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Aggression and risk-taking as adaptive implementations of fast life history strategy

Hui Jing Lu[1] | Lei Chang[2]

[1]Department of Applied Social Sciences, The Hong Kong Polytechnic University, Hong Kong, China

[2]Department of Psychology, University of Macau, Macau, China

Correspondence
Lei Chang, Department of Psychology, University of Macau, Tai Pa, Macau.
Email: chang@umac.edu.mo

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Abstract

Within the evolutionary life history (LH) framework, aggression and risk-taking are adaptive implementations of a fast LH strategy to adapt to environmental unsafety and unpredictability. Based on a longitudinal sample of 198 Chinese adolescents living in rural areas, half of whom were separated from their parents, this study tested LH hypotheses about aggression and risk-taking in relation to safety constraints in the childhood living environments. The results showed that proxies of environmental unpredictability, including parental separation, were positively associated with aggression and risk-taking and negatively associated with slow LH strategy, which in turn was negatively associated with aggression and risk-taking. Children separated from their parents scored lower on slow LH strategies and higher on aggression and risk-taking. These findings support the evolutionary assumption that human development responds to safety cues through behavioral implementations of LH strategies.

KEYWORDS

aggression, child and adolescent development, environmental unpredictability, fast and slow life history strategies, risk-taking

1 | INTRODUCTION

Extrinsic risks cause death and disability despite individual organisms' efforts to survive (Ellis, Figueredo, Brumbach, & Schlomer, 2009). Such extrinsic risks as predation, diseases, disasters, intraspecific violence, and their byproduct, parental separation, have posed recurrent safety threats to children and other primates throughout evolution (Bowlby, 1969). In response, humans and other animals have developed covarying sets of psychological and physiological adaptations aimed at regulating the pace of life to elude and accommodate these and other safety constraints. Known as fast versus slow life history (LH) trade-off strategies, the coordinated tuning of physiological and psychological response systems mediates and modulates human development and behavior (Chang & Lu, 2017; Del Giudice, Gangestad, & Kaplan, 2015; Ellis et al., 2009; Stearns, Allal, & Mace, 2008). Within the LH framework, risk-taking and aggression are correlated behavioral implementations of a fast LH strategy in response to high extrinsic risks (Figueredo & Jacobs, 2010). In a high- versus low-risk environment, human cognition and behavior tend to be more present- than future-oriented, more risk-prone than risk-averse, and more aggressive than affiliative (de Baca, Wahl, Barnett, Figueredo, & Ellis, 2016; Zhu, Hawk, & Chang, 2018). When extrinsic risks are low in engendering a more predictable living environment, human cognitive schemata are oriented toward future planning and long-term coexistence, promoting prosocial, affiliative, and risk-averse behavioral patterns (Figueredo et al., 2018). Although many field studies have examined animal LH under different environmental conditions, similar work with humans is more limited in part because relatively uniform and safe modern living conditions do not provide enough downward variations to render LH-prescribed effects. This study employed a unique population that of "left-behind" children in rural China who have remained in their hometowns after their parents left to seek employment as migrant workers in cities. Parental separation represents a severe safety threat that creates expanded environmental variations when studying these children along with those living in the same village with intact families. This study applied an LH approach to investigate contingent associations among childhood living environment, LH strategy, and aggression and risk-taking among left-behind and non-left-behind rural Chinese children.

1.1 | Environmental conditions and fast–slow LH strategies

LH refers to organisms capturing energy from the environment and allocating it to support different life tasks such as physical growth, learning and development, mating, and raising offspring (Ellison, 2017). Food and safety are essential for this energy-gathering process, i.e., life (Chang & Lu, 2017,2018). However, their acquisition is constrained by stochastic events such as natural disasters, predation, disease, and inter- and intraspecific violence (Ellis et al., 2009). Because these environmental constraints limit energy collection, trade-offs occur among different energy consumption needs—primarily between growth, development, learning, parenting and teaching on one side and mating and reproduction on the other—leading to fast–slow LH trade-off strategies. A fast LH strategy involves rapid growth, early maturation, and active mating efforts, resulting in more offspring with little parental investment. A slow LH strategy is associated with slow growth, late maturation, delayed reproduction in favor of amassing resources, knowledge, and skills that are later converted into parenting and training well-invested, and high-quality offspring (Ellis et al., 2009; Stearns et al., 2008). Fast–slow LH strategies are shaped by and continue to respond to environmental constraints involving the acquisition of food and safety. In an unsafe environment presenting risks of death or disability, fast LH strategists who grow quickly, mature early, and produce more offspring are more likely than slow strategists to escape mortality–morbidity postreproductively. A fast LH strategy is thus selected through these surviving individuals and continues to mediate between the environmental contingencies and developmental and behavioral manifestations. When safety risks are low, thus improving environmental predictability, slow LH strategists who allocate more energy and effort to the physical and mental development of themselves and their offspring will outcompete fast strategists who allocate energy to mating rather than developing themselves or training their offspring. The next generation will sustain the fitness differences, with the parentally well-invested offspring of the slow strategists outlasting those of the fast LH strategists who, as children, were not taught the necessary skills and knowledge for adult intraspecific competition. Over generations, different environmental constraints related to safety select covarying sets of behavioral and physiological response systems known as fast–slow LH strategies.

