical role in the executive or "CEO" functions of the brain which are considered the higher functions of the brain. . . . They are involved when an individual plans and implements goal-directed behaviors by selecting, coordinating, and applying the cognitive skills necessary to accomplish the goal. Neurodevelopmental MRI studies indicate this executive area of the brain is one of the last parts of the brain to reach maturity (APA, 2004, pp. 9-10).

Although one would hardly expect that research on adolescent brain development would play a role in a trial of an alleged Al Qaeda terrorist, I was not surprised when the prosecution team in the Khadr case asked me about adolescent brain development. Was I aware that the "parts" of the brain necessary for some forms of advanced thinking were fully developed by age 15? (Only partially true, I explained, because different brain systems are relevant to different

“advanced” abilities, and while some are fully mature by 15, many are not; Paus, 2009.) Wasn’t it the case that the limbic system was completely mature by age 15? (Again, I replied, it depends on what specific systems one is referring to; many connections between cortical and subcortical regions are still developing very late in adolescence and perhaps into early adulthood; Paus, 2009.) Well, isn’t it true that individuals have adult-like memory abilities by the time they are 15? (Yes, I said, that in fact was the case [e.g., Kail, 1997], although I noted that adolescents’ and adults’ memory abilities might be differentially affected by situational factors, including the conditions under which one’s memory was probed.)

The use of neuroscience to buttress arguments derived mainly from behavioral research is a growing trend worth exploring in some detail. Consider, for instance, the following exchange during oral arguments in *Roper* between Justice Breyer and Seth Waxman, the attorney arguing in favor of the juvenile death penalty’s abolition:

Justice Breyer: Now, I thought that the – the scientific evidence simply corroborated something that every parent already knows, and if it’s more than that, I would like to know what more.

Mr. Waxman: Well, it’s – I think it’s – it’s more than that in a couple of respects.

It – it explains, corroborates, and validates what we sort of intuitively know, not just as parents but in adults that – that – who live in a world filled with adolescents. And – and the very fact that science – *and I’m not just talking about social science here, but the important neurobiological science* that has now shown that these adolescents are – their character is not hard-wired. (U.S.

Supreme Court, 2004, p. 40, italics added).

The implication in Waxman’s response – that social science is “just” social science, but that

neurobiological science is “important” – is consistent with recent studies of what has been called “the seductive allure of neuroscience explanations” (Weisberg, Keil, Goodstein, Rawson, & Gray, 2008). Individuals are more likely to view the results of behavioral research as credible when neuroscience evidence is attached to the social science account. In one widely-cited study, when presented with sensible accounts of psychological phenomena, subjects were equally satisfied regardless of whether the explanations referred to the brain. But when presented with circular or otherwise logically suspect accounts, subjects were dissatisfied when the explanations did not contain information about the brain, but satisfied when they did (Weisberg et al., 2008). Importantly, but not as widely reported in press accounts of this study, this pattern was found among novices and undergraduates in a neuroscience class, but not among neuroscientists themselves.

What Do We Know About Brain Development in Adolescence?

Some advocates for youth have expressed concern about the use of brain research to inform social policy because, in their view, scientists have used this research to diminish the status of teenagers in society, either by unfairly justifying placing limits on adolescents’ rights (Males, 2009), infantilizing young people (Epstein, 2007), or merely perpetuating unflattering stereotypes of youthful impetuosity (Sercombe, in press). I have no quibble with those who argue that just because adolescents’ brains are less mature than adults should we necessarily treat young people differently; surely there are differences between the brains of 25-year-olds and 55-year-olds, but we do not distinguish between these age groups under the law.

Where I do take issue with some of these youth advocates, however, is in their easy dismissal of the neuroscience as too new or flawed to take seriously (but see Sercombe, in press, for a laudable exception). There is incontrovertible evidence of significant changes in brain

structure and function during adolescence. Although most of this work has appeared just in the last 10 years, there is already strong consensus among developmental neuroscientists about the nature of this change. Reasonable people (and even some unreasonable ones) can disagree about what, if anything, these findings tell us about how we should treat young people under the law, but there is little room for disagreement about the fact that adolescence is a period of substantial brain maturation. I suspect that if studies of brain development showed adolescents to be more mature than we had imagined, rather than the reverse, youth advocates would likely jump on the neuroscience bandwagon in a heartbeat.

