ANNUAL REVIEWS

Annual Review of Developmental Psychology

Using Developmental Science to Distinguish Adolescents and Adults Under the Law

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Annu. Rev. Dev. Psychol. 2019. 1:21–40

First published as a Review in Advance on November 26, 2019

The *Annual Review of Developmental Psychology* is online at devpsych.annualreviews.org

https://doi.org/10.1146/annurev-devpsych-121318-085105

Keywords

adolescence, age boundaries, cognitive development, psychosocial development, brain development, legal policy

Abstract

A developmental scientific perspective on drawing legal age boundaries begins with the premise that the age at which the rights and responsibilities of adulthood are conferred to minors must align with the psychological capacities and skills necessary to exercise good judgment in specific contexts. This article examines three aspects of development relevant to this analysis: cognitive capabilities, especially those that support reasoned and deliberative decision making; psychosocial capacities, especially those that facilitate self-regulation under conditions of social or emotional arousal; and neurobiological maturation in brain regions and systems that undergird these cognitive and psychosocial skills. We conclude that the maturation of the capacity to reason and deliberate systematically precedes, by as much as five years, the maturation of the ability to exercise self-regulation, especially in socially and emotionally arousing contexts. Legal age boundaries should distinguish between two very different decision-making contexts: those that allow for unhurried, logical reflection and those that do not.

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INTRODUCTION

All societies, whether developed or developing, create one or more legal age boundaries between adolescence and adulthood. This boundary drawing is driven by the need to regulate the age at which individuals are granted full adult status with respect to the rights and responsibilities associated with adulthood. Although societies differ with respect to the specific age (or ages) at which these boundaries are drawn, the functions that the boundaries serve, and the degree of formality with which the differential status of adolescents and adults is recognized, the need to determine which individuals are ready for the responsibilities and privileges of adulthood and which are not—sometimes referred to as the process of social redefinition—is universal (Steinberg 2020). The purpose of this article is to discuss the ways in which developmental science has, or might, inform this boundary drawing.

Operationalizing Adolescence as a Developmental Stage

Defining adolescence has fascinated students of human development for centuries. Unlike discussions about other stages of development, debates about how to operationalize adolescence have been contentious and controversial. Indeed, there is a long history of scholarship grounded in the view that adolescence is not an objective reality but a social construction created for the convenience of adults. In the more benign version of this perspective, adolescents were artificially separated from adults during the Industrial Revolution for purposes of deciding who should be in the labor force (Fasick 1994). Some contemporary writers, taking a more cynical view, contend that adolescence is a political construction and that the notion of the adolescent brain is a myth constructed to justify the disenfranchisement and negative stereotyping of young people (Epstein 2007, Males 2009). Regardless of the motivation, however, if adolescence is merely a label created to serve specific social purposes, there is no need to look to developmental science to establish its boundaries, because policy makers will ultimately select and modify them to accomplish their desired result.

Neuroscientific research conducted during the past two decades challenges these inventionist views. There now is an extensive literature in cognitive neuroscience, which we review below (see the section titled Neurobiological Approaches), showing that there exist patterns of normative structural and functional brain development in adolescence that can be reliably distinguished from those characterizing childhood or adulthood (Galván 2017). And there is an equally extensive behavioral neuroscience literature showing that juvenile (i.e., adolescent) rodents often behave in ways that differ dramatically from younger or older members of their species and in a manner that is eerily similar to their human counterparts. As it is among humans, the juvenile period in most mammalian species is a time of exploration, risk taking, and independence seeking (Spear 2011). It is unlikely that the characteristic behavioral displays of juvenile mice are a reaction to their more powerful murine associates' interests in oppressing their young, nor should the well-established impulsive, aggressive, and hedonistic inclinations of juvenile mice be taken as signs of rebellion, spite, or irresponsibility. Adolescent mammalian behavior is the way it is because we are biologically wired that way, and as many writers have noted, there is a sensible evolutionary explanation for it (Ellis et al. 2012, Steinberg 2014).

Even among those who believe that adolescence is more than a social construction, there is no universally accepted definition of the stage. It is often said that adolescence begins in biology and ends in culture, but the biological and cultural factors that might be used to mark the beginning and end of the period are fluid and contextually variable, and an operationalization that makes sense at one point in history may not work well at another. For example, one might reasonably propose the onset of puberty as a marker of the beginning of adolescence, but in industrialized societies, puberty begins at a much earlier chronological age today than it did in the past. Similarly, while one might propose to define the end of adolescence with respect to young people's transition into adult roles, the ages at which people marry, enter the labor force, or establish independence fluctuate across time, place, and demography. For example, it is clear that in industrialized countries, the average age at which young people enter the conventional roles of adulthood has risen in recent decades. Although some have attempted to define a new developmental stage that comprises older adolescents, such as youth (Keniston 1970) or emerging adulthood (Arnett 2000), employing a new label skirts the legal issue, since it is not clear whether people in this newly imagined group are adolescents or adults under the law.

Operationalizing adolescence, especially with respect to when the period ends, is more than an academic exercise. Whether individuals are viewed as adolescents or adults affects how they are treated when they break the law, whether they can make decisions about their own health care, whether they are permitted to vote, and when they are granted various constitutional rights, such as the right to free speech or due process. Under US criminal law, the age at which the legal boundary between adolescence and adulthood is set determines whether someone who has been convicted of a serious crime can be sentenced to death or to life without the possibility of parole (Steinberg & Scott 2003). At the present time, these sentences are available for individuals who are 18 or older. But in light of new evidence indicating that important, legally relevant aspects of psychological and brain function continue to mature well beyond this age, many commentators have asked whether this age boundary should be reconsidered (Scott et al. 2016).

