

Reward-Biased Risk Appraisal and Its Relation to Juvenile Versus Adult Crime

Elizabeth P. Shulman

University of Pennsylvania and Temple University

Elizabeth Cauffman

University of California, Irvine

To what extent is criminal behavior in adolescence attributable to risk appraisal? Using two large cross-sectional samples ($N = 929$, age range: 10–30 years; and $N = 1,357$, age range: 12–24 years), we examine whether (a) reward bias in risk appraisal is more prominent in adolescence and (b) the association between risk appraisal and criminal behavior is stronger during adolescence than at other ages. In Study 1, criminal behavior was self-reported; in Study 2, it was defined by involvement with the court. Perceived chances of a negative outcome, seriousness of consequences, and benefits versus costs of various risky activities were assessed to gauge reward bias in risk appraisal. The findings indicate that reward bias is elevated during the adolescence years. Also, risk appraisal bears a stronger relation to self-reported crime in middle adolescence and to official law-breaking behavior in early adolescence than at other ages. The findings are consistent with a dual-systems model of adolescent development and align with recent U.S. Supreme Court decisions addressing juvenile offenders' culpability.

Keywords: risk perception, crime, risk-taking, adolescence, reward-bias

Whether adolescent offenders should be treated as children in need of rehabilitation or as adults deserving of punishment is a question the courts have grappled with repeatedly over the course of U.S. history (Scott & Woolard, 2004). In recent decades, advances in developmental science have impelled the law to reexamine adolescent offenders' legal status; in particular, the courts have had to consider the extent to which adolescent crime arises out of immature cognitive and emotional capacities. Adolescence has long been viewed as a period of relatively high levels of risk-taking. Evidence for this position can be found in data on various categories of hazardous behavior, such as risky driving, risky sexual behavior, and illicit substance use (e.g., Chen, Baker, Braver, & Li, 2000; Finer, 2010; Substance Abuse and Mental Health Services Administration, 2010). Elevated risky behavior during adolescence is observable even in nonhuman mammalian species (including nonhuman primates and rodents; Doremus-Fitzwater, Varlinskaya, & Spear, 2010). The present study investigates the theory that, to some extent, adolescent crime is a manifestation of the same maturational processes that give rise to other forms of adolescent risk-taking.

Superficially, this appears to be plausible: the age pattern for arrest rates is similar to that for other forms of risk-taking, rising sharply during adolescence, peaking in late adolescence, and then declining in adulthood (Stolzenberg & D'Alessio, 2008). Two

mechanisms have been identified in recent developmental research that might jointly contribute to age-related patterns of risk-taking and crime during the transition from childhood to adulthood. First, cognitive–emotional development during this period may bias adolescents' risk perception toward approach tendencies (i.e., taking risks) by rendering rewards relatively more salient and costs relatively less salient (compared to other age groups). Second, underdeveloped self-regulatory capacities may result in adolescents translating favorable risk perceptions more readily into risky behavior compared to adults. If this model is correct, then (a) adolescents should appear less sensitive to costs and more sensitive to reward than either younger or older individuals and (b) risk appraisal should be more strongly correlated with law-breaking behavior for adolescents than for adults. We tested these hypotheses in two large samples, using two different operationalizations of law-breaking behavior.

Reward Bias and Weaker Cognitive Control in Adolescence

Philosophers and behavioral scientists have long been interested in the causes of risky adolescent behavior. It is becoming increasingly clear that legal practitioners also have a stake in understanding the etiology of reckless behavior among adolescents. Over the last two decades, findings in different scientific disciplines have converged on a new developmental model that addresses the causes of risky adolescent behavior, and may, in turn, help explain the prevalence of juvenile crime. The dual-systems theory (Casey, Getz, & Galvan, 2008; Steinberg, 2008) proposes that two networks of brain regions undergo differential patterns of development during adolescence. The first is the socioemotional system, which serves to sensitize individuals to potential rewards, such as the pleasures of peer companionship (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011) and the excitement of novel experi-

This article was published Online First May 6, 2013.

Elizabeth P. Shulman, Psychology Department, University of Pennsylvania and Department of Psychology, Temple University; Elizabeth Cauffman, Department of Psychology and Social Behavior, School of Social Ecology, University of California, Irvine.

Correspondence concerning this article should be addressed to Elizabeth P. Shulman, 3701 Market Street, Suite 216, Philadelphia, PA 19104. E-mail: eshulman@sas.upenn.edu

ences (Spear, 2000). The second is the cognitive control system, which serves a top-down regulatory function, modulating emotion, restraining impulses, and detecting potential harms (Asato, Terwilliger, Woo, & Luna, 2010; Giedd, 2008; Hare & Casey, 2005). Central to the dual-systems theory is the idea that these two systems undergo distinct patterns of development. Around the time of puberty (early adolescence), the socioemotional system begins to undergo the transition to adult functionality, characterized by changes in the distribution and proportions of dopamine receptors in the brain regions involved in the system (e.g., striatum and anterior cingulate cortex; Spear, 2000). This enhancement of reward sensitivity occurs long before the full maturation of cognitive control system, which appears to develop at a slow and steady pace between childhood and early adulthood. As a consequence of this timing, adolescents experience a stage during which the socioemotional system, due to its greater relative functionality, is able to predominate over the cognitive control system (Ernst et al., 2005; Eshel, Nelson, Blair, Pine, & Ernst, 2007; Galvan et al., 2006), producing an intensified desire to seek new, exciting, and pleasurable experiences as well as an increased proclivity for risk-taking (Steinberg, 2010).

A likely mechanism by which this lag in brain development translates into risk-taking (including criminal behavior) is via reward bias in risk appraisal. We propose that enhanced salience of rewards combines with attenuated sensitivity to costs and weak emotion-regulation to yield decisions to take risks. (Here, we are referring not to conscious, rational decision-making, but to evolutionarily older, intuitive, and affect-driven decision-making processes; see Evans, 2003, and Kahneman, 2011, for discussion of the distinction between rational and intuitive decision-making.) Research on effortful, conscious decision-making about risk has found few differences between adolescents and adults (see Reyna & Farley, 2006). However, much of the decision-making that drives our behavior appears to occur outside of conscious awareness (Kahneman, 2011); this form of decision-making may be more influenced by the emotional and physiological changes that unfold during adolescence. Imagine a situation in which one must make a choice that involves potential rewards and costs (e.g., to spray-paint one's name on a highway overpass). At the level of automatic, emotional processing, the individual immediately senses the magnitude of the potential reward, the potential cost, and the chance of a negative outcome. The combination of the emotional inputs yields an impulse (an emotionally mediated decision rendered by nonconscious processes) to approach or avoid: to take the risk or not take the risk. Due to asynchrony in the development of the socioemotional and cognitive control brain systems, adolescents' emotional calculus may assign relatively greater value to the rewards (e.g., admiration of friends, the thrill of a novel and dangerous experience) and, compared to adults, give less weight to the potential costs (e.g., injury, arrest). Consequently, for a comparable risky decision, an adolescent's emotional calculus will give rise more often than an adult's to an impulse to take the risk.

Two recent behavioral studies have provided support for this view of adolescent risk decision-making: Using a computerized card game involving monetary gains and losses to assess age differences in sensitivity to reward and punishment, researchers found that early adolescents exhibited twice as much sensitivity to reward as to punishment (Cauffman et al., 2010). By contrast,

adults—though they were more attuned than early adolescents to both reward and punishment—evinced greater sensitivity to punishment than to reward. The age-related patterns for reward and punishment sensitivity differed, with reward sensitivity peaking in late adolescence and punishment sensitivity increasing steadily with age. In a different study that examined sensitivity to risk and reward simultaneously, participants aged 10–30 years were asked to make rapid (2 s) appraisals of risky scenarios (e.g., How good or bad an idea is it to run across the highway?; Shulman & Cauffman, 2013). Reward bias—the tendency to rate a risky activity as more of a “good idea”—increased with age across adolescence before declining in early adulthood. The results of both studies are consistent with the theory that, in the presence of rewards, adolescent decision-making is biased (compared to adult decision-making) by oversensitivity to reward and insensitivity to cost.