Changes in Brain Structure During Adolescence

Four specific anatomical changes in the brain at adolescence are noteworthy (see Steinberg, 2008). First, there is a decrease in gray matter in prefrontal regions of the brain during adolescence, likely reflective of synaptic pruning, the process through which unused neuronal connections are eliminated. This elimination of unused neuronal connections occurs mainly during preadolescence and early adolescence, the period during which major improvements in basic information processing and logical reasoning are seen (Keating, 2004; Overton, 1990).

Second, also occurring in early adolescence, especially around puberty, are important developmental changes in dopaminergic activity (Chambers et al., 2003; Spear, 2000), involving a proliferation and then reduction and redistribution of dopamine receptors in paralimbic and prefrontal cortical regions. As a result of this remodeling, dopaminergic activity in the prefrontal cortex increases significantly in early adolescence and is higher during this period than at any other point in development. Because dopamine plays a critical role in the brain's reward circuitry, changes in the concentration of dopamine receptors around puberty, especially in

projections from the limbic system to the prefrontal cortex, may have important implications for sensation-seeking. It has been hypothesized, for instance, that early adolescence is a time of increasing sensitivity and efficiency in the dopaminergic system, which may make potentially rewarding stimuli experienced as more rewarding, thereby heightening the salience of rewards in situations when both rewards and costs are present (Ernst & Spear, in press).

Third, there is an increase during adolescence in white matter in prefrontal regions, reflective of myelination, the process through which nerve fibers become sheathed in myelin, thereby improving the efficiency of neural signaling. However, unlike the synaptic pruning of the prefrontal areas, which takes place early adolescence, myelination is ongoing well into late adolescence and early adulthood, and perhaps even beyond (Lenroot, Gogtay, Greenstein, Wells, Wallace, Clasen, et al., 2007). Improved connectivity within the prefrontal cortex is important for higher-order functions subserved by multiple prefrontal areas, including many aspects of executive function, such as response inhibition, planning ahead, weighing risks and rewards, and the simultaneous consideration of multiple sources of information.

Finally, as evidenced in the proliferation of projections of white matter tracts across different brain regions, there is an increase not only in connections among cortical areas, but between cortical and subcortical regions (Eluvathingal, Hasan, Kramer, Fletcher, & Ewing-Cobbs, 2007). This anatomical change is especially important for emotion regulation, which is facilitated by the increased connectivity between regions important in the processing of emotional and social information and regions important in cognitive control processes. This, in turn, improves the efficiency of affective cognition and contributes to changes in the processing of rewarding and threatening stimuli. As is the case with myelination more generally, these gains in interregional connectivity are ongoing well into late adolescence.

Changes in Brain Function During Adolescence

In addition to these structural changes, functional studies indicate that adolescence is also a time of important changes in patterns of brain activity. Several overarching conclusions can be drawn from this work. First, there is a gradual development and strengthening of brain systems involving self-regulation over the course of adolescence and early adulthood. Imaging studies examining performance on tasks requiring cognitive control have shown that adolescents tend to recruit the relevant network of related brain regions less efficiently than adults, and that areas associated with cognitive control become more focally activated with age (Durstun et al., 2006). For example, imaging studies using tasks in which individuals are asked to inhibit a “prepotent” response, like trying to look away from, rather than toward, a point of light, have shown that adolescents recruit the cognitive control network less selectively and efficiently than do adults, perhaps overtaxing the capacity of the regions they activate (Luna et al., 2001).

Second, evidence from fMRI studies indicates that several aspects of reward processing appear to involve regions known to mature during early adolescence. That adolescents, relative to children or adults, may be especially sensitive to rewards is consistent with fMRI studies of activation of the nucleus accumbens, a subcortical brain structure known to play a central role in reward processing. For example, in a study in which participants learned to associate a visual stimulus with a monetary reward, Galvan and colleagues (Galvan et al., 2006) found that adolescents showed a more vigorous accumbens response to reward than both children and adults.

