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Environmental Harshness, Life History, and Crystallized Intelligence of Chinese Adolescents

Yuan Yuan Liu[1], Hui Jing Lu[2], Nan Zhu[1] and Lei Chang[1]

Abstract

The present study examined longitudinal relations between adverse environment (at the community and family level), life history (LH) profile (conceptualized as a suite of behavioral and physical traits with converging adaptive functions), and crystalized intelligence (mathematics and vocabulary test scores) using data on 1,185 Chinese adolescents obtained from the China Family Panel Studies survey. Multilevel structural equation modeling indicates that early familial environmental harshness was negatively associated with slow LH profiles and crystalized intelligence, slow LH profiles were positively associated with crystallized intelligence, and early community-level environmental harshness strengthened the positive association between slow LH and crystalized cognitive abilities. The results underscore the importance of the childhood environment in fostering individual LH and cognitive development.

Keywords

environmental harshness, fast and slow life history, crystallized intelligence, adolescent development, community-level environment

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Introduction

Acquiring new knowledge and sharpening one's cognitive skills can be viewed as an investment in "embodied capital" with future fitness returns (Kaplan et al., 2000). However, individuals growing up in different environments tend to systematically differ in how much they undertake intellectual investments and undergo cognitive development (Coleman, 1988). Cumulative environmental risk factors, such as minority group status, low occupational status, stressful life events, paternal absence, and maternal mental health problems, have long-term negative consequences on children's cognitive abilities (Evans et al., 2013; Sameroff et al., 1993).

From the perspective of life history (LH) theory (Del Giudice et al., 2015), the detrimental effects are among the LH tradeoffs between satisfying present-oriented reproductive needs and investing in future-oriented growth and development. The LH-tradeoff perspective has successfully accounted for the effects of early environments on individual differences in academic performance (Chang & Lu, 2018), moral judgment (Zhu et al., 2018), and cognitive style (Mittal et al., 2015; Wang et al., 2022). A recent study reports a positive association between a Q-sort measure of slow LH and IQ measured by Wechsler Adult Intelligence Scale (Dunkel et al., 2021). Together, these studies point to the cognitive manifestation of LH and environmental influences. However, compared to fluid intelligence that is relatively independent of learning and fostering, crystalized abilities that accrue from life experiences and education (Cattell, 1963) are especially vulnerable to environmental harshness and perturbations and should be more relevant to LH.

In the current study, we investigated the effects of harsh family environments on crystallized intelligence in early adolescence using the LH framework. Unlike many previous studies that have relied solely on the self-reported measures

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

Corresponding author:
Lei Chang, Department of Psychology, University of Macau, Building E21, Avenida da Universidade, Taipa 999078, Macau, China.
Email: chang@um.edu.mo

of LH profiles, the present study utilized a large dataset representing 25 of the 34 provinces and administrative regions of China and 95% of the mainland Chinese population (Xie et al., 2017). It contained data on both behavioral LH profiles reported by participants and interviewers and physical LH profiles reported by caregivers. The multilevel structure of the data also allowed us to distinguish between community-level and individual-level adversity, thus contributing to the literature on the detrimental effects of environmental harshness on crystallized intelligence.

Harshness, Behavioral and Physical Life History Profiles, and Crystallized Cognitive Abilities

LH tradeoffs are mediated by a cluster of physical and behavioral traits that function coherently to divert the individual's finite energy and resources toward meeting the demands from their given environment (Del Giudice et al., 2015; Ellis et al., 2009). For example, exposure to dangerous and unpredictable environments might favor the development of physical and behavioral traits that are conducive to fight-or-flight responses and rapid adjustments but not necessarily to the development of deliberative thinking. Crystalized intelligence accumulates from learning as a slow LH investment in somatic effort (i.e., growth and maintenance, and learning and socilization; Del Giudice et al., 2015) that flurishes in safe and stable environments (Ellis et al., 2009). By contrast, an impulsive cognitive profile (Griskevicius et al., 2011), which tends to impede learning and the accumulation of crystallized intelligence, is associated with fast LH profiles characterized by the prioritization of reproductive efforts (Ellis et al., 2009), which is typically manifested in individuals living in dangerous and unpredictable environments.

