Developmental Psychology
2016, Vol. 52, No. 10, 1593–1605

0012-1649/16/$12.00 http://dx.doi.org/10.1037/dev0000152

Interaction of Reward Seeking and Self-Regulation in the Prediction of Risk Taking: A Cross-National Test of the Dual Systems Model

Natasha Duell
Temple University

Laurence Steinberg
Temple University and King Abdulaziz University

Jason Chein
Temple University

Suha M. Al-Hassan
Hashemite University and Emirates College for Advanced Education

Dario Bacchini
Second University of Naples

Chang Lei
University of Macau

Nandita Chaudhary
University of Dheli

Laura Di Giunta
Università di Roma

Kenneth A. Dodge
Duke University

Kostas A. Fanti
University of Cyprus

Jennifer E. Lansford and Patrick S. Malone
Duke University

Paul Oburu
Maseno University

Concetta Pastorelli
Università di Roma

Ann T. Skinner
Duke University

Emma Sorbring
University West

Sombat Tapanya
Chiang Mai University

Liliana Maria Uribe Tirado
Universidad San Buenaventura

Liane Peña Alampay
Ateneo de Manila University

In the present analysis, we test the dual systems model of adolescent risk taking in a cross-national sample of over 5,200 individuals aged 10 through 30 (M = 17.05 years, SD = 5.91) from 11 countries. We examine whether reward seeking and self-regulation make independent, additive, or interactive contributions to risk taking, and ask whether these relations differ as a function of age and culture. To compare across cultures, we conduct 2 sets of analyses: 1 comparing individuals from Asian and Western

This article was published Online First September 5, 2016.

Natasha Duell, Department of Psychology, Temple University; Laurence Steinberg, Department of Psychology, Temple University and King Abdulaziz University; Jason Chein, Department of Psychology, Temple University; Suha M. Al-Hassan, Queen Rania Faculty for Childhood, Hashemite University, and Emirates College for Advanced Education; Dario Bacchini, Department of Psychology, Second University of Naples; Chang Lei, Department of Psychology, University of Macau; Nandita Chaudhary, Department of Human Development and Childhood Studies, Lady Irwin College, University of Dheli; Laura Di Giunta, Department of Psychology, Università di Roma; Kenneth A. Dodge, Center for Child and Family Policy, Duke University; Kostas A. Fanti, Department of Psychology, University of Cyprus; Jennifer E. Lansford and Patrick S. Malone, Center for Child and Family Policy, Duke University; Paul Oburu, Department of Educational Psychology, Maseno University; Concetta Pastorelli, Department of Psychology, Università di Roma; Ann T. Skinner, Center for Child and Family Policy, Duke University; Emma Sorbring, Department of Psychology, University West; Sombat Tapanya, Department of Psychiatry, Chiang Mai University; Liliana Maria Uribe Tirado, Consultorio Psicológico Popular, Universidad San Buenaventura; Liane Peña Alampay, Department of Psychology, Ateneo de Manila University.

This research was supported by an Award to Laurence Steinberg from the Klaus J. Jacobs Foundation.

Correspondence concerning this article should be addressed to Natasha Duell, Department of Psychology, Temple University, 6th Floor Weiss Hall, 1701 North 13th Street, Philadelphia, PA 19122. E-mail: ntduell@temple.edu

countries, and 1 comparing individuals from low- and high-GDP countries. Results indicate that reward seeking and self-regulation have largely independent associations with risk taking and that the influences of each variable on risk taking are not unique to adolescence, but that their link to risk taking varies across cultures.

Keywords: adolescents, risk taking, dual systems, development, culture

Supplemental materials: http://dx.doi.org/10.1037/dev0000152.supp

Dual systems models of adolescent risk taking posit that heightened risk taking at this age is the result of a maturational imbalance between brain systems responsible for reward processing, which mature early in adolescence, and systems responsible for cognitive control, which do not mature until early adulthood (e.g., Casey, Getz, & Galvan, 2008; Steinberg, 2008). Consequently, during middle and late adolescence, youth experience a heightened sensitivity to reward, which impels them toward sensation seeking, before they have the mature self-regulatory capacities required to rein in impulsive behavior (Steinberg, 2008). Thus, dual systems theories postulate that the adolescent-peak in risk taking is a function of the interaction between brain systems influencing reward seeking and self-regulatory behaviors, which develop along distinct and independent trajectories. Although various terms have been used to describe the behaviors underlying these neurological systems, for the purposes of this article, we use the term reward seeking to broadly describe behaviors related to sensation seeking and reward sensitivity, and self-regulation to describe behaviors related to cognitive control and response inhibition.

Numerous empirical examinations of the dual systems perspective exist in both the neuroscientific and psychological literatures (for a review, see Shulman et al., 2016). However, three issues have not received sufficient attention. First, few researchers have directly examined the independent, additive, and interactive contributions of reward seeking and self-regulation to risk taking; although the brain systems that govern these processes develop independently, they are thought to function interactively (Galvan et al., 2006). Second, it is unclear how the interplay between these two systems differs across developmental periods; their relative importance for risk taking may vary as a function of age. Finally, it is unknown whether the dual systems perspective of adolescent risk taking is generalizable across cultures; although heightened risk taking in adolescence is seen around the world (World Health Organization, 2004), it is unknown whether the underlying contributions of reward seeking and self-regulation to risky behavior are similar in different cultural contexts.

The most robust findings in support of the dual systems model concern cross-sectional data on the differing developmental trajectories of reward seeking and self-regulation (Harden & Tucker-Drob, 2011; Shulman et al., 2016; Steinberg et al., 2008), as well as their underlying neurobiological processes, reward processing, and cognitive control, respectively (Casey, Jones, & Hare, 2008; Smith, Chein, & Steinberg, 2013; Spear, 2013). Both self-report (Harden & Tucker-Drob, 2011; Steinberg et al., 2008) and behavioral indicators (Cauffman et al., 2010) of reward seeking suggest that this trait increases in early adolescence, peaks in mid- to late adolescence, and declines into adulthood. In contrast, self-report (Steinberg et al., 2008) and behavioral indicators (Albert & Steinberg, 2011; Huizinga, Dolan, & van der Molen, 2006; Luna et al., 2004) of self-regulation evince linear changes across age, with some aspects of self-regulation continuing to mature into the mid-20s (Albert & Steinberg, 2011). These self-report and behavioral findings are in line with research on the neurodevelopment of brain regions underlying reward seeking and self-regulation, which show that the development of subcortical regions responsible for reward processing occurs earlier and more rapidly than the development of cortical regions facilitating cognitive control (Luciana & Collins, 2012; Mills, Goddings, Clasen, Giedd, & Blakemore, 2014; Somerville & Casey, 2010; Spear, 2013).

Researchers have also linked individual differences in reward seeking and impulsivity to individual differences in risk-taking. Self-reported reward seeking is associated with self-reported substance use (Castellanos-Ryan et al., 2013), delinquency (Harden, Quinn, & Tucker-Drob, 2012), and risky sexual behavior (Derefinko et al., 2014), as well as risk taking on several laboratory tasks (Figner, Mackinlay, Wilkening, & Weber, 2009; Lauriola et al., 2014; Steinberg et al., 2008). Likewise, researchers have linked self-reported impulsivity to self-reported drug use and unprotected sex (Donohew, Zimmerman, Cupp, Novak, Colon, & Abell, 2000), delinquency (Harden & Tucker-Drob, 2011), and risk taking on laboratory tasks (Collado, Felton, MacPherson, & Lejuez, 2014).

When sensation seeking and impulsivity are examined as simultaneous predictors of adolescent risk taking, most studies find that the two are independently associated with risk taking (but see Steinberg et al., 2008 and Cyders et al., 2009). Donohew and colleagues (2000), for example, found that both sensation seeking and impulsive decision-making significantly increased the odds of 9th graders engaging in unprotected sex and substance use. Similarly, Shulman and Cauffman (2014) found that, across participants between the ages of 10 and 30, sensation seeking and impulse control independently explained variation in risk preference. Although these studies are informative, none has examined whether the two variables interact to influence risk-taking. Relatedly, although there is neuroimaging evidence for age-dependent increases in connectivity between cognitive control regions (e.g., prefrontal cortex) and subcortical regions of the brain implicated in reward processing (e.g., nucleus accumbens; Van Duijvenvoorde, Achterberg, Braams, Peters, & Crone, 2016), there is little evidence regarding how this interaction is manifested behaviorally. Understanding the interaction between reward seeking and self-regulation facilitates our ability to develop practical applications of the dual systems model, for example, by potentially decreasing risk taking through improvements in self-regulation (e.g., Duckworth & Steinberg, 2015).