A third change in brain function during adolescence involves the increasing involvement of multiple brain regions in tasks involving the processing of emotional information. It is not, as has been often reported in the popular press, that adolescents are unequivocally more prone than

adults to activation of subcortical brain systems when presented with emotional stimuli (or that they are more “emotional”). Rather, adolescents are less likely to activate multiple cortical and subcortical areas simultaneously, suggesting deficits, relative to adults, in the synchronization of cognition and affect. Functional studies point to improvements in the coordination of emotion and cognition over the course of adolescence (Steinberg, 2008).

Timing is Everything

These developments do not take place along one uniform timetable, and the differences in their timing raise two important points relevant to the present discussion. First, there is no simple answer to the question of when an adolescent brain becomes an adult brain. Brain systems implicated in basic information processing reach adult levels of maturity by mid-adolescence, whereas those that are active in higher-order executive functions, self-regulation, and the coordination of affect and cognition do not mature until late adolescence or even early adulthood (Steinberg, 2008). To the extent that we wish to rely on developmental neuroscience to inform where we draw age boundaries between adolescence and adulthood for purposes of social policy, it is important to match the policy question with the right science. As my colleagues and I have pointed out, different rights and responsibilities require different skills and capacities, and an adolescent may be, neurobiologically speaking, mature enough for some decisions but not others. For example, although the APA was criticized for apparent inconsistency in its positions on adolescents’ abortion rights and the juvenile death penalty, it is entirely possible for adolescents to be too immature to face the death penalty but mature enough to make autonomous abortion decisions, because the circumstances under which individuals make medical decisions and commit crimes are very different and make different sorts of demands on individuals’ abilities (Steinberg, Cauffman, Woolard, Graham, & Banich, in press).

Second, the specific nature of the difference in the developmental timetables of different brain systems creates a particular kind of vulnerability that is specific to adolescence (Steinberg, 2008). One disjunction concerns the temporal gap between the arousal of the reward system and the maturation of systems involved in self-regulation. The first half of adolescence is a period during which brain systems implicated in reward processing appear to be easily aroused but where systems implicated in both harm avoidance and in self-regulation are still relatively immature. As individuals develop beyond mid-adolescence, the systems important for reward processing become less easily aroused, and those that involve self-regulation become more efficient and effective. The combination in middle adolescence of an easily aroused reward system and a still immature self-regulatory system has been likened to “starting an engine without yet having a skilled driver” (Steinberg, Dahl, Keating, Kupfer, Masten, & Pine, 2006, p. 721).

The overarching consensus to emerge from recent research on the developmental neuroscience of adolescence is that teenagers are not as neurobiologically mature as we once thought they were. This is not, as some have contended (e.g., Males, 2009), an interpretative spin that has been used to package neuroscience in a way that is merely convenient. Adolescents’ neurobiological immaturity, relative to adults, is a fact, and within the neuroscience community, an uncontroversial one at that.

What Does Research on Brain Development Tell Us About Adolescent Behavior?

Although there is a good degree of consensus among neuroscientists about many of the ways in which brain structure and function change during adolescence, it is less clear just how informative this work is about adolescent behavior. Moreover, saying that a particular behavior observed during adolescence is associated with a particular feature of brain development in and

of itself says nothing about the causes or malleability of the behavior, because the relation between neurobiology and behavior is reciprocal. Some of the changes in brain structure and function that take place during adolescence are primarily maturationally driven, universal, and relatively impervious to environmental influence. Others are primarily driven by context, highly variable between individuals, and plastic in response to external input. But most brain changes are probably the product of an interaction between biology and experience.

Because all human behavior has neural underpinnings, arguing that adolescents behave the way they do because of “something in their brain” is an incontrovertible statement of the obvious. How then, does neuroscience contribute to a better understanding of adolescent behavior? First, the developmental neuroscience of adolescence often provides a helpful narrative that links together otherwise disparate findings from behavioral research, and in doing so, may help generate new hypotheses about psychological development that can be tested in behavioral research (Henson, 2006). In this regard, neither neuroscience or psychology has explanatory primacy; instead, work in one tradition is used to inform, and stimulate, work in the other. Second, neuroscience may permit one to distinguish between behavioral phenomena that have similar outward manifestations but that actually are rooted in very different underlying processes; in this respect, neuroscience can help us measure and characterize behavioral phenomena with greater precision, which, in turn, may help reconcile sets of findings that at first glance may appear contradictory. Let me provide an illustration from our work.

