The Development of Reward Sensitivity- Exploring the Role of Culture and Parental Education on Adolescent Development

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Dedication

This paper is dedicated to my parents, grandparents, sister, and brother-in-law. Without your constant encouragement, hugs and meals, there is no way that I could have enjoyed or achieved so much in these past two years.

Ali, your 2 a.m. phone calls, flying kisses and ‘good luck’ messages make my life 100 times more meaningful!

Abstract

The period of adolescence is marked by increased levels of risk taking. One proposed reason for this developmental pattern is a rise during adolescence (relative to earlier and later periods) in the degree to which behaviors are driven by reward-seeking. However, there are individual differences in the extent to which adolescents respond to rewards. One individual difference may arise from the socioeconomic context in which youth develop. Life-history (LH) theory suggests that exposure to early childhood adversity (e.g., more typical in lower SES circumstances) unconsciously predisposes individuals toward decisions that favor instant gratification. Given that reward-seeking may increase during adolescence and early adversity may promote greater risk-taking in pursuit of reward, the present study tested whether individuals exposed to early adversity displayed heightened sensitivity to rewards during adolescence. Reward-seeking behaviors were assessed using measures of sensation-seeking, a psychological manifestation of reward-sensitivity. Participants (*N*= 4620) aged 10-25 from 11 diverse countries (China, Italy, Kenya, Thailand, Colombia, Jordan, Sweden, US, Philippines, India and Cyprus) completed a self-report (a subset of the Sensation-Seeking Scale) and a behavioral measure of reward sensitivity (Stoplight task). Reward sensitivity followed the expected inverted-U age trend across the full sample for both measures. A country by country analysis revealed that risky driving in the Stoplight task followed the expected age-pattern in 4 out of the 11 countries (peaking at age 16), and in 3 out of the 11 countries for self-reported sensation seeking (peaking around age 18). However, age trends did not differ as a function of SES across the full sample or within countries. Overall, these results indicate that although there is variability in how reward-sensitivity develops across cultures, one's socioeconomic status does not appear to influence this development worldwide.

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Introduction

The period of adolescence is marked by increases in risk-taking and sensation seeking (Braams, van Duijvenvoorde, Peper, & Crone, 2015; Dahl, 2004; Defoe, Dubas, Figner, & van Aken, 2015). As defined by Dahl (2001), adolescence is a transitional period that begins with the onset of puberty and ends with the attainment of relative self-sufficiency. Although adolescents are physically and cognitively stronger than children, many risky behaviors may emerge and peak (Arnett, 1992; Boyer, 2006, Patrick, Terry-McElrath, Kloska, & Schulenberg, 2016) during adolescence (e.g., 13-18) and early adulthood (e.g., ages 19-24; Dahl, 2004; Eaton et al., 2007; Reyna & Farley, 2006), often leading to self-inflicted and avoidable causes of injury and death. For example, an international 2012 data collection revealed that road injury, HIV and suicide were the top three global causes of death among adolescents (World Health Organization, 2012).

Several theories (e.g., Britain, Reyna, & Estrada, 2008; Ellis, Del Giudice, Dishion et al., 2012; Steinberg, 2008) have been proposed to explain the apparent predisposition of adolescents to engage in risky behaviors (see Boyer, 2006 for a review). For instance, some scholars suggest that risk-taking is a normative aspect of development as it is driven by neural changes in the brain's reward circuity during adolescence (Romer, Reyna, & Satterthwaite, 2017; Steinberg, 2010). To explain individual differences in risk-taking behaviors, life history theory suggests that risk-taking has evolved to help individuals exposed to early adversity obtain resources necessary for their survival and reproduction (Ellis et al., 2012). Considering that both heightened reward-sensitivity and adversity may incline greater risk-taking, the present study examined whether individuals exposed to childhood adversity would display heightened reward-sensitivity during adolescence across and within 11 diverse countries.

The Development of Reward-Sensitivity

One prominent theory explaining adolescents' heightened vulnerability to risk-taking is the dual-systems model (Steinberg, 2010). According to this model, risky behaviors during adolescence are a result of the developmental lag between two neurobiological systems: the ‘socioemotional' system and the ‘cognitive control' system (Steinberg, 2008). The socio-emotional system, which is involved in the selection, anticipation and recognition of awards (Ernst, Nelson, McClure, Monk, Munsor et al., 2004), is composed of limbic and paralimbic regions, including the ventral striatum, nucleus accumbens, and orbital frontal cortex, etc. According to this model, the socio-emotional system matures throughout early-adolescence and peaks around age 16, before beginning its decline as the individual transitions into adulthood (Steinberg, 2008; Steinberg, Albert, Cauffman, Banich et al., 2008). The cognitive control system is responsible for higher-order cognitive skills such as emotion regulation, response-inhibition, etc. and includes the lateral prefrontal cortex, the parietal cortices, and the anterior cingulate cortex (Steinberg et al., 2008). Unlike the socioemotional system, which is hypersensitive during mid-adolescence, the cognitive control system matures gradually with age (Steinberg et al., 2008). The basic dynamics of this model are illustrated in Fig. 1 (Steinberg, 2013).

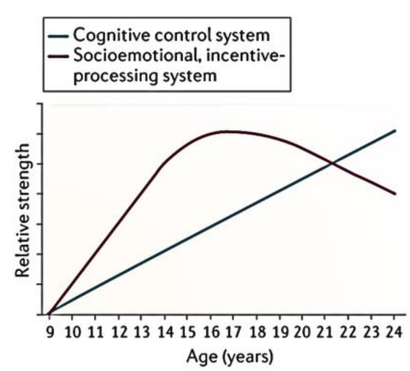


Figure 1. Steinberg's (2013) dual-systems model illustrating the development of the socio-emotional and the cognitive control system during adolescence.

Consistent with this model's proposition regarding the development of the socio-emotional system, dopaminergic activity rises in the midbrain dopamine pathway during puberty (Wahlstrom, Collins, White, & Luciana, 2010) and declines as the brain transitions into adulthood. In the brain, dopamine functions as a neurotransmitter and plays a key role in reward-motivated behavior. Therefore, the rapid increase of the dopamine receptors within the brain's reward circuity during adolescence presumably inclines adolescents to become aroused in the presence of rewards before they have developed sufficient self-regulation (Steinberg, 2008; Steinberg et al., 2008).

To investigate age-trends in reward-sensitivity, researchers have examined whether adolescents show greater neural activity in response to rewards than other age groups (e.g., Galvan et al., 2006; van Duijvenvoorde, 2015). For instance, in a longitudinal study conducted in the Netherlands, Braams, van Duijvenvoorde, Anna, Peper, and Crone (2015) tested participants between the ages of 8-27 to examine age-related changes in self-reported reward-sensitivity and neural responses in the neucleus accumbens (NAcc; a reward region in the brain) to monetary rewards. As predicted by the dual-systems model, a quadratic pattern (peaking during adolescence) for NAcc activation was found. Furthermore, a positive correlation between NAcc activation and self-reported reward-sensitivity suggested that relative to other ages, adolescents reported and displayed greater sensitivity to rewards. Consistent with this finding, de Macks and colleagues (2011), found greater neural activation in reward-sensitive brain regions (e.g. ventral striatum, nucleus accumbens) of adolescents in the presence of rewards than either children or adults. Furthermore, greater activity in the brain's reward-related neural circuitry in anticipation of monetary rewards was associated with greater likelihood of engagement in risk-taking across all ages (Galvan, Hare, Voss, Glover, & Casey, 2007).

However, not all neurodevelopmental studies show support for the dual-systems model. For example, in a study by Bjork, Smith, Chen and Hommer (2010), adolescents (ages 12-17) and adults (ages 22-42) performed a monetary incentive delay task in which they received signals about potential losses and rewards. Contrary to predictions from the model, adolescents showed lower activation in the NAcc relative to adults when receiving reward-predictive cues and comparable levels of activation in the striatum when receiving the reward. Taken together, these results indicate that regions involved in the brain's reward-circuitry (e.g., NAcc, striatal) may be no more sensitive during adolescence in the presence of rewards than during adulthood.

Although several studies have challenged the dual-systems model (e.g., Bjork et al., 2010), considerable neurodevelopmental research has found support for its predictions. Most interestingly, the research seems to suggest that although adolescents do not consistently show greater striatal activation during *reward anticipation*, they do appear to be more sensitive in the presence of rewards, as seen by their heightened striatal activation during *reward-delivery* (Hoogendam, Kahn, Hillegers, van Buuren, & Vink, 2013; Van Leijenhorst, Zanolie, Van Meel, Westenberg et al., 2010b). Therefore, although adolescents may not be as reward-driven as the dual-systems model proposes under all contexts, behaviors during adolescence may still be more motivated by rewards relative to other ages.

The Role and Rise of Sensation Seeking

One psychological manifestation of reward-sensitivity is sensation seeking (SS), which is defined by Zuckerman (1994) as the willingness to engage in new and stimulating experiences despite potential risks. High sensation seekers generally report and display greater sensitivity to rewards (Crone, Vendel, & var der Molen, 2003) and risk-taking tendencies (Rolison & Scherman, 2002; Rolison & Scherman, 2003) across multiple behaviors such as sexual risk-taking (Donohew et al., 2002) alcohol (Arnett, 1996), cigarette (Zuckerman, Black, & Ball, 1990) and other drug use, and risky driving (Arnett, 1996) both within the laboratory (Chein et al., 2011; Steinberg et al., 2008) and in real-life (Vazsonyi & Ksinan, 2017).

Given that the dual-systems model proposes a peak in sensation-seeking during adolescence, Steinberg and colleagues (2008) examined age-trends in self-report and behavioral measures of SS in a sample of 935 American individuals between the ages of 10 and 30. Participants completed a subset of the 19-item Sensation-Seeking Scale (Zuckerman, 1994) and the Stoplight task, a computerized driving stimulation. The Sensation-Seeking Scale contains items measuring reward- and novelty-seeking behaviors and participants are asked to indicate whether each statement is true of their personality. Consistent with the predictions from the dual-systems model, self-reported sensation-seeking peaked during early-adolescence before beginning its decline. Although this age-trend was apparent for both genders, males reported greater sensation-seeking than females. In the Stoplight task, participants must decide whether to brake at several intersections as they ‘drive’ their car to a radio station. If participants choose to brake, they lose a small amount of time. If participants choose not to brake, they can either save time or collide with another vehicle and lose more time. To encourage risky driving, participants are promised a monetary incentive if they can reach the radio station within a given time frame. In theory, participants with heightened reward-sensitivity should display greater riskier driving as it allows them to reach the station faster to maximize their monetary reward. Consistent with this prediction, self-reported sensation seeking significantly predicted performance in the Stoplight task. Further, self-reported SS and risky driving in the Stoplight task both peaked during mid-adolescence (around age 16) before declining into adulthood for both genders.

According to the dual-systems model, the temporary lag between the development of reward-sensitivity and impulse control inclines adolescents toward greater risk-taking tendencies (Steinberg, 2010). Consistent with the predictions from this model, high sensation seeking and low impulse control both uniquely predict risky behaviors (Arnett, 1996; Boyer, 2006; Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Donohew et al., 2002; Martin et al., 2002; Shulman et al., 2015). However, the developmental trajectory of reward sensitivity more closely resembles and predicts the age-related patterns in risk-taking (Shulman, Harden, Chein, Steinberg, 2005; Steinberg et al., 2008) than the development of impulse control. Therefore, I propose that the rise in adolescents' risk-taking propensities may be primarily driven by their hypersensitivity to rewards than by their lack of impulse control. For instance, given that delinquent behaviors during adolescence frequently involve some form of reward-seeking, Vazsonyi and Ksinan (2017) examined whether the dual-systems model could explain why delinquency often rises during adolescence and then declines thereafter. Approximately 15,000 participants across 11 countries completed self-report measures of sensation seeking and the Normative Deviance Scale – a scale designed to assess a broad spectrum of common deviant acts such as drug use, school misconduct, theft, etc. As predicted by the dual-systems model, reward sensitivity peaked during late-adolescence for both genders. Furthermore, reward sensitivity was associated with deviancy, such that high sensation seekers reported greater deviancy. Consistent with these results, Donohew and colleagues (2000) found that sensation seeking was an important predictor of both sexual activity and substance use (e.g., alcohol, marijuana) among ninth-graders. In a similar study examining risk-taking among college students, Cyders (2009) found that an increase in sensation seeking was positively associated with alcohol use. Taken together, these results suggest that the peak in reward sensitivity may partially account for the rise in risk-taking during adolescence.