Initial support for the interaction between reward seeking and self-regulation in influencing adolescent risk taking comes from findings such as those of Donohew and colleagues (2000), who found that 9th graders high in reward seeking but low in impulsive decision-making were less likely to engage in risky sexual behavior than individuals who were high in both. This finding is consistent with those of Castellanos-Ryan and colleagues (2013), who found that adolescent boys high in reward seeking were less likely to use marijuana if they also displayed high levels of self-regulation. Although these studies provide promising preliminary evidence for the interaction between reward seeking and self-regulation on risk taking, they are limited in their generalizability, focusing on male-only (e.g., Castellanos-Ryan et al., 2013) and adolescent-only (Castellanos-Ryan et al., 2013; Donohew et al., 2000) samples, and limiting their outcomes to a single category of risk taking, such as substance use or risky sexual activity. Furthermore, as with most research on risk taking, these studies are limited in their cultural breadth, focusing only on American youth.

The notion that the combination of an easily aroused reward system and immature cognitive control contributes to heightened risk taking has, understandably, been studied mainly in adolescence, the developmental period during which many forms of risky behavior reach their peak. Consequently, the literature is unclear on how relations among reward seeking, self-regulation, and risk taking vary across development. Although some studies have explored the effects of reward seeking and self-regulation in cross-sectional samples spanning from early adolescence to early adulthood (e.g., Shulman & Cauffman, 2014), these studies have not considered whether these relations differ across age groups (e.g., Does reward seeking only predict risk taking among younger individuals? Do adults high in reward seeking and low in self-regulation also take more risks than their peers, as is the case among adolescents?). Prior studies do not adequately test whether the dual systems perspective explains risk taking across early, middle, and late adolescence, as well as in adulthood, during which self-regulation matures.

Perhaps the biggest gap in work exploring the dual systems model is an examination of whether the model applies to risk taking across cultures. Adolescent risk-taking, like all aspects of adolescent behavior, occurs in a broader cultural context (Steinberg, 2014). Adolescents growing up in different parts of the world are exposed to different norms and have different opportunities for risky activity. However, the extent to which development in adolescence is dictated by biology is a longstanding question that has interested scholars since Hall's original treatise on the subject (Hall, 1904). Ergo, an important question is whether the relations between reward seeking, self-regulation, and risk taking are inherent to all adolescents, or vary across cultural contexts. On the one hand, it might be that changes in reward seeking and self-regulation are universal features of adolescent development driven mainly by the biology of the period (Spear, 2013). On the other hand, it is sensible to speculate that factors such as religion in Muslim countries (Mauseth, Skalisky, Clark, & Kaffer, 2016) and the strong emphasis on self-regulation in many Asian countries (Chaudhary & Sharma, 2012; Chen, Cen, Li, & He, 2005; Weisz, Chaiyasit, Weiss, Eastman, & Jackson, 1993) moderate how reward seeking and self-regulation influence risk-taking in adolescence. Cross-cultural tests of the dual systems model can shed light on the external validity of the model, deepen our understanding of adolescent risk-taking, and inform longstanding questions about the relative contributions of biology and culture to the course of adolescent behavioral development more generally.

In the present study, we examine the interaction between reward seeking and self-regulation as predictors of risk taking from a developmental and cross-national perspective, using data from a large-scale investigation of more than 5,200 individuals between the ages of 10 and 30 from 11 countries. All individuals completed a battery of self-report and behavioral tasks that include neuropsychological, psychological, and behavioral indicators of reward seeking, self regulation, and risk taking, many of which are identical or similar to measures used in previous studies of American individuals (Cauffman et al., 2010; Steinberg et al., 2008, 2009). We examine the independent, additive, and interactive contributions of reward seeking and self-regulation to risk taking and ask whether these relations differ across development and culture.

Method

Participants

The sample for the present analysis includes 5,227 individuals between the ages of 10 and 30 ($M = 17.05$ years; $SD = 5.91$) from 11 countries: Guang-Zhou and Shanghai, China ($N = 489$); Medellin, Colombia ($N = 498$); Nicosia, Cyprus ($N = 364$); Delhi, India ($N = 417$); Naples and Rome, Italy ($N = 547$); Amman and Zarqa, Jordan ($N = 450$); Kisumu, Kenya ($N = 483$); Manila, the Philippines ($N = 505$); several cities in the west of Sweden ($N = 416$); Chang Mai, Thailand ($N = 502$); and Durham and Winston-Salem, the United States ($N = 556$). The gender distribution for the full sample is 49.3% male ($N = 2,575$) and 50.7% female ($N = 2,652$), and is also nearly even in each age group within each country.

The participating countries were initially selected for an international study of parenting and child development, Parenting Across Cultures (PAC; Lansford et al., 2014). Participants in the present study were recruited to study age differences in decision making and risk taking, and were drawn from the same communities as the PAC families. For the present study, the samples can be considered primarily working and middle class, and have similar standings in terms of within-country socioeconomic status (SES). Participants in all but the United States did not identify as being members of any ethnic minority groups. In the United States, we aimed to enroll approximately equal numbers of Black, Latino, and White participants.

In each country, the sample was recruited to yield an age distribution that both facilitated the examination of age differences within the adolescent decade and to compare adolescents with three groups of young adults: (a) individuals of traditional college age (18–21; who in some studies of risky decision-making behave in ways similar to adolescents; Gardner & Steinberg, 2005); (b) individuals at an age during which brain maturation is continuing, presumably in regions that subserve impulse control (22–25); and (c) individuals older than this putatively still-maturing group (26–30). To maintain comparability between the present study and previous ones of American individuals using similar measures, we used the age groupings used in those earlier studies (e.g., Steinberg et al., 2008): 10–11, 12–13, 14–15, 16–17, 18–21, 22–25, and 26–30. Although the age groups were comparable with respect to SES and intelligence (IQ), there were small but significant differences on these variables between some age groups. Accordingly, all analyses control for SES and IQ.

Given our interest in the generalizability of findings across culture, we also compared patterns of relations among reward seeking, self-regulation, and risk taking across groups of countries. Although the sample is large, our ability to discern age differences in each country was limited by the number of individuals within each of the age groups. Because we were concerned that analyses comparing individual countries would be underpowered, we created clusters of countries that could be meaningfully grouped together. Two factors along which countries vary in their views and treatment of adolescents are with respect to cultural heritage and economic status. In one set of analyses, based on clusters defined by cultural heritage, we compared Asian countries (China, India, Philippines, and Thailand, $N = 1{,}909$) and Western countries (Colombia, Cyprus, Italy, Sweden, and the United States, $N = 2{,}291$; Jordan and Kenya do not fit into either cluster and were not included in these analyses). In a second set of analyses, we grouped countries according to their relative affluence, using a median split of Gross Domestic Product (GDP) based on data from the World Bank: High-GDP (China, Italy, India, Sweden, the United States, and Thailand, $N = 2{,}899$), and low-GDP countries (Colombia, Philippines, Kenya, Jordan, and Cyprus, $N = 2{,}218$).

Procedures

Participants were recruited via flyers posted in neighborhoods and schools, ads placed in newspapers, and word of mouth. Because of the varied recruitment methods, we cannot determine whether those who responded to recruitment ads differ from those who did not. Informed consent was obtained from all adults age 18 and older, and parental consent and adolescent assent were acquired for all individuals younger than 18.[1] Local Institutional Review Boards (IRBs) approved all procedures.

Participants completed a 2-hr test battery administered on laptop computers that included several behavioral tasks, self-report measures, a demographic questionnaire, computerized tests of executive functions, and an IQ assessment. These sessions were completed individually in participants' homes, schools, or other locations designated by the participants.

To keep participants engaged, they were told they would receive a base payment for participating, and that they could obtain a bonus based on their performance on the computer tasks. In actuality, all participants received the bonus. This strategy was used to increase motivation to perform well on tasks but ensure that no participants were penalized for their performance. In the United States, the base payment was US$30 and the bonus was US$15. In other countries, the principal investigators and site coordinators (with the approval of the local IRB) determined an appropriate amount of payment, accounting for the local standard of living and minimum wage, and ensuring that the amount was sufficient to encourage participation but not so large so as to be coercive. (The participating university in Sweden does not permit research subjects to be paid, so participants were given three movie tickets [two as the base payment and one as a bonus] as compensation.)

Following each assessment, the interviewer answered five questions about the participant's engagement in the assessment and the quality of the data. A small number of assessments (3.2%, $N = 172$) were rated as unusable (e.g., the participant did not appear to understand the questions or tasks, did not pay attention to instructions, or was obviously disengaged); these cases were dropped from the analyses.