Information about environmental adversity lead to the implementation of faster behavioral LH profiles characterized by impulsivity and self-centeredness (Del Giudice et al., 2011; Zhu et al., 2018). The same adversity signals also affect parents by favoring offspring quantity rather than offspring quality, leading to reduced parental investment (Del Giudice et al., 2015; Quinlan, 2007). This is likely to result in faster physical LH profiles in offspring, including low birth weight (Janevic et al., 2010) and higher risks of preterm birth (Auger et al., 2009). Birth weight has been demonstrated to predict the onset of several chronic diseases in adulthood and, therefore, affect key LH outcomes, such as reproductive performance and longevity (Lummaa, 2003). Fast and slow LH profiles have also been demonstrated to predict a variety of outcomes indicative of the LH tradeoff between reproductive effort and intellectual investment (Chisholm, 1999). For instance, individuals with a faster (behavioral and physical) LH profile are more likely to postpone tasks that lead to long-term goals in favor of short-term needs (Chen & Chang, 2016). Researchers have also observed a positive association between birth weight and childhood cognitive abilities (Shenkin et al., 2004). Overall, environmental adversity can erode one's crystallized cognitive abilities by encouraging fast behavioral traits (commonly assessed using psychometric methods; Figueredo et al., 2007, 2017) and fast physical traits (reflected in biodemographic measures; Kwiek & Piotrowski, 2020) as independent pathways.

In addition to family harshness, low neighborhood quality was also revealed to predict cognitive underperormance (e.g., McCulloch & Joshi, 2001). Some recent studies have demonstrated that the relationship between LH profiles and developmental outcomes may be moderated by external environments beyond familial contexts. For instance, childhood environmental adversity was revealed to interact with slow LH profiles measured through the prediction of the internalizing problems during the COVID-19 pandemic (Chang et al., 2021). Therefore, this study also investigated the higher-level effects of community environmental harshness on LH profiles, crystallized intelligence, and their associations.

Present Study

The present study focused on adolescents who are on a transition period from pre-reproductive growth phase to the initiation of a reproductive adult life with increased social and cognitive demands. These changes coincide with intensified school learning that is crucial to the development of crystallized abilities. We performed two-level hierarchical structural equation modeling. At level 1 (the individual level), we examined the relationships between early familial environmental harshness, behavioral and physical LH profiles, and crystallized intelligence (Figure 1). At level 2 (neighborhood level), we used early community environmental harshness to predict behavioral and physical LH profiles, crystallized intelligence, and the associations between these two sets of level 1 constructs. We hypothesized that familial environmental harshness would be negatively associated with both behavioral and physical LH profiles, slow LH profiles would be positively associated with crystallized intelligence, and community-level environmental harshness would enhance the positive association between slow LH profiles and crystallized intelligence.

Method

Participants

We used a publically available dataset, China Family Panel Studies (CFPS; https://www.isss.pku.edu.cn/cfps/en/), which is an ongoing social survey project (Xie et al., 2017). The dataset was collected with approval by Peking University's Institutional Review Board (IRB, protocol number IRB00001052-14010). Using multistage cluster sampling, CFPS follows 14,798 households from 162 county-level administrative units covering 25 of all 34 provinces and administrative regions which represent 95% of the population of mainland China (Xie et al., 2017). The number of randomly sampled households from each county-level unit ranges from 1 to 208. Commenced in 2010, CFPS conducts structured interviews