Gender Differences in the Development of Sensation Seeking

The peak in sensitivity to rewards during adolescence is assumed to be a result of the neural changes within the brain's reward-regions; therefore, this tendency should develop similarly for both genders. Consistent with this prediction, reward sensitivity appears to increase and peak during adolescence for both males and females (Steinberg, 2010; Vazsonyi & Ksinan, 2017). Although some researchers have found that females display greater sensation seeking in laboratory tasks than males (e.g., Steinberg, 2008), a larger body of research indicates that males often report greater sensation seeking (Cross, Cyrenne, & Brown, 2013) across multiple populations (Zuckerman, Eysench, & Eysenck, 1978). In a longitudinal study using a nationally representative sample of American youth by Harden and Tucker-Drob (2011), age trends in sensation seeking were measured. As predicted by the dual-systems model, sensation seeking increased during early adolescence, peaking around at age 16, and began to decline thereafter; once again, suggesting that this tendency is associated with and follows the developmental course of the subcortical regions that respond to rewarding stimuli. Using the same dataset, Shulman, Harden, Chein and Steinberg (2014a) observed that sensation seeking was overall higher and peaked at a later age for males (ages 18-19) than females (ages 16-17). Similarly, Vazsonyi and Ksinan (2017) found that the increase in reward sensitivity until mid-adolescence was more pronounced for boys and its decrease during late-adolescence was more pronounced for girls; thereby, suggesting that sensitivity to rewards is higher in males and takes longer to stabilize (Vazsonyi & Ksinan, 2017). Overall, these results indicate that although reward sensitivity may be higher in males, its development follows the expected inverted-U pattern that underlies the change in the brain's reward circuitry similarly for both genders.

Overall, males engage in greater risk-taking across several domains (e.g., social, financial) than females (Byrnes, 1999). Several explanations have been proposed to explain males' apparent predisposition to engage in risky behaviors. For example, prior research examining the role of genetics on risk-taking has found that males have higher levels of testosterone, a hormone associated with activation of the bilateral ventral striatum (a reward-sensitive brain region; de Macks et al., 2011), throughout the lifespan, and especially after the onset of puberty. Given that the rise of this gonadal hormone during puberty may increase sensitivity to rewards, males' greater willingness to engage in risks may be explained by their heightened reward-sensitivity, especially during adolescence. In a study using a fruit machine gambling task, Coventry and Hudson (2001) found that arousal level (measured by heart rate) increased for male gamblers regardless of whether they were losing or winning; whereas, it only increased for female gamblers while the players were winning. This data suggest that males might also find risk-taking to be more stimulating than females, regardless of its consequences. However, other studies (e.g., Coventry, 2001) have failed to find any gender differences in arousal levels, suggesting that both males and females may find engagement in risky behaviors to be equally arousing.

According to Harris and Jenkins (2006), another factor that may explain the gender difference in risk-taking tendencies is perceptions of risky behaviors. Compared to males, females perceive a higher probability of negative consequences and lower expectations regarding enjoyment of risky activities such as gambling, smoking and drinking. Further, these perceptions partially explain why females report lower risk-propensity (e.g., engagement in past and likelihood of engaging in future risky behaviors) than males. Evolutionary scholars argue that gender differences in risk-taking perceptions and engagement may stem from selection pressures that allowed our human ancestors to survive and reproduce (Archer, 2009). Higher levels of reward sensitivity may have evolved to predispose males toward risky behaviors required to gain resources for mating, especially in competitive societies with limited resources (Wilson & Daly, 1985). In contrast, lower levels of reward sensitivity may exist in females to create risk-aversion that allows for greater parental investment necessary to ensure survival of their offspring (Campbell, 1999).

Cross-Cultural Evidence for the Dual-Systems Model

The dual-systems model posits that the peak in reward-sensitivity during adolescence is primarily influenced by biological factors such as the onset of puberty and the subsequent dopaminergic changes within the socioemotional system (Steinberg, 2010). Therefore, evidence for age-related trends in reward-sensitivity (e.g., sensation seeking) might be expected to be observed cross-culturally. However, biological development does not occur in a vacuum. Cultural expectations for adolescents may have a larger impact on behavior than the changes taking place in the reward circuitry of adolescents' brain.

Given that societal norms and opportunities vary dramatically across cultures (Steinberg, 2016; Steinberg et al., 2018), there may also be cross-cultural variations in the development of sensation seeking. Within Western cultures, adolescence is regarded as a critical period for discovering self-identity and exploring educational, occupational and other novel opportunities (Dahl, 2001). Moreover, Westernized countries score higher on standardized ratings on dimensions of Indulgence-Restraint, a scale measuring the extent to which a country encourages individuals to pursue and satisfy their hedonic goals (Hofstede, 2012), including goals that allow for exploration of stimulating experiences. In contrast, several researchers have suggested that non-Western countries (e.g., China, India) view adolescence as a preparation phase for adult responsibilities (Steinberg, 2016; Steinberg et al., 2018; Vega, Gil, & Wagner, 2002), which consequently influences adolescent self-perception and behaviors (Markus & Kitayama, 1991). Considering the culture-specific expectations for adolescents, it is plausible that individuals living in Western cultures may exhibit greater reward- and novelty-seeking behaviors, especially during adolescence; whereas, for cultures that have a lower tolerance for adolescents' experimentation in non-normative experiences (e.g., binge drinking, drug use, premarital sex; Vega et al., 2002), the peak of reward sensitivity during adolescence may be less pronounced.

To investigate whether the inverted-U relationship between age and reward sensitivity found within Western cultures (Harden & Tucker-Drob, 2011; Shulman et al., 2014; Steinberg et al., 2008) also appeared globally, Steinberg et al. (2018) assessed sensation seeking in a global study that drew convenience samples of children and adults (aged 10 to 30) in 11 diverse countries: China, Italy, Kenya, Philippines, Thailand, Sweden, US, Colombia, Jordan, India and Cyprus. Sensation seeking was assessed using a subset of the sensation seeking scale (Zucker, 1994) and through performance on the Stoplight task. In an analysis that pooled data from all 11 countries, reward sensitivity for both the self-report and behavioral measure increased during adolescence, peaking around age 19, before gradually declining and stabilizing during early adulthood. However, a country by country analysis revealed that the expected inverted-U age-trend appeared in 7 out of the 11 countries. In addition, the magnitude of this age-trend differed in China, Italy and the Philippines. Relative to other countries, the peak in sensation seeking during adolescence was especially pronounced within China and had a steeper decline within Italy and the Philippines. Thus, except for 4 countries (Sweden, Jordan, Cyprus and Colombia), the development of reward sensitivity, as proposed by the dual-systems model was observed cross-culturally.

Using the same database as Steinberg et al., (2018), Duell et al. (2016) further examined differences in risk-taking propensity and real-world risk-taking (using self-reports of health and antisocial risk taking). Risk-taking propensity was assessed using the Stoplight task and a modified version of Balloon Analogue Risk Taking (BART). As mentioned earlier, participants decide whether they wish to brake at several intersections in the Stoplight task. If participants choose to not-brake, they either save time or collide with another vehicle which results in a greater delay. In the BART, participants decide how much air they wish to 'pump' to inflate a balloon for points without knowing when the balloon might burst. The more inflated a balloon becomes, the more points participants earn (or lose if the balloon bursts). Risk-taking propensity was indicated by risky driving (number of no-brakes) in the Stoplight task and high inflation rates (number of pumps) in the BART. As expected, both risk-taking propensity and real-world risk-taking followed the inverted-U pattern across the age groups. Interestingly, the cross-cultural similarities between the age-patterns in risk-taking propensity was higher than the similarities for real-world risk taking. Therefore, the authors concluded that although cultural contexts may influence how the tendency to engage in risk-taking is expressed outside the laboratory, adolescents generally report greater risk-taking inclinations relative to other age groups. Taken together, these results suggest that one psychological manifestation of reward-sensitivity (e.g., the peak in sensation seeking during adolescence) appears to be a common, but perhaps not universal characteristic of adolescent development.

Critiques of the Dual-Systems Model

Considerable empirical evidence supports the dual-systems model with regards to the rise and peak of reward-sensitivity (often measured through sensation seeking) during adolescence (Duell et al., 2016; Galvan et al., 2007; Harden & Tucker-Drob, 2011; Shulman et al., 2005; Shulman et al., 2014a; Steinberg et al., 2008; Steinberg et al., 2018, Vazsonyi & Ksinan; 2017). However as mentioned above, this model has been criticized for being overly simplistic given that several studies fail to find developmental patterns that support it (though few, if any find developmental patterns opposite to those predicted by the model; see Shulman et al., 2016 for a review). For example, the dual-systems model posits that adolescents' vulnerability to risk-taking peaks during mid-adolescence (around age 16), when the developmental gap between the socioemotional and the cognitive control system is the greatest (Steinberg, 2010). However, other researchers suggest that late-adolescents and young- adults are more prone to engage in risk-taking relative to other age groups (e.g., Willoughby, Good, Adachi, Hamza, & Tavernier, 2013). For example, both binge drinking (consumption of 5 or more alcoholic drinks) (Patrick, Terry-McElrath, Kloska, & Schulenberg, 2016) and sexual risk-taking (Fergus, Zimmerman, & Caldwell, 2007) peak around age 21. Although these findings appear to be inconsistent with the predictions from this model, Shulman et al. (2016) argue that the dual-systems model proposes that risk-taking *propensity*, rather than real-life risk-taking peaks during mid-adolescence (e.g., age 16). The dual-systems model suggests that risk-taking propensity is primarily influenced by neurobiological changes in the reward-sensitive brain regions (Steinberg, 2010). However, the extent to which this propensity translates into real-world risk taking may depend on situational factors (Duell et al., 2016). Based on this proposition, both reward-sensitivity and risk-taking should peak among mid-adolescents in settings that offer all ages an equal opportunity to engage in risky behaviors. In contrast, actual risk-taking, which is generally influenced by contextual factors should be more prevalent during early-adulthood and among adolescents with greater financial, legal and social opportunities.

Consistent with this argument, Cauffman and colleagues (2010) found a peak in reward-sensitivity using a controlled laboratory task across ages 10-30 during mid- to late adolescence. In a study by Han, Miller and Waldfogel (2010), adolescents (ages 13-14) with mothers who worked night shifts took greater real-world risks such as engaging in substance use (e.g., alcohol and smoking) and delinquent behaviors. These results were mediated by a lack of time participants spent with their mothers and lower parental knowledge about their whereabouts. Similarly, adolescents drove more recklessly when alone or in the presence of peers than when driving with a parent (Simons-Morton et al., 2011). Taken together, these results suggest that real-world risk-taking is predicted more strongly by social factors such as parental supervision, than by age.

In addition to social factors, legal and financial factors also influence real-world risk-taking. In most societies, older adolescents and adults are granted greater behavioral (e.g., moving away from home to college) and financial autonomy (e.g., applying for loans) than mid-adolescents. Further, legal age-limits often prevent adolescents from engaging in adult-activities such as driving, drinking and gambling (Steinberg, 2016). Not surprisingly then, young adults (e.g., ages 20-24), especially those who live separately from their parents, engage in reckless behaviors that require legal access such as smoking, and binge drinking more commonly than adolescents (ages 15-19); whereas risky behaviors with few legal constraints such as unsafe sex, are more frequent among adolescents than young adults (Galambos & Tilton-Weaver, 1998). Overall, these results suggest that although heightened reward-sensitivity may incline mid-adolescents to engage in greater risk-taking, factors such as greater parental supervision and lack of financial resources, legal accessibility and autonomy (Steinberg, 2016), may prevent them from doing so.

Another common critique (Pfeifer & Allen, 2012) of the dual-systems model arises from its suggestion that risk-taking is primarily driven by neurobiological changes within the reward regions of the brain (Steinberg et al., 2008; Steinberg, 2010). By positing that adolescents' heightened sensitivity to rewards arises from biological factors such as the onset of puberty and the increase of dopamine receptors, the model suggests that risk-taking is a normative experience for all adolescents. However, adolescents do differ in the extent to which they take risks, and under which contexts.

Several researchers have argued for the influence of various factors (e.g., personality traits such as behavioral willingness, types of risk such as known versus unknown; Reyna & Farley, 2006) on risk-taking propensity (see Romer, Reyna, & Satterthwaite, 2017 for review). One aspect that may be especially influential in the development of sensation seeking is childhood adversity (e.g., low socioeconomic status), as it is a well-recognized factor influencing several developmental outcomes (Ackerman, Kogos, Youngstrom, Schoff, & Izard, 1999; Attar, Guerra, & Tolan, 1994; Dodge, Pettit, & Bates, 1994; Dornbusch et al., 1985; Ellis et al., 2003; Ellis, McFadyen–Ketchum, Dodge, Pettit, & Bates, 1999). Therefore, I wanted to examine whether early adversity would also influence the development of reward sensitivity.

The Influence of Early Environmental Adversity – An Evolutionary Approach

Along with cultural norms and expectations, environmental conditions may also impact biological development and behavior. For instance, extensive research has documented the association between childhood adversity and subsequent socioemotional (Aneshensal & Sucoff, 1996; Attar et al., 1994; Hammen, 1992), cognitive (Ackerman et al., 1999; Dodge et al., 1994) and behavioral (Dodge et al., 1994; Sinclair, Pettit, Harrist, Dodge, & Bates, 1994) outcomes in adolescence and early adulthood. One prominent theory explaining the effect of early environmental conditions on later development is the life-history theory. This theory is based on the evolutionary perspective that argues that risk-taking has evolved because it encourages youth to explore new environments and obtain the resources necessary for survival and successful sexual reproduction (Belsky, Schlomer, & Ellis, 2012; Ellis et al., 2012). Life history theory posits that all organisms have three major functions: bodily functions, growth and reproduction (Ellis, Del Giudice, Dishion, Figueredo, Gray et al., 2012, Hill & Chow, 2002). However, organisms have limited time and energy. Therefore, natural selection favors organisms who invest in the appropriate functions (e.g., quality versus quantity of offspring) based on their early environment (Belsky, Steinberg, & Draper, 1991; Belsky et al., 2012).