Measures

Measures were administered in the predominant language at each site, following forward- and back-translation and meetings to resolve ambiguities in linguistic or semantic content (Erkut, 2010; Maxwell, 1996). Translators were fluent in English and the target language. In addition to translating the measures, translators noted items that did not translate well, were inappropriate for the participants, were culturally insensitive, or elicited multiple meanings and worked with site coordinators to make appropriate modifications. Measures were administered in Mandarin Chinese (China), Spanish (Colombia and the United States), Italian (Italy), Arabic (Jordan), Dholuo (Kenya), Filipino (the Philippines), Greek (Cyprus), Hindi (India), Swedish (Sweden), Thai (Thailand), and American English (India, Kenya, the Philippines, and the United States).

The primary variables for the present analyses include indices of self-regulation, reward seeking, and risk taking. We operationalized these items by creating composites of conceptually similar behavioral and self-report measures, allowing for more robust measurement and reducing the likelihood of results being biased by any one measure. Each composite was computed by averaging scores on their component variables that had been standardized either in the sample as a whole, or within each of the four country clusters, as appropriate. Descriptive statistics for the study measures are reported in Tables 1 (individual items) and 2 (composite items) and correlations among the measures in Table 3. Details on measurement invariance (Asparouhov & Muthen, 2014; Muthen & Asparouhov, 2013) in the self-report measures across countries are provided in the supplementary materials.

Risk Taking

The chief outcome variable, risk taking, was computed by averaging standardized scores on self-reported risk preference and two behavioral risk-taking tasks.

Self-reported risk preference. Self-reported *risk preference* is a subscale of the Benthin Risk Perception scale (Benthin, Slovic, & Severson, 1993). The Benthin measure presents respondents with a list of nine risky activities: drinking alcohol, riding in a car with a drunk driver, smoking cigarettes, vandalism, shoplifting, going into a dangerous neighborhood, fighting, threatening or injuring someone with a weapon, and having unprotected sex (this item was omitted for all participants under 13 and individuals of all ages in Kenya, Jordan, and India). Participants are asked to rate the extent to which the potential benefits compare with the costs of each activity on a four-point scale ranging from much more good than bad to much more bad than good. The risk preference subscale was chosen over endorsement of risky behaviors because age differences in self-reported risk taking are likely distorted by opportunities to take risk, which predictably increase with age. Risk preference reflects an individual's *inclination* to take risk,

[1] In Sweden, informed consent was obtained from all participants age 15 and older, and parental consent and adolescent assent were acquired for individuals younger than 15, per Swedish law.

Table 1
Means and SEs for Main Study Variables

Variable and age category	*M*	*SE*	Variable and age category	*M*	*SE*	Variable and age category	*M*	*SE*
Risk taking composite			Self-regulation composite			Reward seeking composite		
10–11	−.183	.018	10–11	−.18	.018	10–11	−.065	.022
12–13	−.077	.025	12–13	−.096	.025	12–13	−.007	.029
14–15	.08	.025	14–15	.014	.025	14–15	−.012	.03
16–17	.116	.025	16–17	.103	.026	16–17	.092	.03
18–21	.14	.024	18–21	.177	.023	18–21	.11	.028
22–25	.096	.024	22–25	.173	.024	22–25	.056	.028
26–30	.052	.025	26–30	.174	.025	26–30	−.026	.029
Total	.032	.009	Total	.052	.009	Total	.021	.011
Risk preference			Planning			Sensation seeking		
10–11	1.309	.011	10–11	.704	.008	10–11	.564	.009
12–13	1.333	.014	12–13	.708	.011	12–13	.576	.012
14–15	1.436	.014	14–15	.69	.011	14–15	.566	.012
16–17	1.464	.015	16–17	.706	.011	16–17	.62	.012
18–21	1.476	.014	18–21	.729	.01	18–21	.614	.011
22–25	1.465	.014	22–25	.74	.011	22–25	.597	.011
26–30	1.452	.014	26–30	.737	.011	26–30	.56	.012
Total	1.419	.005	Total	.716	.004	Total	.585	.004
Stoplight risk index			TOL time to first move			IGT reward sensitivity		
10–11	.421	.007	10–11	4319.231	129.228	10–11	5.469	.666
12–13	.419	.009	12–13	4492.627	174.371	12–13	7.065	.89
14–15	.457	.009	14–15	5397.21	179.497	14–15	7.61	.901
16–17	.427	.009	16–17	5565.75	183.253	16–17	7.945	.906
18–21	.432	.009	18–21	6148.334	165.641	18–21	9.116	.849
22–25	.425	.009	22–25	6152.47	170.981	22–25	8.174	.864
26–30	.385	.009	26–30	6392.952	178.235	26–30	7.384	.895
Total	.424	.003	Total	5495.51	63.757	Total	7.537	.322
BART inflation ratio			Stroop accuracy					
10–11	67.229	.337	10–11	.865	.004			
12–13	70.398	.45	12–13	.894	.005			
14–15	71.39	.458	14–15	.917	.005			
16–17	73.212	.46	16–17	.931	.005			
18–21	73.548	.43	18–21	.93	.004			
22–25	72.97	.439	22–25	.926	.005			
26–30	73.476	.454	26–30	.919	.005			
Total	71.746	.163	Total	.911	.002			

Note. All values are for the entire sample and adjusted for gender (coded 0 = female; 1 = male), intelligence (IQ), and socioeconomic status (SES). Subsample sizes are as follows 10–11 years (n = 1,191), 12–13 years (n = 702), 14–15 years (n = 667), 16–17 years (n = 623), 18–21 years (n = 715), 22–25 years (n = 670), 26–30 years (n = 660). Composite totals represent z-scores (standardized for the whole sample). Overall means and *SE*s for these variables within each of the 11 countries are included in a supplementary table. Risk preference, planning, and sensation seeking are self-report scales, all other items are behavioral tasks. IGT = Iowa Gambling Task; TOL = Tower of London.

which is independent of his or her opportunity to do so. The reliability for the risk perception subscale is α = .84, with reliabilities for separate countries ranging from .78 to .89.

Balloon Analogue Risk Task (BART). A modified version of the BART (adapted from Lejuez et al., 2002) developed for use in brain imaging studies was implemented in this study. The computerized task includes 20 trials in which participants decide how much air to "pump" into a balloon. To initiate inflation, the individual must press the space bar. The balloon inflates continuously until the participant pauses inflation by pressing the space bar again. From this point, participants may continue inflating the balloon bit by bit. When the desired inflation size is reached, participants hit a separate key to obtain the points offered. More points are accrued as the balloon inflates, but at some point, the addition of more air causes the balloon to burst, in which all points earned during that trial are lost.

Each balloon has a unique maximum inflation point based on the number of pumps (either initiated automatically by the computer at the beginning of the trial or by the participant hitting the spacebar after inflation had been paused). The maximum inflation point across the 20 trials ranges from 12 to 69 pumps (M = 40.5). Risk taking is operationalized as the average inflation ratio across the 20 trials (i.e., the inflated size of a balloon divided by its maximum inflation point), with higher inflation ratios indicative of greater risk taking.

Stoplight. The Stoplight game (Steinberg et al., 2008) is an additional computerized behavioral measure of risk taking. The player is asked to "drive" a car to a party at a distant location in as little time as possible, and must pass through 20 intersections, each marked by a traffic signal. The participant's vantage point is that of someone behind the wheel. Before playing, participants are informed that when approaching an intersection in which the traffic signal turns yellow, they must decide whether to stop the car (using the space bar) and wait for the light to cycle back to green, or attempt to cross the intersection. Participants cannot control the car's speed, and the brake only works after the light turns yellow.

Table 2

Means and SEs for Composites Within Country Clusters

Country cluster	Risk taking composite		Reward seeking composite		Self-regulation composite	
	M (*SE*)	Range	*M* (*SE*)	Range	*M* (*SE*)	Range
Asian	.0013 (.014)	−1.8–2.65	−.0002 (.0163)	−3.63–2.02	.0059 (.015)	−2.00–2.24
Western	.0011 (.013)	−2.04–2.46	−.001 (.015)	−3.07–1.87	−.0052 (.013)	−2.25–2.48
Low-GDP	.0015 (.013)	−1.71–2.65	.0001 (.015)	−3.36–2.04	.0062 (.013)	−2.13–2.42
High-GDP	.0003 (.012)	−1.89–2.72	−.0005 (.013)	−3.55–1.92	−.0028 (.012)	−1.97–2.36
Full sample	.0013 (.009)	−1.86–2.77	−.0004 (.001)	−3.46–2.00	.0003 (.009)	−2.30–2.56

Note. Composite items are averages of *z*-scores, computed separately for each country cluster. Asian countries include China, Philippines, Thailand, and India; Western countries include Italy, Sweden, United States, Colombia, and Cyprus. Low-GDP (Gross Domestic Product; see Participants section) countries include Kenya, Philippines, Colombia, Jordan, and Cyprus; High-GDP countries include China, Italy, Thailand, Sweden, United States, and India. Risk taking composite computed with *z*-scores for risk preference, Stoplight, and BART; Reward seeking composite computed with *z*-scores for sensation seeking and IGT; Self-regulation composite computed with *z*-scores for planning, Tower of London, and Stroop.