How Developmental Science Might Contribute to the Development of Legal Age Boundaries

Increasingly, lawmakers have asked developmental scientists to weigh in on drawing a legal boundary between adolescence and adulthood and have relied on their work to reach some of their conclusions. Most notably, in several US Supreme Court cases decided during the first and second decades of the twenty-first century (e.g., *Graham v. Florida* 2010, *Miller v. Alabama* 2012, *Roper v. Simmons* 2005), justices have cited developmental science to support their decision to prohibit the use of exceedingly harsh sanctions in cases involving individuals younger than 18 (e.g., capital punishment, life without the possibility of parole). As **Table 1** indicates, the Court's reliance on developmental science to adjudicate these matters has increased over time (Steinberg 2013).

Table 1 The US Supreme Court's rationale in several cases concerning adolescents

Case	Year decided	Ruling	Rationale
Thompson v. Oklahoma	1988	Capital punishment is found unconstitutional for individuals under the age of 16 but permissible for those 16 and older.	"Contemporary standards of decency confirm our judgment that such a young person is not capable of acting with the degree of culpability that can justify the ultimate penalty." (*Thompson v. Oklahoma*, p. 823)
Roper v. Simmons	2005	Capital punishment is found unconstitutional for individuals under the age of 18.	"As any parent knows and as the scientific and sociological studies…tend to confirm, [a] lack of maturity and an underdeveloped sense of responsibility are found in youth more often than in adults and are more understandable among the young." (*Roper v. Simmons*, p. 15)
Graham v. Florida	2010	Life without parole is found unconstitutional for individuals under the age of 18 convicted of crimes other than homicide.	"No recent data provide reason to reconsider the Court's observations in *Roper* about the nature of juveniles…. Developments in psychology and brain science continue to show fundamental differences between juvenile and adult minds. For example, parts of the brain involved in behavior control continue to mature through late adolescence." (*Graham v. Florida*, p. 3)
Miller v. Alabama	2012	States may not mandate life without parole for individuals under the age of 18, even in cases of homicide.	"The evidence presented to us…indicates that the science and social science supporting *Roper*'s and *Graham*'s conclusions have become even stronger…. It is increasingly clear that adolescent brains are not yet fully mature in regions and systems related to higher-order executive functions such as impulse control, planning ahead, and risk avoidance." (*Miller v. Alabama*, p. 9, n. 5)
Montgomery v. Louisiana	2016	Individuals sentenced to life without parole as juveniles prior to *Miller* are entitled to resentencing or a parole hearing.	"In light of what this Court has said in *Roper*, *Graham*, and *Miller* about how children are constitutionally different from adults in their level of culpability, however, prisoners like Montgomery must be given the opportunity to show their crime did not reflect irreparable corruption; and, if it did not, their hope for some years of life outside prison walls must be restored." (*Montgomery v. Louisiana*, p. 15)

Given the inherent differences between scientific and jurisprudential worldviews (Steinberg et al. 2009), many developmental scientists are reluctant to get involved in discussions about the law. When lawmakers ask developmental scientists to defend the age at which a bright-line legal boundary between adolescence and adulthood is drawn, it is tempting to demur, noting that different aspects of development proceed along different trajectories, that development follows different patterns within different ethnic and socioeconomic groups, that even within any of these trajectories people develop along different timetables, and that science is rarely able to identify a precise dividing line between two adjacent chronological ages at which there is an interruption in the developmental trend. These reasons for hesitancy are real, and it is understandable that some developmental scientists see the field's findings as too nuanced to guide the honing of the law's decidedly blunt instruments. The counterargument, to which we subscribe, is that legal age boundaries are drawn whether or not scientists are involved, and that laws that are informed by science—not dictated, but informed—are preferable to those that ignore it.

In our view, the use of developmental science to inform policy and practice concerning legal age boundaries is no more problematic than the use of developmental science to inform any policy question. Helping lawmakers decide at what age it makes sense to punish an adolescent as an adult, for example, does not strike us as any more challenging than many of the policy questions about which developmental scientists are asked to opine, such as the impact of housing vouchers on children's behavior and development (e.g., Fauth et al. 2007). As we have argued elsewhere, though, helping policy makers make scientifically informed decisions is not the same as advocating for one policy over another, and it is essential that developmental scientists who hope to inform legal policy respect and maintain the line between science and advocacy, even if the policy implications of a particular scientific finding conflict with the scientist's personal values (Grisso & Steinberg 2005).

Until very recently, the role of developmental science in this aspect of legal and public policy making has been negligible. Most societies have established specific chronological age boundaries between minors and adults on the basis of intuitive (e.g., relying on tradition or common sense), administrative (e.g., valuing the simplicity of having one age for many different legal purposes), fairness (e.g., if a legal boundary is drawn at a specific age for one purpose, it is only right to use it for others), or consequentialist (i.e., the likely societal outcomes of setting the boundary at one age or another) considerations. These approaches have also been used to make changes to legal age boundaries: For example, during the Vietnam War, the voting age in the United States was lowered to 18 to make it consistent with the age of military service, and, in response to the steep increase in juvenile crime that occurred during the 1980s, the minimum age for transferring a juvenile offense to criminal court was lowered in many states to deter crime (Scott & Steinberg 2008).

A developmental perspective on boundary drawing provides an alternative to these nonscientific approaches. Rather than relying on intuition, practicality, legal consistency, or strategic concerns, using developmental science for legal boundary drawing seeks to align the age at which adolescents become adults under the law with objective indicia of young people's maturity. For example, consider the legal age at which an adolescent, acting on her own, can be prescribed oral contraception. Rather than basing this boundary on social norms, consistency with other laws concerning adolescent decision making, beliefs about the degree of autonomy young people should be afforded over their sex lives, or a desire to discourage sexual intercourse or encourage safe sex among teenagers, a perspective grounded in developmental science attempts to identify a set of skills necessary to make informed decisions about the matter at hand (e.g., understanding and remembering that failing to adhere to the prescribed regimen can result in pregnancy) and determine the age at which individuals typically attain these competencies (or, alternatively, the age by which the proportion of young people who have the necessary competencies is comparable to the proportion of adults who have them).