The evolutionarily selected coupling of environmental conditions with fast–slow LH trade-off strategies continues to respond to current environments (Pepper & Nettle, 2017) and regulate human behavior and development (Del Giudice & Belsky, 2011). Research showed that the early childhood environment is especially pivotal in activating fast–slow LH strategies (Belsky, Steinberg, & Draper, 1991). Childhood extrinsic risks and unpredictability have been represented by an array of microenvironmental proxies. These include harsh parenting (Mell, Safra, Algan, Baumard, & Chevallier, 2018) and parental absence (Belsky et al., 1991), employment and residential changes, including homelessness (Doom, Vanzomeren-Dohm, & Simpson, 2016; Masten et al., 2014; Zuo, Huang, Cai, & Wang, 2018), exposure to gangs, violence, and crime (Brumbach, Figueredo, & Ellis, 2009; Upchurch, Aneshensel, Sucoff, & Levy-Storms, 1999), and low socioeconomic status (SES) (Belsky, Schlomer, & Ellis, 2012), which being associated in many urban areas with drug use, crime, and dangerous neighborhoods represents unsafe more than resource shortages (Chang & Lu, 2018). Both directly and indirectly through child perceived stress (Belsky et al., 1991; Del Giudice, Ellis, & Shirtcliff, 2011), these indicators of early environmental unsafety have been associated with fast LH characteristics including early menarche (Belsky et al., 1991), early initiation of sex (Simpson, Griskevicius, Kuo, Sung, & Collins, 2012) and higher frequency of sexual activity (Baumer & South, 2001), risky substance use behavior (Brumbach et al., 2009), and aggressive, antisocial, and externalizing behaviors (Chang et al., 2019; Doom et al., 2016; Simpson et al., 2012; Zuo et al., 2018). Parental separation has been extensively documented as facilitating fast LH and its corresponding physical effects (e.g., early menarche; Ellis, 2004) and behavioral manifestations (e.g., antagonistic behavior; Ellis et al., 2003; Newcomber & Udry, 1987).

Research Highlights

- Aggression and risk-taking are adaptive to accommodate unsafe, unpredictable living environments.
- The evolutionarily selected life history strategies continue to regulate human behavior and development.
- Child and adolescent development and behavior respond to safety cues in the living environments.
- Improving the living environment is essential in reducing adolescent aggression and risk-taking.

1.2 | Aggression and risk-taking in implementing LH strategy

The aforementioned fast and slow LH strategies are respectively implemented through physical and behavioral manifestations (Del Giudice et al., 2015). Aggression represents one of two social interactive styles aligned with fast–slow LH strategies (Figueredo & Jacobs, 2010; Figueredo et al., 2018). An aggressive, antagonistic, and more self-centered social strategy focuses on divergent interests with conspecifics, whereas an affiliative, mutualistic, and more other-centered social strategy seeks convergent interests with conspecifics (Figueredo & Jacobs, 2010). Under risky and unpredictable environmental conditions promoting fast LH, humans and other animals pursue opportunistic, antagonistic, divergent-interest sociality to attend to immediate survival needs and discount future interactions or conspecific coexistence. Such social strategies result in crime and violence or disrespecting others and disregarding social propriety all of which inevitably aggravate environmental unpredictability and perpetuate the cycle of fast LH driving antagonistic sociality. With reduced extrinsic risks and increased environmental predictability and controllability, on the other hand, human social schemata orient toward coexistence, cooperation, and orderly competition to maximize resource acquisition through collaboration (Chen & Chang, 2012; Zhu, Hawk, & Chang, 2019; Zhu et al., 2018). Cross-cultural evidence bolsters the linkage between experiences of environmental unpredictability (e.g., family instability) and antisocial, externalizing behavior (Chang et al., 2019).

Risk-taking, which is defined as electing variable outcomes with uncertain losses and gains (March & Shapira, 1992), represents another example of behavioral implementations of fast LH strategy in response to environmental unpredictability. Risk-taking propensity being domain-general (Donovan & Jessor, 1985) supports the LH root of this behavior. Expected losses and gains (i.e., costs and benefits) of risk-taking are often displaced over time (Figueredo & Jacobs, 2010), creating short-term gains but long-term losses or long-term benefits but short-term costs. In a predictable environment that fosters future orientation and life expectancy as part of slow LH, it is adaptive to accept short-term costs in hopes of realizing future gains. Consistent with humans having one of the slowest LH strategies, human socialization has come to advocate long-term thinking and planning by forgoing short-term rewards or hedonic pleasure. However, in an unpredictable environment that presents immediate survival challenges instead of future opportunities, it would be adaptive to implement a fast LH strategy by discounting future costs or losses in favor of current or short-term rewards including hedonic satisfaction. Thus, with fast LH strategic implementation in an unpredictable environment, it is adaptive to increase variance in outcomes that may include possible windfall fortunes, whereas it would be non-adaptive to be invariably risk-averse and discount possible short-term fortunes when there is little certainty of realizing long-term benefits or facing future losses. Empirical evidence supports the LH origin of risk-taking. For example, fast LH has been associated with procrastination, specifically betting on the present against the future (Chen & Chang, 2016). Risk-taking was associated with perceived future unpredictability and actual environmental adversity (Hill, Ross, & Low, 1997). Environmental unpredictability as represented by harsh parenting was shown to be correlated with sexual risk-taking and other risk-taking behavior (Belsky, Steinberg, Houts, & Halpern-Felsher, 2010). Family unpredictability was correlated with future discounting and risk-taking (Hill, Jenkins, & Farmer, 2008), and risk-taking propensity was correlated with subjective life expectancy (Wang, Kruger, & Wilke, 2009).