Patterns that emerge from these trade-offs form life-strategies, which unconsciously predispose individuals toward psychological and behavioral preferences that are most likely to ensure survival and successful reproduction within their environments. Life-strategies range on continuum from slow to fast. Slower life-strategies are characterized by preferences toward stable bonds, later reproductive behaviors, higher parental investment, and greater emphasis in future investments (e.g., budgeting; Figueredo et al., 2006b). Faster-life strategies are characterized by the opposite, in which preferences are given to fewer investments, a greater number of offspring and short-term, more opportunistic behaviors (e.g., sexual promiscuity; Belsky et al., 2012). Consistent with this theory, a faster life strategy is associated with an earlier pubertal onset, a higher number of sexual partners, risk taking attitudes, gambling tendencies and greater deviant behaviors (Mishra, Templeton, & Meadows, 2017). To determine which life strategies promote survival and reproductive success within a certain environment, organisms have evolved to unconsciously detect two key features of their environment: unpredictability and harshness (Belsky et al., 2012). The presence of these two conditions indicates perceptions of an unreliable and short life, which subsequently inclines individuals toward a faster life-strategy.

Environmental unpredictability refers to the extent that environments change randomly (e.g., frequent residential, cohabitant and school changes; Belsky et al., 2012). According to life history theory, perceptions of unpredictability signals that the future cannot be reliably predicted; therefore, there are fewer benefits for making long-term investments (Ellis et al., 2012). Previous researchers manipulating environmental reliability have found that children's willingness to delay gratification is effected by their earlier experiences (Mahrer, 1956). For instance, Kidd et al., (2013) presented children with a researcher who either fulfilled (reliable) or did not fulfill (unreliable) their promise of bringing new art supplies following an art activity. As predicted by life history theory, the average wait time in the marshmallow task was significantly higher for children presented with the reliable researcher than with the unreliable researcher – suggesting, that even from a young age, children's willingness to wait for a larger reward is impacted by their belief in the reliability of the environment, under which the delayed rewards are promised.

Children living in adverse environments are exposed to several sources of environmental unpredictability. For example, children living below the poverty line are more likely to change residences (Federman, Garner, Short, Cutter, Levine, McGough & McMillen, 1996) neighborhoods, day-care arrangements and schools than children above the poverty line (Kohen, Hertzman, & Wiens, 1998). In addition, these children face greater household chaos (e.g. marital conflict, frequent changes in cohabitants and caregivers) residential crowding (Myers, Baer, & Choi, 1996), fluctuating material resources (e.g. food, medical help; Mayer & Jencks, 1989) and are less likely to have established structure and daily routines within their houses; thereby making low-income households a muddled and psychologically distressing environment (Evans, 2001; Matheny, Wachs, Ludwig, & Phillips, 1995). Furthermore, compared to those in affluent households, residents of low-income households have less social capital (e.g., fewer networking opportunities, lower social support, etc.; House, Umberson, & Landis, 1988), experience less social cohesion (Aneshensal & Sucoff, 1996) and trust among members of their neighborhoods and are less likely to be involved in community or organizational networks (Sampson et al., 1997). This lack of social support may arise from housing and environmental instability such as frequent residential and school changes that disrupt peer, neighbor and teacher relationships. Preschoolers and preadolescents living in low socioeconomic status (SES) neighborhoods are also more likely to be affiliated with deviant peers and have greater instability in their peer relationships (Dodge, Pettit, & Bates, 1994).

As predicted by life history theory, environmental unpredictability during early childhood (e.g., changes in peer relations, school moves, cohabitation, household moves, parental employment changes) is associated with a wide range of behaviors indicative of a faster life-strategy. These include earlier pubertal (Ellis et al., 1999) and sexual onset (Belsky et al., 2012), higher rates of teenage pregnancies (Ellis et al., 2003), poorer health (Brumbach, Figueredo, & Ellis, 2009), lower ability to delay gratification for monetary rewards (Weller & Berkowitz, 1975), greater substance abuse (Cicchetti, Doom, Vanzomeren-Dohm, & Simpson, 2016), and other socially disapproved activities (e.g. school misbehavior, smoking) during adolescence and increased externalizing/criminal behaviors in early adulthood (Dornbusch et al., 1985; Cicchetti et al., 2016). Environmental unpredictability is theorized to bias individuals toward behaviors that favor instant gratification because it suggests that the availability of future rewards cannot be reliably predicted. Although this emphasis on immediate gratification may lead to negative long-term consequences, this strategy may be adaptive when fluctuating environmental conditions make it difficult to reliably predict the future.

Another environmental condition which supposedly places individuals on a faster life-strategy is harshness. Environmental harshness refers to the extent of external factors causing early injury, illness or death (e.g., neighborhood, familial or school violence; Belsky et al., 2012; Ellis et al., 2012). Life history theory posits that environmental harshness increases preferences for behaviors that offer immediate satisfaction because it signals a shorter life expectancy and that future rewards and consequences may never be received. Within most societies, socioeconomic status (SES) is a valuable indicator of environmental harshness as lower SES is commonly related to factors causing morbidity and mortality across all ages (Belsky et al, 2012; Cicchetti et al., 2016). These factors can include harsher and punitive parenting styles (Bradley, Corwyn, McAdoo, & Coll, 2001; Grant et al., 2003; Miller & Davis, 1997), limited caregiver investment (Baker & Stevenson, 1986; Newson & Newson, 1976) and familial violence (Emery & Laumann-Billings, 1998). For example, Felner and colleagues (1995) found that lower parental job positions and education levels were significantly associated with increased parental rejection of adolescents.

Overall, children and adolescents from highly disadvantaged neighborhoods are more likely to be exposed to greater levels of risks, injuries and chaos within their households and environments. For instance, low-income households are less likely to have smoke detectors (Sanger & Stocking 1991; Sharp & Carter, 1992), fire extinguishers, gated staircases and adequate heating during the winter (Children’s Defense Fund, 1995; Gielen et al., 1995). Furthermore, these children are also exposed to greater neighborhood (Gallup, 1993; Sampson, Raudenbush, & Earls, 1997) and school violence and accidents. For instance, children living below the poverty line are at a higher risk of pedestrian accidents due to greater street traffic (Macpherson, Roberts, & Pless, 1998) and illnesses due to chronic lead (Brody et al., 1994), pesticide exposure (Moses, Johnson, Anger, Burse, Horstman, et al., 1993) and poor air quality (Freeman, 1972).

Consistent with life history theory, previous research has demonstrated that low SES during childhood is associated with a variety of costly behaviors that are consistent with faster life-strategies. These include social deviance, earlier sexual onset (Michael, 2016), increased sexual risk-taking (Brumbach et al., 2009), higher alcohol-related risky behaviors (Livingston, 2014) and substance abuse (Kipping, Smith, Heron, Hickman, & Campbell, 2015) during adolescence. In a study comparing 77 community areas within Chicago, Illinois, Wilson and Daly (1997) found that neighborhoods with the shortest life expectancies had the highest birth rates for young women. The authors suggested that exposure to an environment with high mortality rates may have placed these women on a faster life trajectory that emphasized earlier and greater focus on sexual reproduction to ensure that they were successful in passing their genes. These findings, consistent with life history theory, suggest that factors associated with environmental adversity appear to promote a faster life strategy, which in turn facilitate greater risk taking.

Present Study

The dual-systems model suggests that the rise in risk-taking during adolescence is a result of the neurobiological changes within the brain’s reward circuity that inclines adolescents toward reward-driven behaviors. Further, life history theory suggests that exposure to early childhood adversity (more typical in lower SES circumstances) unconsciously inclines individuals toward a faster-life strategy, in which individuals benefit more from risky decisions that favour instant gratification. Given that a heightened sensitivity to rewards might facilitate risk taking, this study examines whether a faster life strategy may be associated with greater risk taking for individuals exposed to early adversity due to an even greater sensitivity to rewards during adolescence. Based on the two empirically-supported theories mentioned above, I propose that childhood adversity would influence the development of reward-sensitivity, such that individuals exposed to early adversity would display heightened sensitivity to rewards, especially during adolescence.

In the present study, I used the two empirically-supported theories mentioned above to test whether the development of reward-sensitivity (measured through self-report sensation seeking and risky driving) differed as a function of SES (indexed by parental education) given that both promote greater risk-taking. To do so, I conducted a secondary data analysis using the same dataset as Steinberg and colleagues (2018) and compared age patterns in reward sensitivity across a cross-cultural sample including both Western and non-Western countries. I predicted that the peak in reward sensitivity during adolescence would be more pronounced for individuals with lower SES overall and within each country (see Fig. 2).

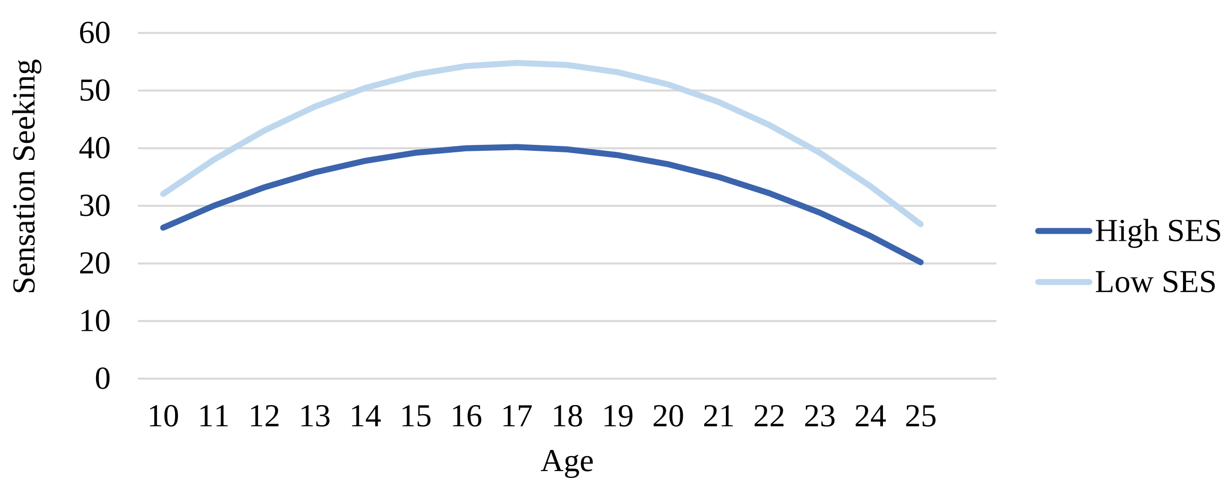


Figure 2. Theorized pattern of results.

Methods

Participants

The sample for the present analyses (*N*= 4619) was comprised of individuals aged 10-25 years old (*M* age =15.5; *SD* = 4.5). Within each country, the age stratification was designed to replicate the age distribution of an American sample that had been previously studied using similar measures (Steinberg et al., 2008). Table 1 portrays the age-distribution within each country for this sample.

Participants were recruited from multiple cities across 11 diverse countries worldwide: Guang-Zhou and Shanghai, China (*n*= 456); Medellin, Colombia (*n*= 447); Nicosia, Cyprus (*n*= 316); Delhi, India (*n*= 357); Naples and Rome, Italy (*n*= 485); Amman and Zarqa, Jordan (*n*= 393); Kisumu, Kenya (*n*= 421); Manila, the Philippines (*n*= 443); Chang Mai, Thailand (*n*= 452); Durham and Winston-Salem, the United States of America (*n*= 493); and several cities within Sweden (*n*= 356). Figure 2b depicts the distribution of participating countries. The sample for the present analyses was evenly split between males (49.6%, *n*= 2271) and females (50.4%, *n*= 2330) overall, across the ages (range: 48.2% - 51.6% male) and approximately within each country (range: 46.1% - 51.1% male; see Fig. 3). Across countries, participants had similar levels of parental education (some college).

Table 1

Age Distribution by Country

Country	10-11	12-13	14-15	16-17	18-21	22-25
China	109	61	60	60	79	60
Italy	185	60	63	58	59	60
Kenya	93	79	68	58	60	61
Philippines	114	64	62	62	72	68
Thailand	131	84	60	44	68	64
Sweden	55	59	60	62	60	60
US	165	62	64	58	75	64
Colombia	143	60	62	59	57	59
Jordan	94	59	60	58	59	63
India	55	59	61	59	61	62
Cyprus	47	55	47	45	65	49

Note: Age was used as a continuous variable in all analyses but is grouped here to save space.

Except in Cyprus and Italy, a majority of 10-11 years old participants were recruited via the ongoing parenting across cultures (PAC) study (Lansford & Bornstein, 2011). In order to ensure a fair participant pool, all remaining participants were recruited from neighborhoods similar to the ones used in the PAC study. The PAC study is a longitudinal study that examines how children are disciplined worldwide. Therefore, the countries selected for these analyses varied along several socio-demographic dimensions, including but not limited to their predominant race and religion, average household income and their international ranking with regards to health and education (see Steinberg, et al., 2018). For example, participating countries ranged from a rank of 10 (United States) to a rank of 146 (Kenya) on the Human Development Index, a composite score of a country's health, income and education status (United Nations Development Programme 2016). In addition to socio-demographic features, the participating countries also varied with respect to cultural factors such as individualism versus collectivism, a construct that likely influences how individuals respond to environmental cues. Although all participating countries had ethnic minority groups, participants did not identify themselves as an ethnic minority except within the United States, where a mix of Black, Latino and Hispanic participants were intentionally recruited. Having this variety in this participant pool granted me the opportunity to explore my research question in a sample that was more ethnically and economically diverse than samples commonly used within studies examining adolescent risk-taking.