Participants are told that one of three things may happen depending on their decision: (a) if brakes are not applied and the car passes through the intersection without crashing, no time is lost, (b) if brakes are applied before the light turns red, the car will stop safely, but 3 s will be lost waiting for the green light, or (c) if brakes are not applied or applied too late and the car crashes (accompanied by squealing tires, a loud crash, and the image of a shattered windshield), 6 s will be lost. Participants must decide between driving through the intersection to save time (but risk losing time if a crash occurs), or to stop and wait (and willingly lose a smaller amount of time). The outcome variable is the proportion of intersections the participant entered without braking.

Among the 20 intersections, there is one in which the light remains green and all cars pass through (data from this intersection are not used). Additionally, there are 14 intersections in which the latency between the yellow and red lights is long enough for participants to stop; 10 of these are configured such that running the red light results in a crash. For two additional intersections, the latency between the yellow light and crossing vehicle is so short that almost all participants crash. Finally, within three intersections, the latency between the yellow light and crossing vehicle is long enough that participants can run the red light without crashing.

Reward Seeking

Reward seeking was computed by averaging standardized scores on a measure of self-reported sensation seeking and a reward processing behavioral task.

Self-reported sensation seeking. Self-reported *sensation seeking* was assessed using a subset of six items from the Sensation Seeking Scale (Zuckerman, Eysenck, & Eysenck, 1978). Many items on the full 19-item scale appear to measure impulsivity (e.g., "I often do things on impulse."). In light of our interest in distinguishing between impulsivity and sensation seeking, our measure includes only items clearly indexing thrill- or novelty-

Table 3

Correlations Among Main Study Variables and Covariates for Entire Sample

Variable	Risk pref	SL	BART	SS	IGT	Planning	TOL	Stroop	Risk comp.	Rew comp.	SR comp.	Age	Gender	IQ
Risk Pref	—													
SL	.11***	—												
BART	.10***	.10***	—											
SS	.22***	.07***	.08***	—										
IGT	.07***	.04*	.03*	.03*	—									
Planning	−.18***	−.03	−.05***	−.26***	−.03*	—								
TOL	.06***	.03*	.08***	−.02	.05***	.08***	—							
Stroop	.07***	.05***	.03*	.04***	.08***	.04***	.07***	—						
Risk Comp.	.59***	.64***	.63***	.18***	.06***	−.13***	.08***	.07***	—					
Rew Comp.	.20***	.07***	.08***	.72***	.72***	−.20***	.02	.09***	.16***	—				
SR Comp.	−.03	.03*	.03*	−.12***	.05***	.60***	.63***	.61***	.01	−.05***	1.00			
Age	.13***	−.03*	.19***	.03*	.04*	.07***	.19***	.21***	.14***	.05***	.26***	1.00		
Gender	.15***	.06***	.14***	.05***	.04***	−.03	.06***	−.03*	.18***	.06***	.004	.00	1.00	
IQ	.001	.06***	.10***	.02	.07***	.09***	.21***	.17***	.06***	.06***	.26***	.16***	.08***	1.00
SES	.04*	.01	.04**	.08***	.04**	.002	.02	−.01	.02	.08***	.01	−.07***	.02	.15***

Note. Risk pref = self-reported risk preference; SL = Stoplight; BART = Balloon Analogue Risk Task; SS = self-reported sensation seeking; IGT = Iowa Gambling Task; Planning = self-reported planning; TOL = Tower of London; IQ = intelligence; SES = socioeconomic status. Items with "comp" reflect *z*-score composites for risk taking (Risk), reward seeking (Rew), and self-regulation (SR), respectively. Risk taking composite includes risk preference, Stoplight, and BART; Reward seeking composite includes sensation seeking and IGT; Self-regulation composite includes planning, Tower of London, and Stroop. Gender coded as (0 = female) and (1 = male).

* $p < .05$. ** $p < .01$. *** $p < .001$.

seeking (e.g., "I like doing things just for the thrill of it"; see Steinberg et al., 2008). Participants responded either true or false. Reliability for the 6-item scale is α = .62, with reliabilities for separate countries ranging from .46 to .78.

Iowa Gambling Task. The Iowa Gambling Task (IGT) was used to measure *reward sensitivity*. In this task, individuals attempt to earn pretend money by playing or passing cards from four different decks, presented on the computer screen. Two decks are advantageous and result in monetary gain over repeated play, and two decks are disadvantageous, producing net loss over repeated play. The task was administered in six blocks of 20 trials each. The standard task (Bechara et al., 1994) was modified in two ways. First, participants decide to play or pass a card from a preselected deck rather than deciding to draw from any of the four decks (see Cauffman et al., 2010 for details). This modification is shown to be more sensitive to individual differences in performance because it separates the independent effects of gains and losses on subsequent card selection (Peters & Slovic, 2000). Second, participants receive information on net gain or loss associated with each card rather than information on gain and loss separately. This modification was made to equate working memory loads across age groups and to ensure that participants did not unequally weight rewards and losses within a given trial.

During the task, one of four decks is highlighted and participants are given 4 s to play or pass the card. A running total of the participant's "earnings" appear on each screen. If the participant passes, the image of the card displays the message "Pass" and the total amount of money earned does not change. If the participant plays, a monetary outcome is displayed on the card and the total amount of money earned is updated. Reward sensitivity is computed as the difference between the percentage of plays from advantageous decks (relative to the total number of advantageous cards presented during each block) in the last and first blocks: (% Play Block 6) – (% Play Block 1; see Cauffman et al., 2010).

Self-Regulation

Self-regulation was assessed by averaging the standardized scores on a measure of self-reported planning and two behavioral self-control tasks.

Self-reported planning. As noted earlier, several items on the 19-item Zuckerman Sensation Seeking Scale (Zuckerman et al., 1978) appear to index impulsivity. We used six items to create an index of self-reported impulsivity, and reverse-scored this scale to create a measure of *planning* (sample item: "I usually think about what I'm going to do before doing it"). All items were answered as either true or false and item scores were averaged. Reliability for this 6-item scale is α = .63, with reliabilities for separate countries ranging from .47 to .73.

Tower of London. A computerized version of the Tower of London task (Shallice, 1982) was used to measure *impulse control* (see Steinberg et al., 2008). The Tower of London measures whether one can inhibit acting before a plan is fully formed. The subject is presented with pictures of two sets of three colored balls distributed across three rods, one of which can hold three balls, one two balls, and the last, one ball. The first picture shows the starting position of the three balls, and the second depicts the goal position. The subject is asked to move the balls in the starting arrangement to match the goal arrangement in as few moves as necessary. Five sets of four problems are presented, beginning with four that can be solved in a minimum of 3 moves, and progressing to trials that can be solved in a minimum of 4, 5, 6, and 7 moves. The variable used for this analysis was the average latency to first move for 6- and 7-move problems (Albert & Steinberg, 2011; Steinberg et al., 2008). Latency to first move was measured as the amount of time that elapses (in milliseconds) between the presentation of each problem and the subject's first move, with longer latencies indicating greater impulse control.

Stroop. A computerized version of the classic Stroop color-word task (Banich et al., 2007) was administered to assess prepotent *response inhibition*. On each trial, the participant is presented either a color-word (e.g., "blue,") or a neutral/noncolor word (e.g., "Math,") and instructed to identify the color of the word (ignoring its semantic meaning) by pressing a corresponding key as quickly as possible. All color-word trials are incongruent, such that the color of the word does not match its semantic meaning (e.g., the word "blue" displayed in yellow). Participants completed two 48-trial experimental blocks. One block includes an equal mix of neutral and incongruent trials, and a second block includes a greater number of neutral than incongruent trials. The order in which these blocks were presented differed randomly across participants. For the present analysis, we used accuracy scores for the hardest trials (incongruent trials within unequal blocks). These scores were calculated as the proportion of correct responses on incongruent trials relative to all trials within unequal blocks. Higher scores indicate greater response inhibition.