Several researchers, including myself, have advanced the hypothesis that heightened risk-taking in adolescence is the product of an easily aroused reward system and an immature self-regulatory system (e.g., Casey, Getz, & Galvan, 2008; Dahl, 2004; Steinberg, 2008). Moreover, it has been hypothesized that the arousal of the reward system takes place early in adolescence

and is closely tied to pubertal maturation, whereas the maturation of the self-regulatory system is independent of puberty and unfolds gradually, from preadolescence through young adulthood.

If this story is correct, several observations should follow. First, we should see different patterns of development evinced in measures of reward-seeking than in measures of impulse control. Second, we should see more developmental change in reward-related behavior in early adolescence than in late adolescence. Third, the development of self-regulation should take place gradually, continue throughout adolescence, and be unrelated to pubertal maturation. Finally, we should see greater inclination toward risk-taking in mid-adolescence than before or after, because this is the period during which reward-seeking is high but self-regulation is still relatively immature.

These observations have been borne out in a recent study my colleagues and I conducted, which involved 935 individuals between the ages of 10 and 30, studied in five different locations in the United States. Our findings indicate that reward sensitivity (Cauuffman, Shulman, Steinberg, Claus, Banich, Graham, et al., in press), preference for immediate rewards (Steinberg, Graham, O'Brien, Woolard, Cauuffman, & Banich, 2009), and sensation-seeking (Steinberg, Albert, Cauuffman, Banich, Graham, & Woolard, 2008) follow a \cap -shaped function, increasing between preadolescence and mid-adolescence, peaking between 14 and 16, and then declining. In contrast, impulse control (Steinberg, Albert, et al., 2008), anticipation of future consequences (Steinberg, Graham, et al., 2009), strategic planning (Albert, Steinberg, Woolard, Banich, Graham, & Cauuffman, 2009), and resistance to peer influence (Steinberg & Monahan, 2007) all increase linearly from preadolescence through late adolescence. Moreover, individuals' preference for risky activity – the extent to which they believe that the benefits of risk-taking outweigh the costs – is higher during mid-adolescence than before or after and predicted

independently and jointly by measures of reward-seeking and self-regulation (see Figure 1) (Steinberg, 2009b).

Insert Figure 1 About Here

Although one can show that preference for taking risks is generally higher in adolescence than before or after without the benefit of neuroscience, knowledge about the course of brain development provides the basis for generating hypotheses about the underlying processes that might account for this pattern. Our decision to independently assess sensation-seeking and impulsivity derived directly from research on brain development, and the finding that both are likely to contribute to risk-taking, although in different ways at different points in development, may have important implications for the development of policies and interventions designed to reduce adolescents' reckless behavior. For example, the findings suggest that interventions designed to capitalize on adolescents' heightened propensity for reward-seeking (e.g., emphasizing the rewarding aspects of alternatives to the risky behavior one wishes to prevent) might be especially effective among younger adolescents but less so among older ones, whereas those that capitalize on individuals' growing capacity for self-regulation (e.g., encouraging adolescents to pause and think before engaging in a risky behavior) might be more effective among older teenagers than among younger ones.

Should Research on Adolescent Brain Development Inform Public Policy?

As a transitional period between childhood and adulthood, adolescence is the stage of development that is most affected by age-specific regulations that define the rights and responsibilities reserved for adult members of the community. Drawing legal or social distinctions between adolescents and adults is a universal phenomenon, found in every culture ever studied by social scientists (Schlegel, 2009). The law defines adolescents, or some portion

of adolescents, either as children, who are viewed as vulnerable, dependent, and lacking the competence to make responsible decisions, or as adults, who are viewed as “autonomous citizens responsible for their own conduct, entitled to legal rights and privileges, and no longer entitled to protections” (Woolard & Scott, 2009, p. 345). But where this chronological dividing line is drawn varies considerably across policy domain, locale, and historical time.