Fast LH driving aggression and risk-taking has been widely observed in other animals. In unpredictable environments characterized by predation or inconsistent food supply, animals are more aggressive toward conspecifics and are bolder and engage in riskier behavior when foraging (Wolf, van Doorn, Leimar, & Weissing, 2007). Boldness and aggression are positively correlated with several fast LH characteristics such as growth and fecundity (Biro & Stamps, 2008), earlier initial reproduction (Réale, Gallant, Leblanc, & Festa-Bianchet, 2000), and reduced parental care (Duckworth & Badyaev, 2007) among various species of ungulates, rodents, fish, birds, and insects (Biro & Stamps, 2008). These positive associations are stronger among populations facing many predators than in those with little history of predation (Biro & Stamps, 2008; Stamps, 2007). For example, populations of the Trinidadian guppy living downstream under high predation pressure adopt a fast LH by exhibiting an earlier age and smaller size at maturity, shorter interbrood intervals, and higher mating frequencies, compared with conspecifics living upstream (Reznick, Rodd, & Cardenas, 1996). In a separate study, these guppies were found to be bolder and more aggressive than upstream populations and risked feeding in the presence of predatory signs (Fraser & Gilliam, 1987). Among wild and captive great tits, faster LH birds have been reported to be bolder, more aggressive, and faster. They have also been observed to be superficial foragers who dared to venture to the edges of a habitat, approach unfamiliar objects, and take risks by feeding in close proximity to predators (Beauchamp, 2000; Marchetti & Drent, 2000; Verbeek, Drent, & Wiepkema, 1994). By contrast, slower-LH individuals tend to be risk-averse and socially affiliative, preferring to forage together in safer habitats (Kurvers et al., 2010).

1.3 | Gender differences stemming from LH

The LH perspective on aggression and risk-taking also explains the widely observed gender differences in these two behaviors. Men are more aggressive and more willing to take risks than women because males are faster LH strategists than females in most animals including humans (Hill et al., 1997). One of the trade-offs distinguishing fast and slow LH concerns mating and parenting. Parental investment represents a slow LH strategy, whereas a fast LH strategy prioritizes mating over parenting (Del Giudice & Belsky, 2011). In most species, obligatory parental investment positions females as the parental investing sex and compels males to compete for access to female parental investment (Trivers, 1972). Two forms of sexual competition or selection ensue mainly among males (Darwin, 1871). Intrasexual competition drives aggression and other physical (e.g., body size, muscularity, and physical strength; Puts, 2010) and behavioral characteristics (e.g., formidability and competitiveness; Lu, Wong, & Chang, 2017; Lu, Zhu, & Chang, 2015). Intersexual selection leads to risk-taking and other features, nearly exclusively in males (Lu et al., 2015). The stark sex dimorphism in physical and behavioral attributes, such as aggression and risk-taking, prompted Darwin to differentiate sexual selection from natural selection (Darwin, 1871; Hill et al., 1997). In this light, men are more aggressive and prone to risk-taking than women because of the added sexual selection pressure that drives male animals into a fast LH track to compete for parental investment through intra- and intersexual competition.

1.4 | Present study

We tested the above LH theorizing in a model (Figure 1) that predicted longitudinal associations among the following factors: extrinsic risks associated with the childhood living environment,

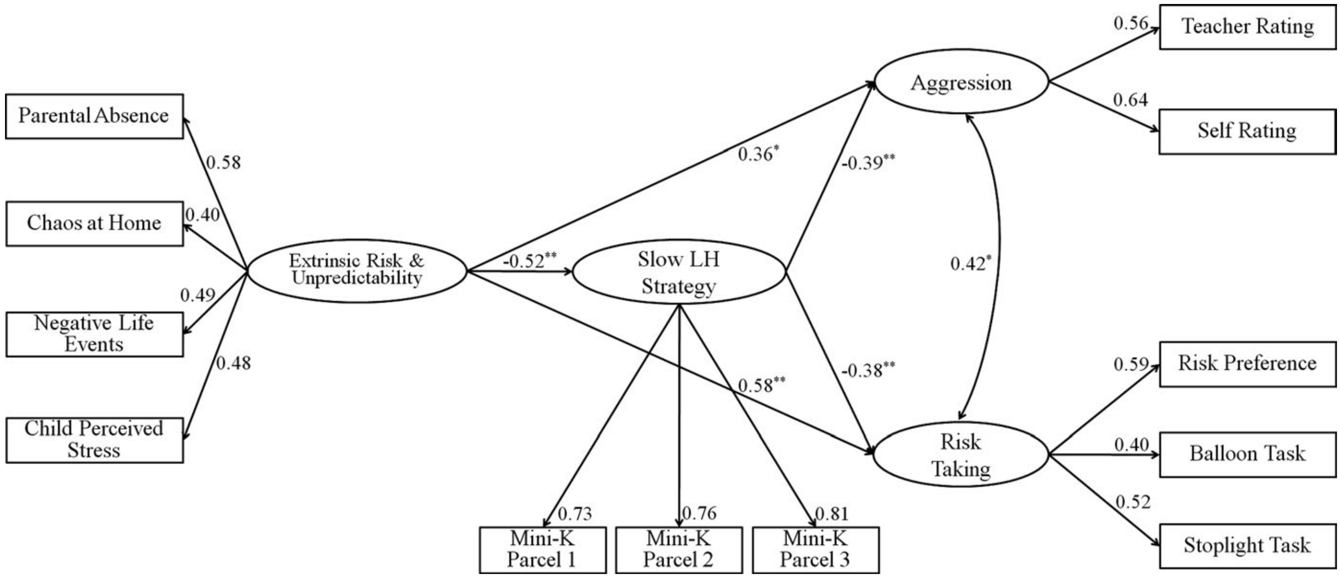

FIGURE 1 Aggression and Risk-taking as LH Implementations. *$p < 0.05$; **$p < 0.01$

measured from children's self-reports and their guardians' reports at Time 1, when participants were 11 years old on average; LH strategy in the direction of slow LH, obtained from child reports at Time 2 (18 months later), when participants were close to 13 years old; and aggression and risk-taking, measured by self-report and experimental tasks at Time 3 (10 months later), when participants were nearly 14 years old. The modeling test was conducted based on a longitudinal sample of 198 rural Chinese adolescents, half of whom were left-behind children separated from their parents. We also conducted mean comparisons between left-behind and non-left-behind adolescents in terms of aggression, risk-taking, and LH variables and examined the main effect and interaction effect involving gender in relation to aggression and risk-taking.