Another factor that may contribute to adolescent risk-taking is that, due to underdeveloped cognitive control mechanisms, adolescents' initial risk appraisals may translate more directly than adults' into behavior. There are at least two points at which self-regulatory mechanisms could come into play. First, they could serve to adjust initial perceived magnitudes of reward and harm, tamping down an initially strong reward responses or amplifying signals of harm (emotional regulation). Second, following the experience of an approach impulse (an affective push to take the risk), inhibitory control could intervene to block the translation of the impulse into behavior (behavioral regulation). Although no direct evidence exists for this model with respect to risk appraisal, adults tend to exhibit higher levels of impulse control in general than adolescents, both according to self-report and performance measures (e.g., Carver, Livesey, & Charles, 2001; Luna et al., 2001; Munoz, Broughton, Goldring, & Armstrong, 1998; Steinberg et al., 2008). Adults also display different patterns of neural activation than adolescents when performing tasks that require cognitive control (e.g., Andrews-Hanna et al., 2011; Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002; Casey et al., 1997; Durston et al., 2002).

Moreover, several recent studies have found evidence that adolescents are particularly likely to experience deficits in cognitive control when experiencing emotional arousal (Figner, Mackinlay, Wilkening, & Weber, 2009) or when confronted with cues that trigger approach responses. One such example is a study that used a go/no-go paradigm in which human faces expressing emotions served as the stimuli (Somerville, Hare, & Casey, 2011). As in all go/no-go tasks, participants were presented with a series of stimuli (in this case, faces) and were instructed to press a button in response to all stimuli, except for a particular target. The reason that this task indexes impulse control is that it is designed to induce a prepotent tendency to respond to all stimuli with a button press. So, to refrain from pressing the button in response to the target (a “no-go” trial) requires restraint of this impulse. This study found that adolescents' ability to suppress the button-press impulse on a no-go trial was particularly impaired when the stimulus was rewarding (i.e., a smiling face), but not when it was neutral (i.e., a calm face) or negative (i.e., a fearful face). When no-go targets were calm or fearful faces, adolescents were better able than children but less able than adults to suppress the impulse to hit the button, consistent with linear increases with age in cognitive control mechanisms. This finding suggests that adolescents' cog-

nitive control is not only generally less mature than adults' (as evidenced by performance on fearful and calm no-go trials), but is particularly weakened by the presence of rewarding stimuli.

If adolescents are less able than adults to suppress approach (risk-taking) responses, then adolescents' risk perceptions should map well onto their behavior: a favorable (reward-biased) risk appraisal should give rise to an impulse to take the risk, which is directly followed by engagement in the risky behavior. On the other hand, increased ability to suppress behavioral impulses should, for adults, serve to decouple initial risk appraisal from actual risky behavior, at least compared to adolescents; favorable risk perception may give rise to an impulse to take the risk, but that impulse may be suppressed by the adult's cognitive control system while a reappraisal of risk takes place.

Reward Bias, Cognitive Control, and Juvenile Crime

The same psychological mechanisms theorized to increase risk-taking among adolescents may operate to alter the perceived rewards and costs of crime during this developmental period and the translation of such perceptions into law-breaking behavior. To the extent that reward bias is more pronounced in adolescence, youths should anticipate greater enjoyment and less cost from participating in crime than adults. Indeed, a study of college students (late adolescents) found that the most commonly cited reason for engaging in property crime was "fun/thrills" (Pfefferbaum & Wood, 1994), suggesting that these behaviors are motivated in part by experiential rewards. Similarly, other research has linked reward-seeking (i.e., pursuit of thrill and excitement) to criminal behavior in adolescence (e.g., Arnett, 1996; Horvath & Zuckerman, 1992; Newcomb & McGee, 1991; White, Labouvie, & Bates, 1985).

Motivational factors related to peer approval may contribute to adolescent risk-taking, especially that which involves crime (Warr, 1993). Adolescence is a time when affiliation with nonfamily members increases in importance (Csikszentmihalyi, Larson, & Prescott, 1977); establishing one's reputation and social status among peers emerges as a motivating force (Emler & Reicher, 1995). Due to the salience of social concerns in this developmental epoch, adolescents are likely to perceive actions that boost peer approval as having substantial associated rewards. Peer approval is often pursued through efforts to appear grown-up or brave (Fishbein & Ajzen, 1975; Romer & Hennessy, 2007). Criminal behavior is likely to be perceived by adolescents (but not adults) as an opportunity to appear adult-like (Moffitt, 1993). Thus, for adolescents, crime may have attendant social rewards that are absent for adults (Csikszentmihalyi & Larson, 1978; Steinberg, 2009). It is therefore likely that perpetration of criminal acts during adolescence—particularly under conditions of arousal (such as peer presence)—may be partially explained by the transitory factors thought to account for other types of adolescent risk-taking: reward bias in risk perception and immature cognitive control.

The extent to which adolescent crime is attributable to transient developmental factors, such as reward bias in risk appraisal, is a question with important implications for the treatment of juvenile offenders. If normative developmental processes that unfold during adolescence increase the odds of criminal behavior, then developmental stage may be viewed as a mitigating circumstance (Steinberg & Scott, 2003). Indeed, several recent U.S. Supreme

Court cases challenging the appropriateness of severe sanctions for crimes committed by juveniles have weighed the scientific evidence that adolescents may be more predisposed to crime and less responsible for their behavior due to developmental immaturity (*Graham v. Florida*, 2010; *Jackson v. Hobbs*, 2012; *Miller v. Alabama*, 2012; *Roper v. Simmons*, 2005). Research that clarifies the course of psychological development in adolescence and its relation to criminal behavior may be able to provide better guidance to the legal system.

Summary and Study Aims

Despite the impact that developmental theory is starting to have on legal policy in the United States (or perhaps because of it), more research is needed to characterize the relations between adolescent development—particularly risk perception—and juvenile crime. We have theorized that criminal behavior in adolescence results, in part, from reward bias in adolescent risk appraisal, reduced capacity to temper initial responses, and weaker ability to restrain approach impulses (resulting from risk appraisal) in the face of potential rewards. To the extent that this developmental model is correct, we would expect that reward bias in risk appraisal—the tendency to perceive greater rewards, fewer costs, and less danger associated with risky activities—would be generally more pronounced in middle adolescence than in the earlier or later stages of development. In addition, if adolescents are less likely to modulate or reappraise their initial risk judgments and are less able to restrain their impulses, then we would expect the relation between risk appraisal and law-breaking behavior to be stronger among adolescents than among adults.

The present study takes advantage of two large data sets to test these hypotheses. First, using a community sample of adolescents and adults—the same data set used by Cauffman et al. (2010) and Steinberg (2010)—we investigate the relation between reward-biased risk appraisal and self-reported law-breaking behavior and how it varies as a function of age. Second, we retest our hypotheses in a sample of court-involved and community participants. In this study, court involvement, rather than self-report, serves as our index of law-breaking behavior. These analyses serve to advance theoretical understanding of the causes of crime in adolescence (vs. adulthood) and provide a stronger empirical foundation for legal decision-making regarding juvenile crime.

Study 1

Method

Participants. A sample of 935 participants, ages 10–30 years, was recruited from five geographic locations: Denver, Colorado; Irvine, California; Los Angeles, California; Philadelphia, Pennsylvania; and Washington, DC. Of the original sample, six were dropped due to missing data on all relevant variables. Of the 929 in the analytic sample, 19 were missing data on reward bias and law-breaking behavior; one was missing sex data, one was missing IQ data, and 18 were missing socioeconomic status (SES) data. The sample was evenly split between males (49%) and females (51%), and was ethnically diverse: 29% African American, 24% White, 22% Hispanic, 15% Asian, and 10% other. Participants were predominantly working and middle class. Each site contrib-

uted an approximately equal number of participants, although site contributions to ethnic groups were disproportionate, reflecting the ethnic composition of each site (see Cauffman et al., 2010, for details).

Participant recruitment targeted neighborhoods with an average household education level of “some college” according to 2000 U.S. Census data. The study was publicized through newspaper advertisements and by posting flyers at community organizations, such as boys and girls clubs, churches, community colleges, and businesses. Participants who contacted the research team were screened to ensure that they could read and understand English. The study was administered at participating universities and at community locations. All participants were provided with verbal and written explanations of the study, and their written consent or assent was obtained. Parental consent was obtained for participants under 18 years of age. The assessment consisted of self-report measures and computer-based tasks designed to assess cognitive, personality, and neurocognitive characteristics; it took approximately two hours to complete. Research assistants read instructions for each section aloud and provided additional assistance as needed. Of note, participants recorded their responses privately. This procedural design was intended to reduce participant reluctance to acknowledge socially undesirable behaviors or attitudes. The institutional review boards of the participating universities approved all research procedures.