This is no easy task, because it requires a fine-grained analysis of the relevant competencies as well as systematic research on their developmental trajectories. Furthermore, and as we discuss in our concluding comments, to the extent that the activities subject to legal regulation differ in the competencies they demand, the developmental approach may result in different age boundaries for different legal matters. The United States uses different age boundaries for different legal purposes (e.g., driving at 16, voting at 18, drinking at 21), although it is clear that these boundaries were rarely established on the basis of developmental science (Icenogle et al. 2019). Most societies, however, use a single age of majority (typically 18) for all legal purposes, primarily for administrative reasons.

Conclusions derived from a developmental science perspective on age boundaries will not necessarily diverge from those derived from intuition, practicality, consistency, or pragmatic considerations. If, for example, adults' judgments of adolescents' maturity are grounded in centuries of observations about the development of logical reasoning, impulse control, or risk appraisal—even if these observations are unscientific—intuitive notions about when adolescents become adults will find support in scientific research on these capacities. Indeed, in the US Supreme Court's decision to abolish the death penalty for individuals under 18 years old (*Roper v. Simmons* 2005, p. 15), the majority opinion cited scientific research on adolescent development but also noted that the conclusions of this research were "what any parent knows." However, 17 years before *Roper*, in a different case concerning the juvenile death penalty, this Court, without citing any science at all, declined to ban capital punishment for 16- and 17-year-olds, even though attorneys arguing the case explicitly asked for this prohibition (*Thompson v. Oklahoma* 1988). In other words, we cannot rely only on common sense when we draw age boundaries, because what seems intuitively obvious at one point in time may not be so obvious at another. The history of developmental science includes myriad examples of common-sense beliefs about child development that have not stood up to scientific scrutiny.

The Origins of Contemporary Age Boundaries

Efforts to bring developmental science to bear on discussions of legal age boundaries must start with the recognition that many such boundaries have existed for decades, if not centuries. Science alone will never dictate wholesale changes in existing boundaries, particularly if these changes result in laws that do not serve their original purpose. Accordingly, any application of developmental science to debates about age boundaries must begin with at least a cursory understanding of why the extant boundaries were drawn where they are.

Until about 50 years ago, in most parts of the world, the age of majority, when individuals are recognized as adults and are presumed to have legal control over their persons, decisions, and actions, was 21. Most historians believe that this choice has its origins in medieval Europe and was based on the age at which young men were presumed strong enough to wear a full coat of armor into battle (James 1960). In 1970, after much debate, British elected officials concluded that the reasons for fixing the age of majority at 21 were no longer relevant in contemporary society (moreover, by then, many rights and privileges had been extended to British 18-year-olds), and the age of majority in Great Britain was lowered to 18. Many other countries, including the United States, followed suit shortly thereafter.

The age of majority is not the same as an age of license, which refers to the age at which an individual is permitted to do something specific, such as drive or purchase alcohol, or an age of consent, which is the age at which an individual is presumed to have the competence to make autonomous decisions. Whereas the age of majority historically has been linked to the voting age, it has not been as closely tied to various ages of license or consent. In the United States, for example, the driving age (16 in most states) is lower than the age of majority (18), and the drinking age (21) is higher. Generally, departures from the age of majority are legislated when it is believed that they are in the best interests of the adolescent, society, or both. For example, the driving age, which at one time was 18 in most states, was lowered to 16 in the 1920s to accommodate young people who needed to drive to either perform or travel to their jobs. Adolescents' right to seek mental health counseling or purchase contraception is also set at an age younger than 18 because we believe that it is in their interest to do so.

On other matters, adolescents' rights are withheld until an age beyond 18 out of an interest in protecting their well-being. Purchasing alcohol is a well-known example. When the US voting age was lowered to 18 in 1971, many states also lowered their minimum drinking age to 18. But amid growing concerns about teen drunk driving fatalities, Congress pressured the states to raise their minimum drinking age to 21. Similar protections set a higher minimum age for other activities deemed potentially harmful to adolescents, including the purchase of tobacco or marijuana, or gambling in casinos.

There are several key lessons to be gleaned from this brief history. First, although one might say that the age boundary between adolescence and adulthood is arbitrary, given its historical fluctuation and inconsistent application across legal domains, any apparent arbitrariness is within a reasonable range—somewhere between 16 and 21.[1] As we see below, there is very little scientific support for setting the age of majority, or various ages of license or consent, outside this range. Developmental science can be helpful in persuading lawmakers to change an age boundary within the reasonable range, but it is unlikely that adult privileges will be granted to adolescents under 16 or withheld from those who are over 21.

Second, even without looking to guidance from science—whether psychological science or brain science—90% of the world's nations have set 18 as the presumptive age of majority. Some of this cross-national consistency is likely due to the influence that countries have on one another. But surely some of the uniformity is due to shared folk wisdom about when individuals attain adult maturity. Given the vast differences in custom and culture that exist around the world, the fact that countries as different as Afghanistan, China, Germany, Mexico, and Tanzania—as well as another 120 countries—all set the age of majority at 18 is noteworthy, as is the fact that this decision is generally consistent with the relevant developmental science.