2 | METHOD

2.1 | Participants

The sample was taken from a randomly selected rural county in Henan Province, which registers the highest number of left-behind children in China (National Women's Confederation, 2013) and one of the lowest per capita incomes (National Bureau of Statistics, 2016). Based on power analysis, we targeted 100 left-behind children and 100 non-left-behind children. Left-behind children were those whose parents had been repeatedly absent for at least 6 months per absence for 3 years or longer at Time 1 of the three data collections of the present study, and non-left-behind children were those who had not been apart from either parent for more than 6 months at a time. At Time 1, the sample contained 109 left-behind (69 male) and 105 non-left-behind (59 male) children, and their parent and non-parent guardians. The average ages of the left-behind children were 10.78 (SD = 0.74) and were 10.69 (SD = 0.85) of the non-left-behind children. At Time 1 of the three data collections, guardians of non-left-behind children who were interviewed were primarily mothers (49.04%) and the rest were fathers (22.12%) and grandparents (28.84). The interviewing guardians of left-behind children were mainly grandparents (65.43%) and the rest were mothers (12.15%), fathers (9.28), and others (1%). The average ages of the guardians at Time 1 were 55.89 (SD = 11.29) for left-behind and 44.18 (SD = 10.71) for non-left-behind children. Time 2 data collection was conducted 18 months later, when the sample contained 103 (67 male) left-behind and 100 (54 male) non-left-behind children. The sample contained 101 (66 male) left-behind and 97 (51 male) non-left-behind children at Time 3 or the final data collection which was conducted 26 months after the initial data collection. Retention rate was high at 94%. Participants who provided complete data across three times did not differ from the initial sample on any of the measures used in the study. The gender ratio was compatible to that of the local population, which had more boys than girls overall and more boys among left-behind children.

2.2 | Data collection procedures

At Time 1, measures were collected from the participating children and their legal guardians through face-to-face interviews conducted individually between a participant and a same-sex interviewer. Two interviewers from Hong Kong who were blind to the purpose of the study conducted the interviews. The interviewers being from a different region from the participants' helped to disinhibit responses. The structured interview involved the interviewer reading standardized questions to the participants and recording their answers. The interview which lasted 1 hour was conducted in participants' homes. A participating child and the guardian were interviewed separately to ensure privacy. The interview procedures and questionnaire content were approved by the Institutional Review Board of the concerning universities. Legal guardians provided written informed consent, and children provided assent. At Time 2, measures were obtained from the children, who were then adolescents, and from the adolescents' homeroom teachers through self-response questionnaires. At Time 3, measures were obtained only from the adolescents through self-response questionnaires and computer games. For all three data collections, children or adolescents were given small gifts and adults were given modest monetary compensation to thank them for their participation.

2.3 | Measures of extrinsic risk and unpredictability from children and guardians at time 1

2.3.1 | Paternal absence

Each guardian estimated the amount of time that each parent spent away from the child for instances of 6 months or longer. This formed a continuous measure of parental absence.

2.3.2 | Chaos at home

The guardians responded to the Confusion, Hubbub, and Order Scale (Matheny Jr, Wachs, Ludwig, & Phillips, 1995) to measure confusion, chaos, and disorder at home (e.g., "It's a real zoo in our home," "The atmosphere in our home is calm" (reverse coded), and "You can't hear yourself think in our home"). The guardians responded to these questions on a 6-point scale ranging from 1 (strongly disagree) to 6 (strongly agree) to describe the family's home environment when the child was growing up. Items were worded or reversely coded in the direction of chaos and disorder. Cronbach's α internal consistency reliability estimate was 0.83.

2.3.3 | Negative life events

The interviewers asked each child to recall and report the number of times he or she ever experienced such negative life events as "severe illness," "accidents or injuries," "death or injuries of important persons" and other traumatic or negative events, which were adapted from the Social Readjustment Rating Scale (Holmes & Rahe, 1967). The total number of recalled events was used to indicate the construct.

2.3.4 | Child-perceived stress

We compiled 12 items from the literature (e.g., Goodman, 1997) to measure self-perceived stress (e.g., When I was growing up, they (my parents or people I lived with) fought a lot; they were not around; we always had dinner together). The items were rated on a 6-point scale ranging from 1 (none of the time) to 6 (all of the time). Items were worded or reversely coded in the direction of perceived stress. Cronbach's α internal consistency reliability estimate was 0.62.

2.4 | Adolescent measure of LH strategy and teacher rating of aggression at time 2

2.4.1 | Slow LH strategy

The most widely used measure of LH strategies has been the 20-item Mini-K which, developed from the Arizona Life History Battery (Figueredo, Vásquez, Brumbach, & Schneider, 2007), measures the behavioral and cognitive aspects of LH strategies on a single continuum in the direction of slow LH (Figueredo et al., 2006). Some items were modified to better fit the Chinese rural adolescent population (e.g., I have a close relationship with my primary caregiver; I believe love is based on emotional closeness more than physical attraction). Adolescents responded to the questions on a 6-point scale ranging from 1 (*strongly disagree*) to 6 (*strongly agree*). Cronbach's α internal consistency reliability estimate was 0.77.

2.4.2 | Aggression (teacher rating)

The home classroom teachers reported on aggressive and antisocial behavioral problems of each adolescent by using 20 items selected from the Youth Report of Behavior Checklist (Achenbach, 1991; e.g., got into fights; hit others; caught bullying others). A 5-point scale ranging from 0 = "never" to 4 = "very often" registers the frequency a student engaged in each of these behaviors. Cronbach's α internal consistency reliability estimate was 0.86.

2.5 | Adolescent measures of aggression and risk-taking at time 3

2.5.1 | Aggression (self-rating)

Adolescents completed 32 items of the Youth Self Report of the Achenbach's Behavior Checklist (CBCL, Achenbach, 1991) to measure aggression and externalizing behavior (e.g., "argue a lot," "scream a lot," and "threaten people"). A 6-point frequency rating scale was used, ranging from 1 (*never*) to 6 (*20 or more times*). Cronbach's α internal consistency reliability estimate was 0.94.