Measures. Study 1 included measures of law-breaking, risk perception, age, and several control variables.

Law-breaking behavior. Participants’ involvement in illegal behavior was assessed via self-report using a subset of four items from the Risk Behavior Subscale of a modified version (Gardner & Steinberg, 2005) of the Benthin Risk Perception Measure (BRPM; Benthin, Slovic, & Severson, 1993; $\alpha = .70$, $M = 1.34$, $SD = 0.51$). Participants reported how many times in the past six months they had engaged in vandalism, theft, fighting, and threatening someone, with response options ranging from 1 (*none*) to 4 (*> 5 times*). The law-breaking scale was calculated as the average of these four items, with higher scores indicating more involvement in law-breaking activities.

Reward-biased risk perception (“reward bias”). To assess reward bias in risk perception, we used four subscales of the modified BRPM. Participants were asked to imagine engaging in several risky behaviors and to rate for each (a) the likelihood that a negative outcome would occur (Risk Estimate subscale), (b) how the potential costs compare to the potential pleasures (Cost/Benefit subscale), and (c) how serious the negative consequences would be if they occurred (Seriousness subscale). Ratings were made on a 4-point scale, with qualitative anchors ranging from 1 (*not at all serious*) to 4 (*very serious*). Risk perception involves a tradeoff between perceived benefits and costs. To the extent that one tends to weigh the rewards more heavily, one’s risk perception is reward-biased (as opposed to cost-biased). We recoded the scores such that higher scores on each subscale indicated greater reward bias (i.e., lower perceived risk, greater perceived benefit, and less concern about consequences). The risky activities included: vandalizing property, stealing from a store, threatening someone, fighting, going to a dangerous area, getting into a car with an intoxicated driver, having unprotected sex, smoking cigarettes, and drinking alcohol. The alcohol items were excluded because the patterns across age were very different for alcohol consumption

than for the other risky activities, probably due to the greater social and legal acceptance of alcohol use among older individuals.

The Risk Estimate ($\alpha = .82$), Cost/Benefit ($\alpha = .80$), and Seriousness ($\alpha = .79$) subscales were internally consistent. Preliminary regression analyses (controlling SES, IQ, and sex) revealed that each subscale bore an inverted U-shaped association with age, indicating greater reward bias in mid-to-late adolescence than in early adolescence or adulthood. Given the strong correlations among the three subscales ($r_s = .6$) and their similar patterns across age, we combined the three subscales into a single index of reward bias ($\alpha = .91$).

Age. Age was assessed using self-report. In our primary analyses, we used age as a continuous variable. Descriptively, we refer to ages 10–11 as preadolescence, 12–13 as early adolescence, 14–15 as middle adolescence, 16–17 as later adolescence, 18–21 as late adolescence, 22–25 as early adulthood, and 26–30 as adulthood. Also, we divided the sample into these age categories for our follow-up analyses to illustrate the nature of the age-related patterns uncovered in the analyses.

Control variables. Sex, SES, and IQ were included as control variables in the analyses because they are potential correlates of criminal behavior, and there were some minor differences among the age groups on these variables.

SES was assessed using self-report. We used household education as a proxy measure of SES. Individuals under age 18 reported their parents’ highest education; participants 18 years and older reported their own educational attainment. The range of 0–12 corresponded to grade completed, with 12 indicating a high school diploma or GED; 13, 14, and 15 corresponded to some college, bachelor’s degree, and postgraduate schooling, respectively.

IQ was estimated using the Vocabulary and Matrix Reasoning subtests of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). The WASI takes approximately 15 min to administer and is correlated with the Wechsler Intelligence Scale for Children ($r = .81$) and the Wechsler Adult Intelligence Scale ($r = .87$). It is approved for use with people ages 6–89 years old. For ease of interpretation, IQ scores were standardized for analysis to have a mean of 0 and standard deviation of 15.

Results

Descriptive statistics for all the variables used in Study 1 are shown in Table 1. Analyses were conducted using MPLUS, Version 5.21, to take advantage of maximum likelihood estimation. This approach is advantageous because it makes use of all available data, even if a participant is missing data on one or more of the variables in the model. We opted, for the sake of simplicity, to report models based on the calculated reward bias and law-breaking behavior variables, and to use linear regression. However, we also ran our analyses two other ways: (a) with reward bias and law-breaking behavior estimated as latent variables and (b) using Poisson regression, which treated law-breaking behavior as a count variable. These analyses yielded the same substantive results as the linear regression analyses based on calculated variables (though the hypothesized effects were a bit stronger in the latent variable model).

Do adolescents have elevated levels of reward bias? To test whether there is a curvilinear relation between reward bias and age, a linear regression analysis was conducted in which reward

Table 1
Descriptive Statistics for Samples in Study 1 and Study 2

Variable	Study 1 sample				Study 2 samples								
	(N = 929)				Community (n = 677)				Court-involved (n = 680)				
	M	SD	Min.	Max.	M	SD	Min.	Max.	M	SD	Min.	Max.	% Person
Reward bias	1.61	0.45	1.00	3.88	1.63	0.41	1.00	3.13	1.86	0.48	1.00	3.73	
Age 10–11	1.52	0.45	1.00	3.33									
Age 12–13	1.63	0.48	1.00	3.88	1.47	0.39	1.00	2.67	1.95	0.59	1.00	3.33	51.50
Age 14–15	1.68	0.46	1.00	3.42	1.72	0.43	1.00	3.13	1.93	0.46	1.00	3.60	33.30
Age 16–17	1.76	0.42	1.00	2.79	1.67	0.41	1.00	2.80	1.87	0.46	1.00	3.73	37.30
Age 18–21	1.61	0.38	1.00	2.71	1.61	0.35	1.00	2.73	1.82	0.46	1.00	3.47	23.70
Age 22–25*	1.56	0.46	1.00	3.54	1.57	0.40	1.00	2.87	1.73	0.46	1.00	2.67	18.10
Age 26–30	1.50	0.40	1.00	2.50									
Law-breaking	1.34	0.51	1.00	4.00									
Age	17.84	5.62	10.00	30.00	16.98	3.10	12.00	24.00	17.12	3.20	12.00	24.00	
Sex (% female)	50.75				43.87				33.97				
IQ	98.66	13.34	70.00	139.00	97.42	15.66	60.00	136.00	86.34	12.97	60.00	130.00	
SES	12.65	1.95	0.00	15.00	1.98	0.85	1.00	3.00	1.82	0.79	1.00	3.00	

Note. % Person is the percentage of individuals in the court-involved sample (Study 2) who were charged with a person (violent) offense. Min. = minimum; Max. = maximum; SES = socioeconomic status.

* This age group contained no 25-year-olds in the Study 2 samples.

bias was regressed on age and age². The age² term permits analysis of a curvilinear relation between age and the outcome variable. The control variables (i.e., sex, IQ, and SES) were also included as predictors in the model. (All continuous independent variables were centered.) The results showed that age² (but not age) was significantly associated with reward bias ($\beta = -0.17, p < .001$), consistent with our predicted inverted-U relation. Sex was the only other variable significantly associated with reward bias ($\beta = -0.21, p < .001$); the negative sign on the coefficient indicates that females exhibited less reward bias in risk perception than did males. The nonsignificant standardized estimates (β s) for age, IQ, and SES were 0.01, 0.01, and 0.05, respectively.

To examine the nature of the age pattern in greater detail, we conducted an analysis of covariance (ANCOVA) with reward bias as the dependent variable and age in seven categories as the independent variable, controlling for sex, IQ, and SES. The estimated marginal means suggest that reward bias is highest in later adolescence (age 16–17). Figure 1 shows the results of this analysis for the community samples in Study 1 and Study 2.

Is reward bias more strongly associated with law-breaking behavior among adolescents than among adults? Next, to examine whether age moderates the relation between reward bias and law-breaking behavior, law-breaking behavior was regressed on reward bias, age, age², Reward Bias \times Age, Reward Bias \times Age², sex, IQ, and SES. (All continuous independent variables were centered.) The interaction terms assess whether the relation between reward bias and law-breaking behavior varies as a function of age, either linearly (Reward Bias \times Age) or curvilinearly (Reward Bias \times Age²). The results (reported in Table 2) indicate that the relation between reward bias and law-breaking behavior varies as a curvilinear function of age. Figure 2 plots the regression estimates for individuals with low, average, and high levels of reward bias by age. It is apparent from Figure 2 that the relation between reward bias and law-breaking behavior is stronger in the middle of the sampled age range than at the poles. Age, IQ, and sex were also linearly associated with law-breaking behavior such that

older individuals, higher IQ individuals, and females reported less law-breaking behavior than did younger individuals, lower IQ individuals, and males.