Finally, there is considerable tolerance, at least within the United States, for having different chronological age boundaries for different legal purposes, but not always in a way that is consistent with developmental science. Developmental science can both justify the use of different ages for different purposes and inform discussions of which ages are appropriate for which issues. Indeed, as we argue below, developmental science supports a regime in which certain legal boundaries are drawn around age 16 and others around age 21.

USING DEVELOPMENTAL SCIENCE TO ADJUST EXISTING AGE BOUNDARIES

We believe that the extant developmental literature provides sufficient justification for an attempt to operationalize maturity on the basis of scientific studies of age differences between adolescents and adults in aspects of psychological functioning that are potentially legally relevant. One might parse this body of research in a variety of different ways, but for the purposes of this article, we have divided the literature into three areas: cognitive, psychosocial, and neurobiological. In each of these domains, researchers have described systematic patterns of maturation during the second decade of life (and sometimes a bit beyond) and attempted to identify an age at which a reasonable case can be made for drawing a legal age boundary either because the rate of maturation slows considerably or because age differences between adolescents and adults change from significant to nonsignificant.

Cognitive Approaches

The law presumes that people are rational agents whose behavior is the product of analytic deliberation. It is no surprise, then, that developmental psychologists concerned with the law have

[1]One notable exception in the United States is the prosecution of adolescents accused of serious crimes as adults, which many states permit as young as age 12, and in some states there is no minimum age of transfer for first-degree murder.

studied trajectories undergirding the ability to reason logically. Numerous skills contribute to this ability, but we focus here on so-called cognitive capacities, which include the basic cognitive faculties supporting complex, goal-directed behaviors, including logical reasoning (Diamond 2013, Zelazo & Carlson 2012). The development of these cognitive abilities is critical to the discussion of age boundaries because they bear so directly on one of the most fundamental reasons we treat children differently than adults—that children simply do not possess the necessary intellectual skills to engage in thoughtful, informed decision making.

Scholars have explored several facets of cognitive functioning relevant to age boundaries, including executive functioning, intellectual capacities, and logical reasoning. Basic cognitive functions include working memory, response inhibition, and cognitive flexibility, all of which support more complex reasoning of the sort that guides mature decision making in the real world. Studies of cognitive development demonstrate that the cognitive abilities that facilitate analytical thought plateau in early to midadolescence. This trend is evident in studies of response inhibition, the ability to withhold a prepotent response (e.g., Andrews-Hanna et al. 2011, Huizinga et al. 2006, Luna et al. 2004); cognitive flexibility, the ability to switch from one task to another (Crone et al. 2004); and one of the most foundational cognitive processes fostering analytical thinking, working memory. Working memory, the ability to hold and manipulate information in mind (Diamond 2013), is the cognitive process that allows the individual to simultaneously consider multiple potential outcomes and choose among them. As with other cognitive functions, performance on working memory tasks tends to level out by early or midadolescence (Huizinga et al. 2006, Luna et al. 2004, Peverill et al. 2016).

Age patterns of higher-order cognitive abilities, like perspective taking, planning, and logical reasoning, also tend to plateau in midadolescence. For example, on the Tower of London task, participants must manipulate a starting configuration of colored balls on pegs into a specific predetermined configuration. To do well, one must think several steps ahead and visualize the positions of the balls. By 15–17 years, adolescents perform at adult levels on this task (Luciana et al. 2009). Adolescents also demonstrate similar logical reasoning capability as adults. For example, when queried about the costs and benefits of specific risky behaviors (e.g., riding with a drunk driver), adolescents and adults generate a similar quality and quantity of positive and negative consequences (Beyth-Marom et al. 1993). Likewise, 16–17-year-olds evince adult-like abilities to make informed decisions in legal contexts and other settings in which mature reasoning is important. Specifically, studies indicate that midadolescents do not differ from adults in their factual understanding of legal proceedings, their ability to process the information they receive and provide their attorneys with relevant information, and their ability to apply abstract information logically to their own case (Grisso et al. 2003, Redlich & Shteynberg 2016). Other studies show that the ability to make informed decisions about granting informed consent in medical or research contexts also plateaus around this same age (Steinberg et al. 2009).

Psychosocial Approaches

As important as it is to be able to deliberate and reason, decision making does not occur in a vacuum. People often find themselves in situations that hinder deliberate decision making. For instance, clarity of thought is difficult to maintain when one is egged on by friends to take a drink, engage in a dangerous activity, or drive in excess of the speeding limit. Thus, a second domain of functioning relevant to discussions of age boundaries is the ability to exert self-control in contexts of emotional arousal. As with the development of cognitive capacity, developmentalists concerned with legal matters have studied age trends in various aspects of self-regulation, including impulse control, risk assessment, resistance to coercive influence, and attentiveness to the future consequences of one's decisions.

In contrast with studies of cognitive capacity, which suggest that there is little growth in this domain after midadolescence, research indicates that adolescents do not evince adult levels of self-regulation until age 18 or later (e.g., Steinberg et al. 2018). For example, self-reported impulse control develops into the early to midtwenties (Harden & Tucker-Drob 2011; Quinn & Harden 2013; Steinberg et al. 2008, 2018), a trend that is mirrored in studies using behavioral measures, especially those that assess self-control in emotionally arousing contexts. For example, in emotional go/no-go tasks that require pressing a button in response to calm faces but withholding a response in response to happy or fearful faces, adolescents consistently perform worse than adults (Cohen-Gilbert & Thomas 2013, Shulman et al. 2016, Somerville et al. 2011).