2.5.2 | Risk preference

Following the literature (e.g., Duell et al., 2016), we adapted a self-report measure of risk preference from the Benthin Risk Perception Scale (Benthin, Slovic, & Severnson, 1993). The scale has 11 risky activities about each of which respondents answer a series of questions. These answers form the measurement of different aspects of risk-taking behavior. We used eight risky activities that were deemed relevant to the rural Chinese adolescent population. These were smoking cigarettes, drinking alcohol, taking a ride by a drunk driver, vandalizing property, going to dangerous places, stealing from stores, engaging in gang fights, and using weapons to threaten someone. About each of the eight activities, adolescent respondents answered the following four questions on a 4-point scale: "How scary are the things that could happen?" (1 = *not scary at all;* 4 = *very scary*; reverse coded); "To what extent are you at risk of something bad happening?" (1 = *very much;* 4 = *not at all*); "How would you compare the benefits of this activity with the risks?" (1 = *the risks are far greater than the benefits;* 4 = *the benefits are far greater than the risks*); "If something bad happened because of this activity, how serious would it be?" (1 = *not at all serious;* 4 = *very serious*; reverse coded). The average of the four ratings over eight activities formed the construct, with a higher score indicating a greater inclination to take risk independent of the actual opportunity to do so (Duell et al., 2016). Cronbach's α internal consistency reliability estimate was 0.94.

2.5.3 | Balloon task

Following the literature (e.g., Duell et al., 2016; Hunt, Hopko, Bare, Lejuez, & Robinson, 2005), we adapted the Balloon Analogue Risk Task (Lejuez et al., 2002) that measures risk-taking in a computer game context. The computer task is for a player to inflate balloons to win points (inflation points). In the present study, there were 20 trials of balloon inflations, presented in a random order. Each participant completed the computer task in a quiet room with an experimenter staying in the room but not watching the participant playing. The experimenter first demonstrated to a participant how to inflate a balloon, illustrated scenarios of balloon exploding and no points being awarded and balloon not exploding and inflation points being awarded, and explained to the participant the rules of accruing points in four demonstration trials. To motivate a participant to gain as many points as possible, the experimenter told him/her that the final reward he/she would receive was based on the inflation points that were gained from the balloon inflation game, although eventually all participants received the same reward. An adolescent participant inflated each balloon by pressing down continuously or tapping the space bar. The participant could see on the screen the inflation points being accrued as he/she inflated the balloon. The participant could stop inflating at any time and the accrued inflation points of a balloon would be awarded to the participant. The participant could continuously inflate the balloon until it exploded and all the accrued points from the balloon would be taken away from the participant. Each balloon has a different maximum inflation point at which it explodes. In the present study, the maximum inflation points across the 20 trials ranged from 12 to 69. Risk-taking is operationalized as the ratio between the player's inflation points accrued from a balloon and the balloon's maximum inflation points, with a ratio of 1 being maximum risk-taking. Following the original design (Lejuez et al., 2002), we used three indices to measure risk-taking in the present study: (a) Exploded Balloons, which was the total number of exploded balloons; (b) Non-exploded Inflation Points, which was the average inflation points of the non-exploded balloons across 20 trials; (c) Inflation Ratio, which was the average inflation ratio across 20 trials (i.e., the inflated size of a balloon divided by its maximum inflation points, which, for exploded trials, equals 1). The first index was a primary dependent measure of BART (Hunt et al., 2005; Lejuez et al., 2002). The second index that was calculated based on balloon inflations that did not explode represented "an index of a more adaptive (non-punitive) form of risk-taking behavior," whereas the first one represented "an index of a more maladaptive form of risk taking" (Hunt et al., 2005) because risk exceeded an acceptable level (i.e., explosion) and received punishment (i.e., loss of points or money). The third index is recommended for assessing risky behavior and risk-taking disposition among children (e.g., Duell et al., 2016). For the structural equation modeling analyses to be reported in the next section, we used a composite by taking the mean of the three indices, after z-standardization, to form one indicator of risk-taking. Cronbach's α internal consistency reliability estimate of the composite score was 0.93.

2.5.4 | Stoplight task

We used the Stoplight computer game (Steinberg et al., 2008) to provide another behavioral measure of risk-taking. In this computer task, the player is asked to "drive" a car to a party at a location that requires passing through 20 traffic intersections. The goal is to pass through the 20 intersections using as little time as possible. The player's vantage point is a driver sitting at the wheel and the traffic intersection marked by a traffic light approaching. The player cannot control the speed of the car and the brake can be applied (by pressing the space bar) only after the yellow light is on. The player is told that, when the traffic light at an intersection turns yellow, the player must decide whether or not to apply the brake to stop the car with three possible outcomes: if the brake is used before the light turns red, the car will stop safely and the player will waste 3 s to wait for the traffic light to cycle back to green; if the brake is not used or is applied too late, the car will crash into another car and the player will waste 6 s for the crash to be cleared (the player can hear the assimilated sound when crashing with another car); if the brake is not used and the car passes through the intersection successfully, the car will not crash and the player will waste 0 s. The latency between the yellow and red light varies among the 20 intersections, with some being long enough for players to pass through the intersection if they so decide and with others presenting different probabilities or difficulties of avoiding a crash.