In contemporary American society, the range of ages used to determine when adolescents are children and when they are adults is wide. Individuals can be tried in adult court at 14 in most states (and in some states, at an even younger age for a serious violent felony) but cannot purchase alcohol until they are 21, and until recently, could not rent an automobile until 25. Between these two extremes are a variety of different ages used to determine when individuals can make autonomous medical decisions, drive, hold various types of employment, marry, view R-rated movies without an adult chaperone, vote, serve in the military, enter into contracts, purchase alcohol, and purchase tobacco. Considered as a group, and viewed through the lens of developmental science, the various chronological boundaries that define the rights and responsibilities of teenagers under the law make little sense. It is difficult, to say the least, to rationalize permitting teenagers to drive before they are permitted to see R-rated movies, sentencing juveniles to life without parole before they are old enough to serve on a jury, or permitting young people to buy tobacco before they can buy alcohol. Whether, how, and to what extent neurobiological research should inform social policies that govern our decisions about these and other matters is an important question, to which I now turn.

Developmental Science and Public Policy

The influence of developmental science on policy is complicated, and in order to understand the potential contribution of neuroscience to public policy concerning young people,

it is important to note a few things about the relation between science and public policy more generally. In rare instances, policy-makers look to developmental science to guide their decision-making, but as a rule, science is only one of many factors that influences the final policy outcome, and frequently the science is consulted after the policy proposal is made, rather than before. That is, policy-makers often look to science for evidence that supports a position they have taken for other reasons (political, economic, pragmatic, legal, and so forth). My experience, at least within the realm of juvenile justice policy, is that the question I'm usually asked is likely to be along the lines of, "We are thinking about changing our policy on X in the following way, and we're interested in your reaction to it as a developmental psychologist," rather than "Based on the science, what would you recommend we do about X?" So when I ask whether neuroscience should inform public policy, it is important to keep in mind that this question is probably best phrased in terms of *whether neuroscience should be consulted by policy-makers in deciding whether a policy that has been proposed is consistent with the available scientific evidence*. This is not to minimize the importance of having good science available to respond to such inquiries, but to reassure those who fear that neuroscience is creating a new form of "biodeterminism" (e.g., Males, 2009) that it is highly unlikely that lawmakers are going to rewrite statutes because of a new study of synaptic pruning, myelination, brain activity, or neurotransmission. If only scientists held such sway in our legislatures.

Nevertheless, as neuroscience comes to play an increasingly prominent role in shaping how we think about adolescence, it will come to play an increasingly important role in how we define and bound the period. And if neuroscience plays an increasingly important role in how we define adolescence, it will be used, and misused, to argue for and against various public policies. After all, if the fundamental issue at the heart of debates over whether individuals of a

certain age should be able to obtain an abortion, drive, drink, vote, or be tried as adults is whether people that age are capable of mature judgment, where better to look than the prefrontal cortex, where mature judgment is popularly believed to be localized?

Down what road is the science of adolescent brain development likely to lead us? If there is an overarching theme to emerge from the science of adolescent brain development, it is that teenagers are less mature than we might have thought. This, in turn, begs the following policy question: If adolescents are less neurobiologically mature than adults, shouldn't our policies and practices involving young people take this immaturity into account? More specifically, doesn't the immaturity of the adolescent brain argue for added protections for young people (e.g., for disqualifying young people from exposure to the possibility of a sentence of life without the possibility of parole, or passing more stringent child labor laws) and, as well, for fewer rights (e.g., raising the driving age to 18 or returning the voting age to 21)?

These are not hypothetical concerns. During the past decade, I have been asked whether research on brain development should lead us to do such things as restrict adolescents' driving privileges, prohibit their service in the military, ban them from summer employment as lifeguards, or exempt them from being tried and punished as adults. My answer to all of these questions is that neuroscience should inform discussions about how adolescents should be treated under the law, just as developmental science does more generally, but that informing the discussion and dictating policy are two very different things. And even if neuroscience is used only to inform the discussion, there are still several potential pitfalls to keep in mind.