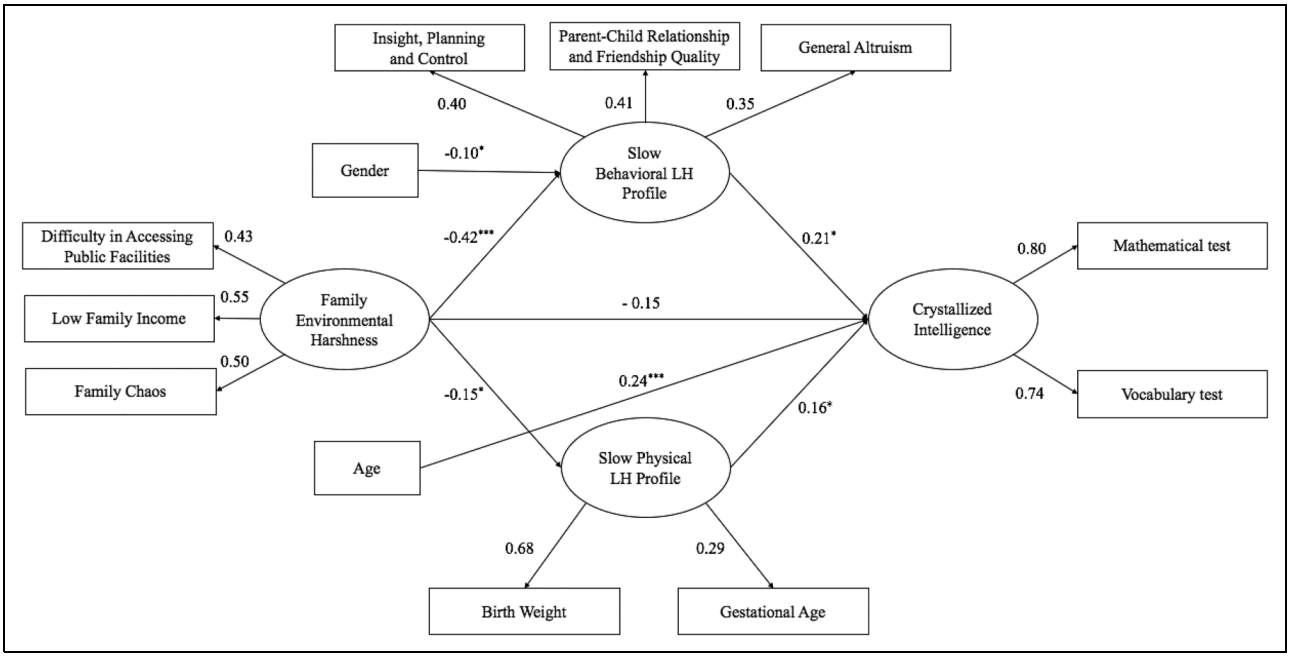

Figure 1. Standardized results of the structural equation model of the relationship among family environmental harshness, life history, and crystallized intelligence. For gender and age, only significant paths ($p < .050$) are shown in the figure ($\chi^2/df = 2.44$; CFI = .96; TLI = .94; RMSEA = .04; SRMR = .03). Data of family environmental harshness and physical profile were collected in 2010, and behavioral profile and crystallized intelligence were collected in 2014.
Note. N = 1185, *$p < .05$, ***$p < .001$. CFI: comparative fit index; RMSEA: root mean squared error of approximation; SRMR: root mean squared error of approximation; TLI: Tucker–Lewis index.

with the participants every two years, either face to face or by telephone. The CFPS survey took serious quality control measures that include accuracy checks of the interview records (Xie et al., 2017).

There are two types of interview questions: core questions that are repeated every 2 years with all households, and rotation and extension questions that are asked of different interviewing members of selected households. The CFPS has a 23.21% attrition rate in 2014. The present study includes 1,185 adolescents (46.08% female) who answered all the rotation and extension questions used in the study. The participating adolescents were between the ages of 6 and 11 in 2010 (time 1 of the present study) 10 and 15 ($M = 12.20$, $SD = 1.74$) in 2014 (time 2). The sample, which represents 141 county-level units of the 25 provinces covered by the CFPS, varies in family annual income level ($M = 6716.15$ yuan, $SD = 7267.41$) and the number of years of parental education (mothers: $M = 6.70$, $SD = 4.36$, $Minimum = 0$, $Maximum = 16.00$; fathers: $M = 7.68$, $SD = 4.10$, $Minimum = 0$, $Maximum = 19.00$). Most of the participants' parents are married (approximately 92%) and employed (approximately 88% of fathers and 82% of mothers).