A participant played in a quiet room with an experimenter staying in the room but not watching the participant playing. Before a participant started the game, the experimenter demonstrated to the participant how to brake and illustrated scenarios of safe braking, successfully running the red light, and running the red light resulting in a car crash. No individualized reward was provided to the participants who received a final reward at the end of the task. However, participants were explicitly instructed to go to the destination as fast as possible, and there was a clock on the screen showing time counting down from 5 min, while participants heard the sound of the clock ticking. Data were not used from one of the 20 intersections which was a trial run where the light stayed green and all players could successfully pass through. Following the literature (Duell et al., 2016; Steinberg et al., 2008), we derived two indices to measure risk-taking: Running Red Light, which was the number of intersections an

TABLE 1 Means, *SDs*, and correlations of the variables used in the study

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
Extrinsic risk and unpredictability													
1 Parental absence	—												
2 Chaos at home	0.26***	—											
3 Negative life events	0.26***	0.30***	—										
4 Child perceived stress	0.28***	0.22**	0.29***	—									
5 Slow LH strategy (mini-K)	−0.30***	−0.29***	−0.25***	−0.30***	—								
Aggression													
6 Teacher rating	0.14*	0.17*	0.14*	0.20**	−0.26***	—							
7 Self-rating	0.21**	0.15*	0.18*	0.27***	−0.36***	0.36***	—						
Risk taking													
8 Risk preference	0.26***	0.18*	0.22**	0.21**	−0.37***	0.35***	0.38***	—					
Balloon task													
9 Inflation ratio	0.21**	0.15*	0.15*	0.17*	−0.20**	0.15*	0.18*	0.14*	—				
10 Non-exploded inflation points	0.23**	0.16*	0.18*	0.21**	−0.22**	0.16*	0.20**	0.22**	0.82***	—			
11 Exploded balloons	0.21**	0.14*	0.15*	0.16*	−0.22**	0.15*	0.19**	0.21**	0.78***	0.83***	—		
Stoplight task													
12 Running red light	0.20**	0.17*	0.14*	0.22**	−0.27***	0.22**	0.20**	0.23**	0.27***	0.28***	0.30***	—	
13 Latency to brake	0.24**	0.14*	0.24**	0.20**	−0.25***	0.25***	0.20**	0.22**	0.19**	0.25***	0.22**	0.54***	—
Mean	3.70	3.93	1.34	1.72	4.06	0.75	1.17	1.85	0.73	28.59	6.82	7.42	1,053
SD	3.73	0.98	1.81	0.57	0.69	0.42	0.29	0.58	0.10	6.25	2.37	3.40	355

$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

TABLE 2 Mean (*SD*) comparisons between left-behind and non-left-behind, male and female adolescents

Variables	Left-behind			Non-left-behind			*F*-test		
	Total	Male	Female	Total	Male	Female	Left-behind main effect	Gender main effect	Interaction
Aggression									
Teacher rating	0.82 (0.43)	0.85 (0.44)	0.75 (0.41)	0.67 (0.39)	0.73 (0.46)	0.60 (0.26)	5.33 (0.026)*	4.01 (0.020)*	0.01 (0.000)
Self-rating	1.24 (0.35)	1.32 (0.35)	1.09 (0.20)	1.10 (0.18)	1.12 (0.22)	1.08 (0.11)	7.45 (0.037)**	11.78 (0.057)**	5.39 (0.027)*
Risk taking									
Risk preference	2.02 (0.61)	2.12 (0.60)	1.83 (0.59)	1.68 (0.48)	1.67 (0.44)	1.68 (0.52)	14.41 (0.069)***	3.22 (0.016)	3.89 (0.020)*
Balloon task									
Inflation ratio	0.75 (0.08)	0.76 (0.08)	0.75 (0.09)	0.70 (0.11)	0.70 (0.11)	0.71 (0.11)	12.30 (0.060)**	0.05 (0.000)	0.46 (0.002)
Non-exploded inflation points	30.29 (5.80)	30.54 (6.11)	29.81 (5.21)	26.81 (6.23)	26.96 (5.69)	26.64 (6.83)	14.72 (0.071)***	0.36 (0.002)	0.06 (0.000
Exploded balloons	7.49 (2.13)	7.56 (2.27)	7.34 (1.86)	6.13 (2.41)	6.16 (2.23)	6.11 (2.63)	15.66 (0.075)***	0.16 (0.001)	0.07 (0.000)
Stoplight task									
Running red light	8.05 (3.41)	8.64 (3.34)	6.94 (3.32)	6.76 (3.28)	7.16 (3.16)	6.33 (3.39)	4.74 (0.024)*	6.87 (0.034)**	0.80 (0.004)
Latency to brake	1,127 (370)	1,200 (381)	989 (306)	976 (323)	1,022 (333)	925 (306)	5.94 (0.030)*	9.60 (0.047)**	1.31 (0.007)
Slow LH strategy (mini-K)	3.87 (0.71)	3.79 (0.75)	4.05 (0.59)	4.26 (0.62)	4.17 (0.62)	4.37 (0.61)	14.41 (0.068)***	6.39 (0.031)*	0.23 (0.001)

Note. Brackets under the *F*-test contain partial η^2.
$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

adolescent participant passed through by not stopping at the yellow light, and Latency to Brake, which was the time elapsed between the yellow light and the brake application when brake was used. For the structural equation modeling analyses, we used a composite by averaging these two indices, after z-standardization, to form an indicator of risk-taking. Cronbach's α internal consistency reliability estimate of the composite was 0.95.

2.6 | Data analyses

We conducted two sets of analyses. One concerned comparing left-behind and non-left-behind adolescents on a set of LH and outcome variables. Specifically, we performed a 2 (left-behind vs. non-left-behind) × 2 (gender) ANOVA to compare left-behind and non-left-behind adolescents on slow LH strategy and the set of aggression and risk-taking variables. Using ANOVA rather than *t* test allowed us to separate out the main and interaction effects involving gender. Because there were nine outcome variables, we corrected Type I error for multiple comparisons by controlling false discovery rate (FDR, Benjamini & Hochberg, 1995; Benjamini & Yekutieli, 2001) to $p < 0.05$.