Covariates

Measures of intelligence and SES (as well as gender) were used as covariates in all analyses.

Intelligence. The Matrix Reasoning subtest of the Wechsler Abbreviated Scale of Intelligence (WASI) was used to produce an estimate of nonverbal intellectual ability. This test provides a brief and reliable measure of general intelligence that is normed across the life span (Psychological Corporation, 1999). Given the variability in language across the research sites, the verbal subscale was not used. Age-normed WASI *T* scores for the Matrix Reasoning subtest range from 20 to 80. Scores lower than 30 were considered outliers and coded as missing.

Socioeconomic status. Participants reported on the highest level of education achieved by each of their parents to generate a measure of SES that was valid across countries. These responses were given numeric values that represented years of education completed. A value of 0 indicates no education, values 1 through 12 correspond to grade level (e.g., value of 10 indicates completion of 10th grade), a value of 13 indicates some college, 14 indicates a college degree, and 15 represents education beyond college. The average of the participant's mother's and father's (or primary caregivers') education levels were computed to index SES, which was also used as a covariate in the analyses.

Results

Reward Seeking and Self-Regulation as Predictors of Risk Taking

Using the entire sample, a linear regression was conducted with dummy variables for each country (except the United States, which was used as the reference variable) entered on the first step; gender, SES, IQ, and age entered on the second step; the reward seeking and self-regulation composites on the third; the two-way interaction between reward seeking and self-regulation on the fourth; the two-way interactions between each of these composites and age on the fifth; and finally, the three-way interaction among the composites and age on the sixth.

Within the full sample, reward seeking and self-regulation demonstrated independent effects on risk taking, controlling for country, gender, SES, and IQ (see Table 4). As expected, greater reward seeking predicted higher risk taking, whereas stronger self-regulation predicted lower risk taking. These effects did not differ across age. Furthermore, the effect of reward seeking on risk taking did not differ across levels of self-regulation.

Differences in the Prediction of Risk Taking Across Country Clusters

We next examined whether these patterns held across groups of countries that differed in cultural heritage (Asian vs. Western) and relative affluence (low- vs. high-GDP). Variables were restandardized within each of the four country clusters (Asian, Western, low-GDP, and high-GDP) before analysis to adjust for cross-national differences in mean levels and variances. We tested differences between age patterns in cultural and economic subgroups by adding the grouping variable (cultural heritage [0 = Asian and 1 = Western] or GDP [0 = low-GDP and 1 = high-GDP]) to the model, and entering the interactions between the grouping variable and the other independent variables (main effects and interactions listed above). Significant interactions between the independent variables and the country group variable were probed further with separate regression analyses within the relevant country cluster.

Asian versus Western countries. Results from the comparison of Asian (China, Philippines, Thailand, and India) versus Western (Italy, Sweden, United States, Colombia, and Cyprus) countries are presented in Table 5. Only the effect of self-regulation on risk taking significantly differed between Asian and Western countries. The two-way and three-way interactions among age, reward seeking, and self-regulation did not differ between Asian and Western countries.

The moderating effect of country cluster was probed further by conducting separate regression analyses within each cultural heritage cluster (see Table 6). As shown in Figure 1, self-regulation was associated with risk taking in Western, but not Asian countries. In Western countries, higher self-regulation was associated with less risk taking, whereas in Asian countries, levels of risk taking did not vary as a function of self-regulation.

Low- versus high-GDP countries. Results from the comparison of low-GDP (Kenya, Philippines, Colombia, Jordan, and Cyprus) and high-GDP (China, Italy, Thailand, Sweden, United States, and India) countries are presented in Table 5. The effect of reward seeking and the interaction between age and self-regulation significantly differed between country groups.

The significant two-way interaction between reward seeking and GDP category, and the three-way interaction among age, self-regulation, and GDP category was probed further by conducting separate regression analyses within each GDP group (see Table 7). Greater reward seeking was significantly associated with higher risk taking in both low-GDP and high-GDP countries, but this effect was stronger in low-GDP countries (see Figure 2). The

Table 4
Regression of Risk Taking on Reward Seeking and Self-Regulation in Entire Sample

Model	Variable	B	*SE* (B)	Standard β	Adjusted R^2
1	China	.295***	.040	.148	.084
	Italy	.262**	.038	.139	
	Kenya	−.120*	.043	−.053	
	Philippines	.097***	.039	.051	
	Thailand	.152***	.043	.066	
	Sweden	.445***	.041	.208	
	Colombia	.227***	.040	.112	
	Jordan	−.179***	.045	−.072	
	India	.394***	.043	.171	
	Cyprus	.170***	.047	.065	
2	Gender	.219***	.018	.179	.132
	SES	.014***	.004	.065	
	IQ	−.001	.001	−.013	
	Age	.013***	.002	.128	
3	Reward	.121***	.013	.139	.152
	Self-Regulation	−.041**	.016	−.041	
4	Reward × Regulation	−.017	.021	−.012	.152
5	Age × Reward	.002	.002	.040	.153
	Age × Regulation	−.013	.007	−.058	
6	Age × Reward × Regulation	.002	.004	.025	.152

Note. Each country represents a dummy variable where (0 = other and 1 = country); United States omitted from country list as reference variable. Gender is a dichotomous variable where (0 = female and 1 = male). Reward reflects the reward seeking *z*-score composite and Regulation reflects the self-regulation *z*-score composite. Composites were standardized for the whole sample. IQ = intelligence; SES = socioeconomic status.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 5
Regression of Risk Taking on Reward Seeking and Self-Regulation Across Country Clusters

Model	Variable	Country: Asian/Western B	SE (B)	Standard β	Adjusted R^2	Country: Low/High-GDP B	SE (B)	Standard β	Adjusted R^2
1	Gender	.205***	.020	.165	.063	.213***	.018	.174	.075
	SES	.010**	.004	.048		.008*	.003	.034	
	IQ	−.003*	.001	−.040		<.001	.001	−.004	
	Age	.015***	.002	.143		.014***	.002	.140	
	Reward Seeking	.103***	.014	.117		.127***	.013	.147	
	Self-Regulation	−.031	.017	−.031		−.027	.016	−.027	
2	Country	.016	.021	.012	.063	.004	.019	.003	.075
3	Reward × Regulation	−.028	.024	−.019	.066	−.020	.022	−.014	.081
	Age × Reward	.003	.003	.070		.002	.002	.042	
	Age × Regulation	−.007*	.003	−.122		−.006*	.003	−.116	
	Age × Country	.005	.004	.073		.012***	.003	.182	
	Reward × Country	.026	.029	.022		−.075**	.027	−.067	
	Regulation × Country	−.092**	.034	−.069		.003	.031	.002	
4	Age × Reward × Country	−.001	.004	−.018	.067	.001	.004	.010	.081
	Reward × Regulation × Country	.062	.049	.031		−.020	.046	−.011	
	Age × Reward × Country	−.003	.005	−.043		.006	.005	.092	
	Age × Regulation × Country	−.010	.006	−.145		−.012*	.005	−.176	
5	Age × Reward × Regulation × Country	.003	.008	.024	.066	−.003	.008	−.035	.081

Note. Results from two separate moderation analyses. *Country* represents a dichotomous variable for country cluster. In the first analysis, the dichotomous variable represented Asian (0) and Western (1) countries; in the second analysis, the dichotomous variable represented low-GDP (0) and high-GDP (1) countries. In this table, *Country* is a stand-in for *both* variables. Gender is a dichotomous variable where (0 = female and 1 = male). Reward and Regulation reflect reward seeking and self-regulation *z*-score composites, respectively. All composites standardized within country cluster. IQ = intelligence; SES = socioeconomic status.
* $p < .05$. ** $p < .01$. *** $p < .001$.

interaction between age and self-regulation was only significant in high-GDP countries. Using data only from high-GDP countries, partial correlations (*pr*) between self-regulation and risk taking were probed within age categories (10–11, 12–13, 14–15, 16–17, 18–21, 22–25, and 26–30, respectively), controlling for SES, IQ, and gender. Results indicated that the interaction was driven by the oldest age category (26–30 years), $pr = -0.155$, $p = .011$. In other words, higher self-regulation was associated with less risk taking among 26- to 30-year-olds only, but risk taking did not differ across levels of self-regulation within the other age groups.

Discussion

According to dual systems models of adolescent risk taking, risky behavior during adolescence is the product of the interplay between an easily aroused reward system and immature self-control. It is not known, however, whether these two presumed influences on risky behavior make independent contributions, and, if so, whether their effects are additive or interactive. Results from this study of more than 5,200 adolescents and young adults from 11 countries indicate that (a) reward seeking and self-regulation have largely independent associations with risk taking, (b) the relations between these traits and risk taking are not unique to adolescence, and (c) the ways in which reward seeking and self-regulation are linked to risk taking vary somewhat across cultures.