Discussion

Study 1 tested two hypotheses consistent with the theory that law-breaking behavior is more strongly associated with risk perception in adolescence than in adulthood. The results found that reward bias was higher in adolescence than in either adulthood or preadolescence. In addition, the relation between reward bias and law-breaking behavior was significantly stronger in middle adolescence than for younger and older age ranges.

A shortcoming of these analyses is that the data for both risk perception and law-breaking behavior were based on self-report. Consequently, the relations found between these variables could

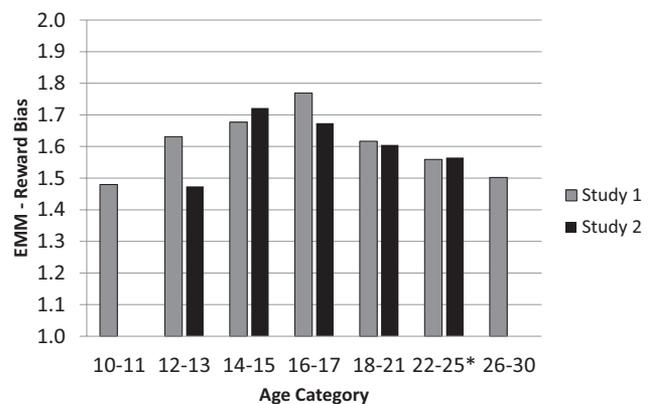


Figure 1. Estimated marginal means (EMM) of reward bias in risk appraisal by age category (controlling sex, IQ, and socioeconomic status) for participants in Study 1 and noncriminally involved participants in Study 2. * The age 22–25 category includes no 25-year-olds in Study 2.

Table 2
Regression of Law-Breaking Behavior on Reward Bias and Age Variables (Study 1)

	B	95% CI		β	R^2 step	R^2 model
		LL	UL			
Step 1					0.087	0.087
Female	−0.204***	−0.266	−0.141	−0.201		
IQ	−0.124***	−0.162	−0.087	−0.219		
SES	0.008	−0.009	0.025	0.032		
Constant	1.432***					
Step 2					0.122	0.209
Female	−0.129***	−0.188	−0.069	−0.127		
IQ	−0.120***	−0.155	−0.085	−0.211		
SES	0.009	−0.007	0.025	0.035		
Reward bias	0.359***	0.291	0.427	0.317		
Age	−0.010**	−0.016	−0.004	−0.116		
Age ²	0.000	−0.001	0.001	−0.031		
Constant	1.409***					
Step 3					0.009	0.218
Female	−0.126***	−0.186	−0.067	−0.125		
IQ	−0.113***	−0.148	−0.078	−0.200		
SES	0.009	−0.007	0.025	0.035		
Reward bias	0.470***	0.370	0.569	0.415		
Age	−0.011***	−0.017	−0.005	−0.118		
Age ²	−0.001	−0.002	0.000	−0.053		
Reward Bias × Age	0.001	−0.012	0.015	0.007		
Reward Bias × Age ²	−0.004**	−0.006	−0.001	−0.145		
Constant	1.410***					

Note. CI = confidence interval; LL = lower limit; UL = upper limit; SES = socioeconomic status.

** $p < .01$. *** $p < .001$.

potentially be accounted for by age differences in shared method variance rather than real differences (by age) in the relations between reward bias and law-breaking behavior. Study 2 addresses this limitation.

Study 2

Method

Participants. Originally, 1,429 participants (age range: 11–24 years) were enrolled in the study; the present analyses omit 10 cases due to excessive missing data, two because participants were too old, and 24 due to low IQ (below 60). In addition, we excluded

11-year-olds ($n = 36$) because only six were court-involved. (For all other ages, the distribution was roughly balanced.) The analytic sample included 1,357 participants (39% female) ages 11–24 years ($M = 17.0$ years, $SD = 3.1$). Participants were drawn from four geographic locations: Los Angeles, California (29%); Philadelphia, Pennsylvania (28%); Virginia (27%); and Florida (16%). Half the sample—the court-involved participants (49%)—were recruited from juvenile detention facilities and adult jails. Nondetained/nonincarcerated “community” participants were individuals residing in the same or similar communities as the court-involved participants. Of note, community participants were screened for past or pending court involvement; only those who had no current charges and had never been detained overnight were recruited. The sample was 40% Black, 24% Hispanic, 35% non-Hispanic White, and 2% other; race and ethnicity did not vary by age or court-involvement (see Grisso et al., 2003, for greater detail on the sample and procedures).

Measures. Study 2 included measures of the following variables.

Law-breaking behavior. Court-involvement was used as an index (albeit imperfect) of law-breaking behavior. Thus, those recruited from the court were coded as law-breaking and those recruited from the community were coded as non-law-breaking. It is important to note that the court-involved subsample was recruited prior to adjudication; therefore, some individuals in this subsample may later have been cleared of the charges against them. Also, the community subsample, though screened for current charges and history of overnight detention by police, could have included individuals involved in crime. Still, it seems reasonable to assume that the court-involved subsample was substantially more

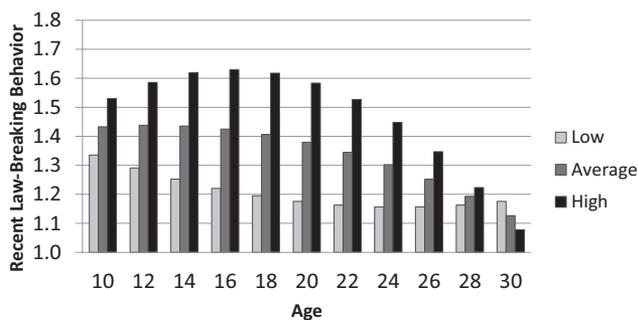


Figure 2. The estimated values for recent criminal behavior by age as a function of reward bias: low (1 SD below the mean), average, and high (1 SD above the mean). Sex, IQ and socioeconomic status were included as control variables in the regression model.

likely (on average) than the community sample to have been involved in law-breaking behavior. Consistent with this assumption, the majority of the court-involved sample (62% of juveniles and 67% of adults) reported a history of pleading guilty to or being found guilty of a crime.

Reward bias. The same measure of reward bias in risk perception was used as in Study 1, except that participants appraised five (rather than nine) risky activities. The modified BRPM included items referring to vandalism, theft, smoking cigarettes, unprotected sex, and getting into a car with a drunk driver. As in Study 1, scores on the subscales for Risk Perception, Benefit/Cost, and Seriousness were highly correlated (r s range: .54–.62), so we calculated a single reward bias score by averaging participants' scores on the items in these subscales ($\alpha = .82$).

Age. Age was assessed via self-report and used as a continuous variable in our analyses. In follow-up analyses examining the developmental patterns in more detail, we grouped age into five levels: early adolescents (12–13 years), middle adolescents (14–15 years), later adolescents (16–17 years), late adolescents (18–21 years), and young adults (22–24 years).

Control variables. Sex and SES were assessed using self-report. SES was grouped into three levels (i.e., upper, middle, lower) based on education and occupation using the Hollingshead (1975) system, with higher scores indicating higher SES (3 = middle class, 2 = working class, and 1 = lower class). The Vocabulary and Matrix Reasoning subtests of the WASI (Wechsler, 1999) were used to create a composite index of intelligence. We used z -scores for IQ in the analyses.

Results

Descriptive statistics for the variables used in Study 2 are presented in Table 1. To enable us to make use of all available data, we conducted the regression analyses in MPLUS, Version 5.21, using maximum likelihood estimation.

Do community adolescents exhibit elevated levels of reward bias? To assess whether reward bias peaked in adolescence in the non-court-involved subsample ($n = 677$), we regressed reward bias on age, age² and the control variables (i.e., sex, IQ, and SES). As predicted, the age² term was significant ($\beta = -0.15, p < .001$); the nature of the effect was that levels of reward bias increased and then decreased with age. (This pattern can be observed by examining the bars for community participants in Figure 3.) In addition, the model revealed that females had lower levels of reward bias ($\beta = -0.09, p < .05$) than males, and individuals with higher IQ scores ($\beta = -0.11, p < .01$) had lower levels of reward bias than those with higher IQ scores. SES was not significantly associated with reward bias ($\beta = 0.02, p > .7$) in this model. For purposes of comparison with the community sample in Study 1, we conducted an ANCOVA with reward bias as the dependent variable and age in five categories as the independent variable, controlling for sex, IQ, and SES. The estimated marginal means suggest that reward bias was highest in this sample in middle adolescence (age 14–15; see Figure 1).