Participants were recruited through newspaper ads, neighborhood flyers, schools and word of mouth. Thus, the subsamples are not representative of their respective countries. Also, it is hard to determine whether participants who volunteered for this study differed significantly from individuals who did not respond. All participants 18 and older (and those 15 and older in Sweden, where that is the age for research consent) provided written informed consent. Parental consent and adolescent assent was obtained for all participants younger than 18 (or younger than 15 in Sweden). All procedures were approved by the local Institutional Review Boards.

Procedure

Across all countries, research staff completed identical training procedures. Participants completed a 2-hour session that included multiple computerized tasks and self-report measures, a demographic questionnaire, computerized tests of executive functions and a measure of intellectual ability. The sessions were completed individually by the participant in a location of their choosing (e.g., participant's home, school, community center). To maintain interest in the tasks, participants were told that they would receive a base pay for their participation and could receive a bonus pay (equal to about 50% of the base pay) based on their performance in the computerized tasks. However, all participants received both the base and bonus pay. In the United States, the base pay was $30, and the bonus was $15. In other countries, site coordinators and principle investigators chose an appropriate base and bonus pay, considering the country's local standard of living to ensure that the bonus pay was high enough to maintain engagement in the tasks but not large enough to appear coercive. In a Swedish university that did not allow participants to receive monetary compensations, participants were given 2 movies tickets as a base pay and an additional movie ticket as their bonus. All base and bonus pays were approved by the local IRBs. In countries where the local IRB asked for a disclosure, participants were informed about the deception regarding the bonus pay at the end of the session. Following each session, the interviewer answered 5 questions regarding the participant's engagement in the tasks and the quality of data. Participants that provided data that was unusable (either because the participant could not understand the tasks, did not pay attention to the instructions or appeared highly disengaged) were dropped from the final sample.

All measures were administered in the predominant language at each site and were translated and back-translated to resolve any linguistic or semantic ambiguities. Translators were fluent in both English and the target language. Any items that the translators believed could not be translated, were culturally insensitive or inappropriate were reviewed by the site coordinators and translators and modified or removed accordingly. The same (translated) versions of each measures were used in all the countries and deemed appropriate by the translators of each site. Across the study sites, the 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 in American English (India, Kenya, the Philippines, and the United States).

Measures

The present analyses drew on a subset of the measures collected by Steinberg and colleagues (2018); with an emphasis on those that could serve as indicators of environmental adversity and reward-sensitivity.

Demographic and control variables. Participants reported their age, gender (0: female, 1: male), country of residence and highest level of education obtained by both their parents.

Intellectual ability. The Matrix Reasoning subset of the Wechsler Abbreivated Scale of Intelligence (WASI; Psychological Corporation, 1999) was administered on a laptop. Other subscales, which rely on verbal abilities, were omitted because of the variability in languages used across the sites. Scores from Matrix Reasoning subtest provided an indication of participants' non-verbal intellectual ability. The WASI has been created for individuals aged 6 to 89 years. An age-normed *T*-score was calculated for each participant. Age-normed *T*-scores for this sample ranged from 30-70, with higher scores indicating greater non-verbal intellectual ability.

Consistent with previous research (Ellis & Walsh, 2003; Steinberg et al., 2018), preliminary analyses of this data indicated small but significant age-related differences in intellectual ability in which intellectual ability increased with age. Similarly, previous research (see Byrnes, Miller, & Schafer, 1999 for a full review) suggests that reward sensitivity peaks at a later age, declines more slowly thereafter and is overall higher in males than females (Shulman & Cauffman, 2014). Therefore, participants' intellectual ability scores and gender were controlled in all analyses.

Socioeconomic status (SES). Parental education was used as a proxy for participant's SES. To calculate this variable, participant's highest level of maternal and paternal education was averaged (e.g., highest grade completed from 0 to 12, with some college coded as 13, a college diploma coded as 14, and education beyond college coded as 15). If a participant only provided information about one of their parents, that became their SES score. The parental education average was then standardized within the participant's country at a mean of 0 and a SD of 1. Although SES was used as a continuous variable for all analyses, participants were grouped as low (1 SD below mean), average (mean) or high SES (1 SD above mean) for all graphs based on their standardized SES score. Though an imperfect indicator, parental education is a widely used proxy for SES. SES, in turn, is an indicator (also imperfect) of the participant's childhood home environment and the extent of material and interpersonal investments made by parents toward their children (Sohr-Preston et al, 2013).

Reward-sensitivity. Two measures were used to index reward-sensitivity: scores on 6- items from Zuckerman's (1994) Sensation Seeking Scale (SSS) and risky driving in the Stoplight task (Steinberg et al., 2008).

Self-reported sensation seeking. Self-reported sensation seeking was assessed using a subset of 6 items from the 19-item Sensation Seeking Scale (Zuckerman, 1994). Although the full scale was administered to the participants, like Steinberg and colleagues (2008), the current analyses only used items that clearly relate to sensation-seeking, and not impulsivity. Sample items include: ‘‘I like to have new and exciting experiences and feelings even if they are a little frightening,’’ ‘‘I like doing things just for the thrill of it,’’ ‘‘I sometimes do “crazy” things just for fun,’’ ‘‘I like wild and ‘crazy’ parties,’’ ‘‘I'll try anything once,’’ and ‘‘I sometimes like to do things that are a little frightening.’’ Participants are asked to read each of the statements and decide whether that statement is true of them. All items are answered either as true (1) or false

(0). A 6- item average is calculated for each participant and multiplied by 100 to obtain a percentage, in which a higher percentage indicates a higher level of sensation seeking.

Risky driving. A performance measure of reward sensitivity was obtained using the Stoplight (SL) task, a computerized driving game that measures participants' willingness to pursue rewards and take risks in uncertain contexts (Steinberg et al., 2008). Performance in this task is correlated with self-reported measures of sensation seeking (Steinberg et al., 2008) and real-world adolescent risk-taking such as earlier onset of and greater substance use (Kim-Spoon et al., 2015), but not with impulsivity. In this computerized driving task, participants are asked to 'drive' to a radio station giving out cash to all participants who can get there under 5 minutes. Participants' view point is that of someone behind the wheel, with roadside scenery visible and changing as their car travels down the road. Participants view the timer on the computer screen that is initially set at 5 minutes and can hear the clock ticking down. As their car approaches the radio station, participants can hear the party music getting louder.

Participants are told that that before reaching the radio station, they will come across several intersections marked by traffic signals. When approaching a yellow traffic light, they must decide whether they wish to stop their car (by hitting the spacebar on the keyboard) and wait for the traffic signal to turn from yellow to red to green or to continue driving. Participants are warned that if they choose to continue driving through the yellow signal, the signal may turn red and they might collide with another vehicle. Participants are not allowed to control the speed of their car and can only choose to brake after the signal has turned yellow.

Before starting the game, participants are informed about the possible consequences of their decision (break versus no brake) at each signal:

1) If the participant chooses to break at the yellow signal, their car will stop for 3 seconds while the signal turns from yellow to red to green. After the signal has turned green, the participant can safely cross;
2) If the participant chooses to not to break at the yellow signal and safely crosses the intersection, no time is lost;
3) If the participant chooses to not break at the yellow signal or brakes when their car has come too close to the signal and collides with another car, their car will crash and result in a 6 second delay.

Therefore, participants must decide whether they wish to drive through each of the yellow signals to save time. If participants choose to brake, they have a definite 3-second delay (safe decision). If participants choose to not-brake, they can either have no-delay (successful risk-taking) or a 6-second delay (unsuccessful delay) if they collide with another vehicle. The probability of colliding with an oncoming vehicle is randomized across the signals for each trial so participants cannot predict the consequences of their no-brakes ahead of time. Risky driving in the Stoplight task is defined as the proportion of intersections where participants do not apply their brakes (successful and unsuccessful risk-taking divided by number of total intersections). Proportions are multiplied by a 100 to create a percentage, where a higher percentage indicates riskier driving.

Analytic Plan

All analyses were conducted using Mplus Version 7.31 (Muthén & Muthén, 1998–2010). The full model for all analyses included age, age^2, SES and the interactions between SES and both age and age^2, with intellectual ability and gender included as covariates. Age was centered at its mean of 15 years and intellectual ability was centered at its mean of 50; both were used as continuous variables. Gender was entered as a dichotomous variable.

To test whether the age-related pattern for reward sensitivity differed as a function of SES, I first tested my model across the full sample. Considering that the prime interest of the study was to examine whether SES influenced the development of reward sensitivity *within* each country, I then conducted a multi-group analysis, identifying country as a grouping variable. Using multiple regression analyses, I investigated whether age patterns in reward sensitivity for each of the two measures (self-reported sensation seeking and risky driving) differed as a function of SES (parental education).

First, to examine whether reward sensitivity peaked during mid- to late-adolescence (around age 16) regardless of parental education, I tested for the main effects of age, age^2 and SES. Having age^2 in the model allowed me to test for quadratic age trends (as predicted by the dual-systems model) in reward sensitivity. In addition, I tested for the interactions between SES and both age and age^2 to determine whether age-patterns in reward sensitivity differed based on level of SES. Given that my primary interest was in examining whether reward sensitivity increased and peaked during adolescence, I added age and age^2 simultaneously in my model. In the presence of a significant quadratic age effect, the linear age effect was not interpreted.

Results

Does Reward Sensitivity Differ as a Function of SES Across the Full Sample?

Intercorrelations between the variables included in the model are presented in Table 2. Means and standard deviations for all variables are presented in Table 3.

Table 2

Correlations Among Main Study Variables Across Full Sample

	1	2	3	4	5	6
1. SSS	**---**					
2. Risky Driving	**0.062**	**---**				
3. Age	**0.073**	0.011	**---**			
4. SES	0.024	0.029	**-0.040**	**---**		
5. IQ	0.021	**0.078**	**0.106**	**0.138**	**---**	
6. Gender	**-0.035**	**-0.053**	-0.003	-0.029	-0.074	**---**

Note: SSS = Self-reported sensation seeking; SES = Socioeconomic status; IQ = Intellectual ability; Gender is dichotomous: 0= Female and 1 = Male. Bolded correlation coefficients are significant at $p < .01$.

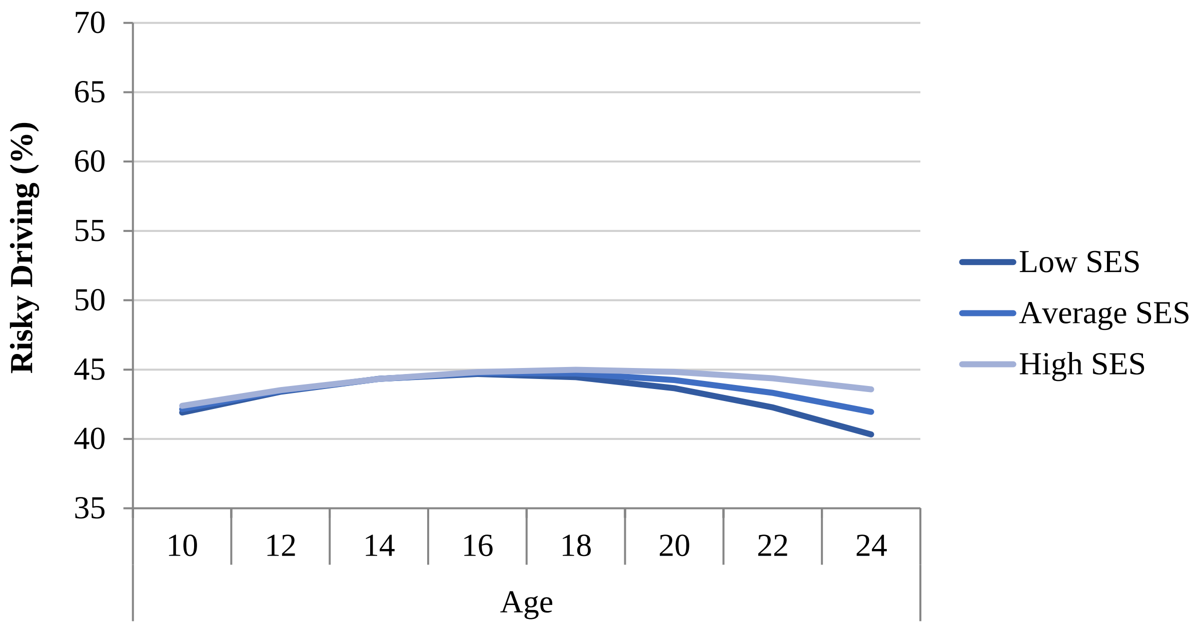
Table 3

Means and Standard Deviations of the Stoplight task, the Sensation Seeking Scale, SES and Intellectual Ability by Age Across Full Sample

Age Group	Stoplight		Sensation Seeking Scale		Parental Education		Intellectual Ability	
	M	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
10-11	0.42	(0.22)	0.56	(0.27)	11.83	(3.00)	50.42	(8.30)
12-13	0.42	(0.21)	0.58	(0.28)	12.07	(2.91)	48.56	(7.70)
14-15	0.44	(0.23)	0.57	(0.30)	12.12	(2.78)	48.35	(7.35)
16-17	0.42	(0.21)	0.62	(0.28)	11.68	(2.88)	48.49	(8.02)
18-21	0.43	(0.23)	0.62	(0.28)	12.01	(2.79)	51.44	(7.32)
22-25	0.42	(0.23)	0.60	(0.28)	11.80	(3.03)	52.50	(8.00)

Note: Parental education was entered as a categorical variable (1-12: highest grade completed, 13: some college, 14: college and 15: beyond college).