Although the basic tenets of the dual systems model appear to hold across cultures, in that risk taking is associated with higher reward seeking and lower self-regulation, there are cultural differences in the ways these factors operate. When countries are compared by region (Asian vs. Western), the effect of self-regulation

Table 6
Follow-Up Regression Analyses Examining the Differential Effect of Self-Regulation on Risk Taking in Asian Versus Western Countries

Model	Variable	Asian countries B	SE (B)	Standard β	Adjusted R^2	Western countries B	SE (B)	Standard β	Adjusted R^2
1	Gender	.179***	.030	.150	.038	.243***	.028	.191	.056
	SES	.010	.005	.051		.014**	.005	.06	
	IQ	−.001	.002	−.018		−.005**	.002	−.061	
	Age	.014***	.003	.137		.015***	.002	.142	
2	Self-Regulation	.012	.025	.013	.037	−.086***	.024	−.083	.062

Note. Regression results from two separate analyses within individual country clusters. Gender is a dichotomous variable where (0 = female and 1 = male). Self-Regulation reflects a *z*-score composite standardized within Asian and Western country clusters, respectively. IQ = intelligence; SES = socioeconomic status.
** $p < .01$. *** $p < .001$.

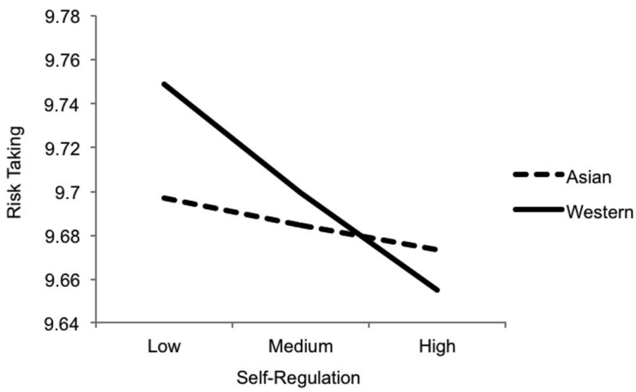

Figure 1. Changes in risk taking as a function of self-regulation between Asian and Western countries. This effect was significant at $p < .01$. Individual regression analyses within the respective country clusters indicated significant slopes for Western ($p < .001$), but not Asian countries. Greater self-regulation was associated with declines in risk taking. Levels of self-regulation along the *x*-axis are based on scores at the 25th (Low), 50th (Medium), and 75th (High) percentiles in the data. Risk taking scores are estimated regression coefficients with a constant value of 10 added to create positive values for the purpose of presentation.

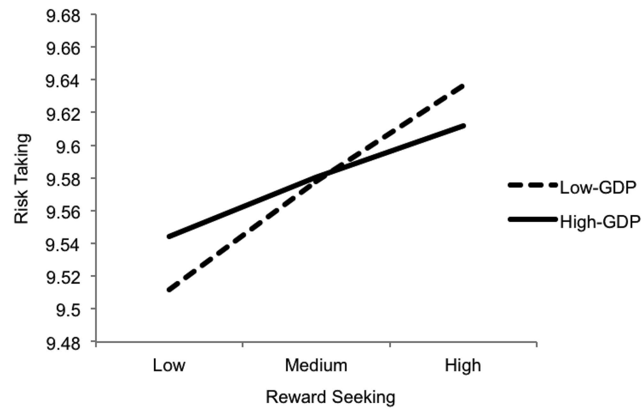

Figure 2. Changes in risk taking as a function of reward seeking between low- and high-GDP countries. This effect was significant at $p < .01$. Individual regression analyses within the respective country clusters indicated significant slopes only for low-GDP ($p < .001$) and high-GDP ($p < .001$) countries. Greater reward seeking was associated with steeper increases in risk taking within high-GDP countries compared with low-GDP countries. Levels of reward seeking along the *x*-axis are based on scores at the 25th (Low), 50th (Medium), and 75th (High) percentiles in the data. Risk taking scores are estimated regression coefficients with a constant value of 10 added to create positive values for the purpose of presentation.

differs. Within Asian countries, only reward seeking predicts risk taking, whereas risk taking does not differ across levels of self-regulation. In contrast, both reward seeking and self-regulation predict risk taking in Western countries. On the other hand, comparing countries by GDP indicates that the effect of reward seeking on risk taking is stronger in poorer countries. Furthermore, stronger self-regulation is not associated with risk taking in low-GDP countries, whereas in high-GDP countries, it is associated with less risk taking, but only among individuals aged 26–30 years.

That reward seeking, but not self regulation, is a consistent predictor of risk taking across the cultures studied here is consonant with the notion that the brain systems governing these phenomena are differentially influenced by biological and environmental mechanisms. In general, studies have found consistent links between pubertal maturation and reward seeking (Blakemore, Burnett, & Dahl, 2010; Urošević et al., 2014). To the extent that puberty is biologically inherent to adolescence and has similar effects on the brain, the inclination to seek rewarding experiences should have similar effects on risky behavior cross-culturally. Our point is not that reward seeking is completely independent of environmental influences; rather, its association with an inherent characteristic of development may account for its robustness as a predictor of risk taking (cf. Chen & Farruggia, 2013). Considering that more advanced pubertal status is also associated with greater risk taking in American samples (e.g., Collado et al., 2014), future research should investigate whether this is also true across cultures, and whether reward seeking mediates the relation between puberty and risk taking around the world.

On the other hand, cultures vary in the extent to which, and the means by which, self-regulation is expressed, which may increase

Table 7
Follow-Up Regression Analyses Examining the Interaction Between Age and Self-Regulation on Risk Taking in Low-GDP Versus High-GDP Countries

		Low-GDP countries				High-GDP countries			
Model	Variable	B	*SE* (B)	Standard β	Adjusted R^2	B	*SE* (B)	Standard β	Adjusted R^2
1	Gender	.28***	.028	.231	.062	.184***	.025	.149	.060
	SES	−.007	.006	−.031		.019***	.004	.089	
	IQ	.004*	.002	.055		−.003	.002	−.037	
	Age	.006**	.002	.063		.020***	.002	.193	
2	Reward	.172***	.020	.195	.101	.095***	.017	.111	.072
	Self Regulation	−.042	.024	−.042		−.021	.021	−.021	
3	Age × Regulation	.001	.004	.014	.101	−.012***	.003	−.217	.077

Note. Regression results from two separate analyses within individual country clusters. Gender is a dichotomous variable where (0 = female and 1 = male). Reward and Self-Regulation reflect *z*-scores composite standardized within Low- and High-GDP country clusters, respectively. IQ = intelligence; SES = socioeconomic status.
* $p < .05$. ** $p < .01$. *** $p < .001$.

variability in the way it is related to other behaviors. Additionally, the development of self-regulation is hypothesized to be more susceptible to environmental influence relative to reward seeking (Smith, Chein, & Steinberg, 2013). The varying role of self-regulation as an influence of adolescent behavior may be due, for example, to the protracted development of the prefrontal cortex, which arguably leaves the development of self-regulatory behaviors susceptible to environmental influences, such as cultural expectations or opportunities affecting the development of self control, for a greater period of time.

The independent effects of reward seeking and self-regulation on risk taking in Western countries observed in the present study are largely consistent with the current literature, which has focused on American samples (e.g., Donohew et al., 2000; Shulman & Cauffman, 2014). Western countries typically view adolescence as a time for self-exploration, and behaviors such as novelty seeking are tolerated and considered normative (Palladino, 1996). Expectations for self-control are less rigid in Western societies (Chen et al., 2005), making it unlikely that variations in self-regulation will have a clear and predictable moderating influence on reward seeking. Thus, while self-regulation is predictive of less risk taking among Western youth, the inconsistency with which it is expected in Western societies may dampen its influence on the effect of reward seeking. Conversely, there is strong emphasis on self-control and discipline in Asian countries (Chaudhary & Sharma, 2012; Chen, Cen, Li, & He, 2005; Weisz et al., 1995). This consistency in expectations for self-regulation may create a context in which the direct impact of self-regulation on risk taking is hard to discern, but where reward seeking may be a more reliable predictor of risk taking because it is more variable than self-regulation. In other words, the moderating impact of self-regulation on reward seeking may be easier to detect within a country in which demands for self-regulation, and the cultural value of this trait, are more reliable and potent.