Six Potential Pitfalls in the Use of Neuroscience to Inform Youth Policy

First, there is a tendency for laypersons to view neuroscience as somehow more real, reliable, or valid than behavioral science. As I noted earlier, people give behavioral research

more credibility when it is accompanied by neuroscience. Although neuroscientific evidence that is consistent with behavioral evidence is often useful for fleshing out a behavioral story, unreliable behavioral research, or behavioral research of questionable rigor, is not magically made reliable or rigorous simply because its findings are consistent with predictions derived from neuroscience. Neuroscientific research is not inherently more valid than behavioral research, and for many policy purposes, it may well be less relevant, which brings me to my second concern.

Behavioral evidence without neurobiological support is not necessarily suspect. Let us imagine a case in which the behavioral and neuroscience are at odds – where, for example, there was behavioral evidence that 15-year-olds performed at adult levels of maturity on some policy-relevant task but appeared significantly less mature than adults on some presumed neural underpinning of performance on that very same measure. Would we argue that the policy in question should be fashioned to be consistent with the neurobiological evidence, even if that made the policy inconsistent with the behavioral science? I think not. As a rule, in the formulation of policy, the scientific evidence in which we should place the most faith is the evidence that is most similar to the actual behavior the policy is intended to regulate. For purposes of driver's licensing, evidence of age differences in actual driving ability is more relevant than evidence of age differences in the neural processes presumed to undergird operating a car.

Third, neuroscience can shed light on how adolescents and adults differ, but it does not make establishing bright line age boundaries for policy purposes any easier than does behavioral science. Although we may be able to make generalizations about the maturation of particular brain systems over time, characterizations of brain development at a given age are necessarily

based on averages. Knowing an individual's chronological age permits us to estimate his or her neurobiological maturity, based on these averages, but there is considerable variation among individuals of a given chronological age in brain structure and function, just as there is variation in psychological functioning. Any system of boundary-drawing that relies on science for guidance, whether neuroscience or behavioral science, is bound to be imperfect, but it will nevertheless sit on a stronger foundation than one that is ignorant about development. How much imperfection we are willing to tolerate (i.e., how often individuals' developmental maturity is out of sync with their legal status), and whether it is better to err on the side of presuming maturity (as we do when we try 14-year-olds as adults) or presuming immaturity (as we do when prohibiting 20-year-olds from purchasing alcohol), are political, moral, and pragmatic considerations that have nothing to do with science.

Fourth, we must think through what it means to be "mature enough." It is true that there is significant brain maturation over the course of adolescence and into young adulthood. But where, along this continuum of brain maturation, individuals attain sufficient maturity to merit adult status is not a question that can be answered by neuroscience alone, just as it is not a question that can be answered by behavioral science alone. Even if more myelination, or synaptic pruning, or interregional connectivity were "better," in the sense of being correlated with improved performance on some policy-relevant task of interest, we cannot say, on the basis of neuroscientific evidence alone, how *much* myelination, or pruning, or connectivity is "good enough." Although the average adolescent's brain may be less mature than the average adult's, the average adolescent's brain may be perfectly suitable for the task under consideration. And the only way to judge this is to evaluate individuals' performance on that task against some predetermined criterion.

Fifth, there is a difference between using neuroscience to guide the formulation of policy and using it to determine how individual cases are adjudicated. Although we frequently can say with confidence how brain structure at one chronological age differ, on average, from structure or function earlier or later in life, neurobiological differences among same-aged individuals are often substantial. Although we may be able to say that *people who are Johnny's age* are typically less mature than adults, we cannot say whether *Johnny* himself is. We may someday have the tools to image an adolescent's brain and draw conclusions about that individual's neurobiological maturity relative to established age norms for various aspects of brain structure and function (as we do in measuring the development of other organs), but such norms do not yet exist, and, for non-medical purposes, the cost of doing such an individualized assessment (e.g., to establish whether an adolescent is mature enough to be tried as an adult) is not only prohibitively expensive but unlikely to produce results that are any more conclusive than those derived from a psychological assessment. Moreover, just as there is *intra*-individual variability with respect to different aspects of psychological maturity, there is *intra*-individual variability with respect to different aspects of neurobiological maturity; as I noted earlier, there is no one age at which the adolescent brain becomes an adult brain.