Research also indicates that sensation seeking, the propensity to seek out new and exciting experiences (often reflecting a lack of self-regulation), peaks during adolescence before declining into adulthood. When asked to self-report their sensation-seeking propensity, adolescents evince higher scores than children or adults (Collado et al. 2014, Khurana et al. 2018, Quinn & Harden 2013, Shulman et al. 2015). Similarly, behavioral measures of sensation seeking and reward sensitivity (a closely related construct referring to the extent to which reward drives or modulates behavior) show that adolescents are more sensation seeking and reward sensitive than adults. For example, adolescents are more likely to run a yellow light on a simulated driving task (Steinberg et al. 2008) and demonstrate greater sensitivity to rewards on the Iowa Gambling Task (Cauffman et al. 2010, Hooper et al. 2004, Prencipe et al. 2011, Smith et al. 2011). There exists some inconsistency across studies regarding the specific age at which sensation seeking peaks. Whereas some find that it peaks around early to midadolescence (around 14 or 15 years; Khurana et al. 2018, Steinberg et al. 2008), others find a peak in later adolescence (closer to 19 years; Romer et al. 2010, Shulman et al. 2015, Steinberg et al. 2018). Regardless of the specific peak age, however, sensation seeking and reward sensitivity decline after late adolescence (Harden & Tucker-Drob 2011, Shulman et al. 2015, Steinberg et al. 2008).

Compared to adults, adolescents also tend to overvalue immediate rewards relative to delayed ones, a finding often interpreted as indicating a weaker ability to delay gratification. Studies find increases in adolescents' self-reported planning, anticipation of future consequences, and future orientation throughout late adolescence (Steinberg et al. 2009, 2018). Consistent with this, in studies of temporal discounting, adolescents are more likely than adults to prefer small but immediately available rewards over large but delayed rewards (Banich et al. 2013, Olson et al. 2007, Romer et al. 2010, Steinberg et al. 2009). Put differently, adolescents discount the consequences of possible future events when an immediate reward is presented. There is some evidence that this myopia extends to legal decision making explicitly. For example, Daftary-Kapur & Zottoli (2014) found that justice-involved adolescents between ages 13 and 18 tend to cite short-term consequences as reasons for accepting their plea offer, such as wanting to hasten the legal process (see also Grisso et al. 2003).

The last domain of self-regulation we discuss here is related to autonomy in the face of external influence and, most notably, adolescents' susceptibility to peers. There is extensive empirical support for the observation that youth act differently when they are among peers and friends than they do when they are alone. Based on self-report measures, adolescents—particularly early to midteens—are less resistant to peer influence than adults (Steinberg & Monahan 2007). As expected, this pattern is borne out on behavioral tasks using an experimental peer manipulation. For example, adolescents who are observed by a peer (real or virtual) take more risks (e.g., are more likely to gamble) than adolescents who are unobserved (Cascio et al. 2015, Kretsch & Harden 2013, MacLean et al. 2013, Reynolds et al. 2014, Smith et al. 2014), an effect that is seen even in studies in which the peers are in a different room and prohibited from speaking to the target subject. In contrast, in studies of decision making and risk taking, adults do not change their behavior when observed by peers (Chein et al. 2011).

Neurobiological Approaches

Prior to the advent of functional magnetic resonance imaging, neuroscience was largely absent from discussions of legal age boundaries. Indeed, for most of the twentieth century, scientists believed that brain maturation ended sometime during late childhood, a conclusion based on the observation that the brain reached its adult size and volume by age 10. Research examining the brain's internal anatomy and brain activity patterns—instead of focusing solely on the brain's appearance—started challenging this widely held belief in the late 1990s (Giedd et al. 1999, Gogtay et al. 2004, Sowell et al. 2004). In recent years, students of adolescent development have increasingly drawn on neuroscience to strengthen the argument that adolescents and adults differ in ways that are relevant to their treatment under the law, in part because studies have shown that laypersons are more persuaded by neuroscience than psychological science (Aspinwall et al. 2012, Weisberg et al. 2008).

The results of these examinations are consistent with findings from studies of cognitive capacity and self-regulation, namely, that whereas brain regions and systems responsible for cognitive capacities such as logical reasoning are largely mature by midadolescence, brain systems and structures involved in self-regulation continue to mature throughout adolescence (Casey et al. 2005). Indeed, research on brain maturation conducted during the past decade has revealed that several aspects of brain development affecting psychosocial capacities that impact legally relevant aspects of decision making, such as impulse control or reward sensitivity, not only are ongoing during early and midadolescence but also continue to mature at least until age 21 (Dosenbach et al. 2010, Fair et al. 2009, Hedman et al. 2012, Pfefferbaum et al. 2013, Simmonds et al. 2014, Somerville et al. 2010, Tamnes et al. 2017, Whitaker et al. 2016).

Many scientists believe that the main underlying cause of psychological immaturity during adolescence is the different timetables along which two important brain systems change during this period, sometimes referred to as a maturational imbalance (Casey et al. 2010, Luna & Wright 2016, Steinberg 2008) (see **Figure 1**). Briefly, the system that is responsible for the increase in sensation seeking and reward seeking that takes place in adolescence, which is localized mainly in the brain's limbic system, undergoes dramatic changes very early in adolescence, around the time of puberty. However, the system that is responsible for self-control, regulating impulses, thinking ahead, evaluating the rewards and costs of a risky act, and resisting peer pressure, which is localized mainly in the prefrontal cortex, is still undergoing significant maturation well into the