Considering the dearth of empirical examinations of the dual systems model in poor versus wealthy countries, we do not have an obvious explanation for why the effect of reward seeking is stronger in low-GDP countries and the effect of self-regulation is limited to adults ages 26–30 in high-GDP countries. Considering the higher prevalence of crime and limited access to resources in low-GDP countries, reward seeking may be associated with the drive to gain access to these resources, which may oftentimes involve taking risks (van Wilsem, 2004). On the other hand, in high-GDP countries, opportunities for prosperity are comparatively abundant and may motivate individuals to invest in future success by restraining impulses in favor of future goals (Pampel, 2007). Considering that self-regulatory processes do not mature until the mid-20s, it may be that the effect of self-regulation on risk taking is not evident until early adulthood; perhaps for younger individuals, factors such as opportunity play a larger role in risk taking. We note, however, that these differences between predictors of risk taking in poor and affluent countries are substantively small.

Most accounts of risky behavior primarily attribute risk taking to poor self-control. The results of this study suggest this view might be reconsidered. As Duckworth and Steinberg (2015) have pointed out, what often looks like poor self control may actually be perfectly adequate self control that is unable to rein in especially strong desires for reward. For example, when a child who is given the famous Marshmallow Test (Mischel, 2014) opts for the immediate reward of one marshmallow rather than waiting for two of them, it is impossible to determine whether the child's choice is driven by poor self control (the usual explanation), a very strong desire for marshmallows, or both (Steinberg & Chein, 2015). Our results indicate that variations in individuals' sensitivity to rewards may be more important for understanding their proclivity to take risks than variations in their capacity for self-regulation. At the very least, the results suggest that both influences on risk-taking ought to be assessed to better understand why some individuals are more likely than others to behave recklessly.

Ultimately, our hypothesis that the effect of reward seeking on risk taking would vary across levels of self-regulation was not confirmed. This may be evidence that functional coupling between reward processing and cognitive control brain systems may not be reliably manifested in observable behavior. Alternatively, it is possible we did not find evidence for an interaction between reward seeking and self-regulation because we measured each at a single time point. Future research would benefit from an examination of *changes* in the development of reward seeking and self-regulation (e.g., Harden & Tucker-Drob, 2011; Quinn & Harden, 2013) and how the interaction between the development of these two systems is related to risk taking.

The present study makes two unique contributions to the literature on adolescent risk taking: first, an examination of both the additive and interactive effects of reward seeking and self-regulation on risk taking across a wide range of age groups; much of the dual systems research focuses on the development of reward seeking and self-regulation, but few studies have examined their role in predicting risk taking. Second, this study is one of the first to examine these relations in a cross-cultural sample. Although our interpretation of the cultural differences observed in this study is speculative, our findings provide preliminary evidence that the relation between reward seeking, self-regulation, and risk taking varies slightly across cultures. Future studies might examine which cultural factors contribute to these differences.

This study also has a number of limitations that warrant caution when interpreting the results. Although the cross-sectional sample allows us to examine the effects of reward seeking and self-regulation across different ages, without longitudinal data we are unable to adequately characterize dynamic changes in these systems that occur with maturation and development. Additionally, although we did our best to modify the tasks and self-report measures so that they could be generalized across cultures, it is still possible that behavior and self-report data on these tasks hold different meanings in different contexts. Our use of laboratory-based measures mitigates this problem somewhat, as the use of computer games by youth is common across the globe. Granted, reliance on such measures raises questions about the generalizability of the results to real-world situations. Finally, one important factor that we did not directly examine is emotional arousal. One possible reason we did not see age differences in the relations between reward seeking, self-regulation, and risk taking is that age differences in risk taking are often only apparent under situations of high arousal (cf. Figner et al., 2009). Thus, the findings of the present study may only be informative regarding risky behavior under "cold" conditions.

Although the dual systems model was developed to explain adolescent risk behavior, it appears that risk taking at all ages is influenced in a similar fashion by high reward seeking and poor self-regulation. Although there were a few departures from the general pattern, the absence of consistent interactions between age and the two predictors of risk taking is striking. Thus, the dual systems model may be not only a useful approach for studying developmental differences in risky behavior, but may also be a helpful framework for understanding individual differences in risk taking at other ages, and across widely disparate cultural contexts.

References

Albert, D., & Steinberg, L. (2011). Age differences in strategic planning as indexed by the tower of London. *Child Development, 82,* 1501–1517. http://dx.doi.org/10.1111/j.1467-8624.2011.01613.x

Asparouhov, T., & Muthén, B. (2014). Multiple-group factor analysis alignment. *Structural Equation Modeling, 21,* 495–508. http://dx.doi.org/10.1080/10705511.2014.919210

Banich, M. T., Crowley, T. J., Thompson, L. L., Jacobson, B. L., Liu, X., Raymond, K. M., & Claus, E. D. (2007). Brain activation during the Stroop task in adolescents with severe substance and conduct problems: A pilot study. *Drug and Alcohol Dependence, 90,* 175–182. http://dx.doi.org/10.1016/j.drugalcdep.2007.03.009

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition, 50,* 7–15. http://dx.doi.org/10.1016/0010-0277(94)90018-3

Benthin, A., Slovic, P., & Severson, H. (1993). A psychometric study of adolescent risk perception. *Journal of Adolescence, 16,* 153–168. http://dx.doi.org/10.1006/jado.1993.1014

Blakemore, S. J., Burnett, S., & Dahl, R. E. (2010). The role of puberty in the developing adolescent brain. *Human Brain Mapping, 31,* 926–933. http://dx.doi.org/10.1002/hbm.21052

Casey, B. J., Getz, S., & Galvan, A. (2008). The adolescent brain. *Developmental Review, 28,* 62–77. http://dx.doi.org/10.1016/j.dr.2007.08.003

Casey, B. J., Jones, R. M., & Hare, T. A. (2008). The adolescent brain. *Annals of the New York Academy of Sciences, 1124,* 111–126. http://dx.doi.org/10.1196/annals.1440.010

Castellanos-Ryan, N., Parent, S., Vitaro, F., Tremblay, R. E., & Séguin, J. R. (2013). Pubertal development, personality, and substance use: A 10-year longitudinal study from childhood to adolescence. *Journal of Abnormal Psychology, 122,* 782–796. http://dx.doi.org/10.1037/a0033133

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. http://dx.doi.org/10.1037/a0016128

Chaudhary, N., & Sharma, N. (2012). India. In J. J. Arnett (Ed.), *Adolescent psychology around the world* (pp. 103–118). New York, NY: Psychology Press.

Chen, C. S., & Farruggia, S. (2013). Culture and adolescent development. *Online Readings in Psychology and Culture*. Advance online publication. http://dx.doi.org/10.9707/2307-0919.1113

Chen, X., Cen, G., Li, D., & He, Y. (2005). Social functioning and adjustment in Chinese children: The imprint of historical time. *Child Development, 76,* 182–195.

Collado, A., Felton, J. W., MacPherson, L., & Lejuez, C. W. (2014). Longitudinal trajectories of sensation seeking, risk taking propensity, and impulsivity across early to middle adolescence. *Addictive Behaviors, 39,* 1580–1588. http://dx.doi.org/10.1016/j.addbeh.2014.01.024

Cyders, M. A., Flory, K., Rainer, S., & Smith, G. T. (2009). The role of personality dispositions to risky behavior in predicting first-year college drinking. *Addiction, 104,* 193–202. http://dx.doi.org/10.1111/j.1360-0443.2008.02434.x

Derefinko, K. J., Peters, J. R., Eisenlohr-Moul, T. A., Walsh, E. C., Adams, Z. W., & Lynam, D. R. (2014). Relations between trait impulsivity, behavioral impulsivity, physiological arousal, and risky sexual behavior among young men. *Archives of Sexual Behavior, 43,* 1149–1158. http://dx.doi.org/10.1007/s10508-014-0327-x

Donohew, L., Zimmerman, R., Cupp, P. S., Novak, S., Colon, S., & Abell, R. (2000). Sensation seeking, impulsive decision-making and risky sex: Implications for risk-taking and design of interventions. *Personality and Individual Differences, 28,* 1079–1091. http://dx.doi.org/10.1016/S0191-8869(99)00158-0

Duckworth, A., & Steinberg, L. (2015). Unpacking self-control. *Child Development Perspectives, 9,* 32–37. http://dx.doi.org/10.1111/cdep.12107

Erkut, S. (2010). Developing multiple language versions of instruments for intercultural research. *Child Development Perspectives, 4,* 19–24. http://dx.doi.org/10.1111/j.1750-8606.2009.00111.x

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. http://dx.doi.org/10.1037/a0014983

Galvan, A., Hare, T. A., Parra, 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. http://dx.doi.org/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. http://dx.doi.org/10.1037/0012-1649.41.4.625

Hall, G. S. (1904). *Adolescence: Its psychology and its relation to physiology, anthropology, sociology, sex, crime, religion, and education: Vol. I. II*. Englewood Cliffs, NJ: Prentice Hall.