Consistent with predictions from the dual-systems model, age patterns in both risky driving and self-reported SS, regardless of SES, followed a curvilinear pattern across the whole sample. Risky driving in the SL task appeared to increase throughout adolescence, peaking around age 18 (b_{age^2}= -0.09, *S.E.* = 0.022, $p < .001$), and then declined into adulthood. Self-reported sensation seeking followed a similar pattern, with a peak occurring around age 19 (b_{age^2}= -0.056, *S. E*= 0.018, $p = .001$). Contrary to predictions from life history theory, age trends for both risky driving (b_{age^2}= 0.016, *S.E*= 0.018, $p > .05$), and self-reported SS (b_{age^2}= -0.039, *S.E.*= 0.022, $p > .05$), did not significantly differ for participants with low or high SES. Figure 3 illustrates the age patterns across the full sample for both measures of reward-sensitivity.



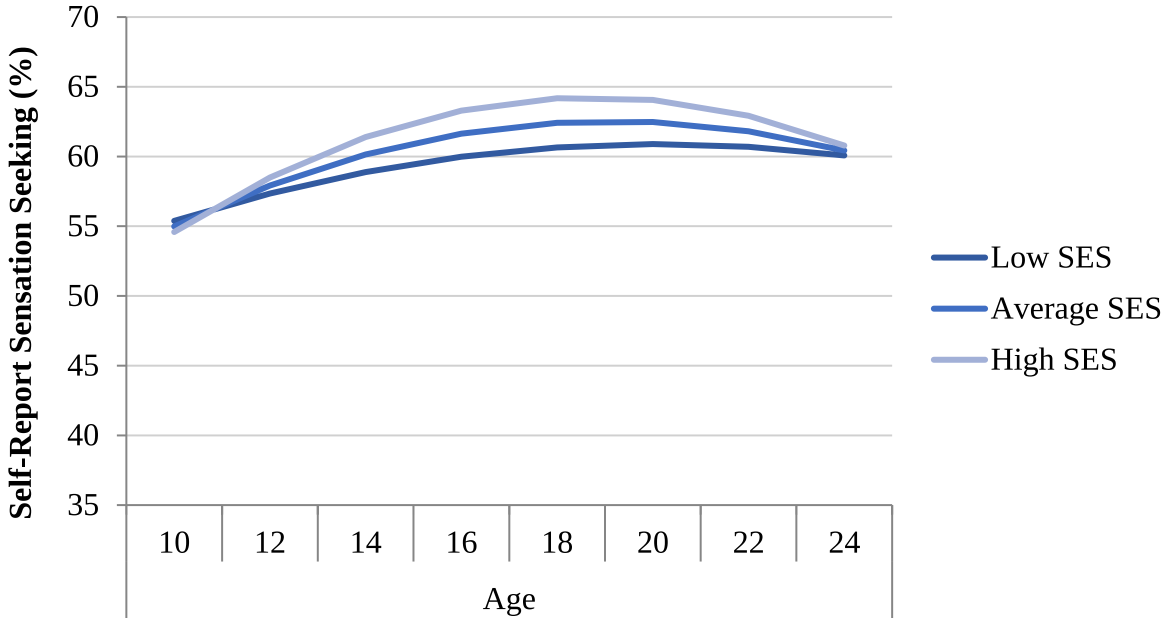


Figure 3. Age patterns of risky driving in the Stoplight task (top) and self-reported sensation-seeking (bottom) by low (1 SD below the mean), average (mean) and high SES (1 SD above the mean) across the full sample. Age trends have been centered at 15 years. Scores for both measures were multiplied by 100. The analysis controlled for IQ and gender.

Does Reward Sensitivity Differ as a Function of SES Similarly Across Countries?

Risky driving. Performance in the Stoplight task was not associated with age in China, Kenya, Thailand, Jordan or India, but risky driving in this task (defined by the percentage of no-brakes) followed a quadratic age-trend for Italy (b_{age^2}= 0.521, *S.E.*= 0.22), Philippines (b_{age^2}= 0.05, *S.E.*= 0.05), Sweden (b_{age^2}= -0.243, *S.E.*= 0.282), USA (b_{age^2}= 0.590, *S.E.*= 0.59) and Cyprus (b_{age^2}= 0.703, *S.E.*= 0.426). Visual checks of these age patterns (see Fig. 4) revealed that as expected, risky driving in Italy, Philippines, Cyprus and the US increased during adolescence, peaking around mid-adolescence (age 16), and then declined. However, risky driving followed the opposite pattern in Sweden in which it decreased until age 16, and then began to rise. Contrary to predictions, the quadratic age-trend for risky driving only differed as a function of SES in Cyprus (b_{age^2}= 0.168, *S.E.*= 0.085). Within Cyprus, the curvilinear relationship between age and performance in the Stoplight task was the most prominent for participants with low SES, with risky driving peaking around age 16 and then declining thereafter.

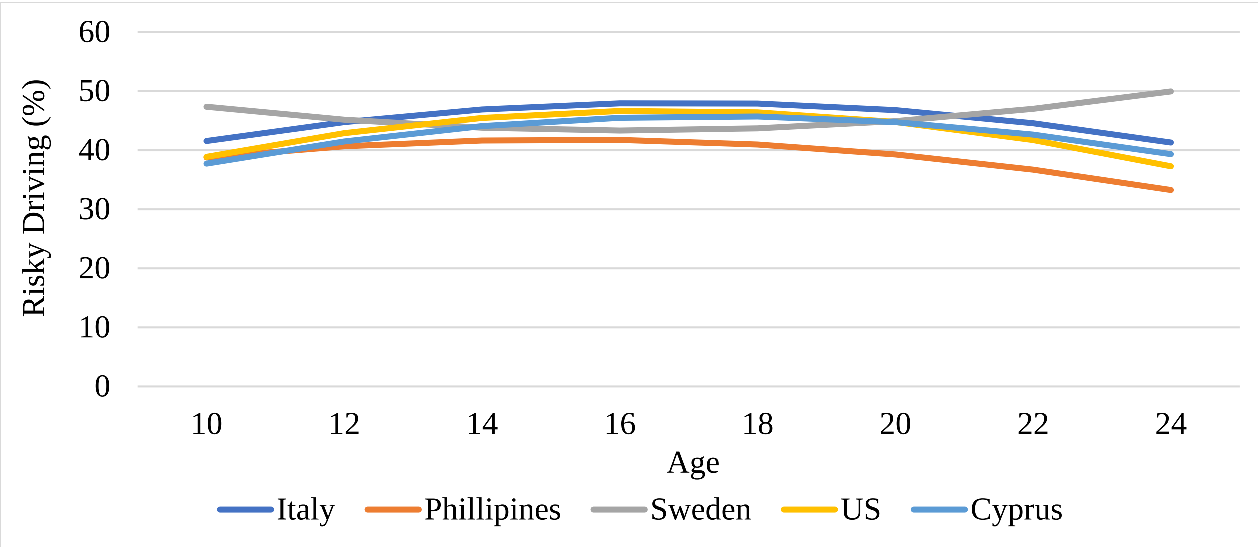


Figure 4. Age differences in risky driving for the Stoplight task (% of no-brakes) by country. Scores were multiplied by 100 and age was centered at age 15. Countries in which there were no significant age-trends are not shown. The analysis controlled for IQ and gender.

Self-reported sensation seeking (SS). Self-reported SS was not associated with age in Sweden, Philippines, US and Cyprus but was linearly related with age in China (b_{age}= 1.732, *S.E*= 0.406), Italy (b_{age} = -1.231, *S.E*= 0.37), Kenya (b_{age} = 1.152, *S.E*= 0.361) and India (b_{age} = 1.542, *S.E*= 0.575). As seen in Figure 6, self-reported SS appeared to increase with age in China, Kenya and India but plateaued around age 20 in India. However, it decreased with age in Italy. As predicted by the dual-systems model, self-reported SS had a curvilinear relationship with age, but only in Thailand (b_{age^2}= 1.484, *S.E*= 0.355), Colombia (b_{age^2}= 1.277, *S.E*= 0.33) and Jordan (b_{age^2}= 1.861, *S.E*= 0.451), with SS peaking around age 18 in all three countries before beginning its decline. Contrary to predictions, except within Cyprus, self-reported SS did not differ as a function of participants' SES. Within Cyprus (b_{age^2}= 0.229, *S.E*= 0.103), participants with low

SES reported lower levels of self-reported SS compared to participants with high SES. However, SS plateaued for both low and high SES groups after age 22.

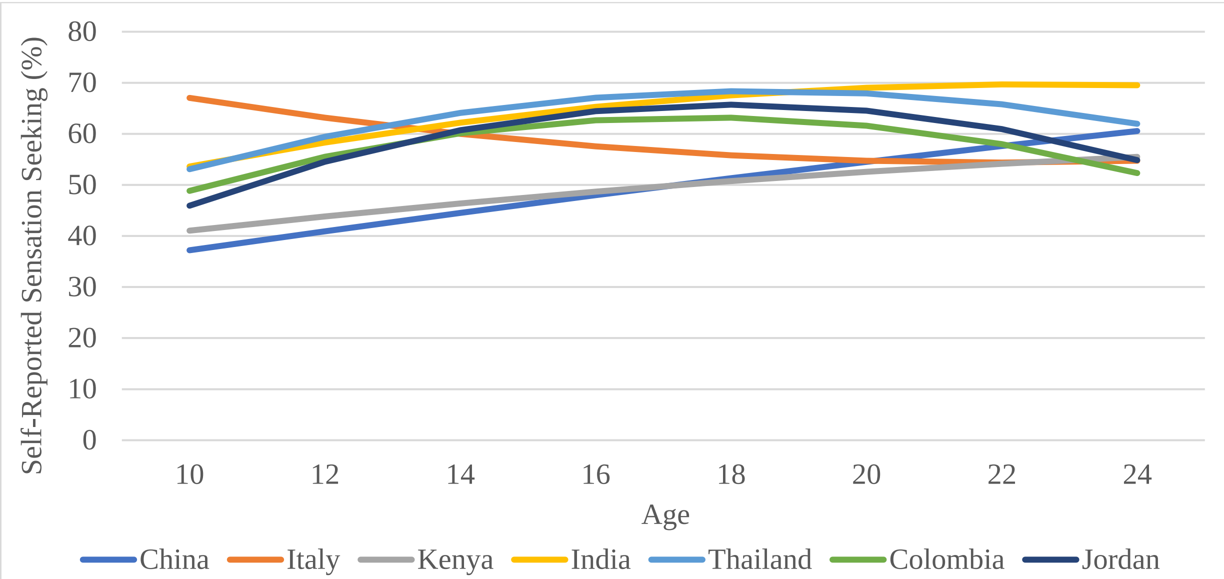


Figure 5. Age differences in self-reported sensation seeking by country. Scores were multiplied by 100 and age was centered at age 15. Countries in which there were no significant age-trends are not shown. The analysis controlled for IQ and gender.

Discussion

Adolescence marks a period of autonomy and exploration across several social contexts, often resulting in reckless and heath-compromising behaviors (Dahl, 2001; Steinberg, 2008, Steinberg, 2017). Previous research suggests that heightened reward-sensitivity during adolescence and exposure to early adversity predisposes individuals to be more risk-prone (e.g., Braam et al., 2015; de Macks et al., 2011; Ellis et al., 2012; Galvan et al., 2007; Romer et al., 2017; Steinberg et al., 2008). However, whether the development of reward-sensitivity is affected by socioeconomic factors remains unclear. To address this question, the present study used self-report and behavioral measures of reward sensitivity to examine whether its development differed as a function of SES (indexed by highest level of parental education) in a sample of eleven ethnically and economically diverse countries around the world. Reward sensitivity followed the expected inverted-U pattern with age in 4 out of the 11 countries for risky driving, and in 3 out of the 11 countries for self-reported sensation seeking. Contrary to predictions from life-history theory, except within Cyprus, age-trends for reward sensitivity did not differ significantly as a function of parental education for both measures. Within Cyprus, participants with lower SES displayed riskier driving but reported lower levels of self-reported sensation seeking.