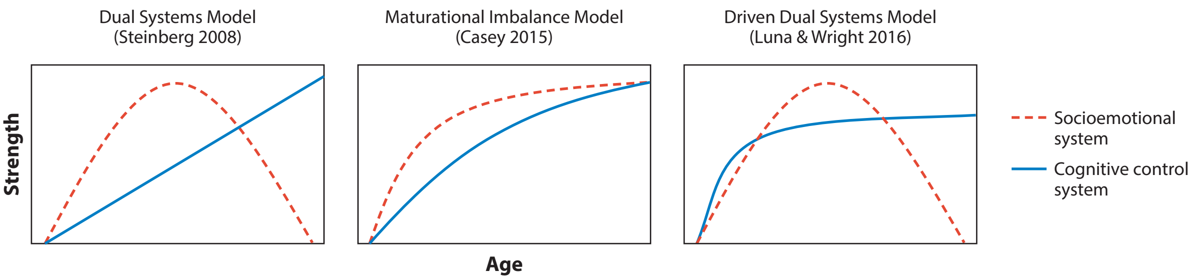

Figure 1

Alternative theoretical models of the development of the socioemotional (reward processing) and cognitive control systems from about age 10 to age 25. Figure adapted from Shulman et al. (2016).

midtwenties. Thus, during middle and late adolescence, there is an imbalance between the reward system and the self-control system that inclines adolescents toward sensation seeking and impulsivity. As this imbalance diminishes, as noted above, there are improvements in such capacities as impulse control, resistance to peer pressure, planning, and thinking ahead. Studies of structural and functional development of the brain are consistent with this view (for excellent summaries of this literature, see Blakemore 2012, Engle 2013, Luciana 2010, Spear & Silveri 2016).

Maturational imbalance models of neurobiological immaturity in adolescence have been criticized as overly simplistic and insufficiently nuanced (but see Shulman et al. 2016 for a response). Some critics have pointed out that not all studies find adolescents to be particularly sensitive to reward (Pfeifer & Allen 2012), although comprehensive reviews of this literature have generally concluded that this characterization is by and large accurate (Galván 2010). Indeed, there is considerable evidence that during reward processing, adolescents engage the striatum to a greater extent than do both children and adults (Barkley-Levenson & Galván 2014, Christakou et al. 2011, Geier et al. 2010, Hoogendam et al. 2013, Jarcho et al. 2012, Padmanabhan et al. 2011, Silverman et al. 2015). Although there are occasional departures from this general pattern, studies focusing specifically on the receipt (rather than anticipation) of a reward, however, consistently find that adolescents engage the striatum to a greater extent than adults (Galván & McGlennen 2013, Hoogendam et al. 2013, Van Leijenhorst et al. 2010), consistent with psychological evidence, discussed above, that adolescents are relatively more sensitive than children or adults are to rewarding outcomes (see the section titled Psychosocial Approaches).

Other critics of maturational imbalance models have noted that cognitive control does not unequivocally improve during adolescence (Crone & Dahl 2012), although here, too, the weight of the evidence shows continued maturation into the early or even midtwenties of brain regions and systems that govern various aspects of self-regulation and higher-order cognitive function. Continuing maturation of cognitive control is often examined in terms of development of the prefrontal cortex, particularly the lateral prefrontal cortex. Across adolescence, most studies find a linear increase in recruitment of this brain region with age (Adleman et al. 2002, Bunge et al. 2002, Durston et al. 2002, Velanova et al. 2009, Vink et al. 2014). Moreover, several studies have demonstrated a direct relationship between age-related increases in prefrontal cortical engagement and successful cognitive control (Adleman et al. 2002, Andrews-Hanna et al. 2011, Bunge et al. 2002, Casey et al. 1997, Durston et al. 2002, Rubia et al. 2006, Velanova et al. 2009).

Developmental improvements in cognitive control over the course of adolescence are supported not only by the maturation of these underlying neural regions but also by enhancements in top-down connectivity between frontal cognitive control regions and other cortical and subcortical areas associated with affective processing. Accordingly, accounts of adolescent neurobiological immaturity have moved away from descriptions of changes in specific brain regions and have instead emphasized changes in connectivity between them. Cognitive control encompasses the integration of several (often simultaneous) processes that support planning behavior in accord with one's intentions (Miller 2000). The effective integration of these processes relies not only on the functional recruitment of implicated brain regions but also on the strength of connectivity among them (Hwang et al. 2010, van Belle et al. 2014), underscoring the potential benefit of moving beyond simplistic models of regional activation toward more elaborate models that consider improvements in the strength and efficiency of intra- and interregional connections, which likely support age-related increases in the acquisition and execution of complex cognitive control skills (e.g., Satterthwaite et al. 2013).

There is reason to believe that continuing changes in connectivity account for the observation, noted above, that some aspects of self-regulation continue to strengthen into early adulthood instead of plateauing in midadolescence. Although the development of the prefrontal cortex is largely complete by age 16, the maturation of connections between this region and regions that govern self-regulation and the brain's emotional centers, facilitated by the continued myelination of these connections, may not be complete until the early or midtwenties (Dosenbach et al. 2010, Khundrakpam et al. 2016). As a consequence of this immaturity, late adolescents often have difficulty controlling their impulses, especially in emotionally arousing situations. Two recent studies of middle adolescents, late adolescents, and individuals in their midtwenties illustrate this point (Cohen et al. 2016, Rudolph et al. 2017). Individuals' impulse control and brain activity were each assessed while their emotional states were experimentally manipulated. Under conditions during which individuals were not emotionally aroused, individuals between ages 18 and 21 exhibited impulse control and patterns of brain activity comparable to those in their midtwenties. But under emotionally arousing conditions, 18- to 21-year-olds demonstrated levels of impulsive behavior and patterns of brain activity that were comparable to those in their midteens. We now know that, in many respects and under certain circumstances, individuals between ages 18 and 21 are more neurobiologically similar to younger teenagers than had previously been thought.

Quantifying Maturity

As we have noted, maturity is the result of a gradual, multifaceted process in which different components of psychological functioning mature at different rates and along different timetables. However, legal policy often necessitates the identification of a discrete chronological cut point before which individuals are considered immature and after which individuals are considered mature. Determining at what age we can comfortably draw this line while remaining true to extant scientific evidence is a challenge. Whereas some scientists argue that this is not possible (Fischer et al. 2009), others assert that an imperfect boundary drawn with science in mind is preferable to a boundary that ignores developmental science entirely (Steinberg et al. 2009). If we were to use science to establish an age of majority, how might we go about it?