It is worth noting that, though no prediction was made about the court-involved subsample, the same age pattern for reward bias was not found for these participants. When the model including age, age², and the control variables was estimated for the court-involved subsample, the results showed a significant main effect of

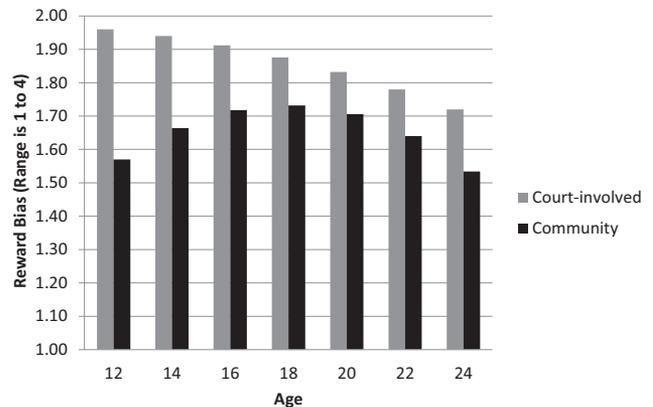


Figure 3. The estimated values for reward bias as a function of age and court-involvement (law-breaking) in Study 2 (the Law-Breaking Behavior \times Age² effect). The control variables are sex, IQ, and socioeconomic status.

age such that reward bias decreased linearly with age ($\beta = -0.12, p < .01$). (This pattern can be observed by examining the bars for court-involved participants in Figure 3.) The age² term was not significant. We account for this difference between the two subsamples in the relation between age and reward bias in the subsequent analyses of reward bias by including an Age² \times Law-Breaking Behavior interaction term in the model.

Is reward bias more strongly associated with law-breaking behavior among adolescents than among adults? To test our second hypothesis—that reward bias is more strongly associated with law-breaking behavior during adolescence—we conducted a linear regression in which reward bias was regressed on law-breaking behavior, age, Law-Breaking Behavior \times Age, age², Law-Breaking Behavior \times Age², sex, IQ, and SES. As predicted, the results (shown in Table 3) revealed that the effect of law-breaking behavior on reward bias was significantly moderated by age ($\beta = -0.12, p < .01$). The nature of the interaction was such that law-breaking behavior was more strongly associated with reward bias for younger individuals than for older individuals (see Figure 3). The age moderation effect did not differ significantly for males and females (Law-Breaking Behavior \times Age \times Sex: $\beta = -0.01, p > .8$). (Note that we opted to use reward bias rather than law-breaking behavior as the dependent variable in our analysis because doing so enabled us to account for variance in reward bias due to sex. However, the finding that age moderates the relation between reward bias and law-breaking behavior, controlling for sex, SES and IQ, also emerged when the analysis was run as a logistic regression with law-breaking behavior as the dependent variable.)

Next, the analysis was repeated, selecting only members of the court-involved sample who reported having pled or been found guilty of a crime previously (44% among those aged 12–13; 66% among 14–15; 66% among 16–17; 64% among 18–21; and 71% among 22–24). This provided greater assurance that the court-involved sample used in the analysis had engaged in law-breaking behavior. As expected, the results obtained were similar, and the p values associated with the focal effects were smaller (due to reduced statistical noise) than in the

Table 3
Regression of Reward Bias on Law-Breaking Behavior and Age Variables (Study 2)

	B	95% CI		β	R^2 step	R^2 model
		LL	UL			
Step 1					0.039	0.039
Female	-0.109***	-0.158	-0.060	-0.117		
IQ	-0.072***	-0.097	-0.047	-0.158		
SES	-0.003	-0.033	0.027	-0.005		
Constant	1.791***					
Step 3					0.051	0.090
Female	-0.091***	-0.139	-0.043	-0.097		
IQ	-0.030*	-0.056	-0.004	-0.066		
SES	0.000	-0.029	0.029	0.000		
Law-breaking behavior	0.204***	0.154	0.255	0.224		
Age	-0.005	-0.014	0.004	-0.034		
Age ²	-0.003**	-0.005	-0.001	-0.085		
Constant	1.713***					
Step 3					0.006	0.096
Female	-0.089***	-0.137	-0.041	-0.095		
IQ	-0.031*	-0.057	-0.005	-0.067		
SES	-0.003	-0.032	0.026	-0.005		
Law-breaking behavior	0.165***	0.099	0.230	0.180		
Age	0.007	-0.005	0.019	0.047		
Age ²	-0.005**	-0.008	-0.002	-0.136		
Law-Breaking Behavior \times Age	-0.025**	-0.042	-0.008	-0.123		
Law-Breaking Behavior \times Age ²	0.004 [†]	0.000	0.009	0.095		
Constant	1.730					

Note. CI = confidence interval; LL = lower limit; UL = upper limit; SES = socioeconomic status.

[†] $p < .07$. * $p < .05$. ** $p < .01$. *** $p < .001$.

original regression analysis. The Law-Breaking Behavior \times Age interaction was again significantly associated with reward-biased risk perception ($\beta = -0.16$, $p < .001$); the Law-Breaking Behavior \times Age² interaction ($\beta = 0.15$, $p < .01$) also reached statistical significance.

A further analysis was conducted to ensure that the findings were not driven by age differences in the proportion of individuals charged with person (violent) offenses. Specifically, we tested whether the age moderation effect held when the model was estimated with only person and then only property offenders (based on court-involved individuals' current charges) included along with the community subsample. (These were the most common charge types, representing 32% and 38% of charges, respectively.) The interaction of Age \times Law-Breaking Behavior remained significant in both the person offender ($\beta = -0.10$, $p < .01$) and the property offender ($\beta = -0.08$, $p < .05$) models.

Discussion

This study examined differences between court-involved individuals and non-court-involved individuals (from comparable communities) in reward bias, taking into account variation due to sex, IQ, and SES. The findings support the hypothesis that reward bias is more strongly associated with law-breaking behavior among adolescents than among adults. The largest difference between court-involved and community individuals in reward bias was observed in the youngest age group—the 12- to 13-year-olds—with court-involved youth exhibiting higher levels of reward bias than community youth. The weakest association between law-breaking behavior and reward bias was found among

the oldest participants, those aged 22–24. Even though the association was significant for the oldest age group, the effect was significantly weaker than for the youngest age group.

This analysis has some limitations, particularly related to the operationalization of law-breaking behavior. Because we use court involvement as a proxy measure for engagement in law-breaking behavior, our results could reflect the association of risk appraisal with being *caught* for a crime and formally charged rather than with the perpetration of crime per se. The factors that lead to being caught for a crime and being charged for a crime may differ somewhat from the factors related to perpetrating crime and could also vary by age. Although we cannot rule out these concerns, it is reassuring that the same pattern of results emerged in the supplementary analysis that restricted the court-involved subsample to those previously found guilty of a crime and in the analyses conducted separately by the type of offense committed (person vs. property).

A second analysis served to replicate the finding in Study 1 that reward bias increases and then decreases with age across the adolescent period. Using just the community subsample, the same result was found as in Study 1: reward bias varied curvilinearly with age, with the highest means observed among middle-to-late adolescents. Overall, the results support the hypotheses that adolescent risk appraisal (compared to that of adults) is biased toward reward (over cost) and translates more directly into criminal risk-taking.

General Discussion

The relation between risk perception and criminal behavior has long been speculated about but has rarely been studied. The results

of the two studies included in the present analysis support two conclusions. First, adolescents are more reward-biased in their risk appraisals than adults or preadolescents. Second, even accounting for this age effect, reward bias correlated more strongly with both self-reported law-breaking behavior (in a large community sample) and with officially alleged law-breaking behavior (in a large sample of detained/incarcerated individuals and a community comparison sample) during early-to-middle adolescence than during adulthood. These patterns are robust to adjustments for sex, intelligence, and social class. In all, the findings are consistent with the dual-systems model of adolescent development (Casey et al., 2008; Steinberg, 2008; Steinberg, 2010), and they support the view that adolescent offending is partly attributable to developmental factors that tip adolescents' risk appraisal toward risk-taking.