Finally, as is the case for any biological influence on psychological functioning, the way in which brain maturation is expressed in real-world behavior depends on the context in which the behavior occurs. I began this paper with a discussion of the role of developmental science in evaluating the behavior of a Guantanamo Bay detainee, Omar Khadr. Although I believe that developmental science informs the discussion of how Khadr should be treated, the scientific study of brain maturation is relevant only in the most general way to determining whether Khadr's involvement in the manufacture and planting of IEDs was likely to have been willing or

coerced, or whether his responses to his interrogation were reliable. Was it helpful to know that Omar Khadr was 15 when these events occurred? Of course it is. Is it useful to know in what ways brain development may still be incomplete at this age? Yes it is, because this is part of what it means to be 15, just as heightened susceptibility to social influence or short-sightedness is. But, far more relevant to the discussion were Khadr's history, the conditions of his confinement, and the techniques used by his interrogators. Clearly this is a case where context is more important than cortex.

However, I can also think of several examples in which drawing attention to the science of adolescent brain development has served a useful purpose. Exposing policy-makers, journalists, and the general public to findings drawn from developmental neuroscience has stimulated a reconsideration and discussion of a wide range of public policies, and this is no small thing. The Supreme Court did not cite neuroscience in *Roper v. Simmons*, but there is no question that new findings about adolescent brain development played a role in marshalling support for the abolition of the juvenile death penalty, and the same is true for the current movement to prohibit sentencing juveniles to life without the possibility of parole, an issue that the Supreme Court has recently agreed to consider (Liptak, 2009). After many years of complacency about the astonishingly high and seemingly intractable rate of automobile fatalities among teen drivers, articles in the popular press about adolescent brain maturation have helped stimulate the development of a large-scale public health campaign to draw attention to the issue. And, just as research on early brain plasticity helped revive interest in the potential benefits of early intervention, new findings on brain plasticity in adolescence are today stimulating discussions about how we educate young people, about the special risks of exposure in early adolescence to potentially addictive substances, and about critical periods for the prevention of

many mental health problems.

Concluding Comments

On March 9, 2009, President Obama made it clear that his administration will “base our public policies on the soundest science,” (Obama, 2009, p. 1), a view that I welcome, and one that I suspect most members of APA welcome, too. To categorically exclude research on adolescent brain development from policy discussions makes little sense, and many who believe that it should be excluded, it seems to me, are confusing the soundness of the science with its potential implications for youth policy, some of which they find objectionable from the vantage point of youth advocacy. Indeed, the state of the science on adolescent brain development is now in some ways more advanced and more consistent than the state of the science on early brain plasticity, yet the latter evidence has fueled a policy investment in early child development of staggering proportion that few people question.

Whether the revelation that the adolescent brain may be less mature than scientists had previously thought – a conclusion that I believe is indisputable – ultimately is a good thing, a bad thing, or a mixed blessing for young people remains to be seen. Some policymakers will use this evidence to argue in favor of restricting adolescents’ rights, and others will use it to advocate for policies that protect adolescents from harm. In either case, as scientists, we should welcome the opportunity to inform policy discussions with the best available empirical evidence. Placing findings from neuroscientific inquiry in a special category of evidence that we should ignore is no more sensible than placing it in a special category of evidence that trumps everything else.

The fact that non-experts may be unduly swayed by neuroscience evidence – including evidence about which neuroscientists themselves may be circumspect – demands that it be presented with special care, however. This does not mean that we should exclude developmental

neuroscience from discussions about how best to align programs and policies with our best understanding of adolescent development. It does mean, however, that we should recognize that neuroscientific evidence has no special claims to validity or reliability, that many policy-makers and laypersons mistakenly believe that it does, and that it is incumbent on those of us who are asked whether and in what ways neuroscience ought to be taken into account when shaping social policy to make its strengths and limitations clear and, to the best of our ability, help non-scientists see that, just like behavioral science, neuroscience can be sensibly applied as well as foolishly misused.