The most widely used approach is to define maturity as the age at which some legally relevant construct (e.g., logical reasoning) reaches adult levels. Researchers may accomplish this by comparing mean-level differences between different age groups and identifying the youngest age beyond which no significant difference in the outcome of interest is found when scores at this age are compared with those at an age designated as the adult age (see **Figure 2**). The simplicity of this approach is appealing, but few developmental studies have sufficient sample sizes at discrete ages across a wide-enough range to provide enough power to detect differences between adjacent chronological ages. To address this problem, researchers often combine discrete ages into groups, but doing so makes it impossible to identify discrete age cut points.

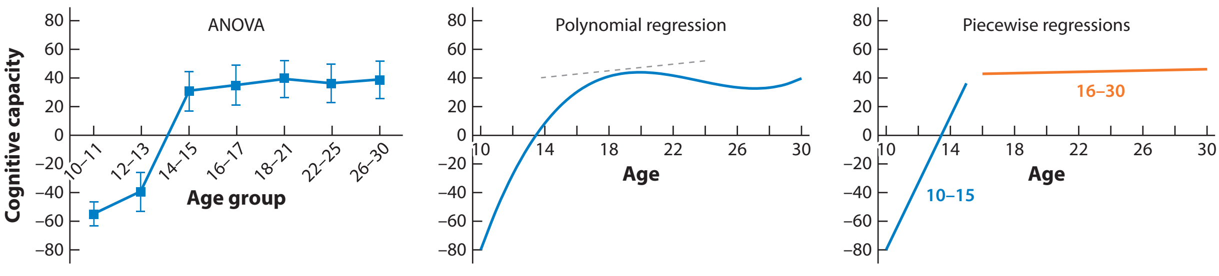

Figure 2

Alternative statistical approaches to quantifying maturity may result in slightly different estimates of where best to create a bright-line chronological age boundary. Abbreviation: ANOVA, analysis of variance.

A second approach is to test for lower- and higher-order polynomial age trends in a regression framework. Developmental researchers typically assess whether a given construct increases linearly from childhood to adulthood, follows a quadratic pattern (e.g., increasing and then decreasing), or evinces an asymptotic pattern (e.g., increasing sharply from childhood to adolescence, then leveling out from adolescence to adulthood). Although exploring the shape of an age pattern is illuminating, polynomial regression on its own does not indicate where along the slope the outcome of interest stops changing (i.e., when maturity is reached). Rather, researchers typically rely on visual inspection of developmental trajectories to roughly designate peaks, nadirs, and plateaus. To supplement polynomial regression, one can compute the instantaneous rate of change (IROC) in the outcome of interest in models of a nonlinear fit (see Steinberg et al. 2018). IROC represents the slope of a curve at a given point on the x axis. Put differently, it is the rate of change at a particular age and is equivalent to the slope of a tangent line at that age. One would compute the IROC at each discrete age to determine whether the slope is increasing, not significantly different from zero, or decreasing. One may then infer the latest age at which the outcome of interest has plateaued.

A third approach involves using piecewise regression (sometimes called spline, or change-point, analysis). Piecewise regression involves estimating two (or more) slopes: one for the younger participants in the sample and one for the older participants. This approach allows for sudden changes in trajectory, unlike polynomial regression. The slopes are connected at a breakpoint (or knot) that indicates the age at which the slope changes. Thus, one can conceivably determine the age at which change in some outcome shifts from significantly increasing to no longer changing (i.e., the age of maturity). With this approach, however, researchers must determine the placement of breakpoints that are then tested and how many are needed to accurately describe the data without overfitting the model (a discussion of these points is beyond the scope of this article, but see Suk et al. 2018).

These different analytic approaches may point to somewhat different conclusions about the age at which maturity is attained, and researchers are encouraged to subject data to multiple analyses and examine them together. As a case in point, we have included in **Figure 2** three panels displaying the age pattern of cognitive capacity in an international sample of 10- to 30-year-olds when analyzed in three ways: using analysis of variance (ANOVA), polynomial regression, and piecewise regression (Icenogle et al. 2019). According to the analyses accompanying these figures, cognitive capacity reaches adult levels at age 14–15 (ANOVA) and increases from ages 10 to 15, with no further significant growth (piecewise regression), but the slope of its trajectory transitions from positive and increasing to nonsignificant much later, at age 19 (polynomial regression with IROC analysis). Thus, two of the three approaches point to age 15 as a reasonable breakpoint between immature and mature cognitive capacity (Icenogle et al. 2019).

CONCLUDING COMMENTS: A PROPOSAL

A developmental scientific perspective on drawing legal age boundaries begins with the premise that the age at which the rights and responsibilities of adulthood are conferred to minors must identify the psychological capacities and skills necessary to exercise good judgment in specific contexts. As we have explained, such a regimen is unlikely to yield a single age boundary that serves all legal purposes, but having multiple boundaries allows society to better align minors' legal privileges and obligations with what they are genuinely equipped to handle and, as such, avoids placing unnecessary constraints on young people's autonomy while protecting them and others from the harmful consequences of immature judgment. In this article, we have examined three aspects of development in adolescence that are relevant to this analysis: cognitive capabilities, especially those that support reasoned and deliberative decision making; psychosocial capacities, especially those that facilitate self-regulation under conditions of social or emotional arousal; and neurobiological maturation, especially in brain regions and systems that undergird these cognitive and psychosocial skills.