It is particularly noteworthy that we were able, with an instrument as blunt as self-reported risk perception, to identify the predicted curvilinear age pattern in reward bias. Other research that has tried to identify age differences in risk perception by asking adolescents to explicitly judge or estimate risk has typically failed to find differences between adults' and adolescents' responses (at least beyond middle adolescence; see Reyna & Farley, 2006, for a review). Though empirical evidence exists for reward-biased risk perception during adolescence, it mostly derives from studies that have used performance outcomes and/or brain imaging to infer risk perception (e.g., Cauffman et al., 2010; Ernst et al., 2005; Eshel et al., 2007; Figner et al., 2009; Gardner & Steinberg, 2005; Galvan et al., 2006). Surely, the large sample sizes and wide age ranges of our samples enabled us to uncover this small, but significant effect of age. In addition, two characteristics of the reward-bias measure likely facilitated the finding. First, it included items that asked participants to weigh benefits as well as risks. This is important when trying to capture age differences that may be largely driven by differences in reward sensitivity. Second, the measure likely elicited more intuitive or emotion-driven risk appraisals by asking for qualitative rather than quantitative judgments (i.e., Would you expect the harmful effects to be mild or serious?) rather than asking participants to simply estimate numerical likelihoods of negative outcomes (e.g., 5% chance). Previous research has suggested that qualitative measures of reward bias are more useful for predicting of risky behavior than quantitative measures, at least among adolescents (Mills, Reyna, & Estrada, 2008). Such measures may be more sensitive than quantitative measures to the emotional components of risk perception (e.g., the subjective magnitude of reward vs. cost), which are the aspects believed to change curvilinearly with age.

The finding that reward bias in risk appraisal is more associated with adolescent than with adult crime fits with a larger body of research indicating that adolescent crime is etiologically distinct from adult crime. It converges, for example, with results from several studies that have examined the relation between psychosocial immaturity and antisocial tendencies. In one such study, Cauffman and Steinberg (2000) found that, when individuals were presented with vignettes and asked what they would do, young people provided more antisocial responses. Moreover, the relation between age and antisocial decision-making was explained by younger participants' lesser psychosocial maturity. Modecki (2008) found that psychosocial immaturity was associated with greater self-reported antisocial behavior in a diverse sample of adolescents and adults that included court-involved individuals. In

a study that compared delinquent and nondelinquent adolescents, delinquency was found to be associated with low future orientation (a facet of psychosocial maturity), even after controlling for a wide range of cognitive, familial, and biological factors (Cauffman, Steinberg, & Piquero, 2005).

However, not all studies have yielded evidence in support of psychosocial immaturity predicting law-breaking behavior. Two other studies that (like the present study) used court involvement as an index of crime failed to find evidence that psychosocial immaturity predicts criminal involvement in adolescence; Fried and Reppucci (2001) and Modecki (2008) found no significant differences between delinquent and nondelinquent adolescents in psychosocial maturity. It may be that official measures of crime are too "noisy" to consistently yield correlations with constructs that do in fact contribute to law-breaking; such measures are weakened by discriminatory policing, biases in police discretion, omission of transgressors who are better at avoiding detection, and numerous other factors that make officially charged offenders less representative of the population of offenders. Then again, self-report of offending has its drawbacks as well. For example, adults may be more reluctant than adolescents to admit to criminal behavior due to greater attention to self-presentation. This concern is mitigated in the present study by the use of computer- rather than interviewer-administered questionnaires.

Fortunately, one of the strengths of the present study is that it did not rely on a single operationalization of criminal behavior. Rather, it investigated the research questions using both self-reported and official measures of crime. The fact that the hypotheses were supported in both studies allows for greater confidence in the validity of our conclusions. The findings are also strengthened by our ability to account for the effects of potential confounds and moderators, including sex, intelligence, and SES. Nevertheless, several limitations of the study warrant consideration. Most important, the cross-sectional and correlational nature of both studies requires that we employ caution when interpreting the results through a developmental lens and making claims about causality. For example, in Study 2, we cannot be sure that the younger and older members of the criminally involved subsample represent the same population of offenders. If they do not, it does not make sense to draw conclusions about development from observed age differences in the sample. However, the fact that our hypotheses were confirmed in both studies, despite the differences between the samples and the manner of defining law-breaking behavior, lends credence to our conclusions.

Another issue to consider is that all the individuals in the criminally involved subsample had, by definition, experienced negative consequences for criminal behavior (i.e., arrest and detention). One might be tempted to speculate that the inverse relation between age and reward bias in the criminally involved subsample reflects developmental increases in sensitivity to these sanctions (Cauffman et al., 2010). However, this position is contradicted by the relatively small magnitude of the difference in reward bias between court-involved and community adults compared to the large gap between court-involved and community adolescents. Sanctions for crime are generally harsher for adults than for juveniles. Therefore, if the experience of sanctions had a powerful effect on risk appraisal, one would expect that effect to be greatest—not smallest—in the age groups likely to face the most serious legal repercussions.

An unexpected result to emerge from the analysis was that, in the community sample in Study 1, the pattern for law-breaking behavior across age did not conform to the typical inverted-U curve seen in other studies of self-reported offending. Rather, criminal behavior declined with increasing age in this sample (even before accounting for the effects of reward bias). This finding is likely attributable to the instrument used to gauge criminal behavior; it may not have been comprehensive enough to capture the wider range of behaviors usually assessed in research on the correlates of crime.

It is also intriguing that the peak correlation between reward bias and crime occurred in a younger age group in Study 2 than in Study 1. In Study 1, the peak correlation occurred in the 14- to 15-year-old age group; in Study 2, the 12- to 13-year-old age group evinced the strongest association. One possible explanation for this difference inheres in Study 2's use of a very different definition of criminal behavior than used in Study 1. It may be that detained 12- to 13-year-olds, due to selection effects within the legal system, fall closer to the extreme in the reward-bias distribution for their age range than do detained 14- to 15-year-olds. This could result if the police or probation officers were more inclined to let a 12- or 13-year-old off with a warning (or other informal response) than a 14- or 15-year-old. In other words, the 12- to 13-year-olds could represent a more serious offender population than the other age groups. The youngest age group did contain a larger proportion of accused person offenders than any of the other age groups (see Table 1). Yet, as noted previously, the pattern of results did not differ when the analysis included only accused person offenders or only accused property offenders. Still, future research relying on official indices of offending to investigate the relation between risk perception and crime should include more detailed measures of offense severity in order to better account for possible moderating effects.

Study Implications

Scientific evidence, such as that presented here, that developmental factors may contribute to adolescent offending has begun to influence legal policy. A decade ago, Steinberg and Scott (2003) reviewed developmental research in multiple fields suggesting that adolescent crime is in part a product of developmental immaturity. They argued that, in light of the developmental evidence, adolescence itself should be viewed as a mitigating circumstance and adolescent defendants should be considered categorically distinct from adult defendants. The U.S. Supreme Court has shown signs of agreement with this position. Thrice in the past decade, the Court has considered whether immaturity mitigates culpability and how it should moderate the sentences imposed on juveniles for the most serious crimes. In *Roper v. Simmons* (2005), which abolished the death penalty for juvenile offenders, the majority opinion cited the developmental science in deciding that juveniles' impulsivity, susceptibility to outside influence, and inchoate characters compel the Court to afford juveniles different legal treatment than adults. The majority decisions in *Graham v. Florida* (2010), which proscribed life without parole sentences for juveniles convicted of nonhomicide offenses, and in *Miller v. Alabama* (2012), in which the Court eliminated mandatory life without the possibility of parole sentences for all juveniles, cite the same reasoning detailed in *Roper*. By clarifying the extent to which adolescents' "impetu-

ous and ill-considered actions and decisions" (Justice Kennedy in *Roper v. Simmons*, 2005, p. 569) may result from reward bias in risk perception, the present study's findings help to advance the science on which the Court relies.