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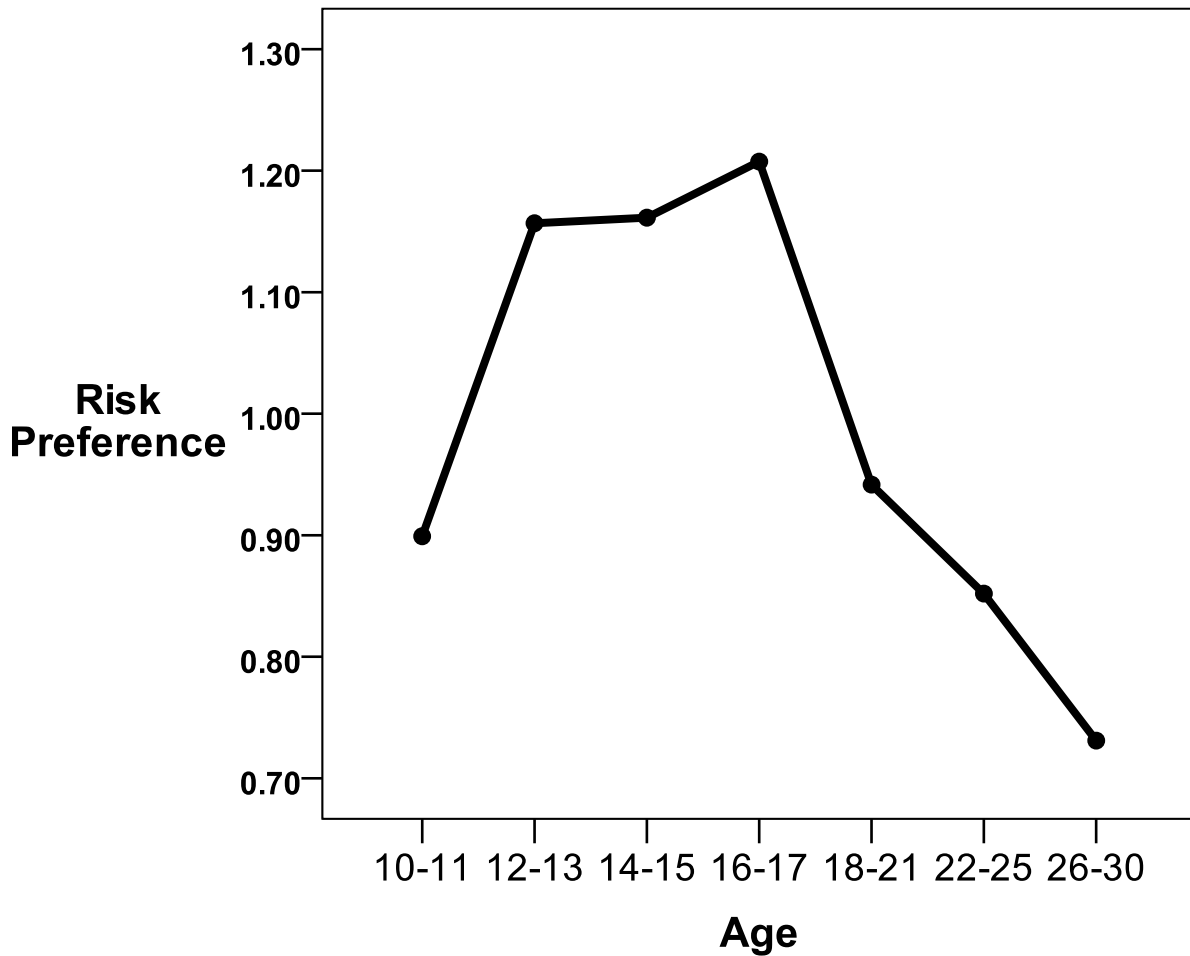


Figure 1. Age differences in risk preference, as indexed by averaging responses to the question, “How would you compare the benefits (or pleasures) of this activity with the risks?” posed in reference to a list of risky activities (e.g., unprotected sex, smoking, shoplifting). Scores have been standardized, and a constant of 1 has been added for ease of presentation. See Steinberg, Cauffman, Woolard, Graham, & Banich (in press) for a description of the program of work from which these data are drawn.