The other set of analyses concerned testing our LH model in Figure 1. We conducted structural equation modeling (*SEM*) tests using Mplus 7.0 (Muthén and Muthén (1998–2012).) and using full information maximum likelihood estimation procedures to treat missing data (Schafer & Graham, 2002). We used multiple stand-alone variables to measure each construct except slow LH strategy which was measured by randomly formed item parcels from the mini-K scale. Item parceling has been used extensively as an effective data simplification method when the underlying construct is unidimensional (Little, Cunningham, Shahar, & Widaman, 2002), as was mini-K in this study. The goodness of fit of the model testing was based on the following recommended fit index cut-off values that indicate adequate model fit: Goodness of Fit Index (GFI) >0.95; Comparative Fit Index (CFI) >0.95; Tucker-Lewis Index (TLI) >0.95; Root Mean Square Error of Approximation (RMSEA) <0.05; Standardized Root Mean Square Residual (SRMR) <0.08 (Hu & Bentler, 1999; Schreiber, Stage, King, Nora, & Barlow, 2006) as well as the χ^2-to-degree of freedom ratio (χ^2/df) <2.0 (Kline, 1998). The data that support the findings of this study are available from the corresponding author upon reasonable request.

3 | RESULTS

3.1 | Descriptive statistics

Table 1 presents the means, standard deviations (*SD*), and correlations of the variables used in the study. The correlations were in the predicted directions and were mostly statistically significant supporting the LH hypotheses and conceptions. Specifically, the set of proxies of extrinsic risks and unpredictability were negatively correlated with slow LH strategy and were positively correlated with different measures of aggression and risk-taking, which were negatively correlated with slow LH. These results were robust especially given the fact that they were longitudinal associations across 10- to 26-month time span derived from multiple informants using multiple methods (i.e., surveys and computer tasks).

3.2 | Mean comparisons

Among the variables included in the ANOVA analyses, self-ratings and teacher-ratings of aggression were positively skewed (*Skew* = 2.79 and 2.30, respectively). We conducted additional ANOVA analyses using log-transformed values of these two variables. The results were highly similar to those based on the original non-transformed variables, which are reported. All the ANOVA results are reported in Table 2. As predicted, left-behind adolescents scored significantly lower on slow LH strategy and significantly higher on all the aggression and risk-taking measures compared to the non-left-behind adolescents. These comparisons were significant ($p < 0.05$) after correcting for multiple comparisons by FDR adjustment (Benjamini & Hochberg, 1995; Benjamini & Yekutieli, 2001). The partial η^2 of these significant mean differences ranged from 0.02 to 0.075 representing moderate effect sizes. Boys scored higher on aggression and on the set of stoplight computer measures of risk-taking, whereas there were no gender differences with respect to the balloon inflation tasks. There was one statistically significant gender interaction involving self-ratings of aggression; left-behind male adolescents scored much higher (M = 1.32, SD = 0.35) than left-behind girls (M = 1.09, SD = 0.20), whereas, for non-left-behind adolescents, the two genders were more similar with boys (M = 1.12, SD = 0.22) still scoring higher than girls (M = 1.08, SD = 0.11).

3.3 | SEM model testing

The *SEM* testing and parameter estimates are reported in Figure 1. The chi-square test, which is often not considered for goodness of fit evaluation because of its sensitivity to sample size, was significant (χ^2 (49, n = 198) = 71.57, p =0.019) but the χ^2-to-degree of freedom ratio (χ^2/df = 1.46) was adequate, even according to the more stringent criterion (Kline, 1998). The other goodness of fit statistics (GFI = 0.94; CFI = 0.95; TLI = 0.93; RMSEA = 0.048; SRMR = 0.052) showed mostly adequate fit according to the recommended cut-off values for model fit (Hu & Bentler, 1999; Schreiber et al., 2006).

All the parameter estimates were in the expected directions and were statistically significant. Most of the factor loadings were above 0.50 with an average of 0.58, suggesting adequate measurement models. The structural model was consistent with our LH theorizing. In the predicted directions, extrinsic risk/unpredictability was negatively associated with slow LH strategy (β = −0.52, $p < 0.01$) and was positively associated with aggression (β = 0.36, $p < 0.05$) and risk-taking (β = 0.58, $p < 0.01$). Both sets of associations were longitudinal one and half to two and half years apart. Also as predicted, slow LH strategy was negatively and longitudinally associated with aggression (β = −0.39, $p < 0.01$) and risk-taking (β = −0.38, $p < 0.01$). These results support the LH theorizing that environmental risk and unpredictability facilitated aggressive and risk-taking behaviors directly and, more importantly, indirectly by shaping LH strategy that in turn regulated behavior and development.

4 | DISCUSSION

Through coordinated physiological and psychological systems (Del Giudice et al., 2015), LH trade-off strategies are formed by and respond to safety constraints. Unsafe and unpredictable environments shape the fast LH strategy by which organisms accelerate growth, maturation, and reproduction to benefit from an increased probability of surviving high mortality–morbidity threats postreproductively. Psychological responses center on present orientation and risk-taking along with self-serving, antagonistic, and exclusive sociality, all of which favor immediate fitness gains in coordination with fast, present- and mating-oriented physical adaptations. Relatively safe and predictable environments foster the slow LH strategy by which animals grow and develop at a slow pace to cultivate physical (e.g., large body) and mental abilities (e.g., knowledge and skills) that encourage more fruitful and higher quality reproductive effort in the future. The coordinated psychological system focuses on future orientation, risk aversion, and affiliative sociality that serves to maximize environmental safety and predictability to acquire higher future fitness returns (Wolf et al., 2007). The evolutionarily selected contingent coupling of environmental conditions with LH strategies continues to regulate development and behavior (Pepper & Nettle, 2017) so that individuals from unpredictable living environments are expected to be more aggressive and take more risks than individuals raised in relatively predictable environments.