Age-Trends in Reward-Sensitivity

Consistent with prior research examining age-trends in the development of reward-sensitivity (Braams et al., 2015; Shulman et al., 2016), an inverted-U pattern between age and both measures of reward sensitivity emerged across the full sample. For instance, using the same dataset, Steinberg and colleagues (2018) observed that reward sensitivity (measured through self-reported sensation seeking and performance in the Stoplight and the Iowa Gambling Task) increased with age, peaking at age 19 before declining across the full sample and followed the expected age trend (with differences in magnitude) in 7 out of the 11 countries. In the current study, risky driving in the Stoplight task increased during adolescence, peaking around age 18 before it began to decline; whereas self-reported sensation seeking followed the same pattern, but appeared to peak around age 19. However, a country by country analysis revealed that only 4 (Italy, Philippines, USA and Cyprus) out of the 11 countries followed the expected pattern for risky driving. Similar results were found for self-reported sensation seeking, such that only 3 (China, Kenya and India) out of the 11 countries had a peak in development during adolescence. Further, self-reported sensation seeking appeared to increase with age in China, Kenya and India but decreased with age in Italy, suggesting that adolescent risk-taking may be driven by factors other than their heightened sensitivity to rewards.

This pattern of findings has more than one plausible interpretation. Given that many of the results from the within-country analyses are inconsistent with the predictions from the dual-systems model, one could argue against the validity of this model. Indeed, the findings of several past studies (e.g., Bjork et al., 2004) challenge the notion that adolescents are more reward-driven than adults. This possibility may be especially likely, given the choice of measures used to assess reward sensitivity. For instance, participants in the Stoplight task were unaware of which intersections allowed for successful risk-taking (crossing an intersection without braking or colliding with another vehicle) and were therefore making their decision to brake or not to brake under uncertain contexts. As noted by previous researchers, this form of risk-taking is thought to be especially sensitive to sensation seeking tendencies that encourage exploration of outcomes emerging from different decisions (Romer et al., 2017). Therefore, the failure to find the expected peak in reward sensitivity during mid- to late-adolescence in all countries argues against the universality of the developmental pattern for reward sensitivity postulated by the dual systems model.

However, it is also possible that the Stoplight task failed to capture age trends predicted by the dual-systems model because of the nature of the rewards it offered. In this task, participants are encouraged to reach the radio station within a 5-minute time frame to maximize their monetary rewards. Therefore, the decision to drive riskily is primarily driven by the anticipation of the bonus pay. However, past scholars have noted that adolescents show greater sensitivity to rewards relative to other ages during reward-delivery and in the presence of immediate feedback (Defoe et al., 2015), but not necessarily during reward-anticipation

(Hoogendam et al., 2013). Further, previous research on age-trends in reward sensitivity indicates that adolescents perform comparably to young adults and adults on the Stoplight task when driving alone (Chein et al., 2011; Steinberg & Gardner, 2005). However, only adolescents take significantly more risks in the presence of peers, suggesting that adolescents may be more sensitive than other ages to some (e.g., peer approval), but not all rewards (e.g., monetary). Therefore, a modified version of the Stoplight task in which participants are provided with social rewards instantaneously for their risky decisions might result in age-patterns more consistent with the expected results.

For countries that did not display the expected peak in reward sensitivity during adolescence for the self-report (Sweden, Philippines, US, Cyprus, China, Italy, Kenya and India) or behavioral measure (China, Kenya, Thailand, Jordan, Sweden and India), it is difficult to speculate about a common factor that may have altered the developmental trajectory of reward sensitivity. This is primarily because these countries differ with respect to their cultures, laws, geography, and various other factors that may affect decision-making processes. Despite these cultural differences, only two countries followed developmental patterns that significantly contradict the dual-systems model. Risky driving followed an U-shaped age-trend in Sweden, and self-reported sensation seeking decreased linearly with age in Italy. Given the diversity of this sample, the variations of findings across countries highlight the importance of contextual factors influencing developmental patterns of psychological and cognitive outcomes such as sensitivity to rewards.

The Role of Environmental Adversity

There is a strong link between low socioeconomic status and exposure to early adversity (e.g., harsh parenting styles, residential crowding and changes, fluctuating material resources, neighborhood crime rates, etc.; Evans, 2001; Mayer & Jencks, 1989; Myers et al., 1996). According to life history theory, risk-taking is presumed to indicate faster life strategies, which have evolved to ensure the survival and successful sexual reproduction of individuals facing harsh or unpredictable environments (Belsky et al., 2012; but see Pianka, 1970). Given that heightened reward sensitivity might facilitate a faster life strategy by predisposing individuals exposed to adverse environments to favor risks that offer instant gratification, I had predicted that adolescents with lower SES would report and display greater sensitivity to rewards than adolescents with higher SES. However, there was little support observed for this prediction across the full sample and within each country. The only exception was Cyprus, in which participants with lower SES reported lower levels of sensation seeking during early-adolescence. However, self-reported sensation seeking was comparable between participants with low and high SES after mid-adolescence (around age 16). In contrast, participants with lower SES followed the expected inverted-U age-trend in risky driving (peaking around age 17) and displayed riskier driving than participants with high SES, but only during mid-adolescence. Given the inconsistencies in these results, it is hard to speculate on why lower SES participants report lower levels of sensation seeking during early-adolescence but display riskier driving during mid-adolescence or why these results are limited to Cyprus. Therefore, I caution against interpreting the results found from Cyprus as support for my prediction. Overall, these results indicate that despite the various adverse developmental outcomes associated with lower SES, reward-sensitivity appears to develop similarly across all socioeconomic groups. Considering the multiple explanations for these results, the lack of insignificant findings does not demerit life history theory Reward sensitivity may indeed facilitate greater risk taking for individuals exposed to early adversity. However, I may have been unable to find support for this prediction due to the indirect (and fairly weak) measure of childhood adversity used in these analyses. However, it may also be that impulsivity (rather than reward sensitivity) facilitates risk taking. Consistent with this prediction, Mishra and colleagues (2017) have found higher levels of impulsivity among individuals on a faster life strategy. Therefore, one possibility may be that exposure to childhood adversity leads to higher impulsivity which in turn, leads to greater risk taking.

Strengths, Limitations and Future Directions

Perhaps the greatest strength of the current study lies within its sample size and diversity. Participants in this sample came from eleven countries that varied on several psychological (e.g., individual versus collectivism) constructs, socio-demographic dimensions (e.g., predominant race, indicators of child well-being), as well as their international ranking on health, education and income (United Nations Development Programme 2016). This diversity allowed me to examine my research question outside of Western samples and to better understand and appreciate the cross-cultural similarities in the influence of SES on the development of reward-sensitivity. Further, this diversity granted me the opportunity to apply my findings to adolescents living in (fairly) understudied populations around the world.

There are limitations to the present study that need to be addressed, as well as interesting possibilities for future directions. One limitation of this study was in its use of an adult-centric self-report measure of sensation-seeking (Boyer, 2006). Despite the broad age range of participants, the sensation seeking scale consisted of items that were more relevant to the older ages in the sample (e.g., I like wild and ‘crazy’ parties) than to the younger ages. This is because the behaviors that these items measured are more likely to occur in lieu of lower parental supervision and greater individual autonomy – two factors that are commonly found during later-but not during early-adolescence, especially for males (Gerard, Gibbons, Houlihan, Stock, & Pomery, 2008; Steinberg, 2017). Therefore, the inconsistent age-trends in self-reported sensation seeking found across the different countries may indicate that the self-report items were not equally relevant to all ages included in the sample. Future studies examining the development of reward-sensitivity would benefit from using measures consisting of developmentally-appropriate items to capture the full range of sensation-seeking behaviors that occur from early-adolescence to emerging adulthood.

A second limitation of this study arises from its indirect measure of childhood adversity. Given that this was a secondary data analyses, I did not have a direct measure of adversity. Therefore, I used parental education as an indicator of SES, which in turn was an indicator of early adversity. Prior studies have often used parental education as an indicator of SES (e.g., Steinberg et al., 2018). However, parental education may not provide a true reflection of childhood adversity as it fails to account for other aspects of childhood environment (e.g., household income, parental/familial investment, neighborhood quality) that are known to influence later developmental outcomes (e.g., sexual risk-taking, substance abuse; Brumbach et al., 2009; Kipping et al., 2015). This may be especially problematic considering that although this sample consisted of countries that were economically diverse from one another, there was a restricted SES range within each country. Further, the sample's SES did not represent the country's SES, possibly because a majority of the participants came from middle-class families and were recruited from metropolitan cities. Therefore, comparing the development of reward-sensitivity across different levels of SES might have yielded more accurate results had I used a more direct measure of childhood adversity (e.g., exposure to neighborhood, familial or school violence) or had this sample consisted of individuals on the more extreme ends of the SES spectrum (e.g., below the country's poverty line).

A third limitation of this study lies in its use of a laboratory measure to gauge reward-seeking tendencies that encourage risky behaviors in the real-world. As noted by past scholars, risky behaviors such as reckless driving, binge drinking and acts of delinquency during adolescence most commonly occur under high arousal contexts such as in the presence of peers (Chein et al., 2011; Gardner & Steinberg, 2005; Steinberg et al., 2008) or when the perceived benefits outweigh the perceived costs (Reyna & Farley, 2006). The Stoplight task is a well-validated behavioral measure of reward sensitivity that has been shown to correlate with self-reported sensation seeking both in previous studies (Steinberg et al., 2008) and within the current sample. Further, the computerized driving stimulation resembles an ecologically friendly concept that is familiar across the full age range (e.g., experience with real-life driving, videogames). However, unlike the context under which real-life risk-taking occurs, participants complete the SL task inside a quiet testing room where a small monetary incentive is provided to elicit risky driving and there are no serious consequences of unsuccessful risk-taking. In contrast, the benefits (e.g., peer acceptance) and costs (e.g., accidents) of real-life risk-taking (e.g., speeding) are often much greater, and therefore, may play a larger role in the decision-making process. Thus, it is important for laboratory tasks measuring risk-taking to reflect real-life risk-taking scenarios (e.g., behavioral tasks with stronger risks) to better understand the cognitive and environmental factors that predispose adolescents toward greater risk-taking.

A promising direction for future studies interested in the role of the environment on the development of neurobiological changes within the brain, specifically the regions associated with risk-taking, would be to examine whether manipulations in environmental harshness and unpredictability result in more reward-driven behaviors among different ages. For example, the dual-systems model suggests that risky behaviors during adolescence are driven by a hypersensitivity to rewards and a lack of self-regulation. In this study, I examined the development of reward-sensitivity and found little evidence indicating that early adversity impacts its developmental trajectory. However, it is also possible that childhood adversity effects when the peak in reward-sensitivity occurs. Children exposed to early adversity are at a higher risk of earlier age at menarche (James-Todd, Tehranifar, Rich-Edwards, Titievsky, & Terry, 2010; Sun, Mensah, Azzopardi, Patton, & Wake, 2017). Given that earlier pubertal onset is associated with higher sensation seeking and risk taking (Martin, Kelly, Rayens, Brogli et al., 2002; Martin, Logan, Leukefeld, Milich et al., 2001), children from lower SES households may have an earlier peak in reward-sensitivity (e.g., early adolescence) compared to high SES households, rather than higher levels of sensation seeking during mid- to late-adolescence. Further, given that impulsivity is also associated with greater risk-taking (Vazsonyi & Ksinan, 2017), it would be interesting to examine whether poor impulse control (along with other personality traits such as extraversion) may also serve as mechanisms through which a faster life strategy is translated into risky behavior.

In addition, it would also be beneficial if future researchers could study risky behaviors outside the laboratory to enhance our understanding of the developmental patterns underlying specific types of risks (e.g., informed versus uninformed versus unaware risk-taking) in different subsets of our population (e.g., ethnic minorities, high-risk youth). Although this research provides mixed-findings for both the dual-systems model and life history theory, several researchers have found consistent age-trends in reward-sensitivity, suggesting that adolescents are more risk-prone in the presence of immediate rewards (Defoe et al., 2015). However, limited literature exists regarding the role of punishment-sensitivity on adolescent decision-making. Therefore, it would be interesting to examine whether individual differences that predict greater reward-sensitivity also predict greater punishment-sensitivity to see how these factors interact to predict real-life risk-taking.

Concluding Statements

The primary objective of the present study was to determine the influence of childhood adversity on the development of reward-sensitivity across both Western and non-Western countries. Overall, our results suggest modest support for the dual-systems model, in that reward sensitivity followed an inverted-U shaped pattern across ages in some, but not all countries. However, despite the well-documented association between exposure to environmental adversity and risky behaviors, I found very little evidence suggesting that the development of reward sensitivity differed for those relatively high or low in SES. Thus, having poorly educated parents may not be sufficient to channel one into a faster life course strategy. Taken together, these results suggests that although there is variability in how reward-sensitivity develops across ages in different cultures, there are few differences in how one's socioeconomic status affects this development worldwide.

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Appendix A

Table 4

Means and Standard Deviations of the Stoplight task, the Sensation Seeking Scale, SES and Intellectual by Age and Country.