Measures

Community Environmental Harshness

Disaster Frequencies. The administrative officer of the village/neighborhood committee records the number of natural disasters (e.g., floods, typhoon, and landslide) that occurred in the region from 2010 to 2014.

Neighborhood Disorganization. The interviewers rated on a seven-point scale six aspects of the neighborhood conditions in 2010, such as the economic status (ranging from 1 = *very poor* to 7 = *very rich*), and the layout of the community (ranging from 1 = *very disorderly* to 7 = *very orderly*). The items were reverse coded so that higher scores indicate neighborhood disorganization. The internal consistency reliability estimate of the six items was .83.

Community Facility Scarcity. Local administrative officers provided the information in 2010 regarding the numbers of hospital/medical facilities, drug stores, activity facilities/community service centers for the elderly, and nursing homes/almshouse in their precinct. The number of community facilities was reversed so that higher numbers indicate facility scarcity.

High disaster frequencies, high level of neighborhood disorganization, and scarce community facilities form the construct of community environmental harshness.

Time 1 Measures: Early Family Environmental Harshness

Difficulty in Accessing Public Facilities. Four items forming this construct are perceived distance from the household location to the nearest hospital/medical center and high school, respectively, and perceived traveling time to the nearest business center and hospital/medical center, respectively. After

standardization, the internal consistency reliability estimate was .68.

Low Family Income. The adjusted net family income per capita was obtained and calculated by the interviewers on a five-point scale ranging from 1 = *top 20%* to 5 = *bottom 20%*.

Family Chaos. Interviewers reported on a seven-point scale six items. Sample items include "cleanliness of respondent's home (ranging from 1 = *very messy* to 7 = *very clean*)." These items were reverse coded so that higher numbers indicate chaos in the family. The internal consistency reliability estimate was .92.

The family's difficulty in accessing to public facilities (long distance and traveling time), low family income, and high degree of family chaos form the family environmental harshness construct.

Time 2 Measures: Slow Behavioral LH Profiles. Slow LH behavioral profiles were represented by 23 questions obtained in 2014 when the adolescent participants were 10 to 15 years old. These 23 items of the CFPS approximate relevant subscales of the Arizona Life History Battery (ALHB; Figueredo, 2007) and relevant items of Mini-K which is a 20-item scale that captures the meaning but does not use the actual items of ALHB (Figueredo, Garcia et al., 2017; Figueredo, Vásquez et al., 2007).

Insight, Planning, and Control. Four self-report items were used to represent the "insight, planning, and control" aspect of the ALHB (Figueredo, 2007). Sample items include "don't make too much effort since it will never be helpful." Participants responded to the questions on a five-point scale ranging from 1 (*strongly agree*) to 5 (*strongly disagree*). Higher scores represent slower LH profiles. The internal consistency reliability estimate was .54.

Parent–Child Relationship and Friendship Quality. Sixteen items were used to represent the "parental relationship quality" and "friends contact and support" dimensions of the ALHB (Figueredo, 2007). Sample items include "parents/guardians were gentle while talking with you (ranging from 1 = *never* to 5 = *always*)," and "it is easy for you to get on well with others (ranging from 0 = *very hard* to 10 = *very easy*)." These measures indirectly reflect participants' investment in stable, long-term relationships with important others, which are associated with slow LH. These items were standardized and averaged to form a composite score of relationship quality, with higher scores representing better relationship quality. The internal consistency reliability estimate was .81.

General Altruism. Using a seven-point scale ranging from 1 (*very low*) to 7 (*very high*), the interviewer rated the adolescents on "cooperation," "courteousness," and "reliability" which are used to the "general altruism" dimension of the ALHB (Figueredo, 2007). The internal consistency reliability estimate was .87.

Slow Physical LH Profiles. The adolescents' birth weight and maternal gestational age were reported retrospectively by the mothers in 2010. Specifically, higher birth weight and larger maternal gestational age indicated slow physical LH profiles.

Time 2 Measure of Crystalized Intelligence. In the CFPS 2014 survey, mathematical and verbal achievement tests were used to represent crystallized intelligence (Huang et al., 2015).

Mathematical Test. The mathematic problems included 24 items that assessed "addition, subtraction…sequence, permutation and combination" (Xie et al., 2017, p. 94).