In addition to having implications for blameworthiness, immature risk appraisal during adolescence also bears on the issue of incapacitation. One of the goals of sentencing is to enable the court to prevent individuals from inflicting further harm or damage on the public. Indeed, past criminal behavior is a potent predictor of future criminal behavior among adults. However, to the extent that immaturity contributes to juvenile crime, delinquent behavior may be less prognostic of future offending patterns among adolescents. Delinquency appears to be common in adolescence, with between one third and two thirds of adolescents self-reporting involvement in criminal behavior (Abe, 2001). Furthermore, about 90% of youth who come into contact with the law as juveniles cease to have further police contact by early adulthood (D'Unger, Land, McCall, & Nagin, 1998). If a juvenile is likely to "outgrow" the factors (e.g., reward-biased risk perception, weak self-regulation) that contributed to his or her criminal behavior, then it may be unnecessary (and perhaps counterproductive; Bayer, Hjalmarsson, & Pozen, 2009) to institutionalize a youth in the interest of protecting the public (Steinberg, 2008).

Finally, as discussed by Deutsch (2008), the nature of adolescent risk perception may not only increase the chances of criminal behavior, it may interfere with the deterrent intent of legal sanctions. If, as suggested by the developmental literature, adolescents tend to discount risks and future consequences, they are unlikely to give sufficient weight to the potential legal consequences of law-breaking prior to indulging in it. Rather, they will be more swayed by the potential short-term rewards of the illegal action (e.g., thrill, novelty, revenge, enhanced social status).

To summarize, developmental immaturity, insofar as it contributes to criminal behavior, diminishes adolescent culpability, reduces the benefit-to-cost ratio of incarcerating juvenile offenders, and impedes the deterrent effect of punitive responses. However, even if adolescent crime is partly a manifestation of a transient increase in risky behavior that is normative in adolescence, it does not follow that adolescent crime should go unpunished; only that it should be treated differently than adult crime. There are many ways in which converging scientific evidence about reward bias in adolescent risk perception could be used to inform juvenile justice practice. For example, judicial decision-makers, when considering how to handle a case, could consider the circumstances of the crime and whether it included features that might suggest developmental immaturity played a role in the event, such as high emotional arousal, opportunity to obtain a valuable or socially relevant reward, and/or the involvement of cooffenders (Steinberg, 2009). In addition, probation officers and judges could capitalize on adolescents' responsiveness to reward by designing dispositions that integrate incentives for achieving goals (e.g., school attendance) rather than threatening additional sanctions for failure to meet requirements. Also, because adolescents have poorer impulse control and may be slower to learn from negative feedback, it makes sense to give them more chances than adults to correct course if they falter. To be sure, it is difficult to know how to apply general findings about the effects of development on criminal behavior to individual cases. However, if law enforcement and juvenile justice decision-makers can identify adolescents who will

likely “mature out” of risky or criminal behavior (and the vast majority of adolescent offenders will) and prevent those youth from becoming ensnared in the justice system, society will benefit. As baseball player, Earl Wilson observed: “Snow and adolescence are the only problems that disappear if you ignore them long enough.”

References

- Abe, Y. (2001). Changes in gender and racial gaps in antisocial behavior: The NLSY97 versus the NLSY79. In R. T. Michael (Ed.), *Social awakening: Adolescent behavior as adulthood approaches* (pp. 339–379). New York, NY: Russell Sage Foundation.
- Andrews-Hanna, J. R., Mackiewicz Seghete, K. L., Claus, E. D., Burgess, G. C., Ruzic, L., & Banich, M. T. (2011). Cognitive control in adolescence: Neural underpinnings and relation to self-report behaviors. *PLoS ONE*, *6*, e21598. doi:10.1371/journal.pone.0021598
- Arnett, J. J. (1996). Sensation seeking, aggressiveness, and adolescent reckless behavior. *Personality and Individual Differences*, *20*, 693–702. doi:10.1016/0191-8869(96)00027-X
- Asato, M. R., Terwilliger, R., Woo, J., & Luna, B. (2010). White matter development in adolescence: A DTI study. *Cerebral Cortex*, *20*, 2122–2131. doi:10.1093/cercor/bhp282
- Bayer, P., Hjalmarsson, R., & Pozen, D. (2009). Building criminal capital behind bars: Peer effects in juvenile corrections. *The Quarterly Journal of Economics*, *124*, 105–147. doi:10.1162/qjec.2009.124.1.105
- Benthin, A., Slovic, P., & Severson, H. (1993). A psychometric study of adolescent risk perception. *Journal of Adolescence*, *16*, 153–168. doi:10.1006/jado.1993.1014
- Bunge, S. A., Dudukovic, N. M., Thomason, M. E., Vaidya, C. J., & Gabrieli, J. D. (2002). Immature frontal lobe contributions to cognitive control in children: Evidence from fMRI. *Neuron*, *33*, 301–311. doi:10.1016/S0896-6273(01)00583-9
- Carver, A. C., Livesey, D. J., & Charles, M. (2001). Age related changes in inhibitory control as measured by stop signal task performance. *International Journal of Neuroscience*, *107*, 43–61. doi:10.3109/00207450109149756
- Casey, B. J., Getz, S., & Galvan, A. (2008). The adolescent brain. *Developmental Review*, *28*, 62–77. doi:10.1016/j.dr.2007.08.003
- Casey, B. J., Trainor, R. J., Orendi, J. L., Schuber, A. B., Nystrom, L. E., Giedd, J. N., & Castellanos, F. X. (1997). A developmental functional MRI study of prefrontal activation during performance of a go-no-go task. *Journal of Cognitive Neuroscience*, *9*, 835–847. doi:10.1162/jocn.1997.9.6.835
- Cauffman, E., Shulman, E. P., Steinberg, L., Claus, E., Banich, M. T., Graham, S., & Woolard, J. (2010). Age differences in affective decision making as indexed by performance on the Iowa Gambling Task. *Developmental Psychology*, *46*, 193–207. doi:10.1037/a0016128
- Cauffman, E., & Steinberg, L. (2000). (Im)maturity of judgment in adolescence: Why adolescents may be less culpable than adults. *Behavioral Sciences & the Law*, *18*, 741–760. doi:10.1002/bsl.416
- Cauffman, E., Steinberg, L., & Piquero, A. R. (2005). Psychological, neuropsychological and physiological correlates of serious antisocial behavior in adolescence: The role of self-control. *Criminology*, *43*, 133–176. doi:10.1111/j.0011-1348.2005.00005.x
- Chein, J., Albert, D., O'Brien, L., Uckert, K., & Steinberg, L. (2011). Peers increase adolescent risk taking by enhancing activity in the brain's reward circuitry. *Developmental Science*, *14*, F1–F10. doi:10.1111/j.1467-7687.2010.01035.x
- Chen, L., Baker, S. P., Braver, E. R., & Li, G. (2000). Carrying passengers as a risk factor for crashes fatal to 16- and 17-year-old drivers. *JAMA: Journal of the American Medical Association*, *283*(12), 1578–1582.
- Csikszentmihalyi, M., & Larson, R. (1978). Intrinsic rewards in school crime. *Crime & Delinquency*, *24*, 322–335. doi:10.1177/00111287780240030
- Csikszentmihalyi, M., Larson, R., & Prescott, S. (1977). The ecology of adolescent activity and experience. *Journal of Youth and Adolescence*, *6*, 281–294. doi:10.1007/BF02138940
- Deutsch, M. (2008). Minor league offenders strike out in the major league: California's improper use of juvenile adjudications as strikes. *Southwestern University Law Review*, *37*, 375–392.
- Doremus-Fitzwater, T. L., Varlinskaya, E. I., & Spear, L. P. (2010). Motivational systems in adolescence: Possible implications for age differences in substance abuse and other risk-taking behaviors. *Brain and Cognition*, *72*, 114–123. doi:10.1016/j.bandc.2009.08.008
- D'Unger, A. V., Land, K. C., McCall, P. L., & Nagin, D. S. (1998). How many latent classes of delinquent/criminal careers? Results from mixed Poisson regression analyses. *American Journal of Sociology*, *103*, 1593–1630. doi:10.1086/231402
- Durston, S., Thomas, K. M., Yang, Y., Uluğ, A. M., Zimmerman, R. D., & Casey, B. (2002). A neural basis for the development of inhibitory control. *Developmental Science*, *5*, F9–F16. doi:10.1111/1467-7687.00235
- Emler, N., & Reicher, S. (1995). *Adolescence and delinquency: The collective management of reputation*. Cambridge, MA: Blackwell Publishing.
- Ernst, M., Nelson, E. E., Jazbec, S., McClure, E. B., Monk, C. S., Leibenluft, E., & Blair, J. (2005). Amygdala and nucleus accumbens in responses to receipt and omission of gains in adults and adolescents. *NeuroImage: A Journal of Brain Function*, *25*, 1279–1291. doi:10.1016/j.neuroimage.2004.12.038
- Eshel, N., Nelson, E. E., Blair, R. J., Pine, D. S., & Ernst, M. (2007). Neural substrates of choice selection in adults and adolescents: Development of the ventrolateral prefrontal and anterior cingulate cortices. *Neuropsychologia*, *45*, 1270–1279.
- Evans, J. S. (2003). In two minds: Dual-process accounts of reasoning. *Trends in Cognitive Sciences*, *7*(10), 454–459.
- Figner, B., Mackinlay, R. J., Wilkening, F., & Weber, E. U. (2009). Affective and deliberative processes in risky choice: Age differences in risk taking in the Columbia Card Task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*, 709–730. doi:10.1037/a0014983
- Finer, L. B. (2010). Unintended pregnancy among U.S. adolescents: Accounting for sexual activity. *Journal of Adolescent Health*, *47*(3), 312–314.
- Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention, and behavior: An introduction to theory and research*. Reading, MA: Addison Wesley.
- Fried, C. S., & Reppucci, N. D. (2001). Criminal decision making: The development of adolescent judgment, criminal responsibility, and culpability. *Law and Human Behavior*, *25*, 45–61. doi:10.1023/A:1005639909226
- Galvan, A., Hare, T. A., Perra, C. E., Penn, J., Voss, H., Glover, G., & Casey, B. J. (2006). Earlier development of the accumbens relative to orbitofrontal cortex might underlie risk-taking behavior in adolescents. *The Journal of Neuroscience*, *26*, 6885–6892. doi:10.1523/JNEUROSCI.1062-06.2006
- Gardner, M., & Steinberg, L. (2005). Peer influence on risk taking, risk preference, and risky decision making in adolescence and adulthood: An experimental study. *Developmental Psychology*, *41*, 625–635. doi:10.1037/0012-1649.41.4.62
- Giedd, J. N. (2008). The teen brain: Insights from neuroimaging. *Journal of Adolescent Health*, *42*, 335–343. doi:10.1016/j.jadohealth.2008.01.007
- Graham v. Florida, 129 S. Ct. 2157 (2010).
- Grisso, T., Steinberg, L., Woolard, J., Cauffman, E., Scott, E., Graham, S., & Lexcen, F. (2003). Juveniles' competence to stand trial: A comparison