Our review of the relevant literatures indicates that the maturation of the capacity to reason and deliberate systematically precedes, by as much as five years, the maturation of the ability to exercise self-regulation, especially in socially and emotionally arousing contexts. Differences in the timetables of these two sets of skills are consistent with findings from the field's emerging understanding of adolescent brain maturation, which suggests that brain systems responsible for logical reasoning and basic information processing mature earlier than those that undergird more advanced executive functions and the coordination of affect and cognition. In light of this evidence, policy makers seeking guidance about the establishment or modification of chronological age boundaries should distinguish between two very different decision-making contexts: those that allow for unhurried, logical reflection and those that do not.

For legal matters that permit unhurried deliberation in the absence of emotional arousal, and where adolescents can be encouraged to think through their decisions before acting on them, it would be reasonable to set an age boundary around 16, because decision making in this context relies mainly on various aspects of so-called cold cognition, which is mature by this age. A partial list of legal situations for which mature cold cognitive abilities likely suffice includes voting, granting informed consent for participation in research, and making autonomous decisions in medical and legal contexts. We see no scientific reason that 16-year-olds should be prohibited from voting in political elections, serving as research subjects in studies that have been approved by institutional review boards, obtaining medical services of their choosing after consulting with a qualified health-care provider, or serving as competent defendants in criminal proceedings.

Adolescents as young as 16 should not be treated as adults for all purposes, however. A second age boundary would reasonably be set at 18 or older, and perhaps as old as 21, for legal matters where thoughtful deliberation is easily disrupted by the inherently arousing circumstances in which the relevant decisions usually take place. These decisions are typically made under time pressure, when strong emotions prevail, when peers are present, and when adults are usually absent. Because young people—even after they have matured cognitively—evince higher sensation seeking, impulsivity, sensitivity to peer influence, reward sensitivity, and short-sightedness than adults, it is sensible to withhold certain privileges and responsibilities before individuals are socially and emotional mature. Some of the legal situations that require mature self-regulatory capacities are driving, consuming alcohol, gambling, and resisting impulses and urgings to engage in criminal behavior. Based on evidence from developmental science, adolescents under 18 should not be permitted to drive, purchase liquor, or enter casinos, nor should they be held to adult standards of criminal responsibility. Whether specific prohibitions of this sort should extend up to age 21 should take into account the likely consequences, both good and bad, of doing so.

We acknowledge that creating legal age boundaries that are grounded in developmental science is an imperfect approach for several reasons. There may be pressing societal considerations that warrant establishing a legal age boundary that is inconsistent with the results of scientific analysis. For example, setting the driving age at 21, while sensible from a scientific point of view, would make employment difficult for many people who need the income from employment to support themselves or their families.

Second, the distinction between cold and hot contexts is not always clear-cut, and strong feelings that are evoked in some situations (e.g., when a pregnant adolescent is contemplating an abortion) may interfere with adolescents' otherwise adult-like ability to engage in thoughtful deliberation. In these contexts, the provision of specific policies, such as requiring a waiting period between an initial consultation and the actual procedure, may help transform an impulsive decision into a more reasoned one. By the same token, whereas juvenile crime is by and large impulsive and influenced by peers (Steinberg et al. 2009), some adolescents' crimes are premeditated acts. Because judgments as to whether a juvenile is adult-like are influenced by factors unrelated to the act itself, including the juvenile's race (Graham & Lowry 2004), having a chronological age boundary with respect to criminal sanctions provides some protection against biased decisions by juries or judges.

Finally, there is individual variability among people of the same chronological age that will make the enforcement of a legal age boundary overly restrictive or unduly lenient for some individuals (e.g., some 16-year-olds undoubtedly have the self-regulatory competence necessary to drink responsibly, whereas some 19-year-olds likely lack the impulse control to be granted driving privileges). In some instances, this can be dealt with by having additional, skill-based requirements (e.g., driver licensing exams). But for the most part, any age-based regime will mistakenly classify some immature individuals as adults and some mature ones as minors. Using science to inform where the boundary is drawn will minimize, although not eliminate, this problem. Developmental science alone cannot dictate where legal age boundaries are drawn, but, in our view, an approach to the legal regulation of minors that is grounded in science—even if imperfect—is preferable to one that is based solely on convenience or intuition.

SUMMARY POINTS

1. All societies create one or more legal age boundaries between adolescence and adulthood to regulate the age at which individuals are granted full adult status with respect to the rights and responsibilities associated with adulthood.
2. Developmental science has played an increasingly important role in debates about the age at which various legal boundaries between minors and adults should be drawn.
3. A developmental perspective on legal age boundaries begins with the premise that the age at which the rights and responsibilities of adulthood are conferred to minors must identify the psychological capacities and skills necessary to exercise good judgment in specific contexts.
4. Contemporary lawmakers have drawn on studies of three different aspects of development to set or modify legal age boundaries: cognitive capabilities, such as logical reasoning; psychosocial capacities, such as self-regulation; and structural and functional features of adolescent brain development.
5. Research indicates that the maturation of cognitive capabilities is complete by age 16 and precedes the maturation of psychosocial capacities, which is not complete until at least age 21. This pattern is consistent with recent studies of adolescent brain development.
6. Policy makers seeking guidance about the establishment or modification of chronological age boundaries should distinguish between two very different decision-making contexts: those that allow for unhurried, logical reflection and those that do not. Whereas age 16 is a reasonable age boundary for the first of these contexts, setting a legal age boundary beyond 18, and perhaps as old as 21, is more appropriate for the second.

DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

ACKNOWLEDGMENTS

Work on this article was supported by a grant to L.S. from the John D. and Catherine T. MacArthur Foundation. We are grateful to Elizabeth Scott for helping to clarify historical approaches to setting legal age boundaries.

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