Vocabulary Test. Participants were asked to recognize Chinese characters on 34 cards.

In the two tests, problems were presented from the easiest to the hardest in terms of difficulty. The scores were assigned according to the question number of the most difficult problem that the respondent had answered correctly. Higher scores indicate better crystallized abilities.

For scales comprising more than one item, we used average scores to create the composite in structural equation modeling (SEM). For questions with only one item, such as disaster frequency, family income, birth weight, and gestational age, we used the item directly in the SEM model.

Results

Table 1 presents the means, standard deviations, and correlations of all the variables used in the study. The correlations were based on different informants (i.e., children and interviewers) and over time lags of up to 4 years. Indicators of family environmental harshness longitudinally and significantly correlated with indicators of slow behavioral LH profiles and slow physical LH profiles. These indicators were also correlated with crystallized intelligence in the expected directions.

We used Mplus 7.0 (Muthén & Muthén, 1998–2012) to conduct hierarchical linear modeling (HLM, Raudenbush & Bryk, 2002) based on structural equation models or HLM-SEM. Because our data represent two levels (i.e., 1185 individuals nested within 141 counties), our analysis is two-level HLM-SEM, where HLM is based on latent constructs rather than observed variables, and SEM is the same as the conventional SEM except that the level 1 parameter estimates (i.e., intercepts and slopes or path coefficients) were allowed to vary across the level 2 units (counties).

We tested the level 1 model and its results are presented in Figure 1. Specifically, we tested a latent path model, using family environmental harshness as the predictor of slow behavioral and physical LH profiles as well as crystallized intelligence, and LH profiles as predictors of crystallized intelligence. Gender (0 = female, 1 = male) and age were included as control variables. Overall, the model fit was satisfactory. All goodness of fit statistics (Chi-square to degrees of freedom ratio (χ^2/df) = 2.44; comparative fit index = .96; Tucker–Lewis index = .94; root mean squared error of

Table 1. Correlations, Means, and Standard Deviations of Variables.

		1	2	3	4	5	6	7	8	9	10	11	12	13
Community environmental harshness														
1	Disaster frequencies	-												
2	Neighborhood disorganization	.24***	-											
3	Community facility scarcity	.22***	.17***	-										
Family environmental harshness														
4	Difficulty in accessing public facilities	.43***	.20***	.22***	-									
5	Low family income	.24***	.16***	.20***	.24***	-								
6	Family chaos	.21***	.36***	.12***	.17***	.29**	-							
Slow behavioral LH profile														
7	Insight, planning, and control	−.12***	−.10**	−.08**	−.09**	−.12***	−.10**	-						
8	Parent–child relatinship and friendship quality	−.19***	−.10***	−.09**	−.10***	−.19***	−.13***	.14***	-					
9	General altruism	−.06*	−.08**	−.07*	−.09**	−.12***	−.23***	.16***	.14***	-				
Slow physical LH profile														
10	Birth weight	−.16***	−.07*	−.06*	−.17***	−.11***	−.12***	0.01	.07*	.06*	-			
11	Gestational age	−.07*	−.03	.02	−.08**	−.04	−.04	−.04	.06*	−.01	.19***	-		
Crystallized intelligence														
12	Mathematical test	−.17***	−.09***	−.12**	−.22***	−.15***	−.15***	.23***	.11**	.20***	.11**	.08***	-	
13	Vocabulary test	−.12***	−.11**	−.07***	−.16***	−.15***	−.14***	.22***	.09***	.18***	.09***	.10**	.59***	-
Mean		1.60	−4.49	−1.07	.00	3.01	−4.92	3.58	−.00	5.80	6.40	9.30	10.36	21.03
SD		1.83	1.00	1.08	.71	1.41	1.06	.64	.50	.96	1.17	.59	4.35	7.09
Minimum		.00	−7.00	−8.00	−.58	1.00	−7.00	1.00	−1.76	1.67	2.00	6.00	.00	.00
Maximum		8.00	−2.00	.00	7.07	5.00	−1.50	5.00	1.47	7.00	11.50	12.00	24.00	34.00