- of adolescents' and adults' capacities as trial defendants. *Law and Human Behavior*, 27, 333–363. doi:10.1023/A:1024065015717
- Hare, T. A., & Casey, B. J. (2005). The neurobiology and development of cognitive and affective control. *Cognition, Brain, Behavior: An Interdisciplinary Journal*, 9(3), 273–286.
- Hollingshead, A. (1975). *Four factor index of social status*. New Haven, CT: Department of Sociology, Yale University.
- Horvath, P., & Zuckerman, M. (1992). Sensation seeking, risk appraisal, and risky behavior. *Personality and Individual Differences*, 14, 41–52. doi:10.1016/0191-8869(93)90173-Z
- Jackson v. Hobbs, S. Ct. Docket No. 10–9647 (2012).
- Kahneman, D. (2011). *Thinking, fast and slow*. New York, NY: Farrar, Straus & Giroux.
- Luna, B., Thulborn, K., Munoz, D., Merriam, E. P., Garver, K. E., Minshew, N. J., & Keshavan, S. M. (2001). Maturation of widely distributed brain function subserves cognitive development. *NeuroImage: A Journal of Brain Function*, 13, 768–793. doi:10.1006/nimg.2000.0743
- Miller v. Alabama, S. Ct. Docket No. 10–9646 (2012).
- Mills, B., Reyna, V. F., & Estrada, S. (2008). Explaining contradictory relations between risk perception and risk taking. *Psychological Science*, 19, 429–433. doi:10.1111/j.1467-9280.2008.02104.x
- Modecki, K. (2008). Addressing gaps in the maturity of judgment literature: Age differences and delinquency. *Law and Human Behavior*, 32, 78–91. doi:10.1007/s10979-007-9087-7
- Moffitt, T. E. (1993). Adolescence-limited and life-course-persistent antisocial behavior: A developmental taxonomy. *Psychological Review*, 100, 674–701. doi:10.1037/0033-295X.100.4.674
- Munoz, D. P., Broughton, J. R., Goldring, J. E., & Armstrong, I. T. (1998). Age-related performance of human subjects on saccadic eye movement tasks. *Experimental Brain Research*, 121, 391–400.
- Newcomb, M. D., & McGee, L. (1991). Influence of sensation seeking on general deviance and specific problem behaviors from adolescence to young adulthood. *Journal of Personality and Social Psychology*, 61(4), 614–628.
- Pfefferbaum, B., & Wood, P. B. (1994). Self-report study of impulsive and delinquent behavior in college students. *Journal of Adolescent Health*, 15, 295–302. doi:10.1016/1054-139X(94)90602-5
- Reyna, V. F., & Farley, F. (2006). Risk and rationality in adolescent decision making: Implications for theory, practice, and public policy. *Psychological Science in the Public Interest*, 7, 1–44. doi:10.1111/j.1529-1006.2006.00026.x
- Romer, D., & Hennessy, M. (2007). Biosocial-affect model of adolescent sensation seeking: The role of affect evaluation and peer-group influence in adolescent drug use. *Prevention Science*, 8, 89–101. doi:10.1007/s11121-007-0064-7
- Roper v. Simmons, 125 S. Ct. 1183 (2005).
- Scott, E., & Woolard, J. (2004). The legal regulation of adolescence. In R. Lerner & L. Steinberg (Eds.), *Handbook of adolescent psychology* (2nd ed., pp. 523–550). New York, NY: Wiley.
- Shulman, E. P., & Cauffman, E. (2013). *Deciding in the dark: Age differences in intuitive risk judgment*. Manuscript submitted for publication.
- Somerville, L. H., Hare, T., & Casey, B. J. (2011). Frontostriatal maturation predicts cognitive control failure to appetitive cues in adolescents. *Journal of Cognitive Neuroscience*, 23, 2123–2134. doi:10.1162/jocn.2010.21572
- Spear, L. P. (2000). The adolescent brain and age-related behavioral manifestations. *Neuroscience & Biobehavioral Reviews*, 24, 417–463. doi:10.1016/S0149-7634(00)00014-2
- Steinberg, L. (2008). A social neuroscience perspective on adolescent risk-taking. *Developmental Review*, 28, 77–106. doi:10.1016/j.dr.2007.08.002
- Steinberg, L. (2009). Adolescent development and juvenile justice. *Annual Review of Clinical Psychology*, 5, 47–73. doi:10.1146/annurev.clinpsy.032408.153603
- Steinberg, L. (2010). A dual systems model of adolescent risk-taking. *Developmental Psychobiology*, 52, 216–224. doi:10.1002/dev.20445
- Steinberg, L., Albert, D., Cauffman, E., Banich, M., Graham, S., & Woolard, J. (2008). Age differences in sensation seeking and impulsivity as indexed by behavior and self-report: Evidence for a dual systems model. *Developmental Psychology*, 44, 1764–1778. doi:10.1037/a001295
- Steinberg, L., & Scott, E. (2003). Less guilty by reason of adolescence: Developmental immaturity, diminished responsibility, and the juvenile death penalty. *American Psychologist*, 58, 1009–1018. doi:10.1037/0003-066X.58.12.1009
- Stolzenberg, L., & D'Alessio, S. J. (2008). Co-offending and the age-crime curve. *Journal of Research in Crime and Delinquency*, 45, 65–86. doi:10.1177/0022427807309441
- Substance Abuse and Mental Health Services Administration. (2010). *Results from the 2009 National Survey on Drug Use and Health: Volume I. Summary of national findings*. Rockville, MD: U. S. Department of Health and Human Services.
- Warr, M. (1993). Age, peers, and delinquency. *Criminology*, 31, 17–40. doi:10.1111/j.1745-9125.1993.tb01120.x
- Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence*. San Antonio, TX: Psychological Corporation.
- White, H. R., Labouvie, E. W., & Bates, M. E. (1985). The relationship between sensation seeking and delinquency: A longitudinal analysis. *Journal of Research in Crime and Delinquency*, 22, 197–211. doi:10.1177/0022427885022003002

Received September 6, 2012

Revision received February 9, 2013

Accepted February 16, 2013 ■