Country	Age Group	Stoplight Task		Sensation Seeking Scale		Parental Education		Intellectual Ability	
		M	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
China	10-11	0.44	(0.20)	0.43	(0.26)	12.10	(2.39)	55.61	(6.32)
	12-13	0.46	(0.26)	0.40	(0.29)	10.37	(2.00)	50.15	(8.01)
	14-15	0.48	(0.19)	0.34	(0.26)	10.23	(1.87)	50.67	(7.11)
	16-17	0.45	(0.19)	0.58	(0.28)	09.73	(2.30)	53.32	(5.64)
	18-21	0.50	(0.20)	0.57	(0.29)	09.41	(2.11)	52.22	(5.90)
	22-25	0.47	(0.24)	0.59	(0.27)	09.53	(1.99)	54.77	(6.86)
Italy	10-11	0.42	(0.17)	0.64	(0.26)	11.12	(2.75)	49.31	(7.04)
	12-13	0.45	(0.18)	0.71	(0.26)	11.93	(2.40)	48.55	(6.28)
	14-15	0.50	(0.16)	0.57	(0.31)	12.10	(1.88)	49.57	(6.72)
	16-17	0.49	(0.16)	0.52	(0.29)	12.42	(1.94)	50.86	(6.87)
	18-21	0.45	(0.16)	0.59	(0.29)	11.52	(2.51)	52.02	(6.46)
	22-25	0.44	(0.17)	0.52	(0.30)	11.55	(2.09)	53.25	(6.68)
Kenya	10-11	0.37	(0.27)	0.42	(0.24)	12.66	(1.67)	45.56	(7.24)
	12-13	0.35	(0.23)	0.44	(0.24)	11.94	(2.31)	45.61	(6.56)
	14-15	0.41	(0.27)	0.44	(0.25)	11.82	(2.67)	42.93	(6.16)
	16-17	0.34	(0.24)	0.42	(0.23)	11.52	(2.52)	44.05	(8.29)
	18-21	0.40	(0.25)	0.59	(0.21)	13.05	(1.32)	47.13	(7.34)
	22-25	0.40	(0.28)	0.56	(0.26)	12.71	(1.28)	46.30	(7.38)
Philippines	10-11	0.38	(0.21)	0.66	(0.23)	13.04	(1.96)	51.89	(8.27)
	12-13	0.43	(0.20)	0.68	(0.25)	13.76	(0.65)	54.53	(6.82)
	14-15	0.44	(0.19)	0.72	(0.25)	13.86	(0.45)	52.15	(5.88)
	16-17	0.38	(0.21)	0.68	(0.25)	13.76	(1.04)	53.35	(5.36)
	18-21	0.39	(0.26)	0.66	(0.27)	13.79	(0.49)	57.31	(5.22)
	22-25	0.36	(0.21)	0.66	(0.23)	13.56	(1.00)	57.57	(5.76)
Thailand	10-11	0.45	(0.20)	0.56	(0.26)	10.09	(3.58)	50.01	(8.14)
	12-13	0.43	(0.18)	0.60	(0.26)	09.59	(3.97)	47.11	(7.76)
	14-15	0.45	(0.22)	0.65	(0.27)	09.03	(3.95)	47.22	(6.62)
	16-17	0.45	(0.19)	0.70	(0.22)	08.43	(3.21)	46.68	(7.80)
	18-21	0.49	(0.22)	0.68	(0.25)	09.06	(3.57)	49.21	(7.46)
	22-25	0.45	(0.22)	0.61	(0.23)	08.39	(3.89)	52.23	(6.21)
Sweden	10-11	0.48	(0.16)	0.62	(0.28)	14.56	(1.38)	51.76	(9.66)
	12-13	0.46	(0.16)	0.61	(0.25)	14.69	(1.08)	49.53	(7.68)

	14-15	0.44	(0.16)	0.57	(0.25)	14.69	(0.85)	49.28	(7.51)
	16-17	0.44	(0.17)	0.68	(0.26)	14.44	(1.09)	48.38	(7.55)
	18-21	0.44	(0.20)	0.61	(0.27)	14.54	(0.91)	53.70	(5.88)
	22-25	0.49	(0.19)	0.62	(0.26)	14.31	(1.32)	54.38	(7.98)
US	10-11	0.41	(0.19)	0.60	(0.27)	12.44	(2.88)	52.72	(7.81)
	12-13	0.40	(0.19)	0.63	(0.29)	12.61	(3.26)	49.26	(7.97)
	14-15	0.48	(0.18)	0.66	(0.31)	13.82	(1.49)	51.64	(6.71)
	16-17	0.48	(0.18)	0.65	(0.29)	13.53	(1.10)	50.14	(8.53)
	18-21	0.42	(0.20)	0.66	(0.26)	13.38	(1.48)	52.43	(8.52)
	22-25	0.40	(0.19)	0.67	(0.28)	13.47	(1.17)	54.05	(8.54)
Colombia	10-11	0.46	(0.20)	0.50	(0.26)	09.74	(3.66)	46.44	(8.84)
	12-13	0.45	(0.16)	0.57	(0.28)	11.01	(2.35)	46.35	(7.67)
	14-15	0.44	(0.15)	0.59	(0.30)	10.81	(3.02)	46.32	(6.36)
	16-17	0.45	(0.18)	0.65	(0.24)	10.39	(2.83)	46.42	(5.83)
	18-21	0.40	(0.18)	0.58	(0.26)	11.25	(2.97)	49.67	(7.74)
	22-25	0.42	(0.19)	0.55	(0.27)	10.83	(3.83)	50.56	(7.60)
Jordan	10-11	0.22	(0.21)	0.52	(0.28)	12.94	(1.98)	49.69	(7.23)
	12-13	0.24	(0.20)	0.59	(0.26)	13.18	(1.71)	44.21	(6.96)
	14-15	0.22	(0.20)	0.54	(0.27)	12.87	(2.10)	43.52	(7.87)
	16-17	0.25	(0.18)	0.64	(0.30)	12.35	(2.45)	44.58	(8.63)
	18-21	0.29	(0.22)	0.67	(0.28)	11.99	(2.58)	48.07	(6.75)
	22-25	0.27	(0.25)	0.58	(0.31)	10.95	(3.10)	48.18	(9.13)
India	10-11	0.64	(0.29)	0.55	(0.33)	12.18	(2.88)	54.15	(8.46)
	12-13	0.46	(0.23)	0.54	(0.33)	12.21	(3.32)	48.90	(6.54)
	14-15	0.62	(0.31)	0.57	(0.37)	11.99	(2.45)	49.67	(6.50)
	16-17	0.48	(0.30)	0.62	(0.32)	10.80	(3.83)	44.32	(7.74)
	18-21	0.53	(0.24)	0.70	(0.30)	12.36	(3.09)	49.69	(6.86)
	22-25	0.57	(0.24)	0.68	(0.31)	12.35	(3.08)	51.59	(7.01)
Cyprus	10-11	0.38	(0.19)	0.63	(0.27)	13.17	(1.51)	49.47	(7.73)
	12-13	0.44	(0.19)	0.59	(0.23)	12.89	(1.69)	51.20	(7.31)
	14-15	0.41	(0.25)	0.67	(0.25)	12.15	(1.89)	49.45	(6.95)
	16-17	0.43	(0.23)	0.67	(0.21)	12.10	(1.52)	51.14	(7.99)
	18-21	0.40	(0.25)	0.59	(0.21)	13.05	(1.32)	47.13	(7.34)
	22-25	0.41	(0.18)	0.55	(0.30)	11.81	(2.57)	65.55	(8.18)

Appendix B

Table 5

Correlations Among Main Study Variables by Country

		1	2	3	4	5	6
China	1. SSS	---					
	2. Int. Ability	0.043	---				
	3. Gender	0.009	-0.048	---			
	4. Stoplight	0.050	0.044	0.005	---		
	5. Par. Ed.	-0.061	**0.166**	0.087	0.040	---	
	6. Age	**0.247**	-0.085	-0.041	0.025	-0.440	---
Italy	1. SSS	---					
	2. Int. Ability	-0.046	---				
	3. Gender	-0.016	-0.078	---			
	4. Stoplight	0.026	0.085	0.003	---		
	5. Par. Ed.	**-0.127**	0.034	0.030	-0.001	---	
	6. Age	**-0.158**	**0.201**	0.010	0.036	0.062	---
Kenya	1. SSS	---					
	2. Int. Ability	0.017	---				
	3. Gender	-0.057	-0.014	---			
	4. Stoplight	0.024	0.028	**0.133**	---		
	5. Par. Ed.	0.108	0.193	-0.046	-0.048	---	
	6. Age	**0.221**	0.086	-0.048	0.041	0.064	---
Philippines	1. SSS	---					
	2. Int. Ability	-0.020	---				
	3. Gender	-0.009	0.019	---			
	4. Stoplight	0.067	0.022	-0.054	---		
	5. Par. Ed.	0.024	**0.331**	0.002	-0.003	---	
	6. Age	-0.010	**0.293**	-0.006	-0.056	**0.123**	---
Thailand	1. SSS	---					
	2. Int. Ability	-0.015	---				
	3. Gender	-0.001	-0.036	---			
	4. Stoplight	0.085	-0.044	-0.024	---		
	5. Par. Ed.	0.059	**0.253**	0.034	-0.013	---	
	6. Age	0.113	0.100	0.003	0.035	**-0.140**	---
Sweden	1. SSS	---					
	2. Int. Ability	-0.150	---				
	3. Gender	-0.038	-0.037	---			
	4. Stoplight	**0.144**	-0.103	0.042	---		
	5. Par. Ed.	-0.015	-0.037	-0.105	-0.048	---	
	6. Age	0.032	**0.182**	0.000	0.022	-0.089	---
US	1. SSS	---					
	2. Int. Ability	0.017	---				

	3. Gender	-0.079	-0.047	**---**			
	4. Stoplight	0.020	0.042	-0.006	---		
	5. Par. Ed.	0.115	**0.147**	-0.053	0.083	**---**	
	6. Age	0.080	0.056	0.070	0.016	**0.176**	**---**
Colombia	1. SSS	**---**					
	2. Int. Ability	0.009	**---**				
	3. Gender	-0.041	-0.155	**---**			
	4. Stoplight	0.008	-0.015	**-0.130**	**---**		
	5. Par. Ed.	**0.122**	**0.242**	-0.143	0.038	**---**	
	6. Age	0.102	**0.190**	-0.026	-0.095	0.117	**---**
Jordan	1. SSS	**---**					
	2. Int. Ability	0.048	**---**				
	3. Gender	-0.020	-0.323	**---**			
	4. Stoplight	0.056	0.125	**-0.483**	**---**		
	5. Par. Ed.	-0.027	-0.021	-0.067	0.004	**---**	
	6. Age	0.109	0.003	0.017	0.079	**-0.303**	**---**
India	1. SSS	**---**					
	2. Int. Ability	0.008	**---**				
	3. Gender	-0.093	0.035	**---**			
	4. Stoplight	**0.169**	**0.204**	-0.068	**---**		
	5. Par. Ed.	0.131	**0.223**	-0.013	**0.295**	**---**	
	6. Age	**0.147**	-0.024	-0.037	-0.015	0.020	**---**
Cyprus	1. SSS	**---**					
	2. Int. Ability	-0.064	**---**				
	3. Gender	-0.019	-0.098	**---**			
	4. Stoplight	0.038	0.105	-0.042	**---**		
	5. Par. Ed.	-0.019	0.026	-0.140	-0.020	**---**	
	6. Age	-0.114	**0.240**	-0.002	0.041	**-0.185**	**---**

Note. SSS = Sensation seeking scale; Par. Ed. = Parental education; Int. Ability = Intellectual Ability; Gender is dichotomous: 0= Female and 1 = Male. Stoplight is a behavioral measure and sensation seeking scale is a self-report measure of reward sensitivity. Bolded correlation coefficients are significant at $p < .01$.

Appendix C

Table 6

Regression Results for Within-Country Analyses of Risky Driving (% of No-Brakes) in the Stoplight Task

Country	Variable	B	95% C. I	β	*p-value*
China	Age	0.563	(-0.052, 1.179)	0.123	0.073
	Gender	0.248	(-3.705, 4.202)	0.006	0.902
	Age²	-0.072	(-0.185, 0.042)	-0.079	0.215
	SES	0.444	(-2.987, 3.875)	0.020	0.800
	IQ	0.182	(-0.117, 0.481)	0.060	0.233
	SES*Age	-0.038	(-0.571, 0.494)	-0.008	0.888
	SES*Age²	0.054	(-0.060, 0.169)	0.078	0.354
Italy	Age	**0.521**	(0.089, 0.952)	0.138	**0.018**
	Gender	0.560	(-2.419, 3.538)	0.017	0.713
	Age²	**-0.135**	(-0.220, -0.050)	-0.182	**0.002**
	SES	0.716	(-1.938, 3.370)	0.042	0.597
	IQ	0.190	(-0.031, 0.412)	0.078	0.092
	SES*Age	-0.288	(-0.718, 0.141)	-0.073	0.188
	SES*Age²	-0.072	(-0.176, 0.031)	-0.109	0.170
Kenya	Age	0.274	(-0.500, 1.049)	0.047	0.487
	Gender	**6.623**	(1.608, 11.639)	0.128	**0.010**
	Age²	0.013	(-0.126, 0.153)	0.013	0.851
	SES	0.065	(-3.132, 3.263)	0.003	0.968
	IQ	0.098	(-0.250, 0.446)	0.028	0.582
	SES*Age	0.256	(-0.640, 1.152)	0.034	0.576
	SES*Age²	-0.117	(-0.276, 0.042)	-0.102	0.148
Philippines	Age	0.050	(-0.519, 0.618)	0.011	0.864
	Gender	-2.180	(-6.144, 1.784)	-0.051	0.281
	Age²	**-0.111**	(-0.218, -0.005)	-0.128	**0.040**