Note. *$p < .05$, **$p < .01$, ***$p < .001$. LH: life history.

approximation = .04; standardized root mean square residual = .03; minimum factor loading > .32) met the recommended cut-off values for adequate to excellent model fit (Kline, 1998; Marsh et al., 1988; Tabachnick & Fidell, 2013). Except for one (gestational age), factor loadings exceeded the minimum standard for adequate measurement models. The path coefficients were consistent with our LH theorizing. In the predicted directions, family environmental harshness was longitudinally and negatively associated with behavioral ($\beta = -.42$, $p < .001$) and physical LH profiles ($\beta = -.15$, $p = .04$), and both of the slow LH components were positively associated with crystallized intelligence ($\beta = .21$, $p = .02$, for behavioral LH profiles; $\beta = .16$; $p = .05$ for physical LH profiles). Family environmental harshness, however, did not directly predict crystallized intelligence ($\beta = -.15$, $p = .09$). Gender only had an effect on behavioral LH profiles, with boys scoring lower than girls ($\beta = -.10$, $p = .04$), consistent with the LH perspective that females generally adopt and exhibit slower LH strategies than males (Hill et al., 1997). Age was positively correlated with crystallized intelligence ($\beta = .24$, $p < .001$). This finding is consistent with the definition of crystallized intelligence (Cattell, 1963). There were no other statistically significant results involving gender and age.

All the level 2 variance components associated with the aforementioned parameter estimates (i.e., slopes or path coefficients) were robust and statistically bigger than zero ($p < .001$), supporting level 2 analysis. We then used the level 2 predictor, the community environmental harshness construct, to account for the random variations of the level 1 intercepts (constructs) and slopes or path coefficients. Community environmental harshness negatively predicted the intercepts of crystallized intelligence ($\beta = -.45$, $p = .02$) and physical LH profiles ($\beta = -.35$, $p = .03$) but not behavioral LH profiles ($\beta = -.19$, $p = .09$). This indicates that individuals under harsh community conditions demonstrated reduced cognitive performance and faster physical LH profiles. Community harsh environment also moderately enhanced the positive association between slow behavioral LH profiles and crystallized intelligence ($\beta = .44$, $p = .045$), suggesting that the facilitating effect of slow behavioral LH profiles on crystallized intelligence is relatively stronger in harsher community environments. There were no other statistically significant effects associated with this level 2 predictor.

Discussion

This study elucidates the detrimental effects of a harsh environment on crystallized intelligence from an LH perspective. Our findings largely indicate that familial environmental harshness is longitudinally linked to behavioral and physical indicators of fast LH, and that fast LH profiles are linked to deficits in crystallized intelligence. The results further demonstrated that community environmental harshness not only has a similarly negative influence on crystallized intelligence but also amplifies the link between behavioral LH profiles and crystallized intelligence.

The association between familial environmental harshness and LH profiles is consistent with the prediction that faster LH profiles are adaptations to harsh and unpredictable environments (Ellis et al., 2009). Researchers have proposed several underlying mechanisms for this association, including parental investment (Quinlan, 2007), and neuroendocrinal adjustments (Del Giudice et al., 2011). Slow LH profiles in humans have a behavioral facet, which includes future-oriented planning and self-control, better long-term relationships with family and friends, and altruistic contributions to society (Figueredo et al., 2017). In addition, slow LH profiles include a physical facet, which can reflect initial parental investment in the child's somatic growth and physical health, and can serve as internal cues for other developmental outcomes (Chang et al., 2019), including the development of cognitive abilities. Although both the behavioral and physical indicators used in this study are conceptually related to slow LH in humans, they might be largely independent from each other, as indicated by the low magnitudes of correlation between behavioral and physical indicators. This finding is also consistent with those of other studies demonstrating that biodemographic and psychometric LH dimensions are only weakly correlated (e.g., Kwiek & Piotrowski, 2020).