Harden, K. P., Quinn, P. D., & Tucker-Drob, E. M. (2012). Genetically influenced change in sensation seeking drives the rise of delinquent behavior during adolescence. *Developmental Science, 15,* 150–163. http://dx.doi.org/10.1111/j.1467-7687.2011.01115.x

Harden, K. P., & Tucker-Drob, E. M. (2011). Individual differences in the development of sensation seeking and impulsivity during adolescence: Further evidence for a dual systems model. *Developmental Psychology, 47,* 739–746. http://dx.doi.org/10.1037/a0023279

Huizinga, M., Dolan, C. V., & van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia, 44,* 2017–2036. http://dx.doi.org/10.1016/j.neuropsychologia.2006.01.010

Lansford, J. E., Sharma, C., Malone, P. S., Woodlief, D., Dodge, K. A., Oburu, P., . . . Di Giunta, L. (2014). Corporal punishment, maternal warmth, and child adjustment: A longitudinal study in eight countries. *Journal of Clinical Child and Adolescent Psychology, 43,* 670–685. http://dx.doi.org/10.1080/15374416.2014.893518

Lauriola, M., Panno, A., Levin, I. P., & Lejuez, C. W. (2014). Individual differences in risky decision making: A meta-analysis of sensation seeking and impulsivity with the Balloon Analogue Risk Task. *Journal of Behavioral Decision Making, 27,* 20–36. http://dx.doi.org/10.1002/bdm.1784

Lejuez, C. W., Read, J. P., Kahler, C. W., Richards, J. B., Ramsey, S. E., Stuart, G. L., . . . Brown, R. A. (2002). Evaluation of a behavioral measure of risk taking: The Balloon Analogue Risk Task (BART). *Journal of Experimental Psychology: Applied, 8,* 75–84. http://dx.doi.org/10.1037/1076-898X.8.2.75

Luciana, M., & Collins, P. F. (2012). Incentive motivation, cognitive control, and the adolescent brain: Is it time for a paradigm shift? *Child Development Perspectives, 6,* 392–399.

Luna, B., Garver, K. E., Urban, T. A., Lazar, N. A., & Sweeney, J. A. (2004). Maturation of cognitive processes from late childhood to adulthood. *Child Development, 75,* 1357–1372. http://dx.doi.org/10.1111/j.1467-8624.2004.00745.x

Mauseth, K. B., Skalisky, J., Clark, N. E., & Kaffer, R. (2016). Substance use in Muslim culture: Social and generational changes in acceptance and practice in Jordan. *Journal of Religion and Health, 55,* 1312–1325.

Maxwell, J. A. (1996). *Qualitative research design: An interactive approach*. New York, NY: Sage.

Mills, K. L., Goddings, A. L., Clasen, L. S., Giedd, J. N., & Blakemore, S. J. (2014). The developmental mismatch in structural brain maturation during adolescence. *Developmental Neuroscience, 36,* 147–160. http://dx.doi.org/10.1159/000362328

Mischel, W. (2014). *The Marshmallow Test: Mastering self-control*. New York, NY: Little, Brown, and Company.

Muthén, B., & Asparouhov, T. (2013). *New methods for the study of measurement invariance with many groups* (Mplus Tech. Rep. No.). Retrieved from http://www.statmodel.com

Palladino, G. (1996). *Teenagers: An American history*. New York, NY: Basic Books.

Pampel, F. (2007). National income, inequality and global patterns of cigarette use. *Social Forces, 86,* 445–466. http://dx.doi.org/10.1093/sf/86.2.445

Peters, E., & Slovic, P. (2000). The springs of action: Affective and analytical information processing in choice. *Personality and Social Psychology Bulletin, 26,* 1465–1475. http://dx.doi.org/10.1177/01461672002612002

Psychological Corporation. (1999). *Wechsler abbreviated scale of intelligence*. San Antonio, TX: Pearson.

Quinn, P. D., & Harden, K. P. (2013). Differential changes in impulsivity and sensation seeking and the escalation of substance use from adolescence to early adulthood. *Development and Psychopathology, 25,* 223–239. http://dx.doi.org/10.1017/S0954579412000284

Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences, 298,* 199–209. http://dx.doi.org/10.1098/rstb.1982.0082

Shulman, E. P., & Cauffman, E. (2014). Deciding in the dark: Age differences in intuitive risk judgment. *Developmental Psychology, 50,* 167–177. http://dx.doi.org/10.1037/a0032778

Shulman, E. P., Smith, A. R., Silva, K., Icenogle, G., Duell, N., Chein, J., & Steinberg, L. (2016). The dual systems model: Review, reappraisal, and reaffirmation. *Developmental Cognitive Neuroscience, 17,* 103–117. http://dx.doi.org/10.1016/j.dcn.2015.12.010

Smith, A. R., Chein, J., & Steinberg, L. (2013). Impact of socio-emotional context, brain development, and pubertal maturation on adolescent risk-taking. *Hormones and Behavior, 64,* 323–332. http://dx.doi.org/10.1016/j.yhbeh.2013.03.006

Somerville, L. H., & Casey, B. J. (2010). Developmental neurobiology of cognitive control and motivational systems. *Current Opinion in Neurobiology, 20,* 236–241. http://dx.doi.org/10.1016/j.conb.2010.01.006

Spear, L. P. (2013). Adolescent neurodevelopment. *Journal of Adolescent Health, 52*(Suppl. 2), S7–S13. http://dx.doi.org/10.1016/j.jadohealth.2012.05.006

Steinberg, L. (2008). A social neuroscience perspective on adolescent risk-taking. *Developmental Review, 28,* 78–106. http://dx.doi.org/10.1016/j.dr.2007.08.002

Steinberg, L. (2014). *Age of opportunity: Lessons from the new science of adolescence*. New York, NY: Houghton Mifflin Harcourt.

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. http://dx.doi.org/10.1037/a0012955

Steinberg, L., & Chein, J. M. (2015). Multiple accounts of adolescent impulsivity. *Proceedings of the National Academy of Sciences of the United States of America, 112,* 8807–8808. http://dx.doi.org/10.1073/pnas.1509732112

Steinberg, L., Graham, S., O'Brien, L., Woolard, J., Cauffman, E., & Banich, M. (2009). Age differences in future orientation and delay discounting. *Child Development, 80,* 28–44. http://dx.doi.org/10.1111/j.1467-8624.2008.01244.x

Urošević, S., Collins, P., Muetzel, R., Lim, K. O., & Luciana, M. (2014). Pubertal status associations with reward and threat sensitivities and subcortical brain volumes during adolescence. *Brain and Cognition, 89,* 15–26. http://dx.doi.org/10.1016/j.bandc.2014.01.007

van Duijvenvoorde, A. C. K., Achterberg, M., Braams, B. R., Peters, S., & Crone, E. A. (2016). Testing a dual-systems model of adolescent brain development using resting-state connectivity analyses. *NeuroImage, 124,* 409–420. http://dx.doi.org/10.1016/j.neuroimage.2015.04.069

van Wilsem, J. (2004). Criminal victimization in cross-national perspective: An analysis of rates of theft, violence, and vandalism across 27 countries. *European Journal of Criminology, 1,* 89–109. http://dx.doi.org/10.1177/1477370804038708

Weisz, J. R., Suwanlert, S., Chaiyasit, W., Weiss, B., Achenbach, T. M., & Eastman, K. L. (1993). Behavioral and emotional problems among Thai and American adolescents: Parent reports for ages 12–16. *Journal of Abnormal Psychology, 102,* 395–403. http://dx.doi.org/10.1037/0021-843X.102.3.395

World Health Organization. (2004). Young people's health in context. Health behavior in school-aged children (HBSC) study: International report from the 2001/2002 survey. In C. Currie, C. Roberts, A. Morgan, R. Smith, W. Settertobulte, O. Samdal, & V. Barnekow Rasmussen (Eds.), *Health policy for children and adolescents, 4*. Copenhagen, Denmark: WHO Regional Office for Europe.

Zuckerman, M., Eysenck, S., & Eysenck, H. J. (1978). Sensation seeking in England and America: Cross-cultural, age, and sex comparisons. *Journal of Consulting and Clinical Psychology, 46,* 139–149. http://dx.doi.org/10.1037/0022-006X.46.1.139

Received September 22, 2015
Revision received February 29, 2016
Accepted April 24, 2016 ■