The results of our study are consistent with LH conceptions. As indicated by four proxies (parental absence, chaos at home, negative life events, and child perceived stress), extrinsic risk and unpredictability was negatively associated with a slow LH strategy measured one and half years after study initiation and was positively associated with aggression and risk-taking as assessed by multiple indicators close to another year later. Slow LH was negatively associated with aggression and risk-taking. These longitudinal associations support the LH conceptualization that aggression and risk-taking are implementations of a fast LH strategy in response to extrinsic risks and unpredictability in one's living environment. Also consistent with LH predictions, left-behind children scored lower on slow LH and higher on aggression and risk-taking compared with non-left-behind children; parental separation represented a severe extrinsic risk, promoting a fast LH strategy and accompanying behavioral manifestations. The findings that boys were more aggressive and prone to risk-taking than girls may otherwise lack defensible explanations, or be considered truism. LH theory provides a parsimonious functional explanation that obligatory parental investment makes women slower LH strategists and thus less aggressive and more risk-averse compared with men.

All behaviors are LH manifestations (Del Giudice & Belsky, 2011) and our findings provide empirical evidence with respect to aggression and risk-taking. One major human evolutionary milestone is complex sociality (Dunbar, 1995), which drives the development of the human brain and modern human race (Barton, 2000). Human sociality relies on two systems aligned with fast and slow LH (Chang et al., 2019; Figueredo & Jacobs, 2010). One may be predominant, aligned with slow LH, and fostered by more controllable environments with more predictable future prospects. This sociality is affiliative, inclusive, and mutualistic, intended to facilitate long-term conspecific coexistence, cooperation, and orderly competition (Zhu et al., 2018). The other, which may be secondary, is aligned with fast LH and shaped by extrinsic risks and environmental unpredictability diminishing future opportunities and accountability. Aggression falls under this sociality, which is generally characterized as antagonistic, exclusive, and self-centered. This system helps one to disregard future cooperation with conspecifics and to forge ahead and manage immediate extrinsic mortality–morbidity threats. Similarly, risk-taking may represent one of two resource management styles aligned with LH (Chen & Chang, 2012; Hawley, 1999) that is defined as animals capturing resources from the environment and turning them into reproduction (Ellison, 2017). In an unpredictable environment that delinks present actions with future outcomes, the resource management style should be opportunistic, risk-tolerant, and carefree. Species should also be willing to spend and squander resources or seek hedonic pleasure in the moment, spare present effort, or procrastinate (Chen & Chang, 2016) as well as gamble on windfall opportunities with little concern about potential losses or future consequences. In a predictable environment fostering slow LH, the response style should be future-oriented by conserving, planning, and being risk-averse to spread out potential benefits and costs and ensure lasting resource availability.

Because of this distal LH root, aggressive and risk-taking behaviors are partly dispositional (Reif et al., 2007; Zuckerman & Kuhlman, 2000), representing the Dark Triad personalities (Jonason, Li, Webster, & Schmitt, 2009), and may not be fully sensitive or responsive to reformatory education and socialization. It may be difficult to merely teach children and adolescents not to engage in aggressive or risky behaviors when the functional cause (i.e., an unsafe or unpredictable living environment) remains unchanged. Efforts to improve environmental safety and predictability should serve to reduce aggression and risk-taking more fundamentally by fostering slow LH strategies. However, the implied evaluative judgement of aggression and risk-taking as undesirable and maladaptive is based on the premise that individuals' living environment is orderly, predictable, and accountable. Under uncertainty or chaos that reduces future accountability, it is adaptive to be socially exclusive in pursuing immediate instrumental goals, to focus on short-term benefits including procrastination and excessive hedonic pursuit, or to gamble on windfall rewards when there may not be a need to face future consequences. In this evolutionary light, aggression and risk-taking may be adaptive depending on the environment.

The present study has several limitations. First, we did not control for potential genetic influences on LH (Braendle, Heyland, & Flatt, 2011). Genetic confounding presents a validity threat especially to evolutionary studies because of their distal focuses. It may be particularly relevant in this study by contributing both to the left-behind children exhibiting fast LH characteristics and their parents showing similarly fast LH attributes of leaving or abandoning their children. However, enduring the present hardship of leaving home and performing hard labor to earn and save money also represents competitive and future-oriented slow LH behavioral attributes (Zhu et al., 2018). Either possibility may also be overridden by the fast-moving urbanization process in China, where labor outflows from poor rural regions into the cities so rapidly that it is only a matter of time before all adults depart to seek urban employment, leaving children and older people behind in the villages (Li, 2010; Wang, 2016). Thus, individual difference variables such as genetics should demonstrate a more muted confounding effect, but future LH research could employ twins or siblings to distinguish between environmental and potential genetic influences. Second, some of the measurements used (e.g., mini-K) and the overall psychometric approach adopted to define LH strategies could be illuminated more comprehensively by using both biometric and psychometric observations. Third, some of our results, particularly some of the factor loadings and the mean comparisons between left-behind and non-left-behind adolescents, were moderate, implying that we may not have fully represented the distal evolutionary processes under investigation. However, distal evolutionary effects may also be moderate in nature, whereas our use of multidimensional, multiinformant, longitudinal data should yield more reliable results at least less inflated by method variance. Finally, as a delimitation, we focused on safety rather than food or resource in our LH investigation because the former is far more relevant especially in shaping LH (Ellis et al., 2009) and has therefore become the sole focus of human LH studies (Chang & Lu, 2018). Despite these and other limitations, this is one of the first LH studies regarding child and adolescent social development. The findings on LH strategies in response to environmental safety constraints and corresponding social behaviors provide a new perspective on child and adolescent development and behavior. Specifically, aggression and risk-taking are adaptive implementations of a fast LH strategy to adapt to risky, unsafe living environments.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Lei Chang https://orcid.org/0000-0001-6457-0254

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