As expected, in this study, both the behavioral and physical facets of slow LH profiles are positively associated with crystallized intelligence, which represents long-term investment in one's embodied capital (Del Giudice et al., 2011), and should be distinguished from cognitive functions that are intrinsic to survival instinct (e.g., recognizing, detecting, and quickly responding to impending threats). Early adversity does not necessarily impair such cognitive functioning. As Frankenhuis et al. (2020) posited, cognitive abilities can be either impaired or enhanced by environmental adversities in ways that improve the adaptive fit between individuals and their environments. For example, studies have demonstrated that growing up in unpredictable and harsh environments is associated with enhanced performance in cognitive updating (Young et al., 2018), attention shifting (Mittal et al., 2015), and speeded visual processing (Wang et al., 2022). By contrast, other fluid abilities such as deliberate thinking (Wang et al., 2022) and working memory capacity (Young et al., 2018) are associated with slow LH and are likely impaired in adverse environments. Similarly, as shown in the present study, crystalized abilities that represent long-term investment in embodied capital are associated with slow LH and well-functioning in stable but not adverse environments.

Community environmental harshness measured at the neighborhood level is associated with not only lower levels of crystallized intelligence but also a faster physical LH profile (e.g., low birth weight and shorter maternal gestational age). This is consistent with the view that environmental unpredictability renders parental efforts less worthwhile in reproductive fitness terms (Quinlan, 2007). Children born in harsh neighborhoods might be disadvantaged because they receive lower initial parental investment (Patacchini & Zenou, 2011), which contributes to fast physical LH profiles (Belsky et al., 2010) and lower

continued parental investment (e.g., low educational expenditure), which might contribute to lower levels of cognitive performance (Lugo-Gil & Tamis-LeMonda, 2008).

Another key finding regarding community environmental harshness is that it enhances the association between slow behavioral LH profiles and crystallized intelligence measured at the individual level. This indicates that community environmental harshness might function at a higher-level and moderate lower-level effects. Specifically, our finding indicates that slow behavioral traits are especially conducive to the development of improved crystallized intelligence in harsher communities. Given the association between familial environmental harshness and behavioral LH profiles, this suggests that benign family environments might serve as a buffer against an otherwise threatening external environment. Moreover, when the external environment (beyond one's family) is not facilitative of cognitive development, future-oriented personal choices and behavioral efforts might allow individuals to eventually leave such environments (e.g., getting admitted to a better school in a different neighborhood). This might explain the aforementioned finding that slow behavioral LH profiles exhibit a stronger protective effect in individuals from harsher neighborhoods.

There are limitations of the present study, many of which stem from our use of an existing dataset that was not initially collected to address our research questions and therefore limits the choice of variables we could use to investigate our questions. For example, we only had two physical LH-profile indicators because other relevant indicators of physical development such as the age of menarche were not included in the CFPS dataset. Similarly, we could not use more items to approximate ALHB and Mini-K which, representing cognitive and behavioral aspects of LH, have already been criticized for being narrower in meaning than the original construct derived in biology from biological as well as behavioral observations. However, we were able to supplement the measure with additional physical indicators of LH. Whereas most of the measures we used had satisfactory psychometric properties, some of the measures had low internal consistency reliability. Because much of the data were longitudinal, we were able to obtain test–retest correlations for some of these measures which showed much improved reliability. We also did not control for and future research should look into potential genetic confounding as both LH strategies and cognitive abilities have been shown to be heritable (Kirk et al., 2001; Willoughby et al., 2021). Despite these and other limitations, this is one of the first LH studies to use large-scale data in China to examine the longitudinal relations between environmental harshness, the behavioral and physical indicators of slow LH, and crystallized intelligence. This is also one of the first LH studies that use community-level indicators of environmental adversity and that examine children's cognitive rather than social developmental outcomes. The results suggest that harsh childhood environment is negatively associated with slow LH and crystalized intelligence in adolescence and reinforces the positive association between LH and crystalized intelligence.

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Ethical Statement

The dataset was collected with approval by Peking University's Institutional Review Board (IRB, protocol number IRB00001052-14010).

ORCID iDs

Hui Jing Lu https://orcid.org/0000-0003-4025-3160
Lei Chang https://orcid.org/0000-0001-6457-0254

Supplemental Material

Supplemental material for this article is available online.

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