	SES	-0.347	(-4.682, 3.988)	-0.017	0.875
	IQ	0.198	(-0.121, 0.516)	0.064	0.224
	SES*Age	0.178	(-0.361, 0.717)	0.042	0.518
	SES*Age^2	0.002	(-0.122, 0.126)	0.003	0.975
Thailand	Age	0.248	(-0.333, 0.829)	0.055	0.403
	Gender	-1.307	(-5.172, 2.558)	-0.032	0.507
	Age^2	-0.014	(-0.124, 0.095)	-0.017	0.796
	SES	-0.606	(-3.625, 2.413)	-0.029	0.694
	IQ	-0.125	(-0.389, 0.139)	-0.047	0.352
	SES*Age	-0.050	(-0.647, 0.548)	-0.011	0.871
	SES*Age^2	0.034	(-0.076, 0.144)	0.054	0.545
Sweden	Age	-0.243	(-0.795, 0.309)	-0.062	0.389
	Gender	1.329	(-2.291, 4.948)	0.038	0.472
	Age^2	**0.107**	(0.012, 0.202)	0.160	**0.028**
	SES	-1.116	(-4.046, 1.815)	-0.061	0.456
	IQ	**-0.277**	(-0.506, -0.048)	-0.129	**0.018**
	SES*Age	-0.202	(-0.728, 0.323)	-0.055	0.451
	SES*Age^2	0.023	(-0.076, 0.123)	0.046	0.643
US	Age	**0.590**	(0.104, 1.075)	0.142	**0.017**
	Gender	-0.311	(-3.626, 3.003)	-0.008	0.854
	Age^2	**-0.176**	(-0.268, -0.083)	-0.220	**0.000**
	SES	-0.148	(-3.729, 3.432)	-0.008	0.935
	IQ	0.117	(-0.093, 0.328)	0.051	0.274
	SES*Age	-0.127	(-0.691, 0.437)	-0.029	0.659
	SES*Age^2	0.037	(-0.086, 0.160)	0.047	0.554
Colombia	Age	-0.409	(-0.847, 0.030)	-0.103	0.068
	Gender	**-4.545**	(-7.955, -1.136)	-0.125	**0.009**
	Age^2	0.003	(-0.083, 0.089)	0.004	0.941
	SES	0.531	(-2.425, 3.488)	0.028	0.725

	IQ	-0.063	(-0.286, 0.160)	-0.027	0.578
	SES*Age	0.192	(-0.234, 0.618)	0.052	0.377
	SES*Age²	0.009	(-0.080, 0.099)	0.018	0.836
Jordan	Age	0.539	(-0.110, 1.189)	0.113	0.104
	Gender	**-21.389**	(-25.515, -17.263)	-0.495	**0.000**
	Age²	-0.011	(-0.128, 0.105)	-0.013	0.849
	SES	-1.382	(-4.557, 1.793)	-0.059	0.394
	IQ	-0.105	(-0.369, 0.159)	-0.039	0.436
	SES*Age	-0.451	(-1.268, 0.366)	-0.103	0.279
	SES*Age²	0.081	(-0.039, 0.200)	0.148	0.186
India	Age	-0.327	(-1.284, 0.631)	-0.051	0.504
	Gender	-4.010	(-9.751, 1.731)	-0.072	0.171
	Age²	0.045	(-0.122, 0.212)	0.040	0.600
	SES	**6.799**	(3.057, 10.540)	0.250	**0.000**
	IQ	**0.505**	(0.102, 0.908)	0.140	**0.014**
	SES*Age	-0.013	(-1.007, 0.980)	-0.002	0.979
	SES*Age²	0.017	(-0.130, 0.163)	0.021	0.824
Cyprus	Age	0.703	(-0.133, 1.539)	0.151	0.099
	Gender	-2.495	(-7.533, 2.542)	-0.058	0.332
	Age²	**-0.147**	(-0.279, -0.015)	-0.181	**0.029**
	SES	-4.193	(-8.835, 0.449)	-0.180	0.077
	IQ	0.312	(-0.032, 0.656)	0.110	0.075
	SES*Age	-0.698	(-1.838, 0.442)	-0.178	0.230
	SES*Age²	**0.168**	(0.001, 0.336)	0.350	**0.048**

Note. Values represent regression coefficients for the quadratic models tested separately for each country. Age was centered at 15 years. IQ (centered at its mean of 50) and gender (dichotomous: 0 = female and 1 = male) were entered as covariates. Unstandardized regression coefficients in bold are significant as $p < .05$.

Appendix D

Table 7

Regression Results for Within-Country Analyses of Self-Reported Sensation Seeking

Country	Variable	B	95% C. I	β	*p-value*
China	Age	**1.732**	(0.937, 2.528)	0.283	0.000
	Gender	1.124	(-3.971, 6.219)	0.020	0.665
	Age^2	-0.016	(-0.162, 0.130)	-0.013	0.834
	SES	1.556	(-2.862, 5.974)	0.054	0.490
	IQ	0.290	(-0.096, 0.675)	0.071	0.141
	SES*Age	0.293	(-0.393, 0.979)	0.045	0.403
	SES*Age^2	0.003	(-0.145, 0.151)	0.003	0.969
Italy	Age	**-1.231**	(-1.956, -0.506)	-0.192	0.001
	Gender	-0.715	(-5.735, 4.306)	-0.013	0.780
	Age^2	0.088	(-0.055, 0.231)	0.070	0.230
	SES	-3.025	(-7.532, 1.481)	-0.106	0.188
	IQ	-0.051	(-0.423, 0.320)	-0.012	0.787
	SES*Age	0.218	(-0.503, 0.939)	0.033	0.554
	SES*Age^2	0.003	(-0.172, 0.178)	0.002	0.976
Kenya	Age	**1.152**	(0.445, 1.860)	0.209	0.001
	Gender	-2.068	(-6.598, 2.462)	-0.042	0.371
	Age^2	-0.030	(-0.156, 0.095)	-0.031	0.635
	SES	**3.282**	(0.365, 6.199)	0.133	0.027
	IQ	-0.071	(-0.389, 0.246)	-0.021	0.660
	SES*Age	**1.040**	(0.236, 1.845)	0.145	0.011
	SES*Age^2	-0.058	(-0.201, 0.086)	-0.053	0.432
Philippines	Age	0.201	(-0.453, 0.855)	0.038	0.547
	Gender	-0.343	(-4.904, 4.217)	-0.007	0.883
	Age^2	-0.070	(-0.192, 0.053)	-0.070	0.263
	SES	-0.144	(-5.135, 4.847)	-0.006	0.955

	IQ	-0.079	(-0.445, 0.288)	-0.022	0.673
	SES*Age	-0.021	(-0.642, 0.599)	-0.004	0.947
	SES*Age²	0.026	(-0.117, 0.169)	0.034	0.720
Thailand	Age	**1.484**	(0.789, 2.178)	0.263	0.000
	Gender	-0.428	(-5.067, 4.212)	-0.008	0.857
	Age²	**-0.212**	(-0.344, -0.079)	-0.200	0.002
	SES	1.558	(-2.079, 5.194)	0.060	0.401
	IQ	-0.095	(-0.413, 0.222)	-0.029	0.557
	SES*Age	-0.576	(-1.287, 0.135)	-0.102	0.112
	SES*Age²	0.036	(-0.097, 0.168)	0.045	0.596
Sweden	Age	0.415	(-0.410, 1.239)	0.070	0.324
	Gender	-2.261	(-7.691, 3.168)	-0.043	0.414
	Age²	-0.017	(-0.160, 0.125)	-0.017	0.811
	SES	-0.027	(-4.302, 4.248)	-0.001	0.990
	IQ	**-0.530**	(-0.875, -0.185)	-0.162	0.003
	SES*Age	-0.161	(-0.944, 0.623)	-0.029	0.688
	SES*Age²	-0.016	(-0.162, 0.131)	-0.020	0.834
US	Age	0.588	(-0.142, 1.318)	0.095	0.114
	Gender	-4.483	(-9.471, 0.505)	-0.080	0.078
	Age²	-0.044	(-0.183, 0.095)	-0.037	0.538
	SES	2.373	(-2.971, 7.716)	0.088	0.384
	IQ	0.003	(-0.313, 0.320)	0.001	0.983
	SES*Age	-0.111	(-0.956, 0.734)	-0.017	0.797
	SES*Age²	-0.009	(-0.193, 0.176)	-0.007	0.928
Colombia	Age	**1.277**	(0.631, 1.923)	0.216	0.000
	Gender	-1.385	(-6.396, 3.625)	-0.025	0.588
	Age²	**-0.257**	(-0.383, -0.131)	-0.220	0.000
	SES	2.025	(-2.314, 6.363)	0.073	0.360
	IQ	-0.103	(-0.431, 0.224)	-0.030	0.536

	SES*Age	-0.135	(-0.761, 0.491)	-0.025	0.672
	SES*Age²	0.023	(-0.108, 0.154)	0.029	0.734
Jordan	Age	**1.861**	(0.978, 2.744)	0.294	0.000
	Gender	1.364	(-4.593, 7.321)	0.024	0.654
	Age²	**-0.306**	(-0.470, -0.143)	-0.265	0.000
	SES	0.541	(-4.015, 5.096)	0.017	0.816
	IQ	0.303	(-0.072, 0.679)	0.086	0.113
	SES*Age	-0.752	(-1.723, 0.218)	-0.130	0.129
	SES*Age²	0.037	(-0.119, 0.193)	0.051	0.643
India	Age	**1.542**	(0.415, 2.668)	0.202	0.007
	Gender	-4.684	(-11.443, 2.076)	-0.071	0.174
	Age²	-0.101	(-0.300, 0.098)	-0.077	0.319
	SES	**4.431**	(0.231, 8.631)	0.137	0.039
	IQ	0.015	(-0.451, 0.481)	0.004	0.949
	SES*Age	-0.947	(-2.056, 0.163)	-0.132	0.094
	SES*Age²	0.056	(-0.112, 0.224)	0.060	0.512
Cyprus	Age	-0.268	(-1.267, 0.731)	-0.045	0.599
	Gender	-2.936	(-9.178, 3.306)	-0.053	0.357
	Age²	-0.092	(-0.254, 0.069)	-0.089	0.263
	SES	**-7.038**	(-12.645, -1.43)	-0.239	0.014
	IQ	-0.081	(-0.501, 0.339)	-0.022	0.707
	SES*Age	-0.734	(-2.101, 0.633)	-0.147	0.293
	SES*Age²	**0.229**	(0.027, 0.431)	0.375	0.026

Note. Values represent regression coefficients for the quadratic models tested separately for each country. Age was centered at 15 years. IQ (centered at its mean of 50) and gender (dichotomous: 0 = female and 1 = male) were entered as covariates. Unstandardized regression coefficients in bold are significant as $p < .05$.

Appendix E

In these questions, you will read sentences that either do or do not describe you.

If the sentence describes you, press "true".

If the sentence does not describe you, press "false".

Upon making a response a “*” will appear on the screen, and no one will be able to see whether you responded “true” or “false”

1. *I tend to begin a new project without much planning on how I will do it.
   a. ORIGINAL: I tend to start a new task or project, without much advance planning on how I will do it.
2. I usually think about what I am going to do before doing it.
3. *I often act without thinking.
   a. ORIGINAL: I tend to do things on impulse.
4. *I hardly ever spend much time on the details of planning ahead.
   a. ORIGINAL: I very seldom spend much time on the details of planning ahead.
5. **I like to have new and exciting experiences and feelings even if they are a little frightening.**
6. *Before I begin a difficult project, I make careful plans about how I would complete it.
   a. ORIGINAL: Before I begin a complicated job or project, I tend to make careful plans.
7. *I would like to take a trip without planning where I would go or what I would do.
   a. ORIGINAL: I would like to take off on a trip with no preplanned or definite routes or timetable.
8. *I enjoy getting into new situations where I can't tell whether it will end up bad or good.
   a. ORIGINAL: I enjoy getting into new situations where I can’t predict how things will turn out.

9. I like doing things just for the thrill of it.

10. *I tend to change the things I like to do often.

    a. ORIGINAL: I tend to change interests frequently.

11. I sometimes like to do things that are a little frightening.

12. I'll try anything once.

13. *I would like the kind of day where there is lots of change and excitement.

    a. ORIGINAL: I would like the kind of life where I am on the move and traveling a lot, with lots of change and excitement.

14. I sometimes do "crazy" things just for fun.

15. *I like to explore a new neighborhood by myself, even if it means getting lost.

    a. ORIGINAL: I like to explore a strange city or section of town by myself, even if it means getting lost.

16. *I think friends who do things that you don't expect are exciting.

    a. ORIGINAL: I prefer friends who are excitingly unpredictable.

17. *I often get so carried away by new and exciting things and ideas that I never think of possible problems that might happen.

    a. ORIGINAL: I often get so carried away by new and exciting things and ideas that I never stop to consider possible complications.

18. *I usually act before I think about what I want to do.

    a. ORIGINAL: I am generally an impulsive person.

19. *I like wild and "crazy" parties.

    a. ORIGINAL: I tend to enjoy "wild" uninhibited parties.

*Indicates that wording was modified from original Impulsive Sensation Seeking Scale from the Zuckerman Kuhlman Personality Questionnaire (ZKPQ) (Zuckerman, 1994).

* SS subset of 6 items bolded