Published in final edited form as:

J Child Psychol Psychiatry. 2017 August ; 58(8): 902–909. doi:10.1111/jcpp.12718.

A life history approach to delineating how harsh environments and hawk temperament traits differentially shape children's problem-solving skills

Jennifer H. Suor,

University of Rochester

Melissa L. Sturge-Apple,

University of Rochester

Patrick T. Davies, and

University of Rochester

Dante Cicchetti

Institute of Child Development, University of Minnesota, and Mt. Hope Family Center

Abstract

Background—Harsh environments are known to predict deficits in children's cognitive abilities. Life History Theory (LHT) approaches challenge this interpretation, proposing stressed children's cognition becomes specialized to solve problems in fitness-enhancing ways. The goal of this study was to examine associations between early environmental harshness and children's problem-solving outcomes across tasks varying in ecological relevance. In addition, we utilize an evolutionary model of temperament towards further specifying whether hawk temperament traits moderates these associations.

Methods—Two hundred and one mother-child dyads participated in a prospective multi-method study when children were 2 and 4 years old. At age 2, environmental harshness was assessed via maternal report of earned income and observations of maternal disengagement during a parent-child interaction task. Children's hawk temperament traits were assessed from a series of unfamiliar episodes. At age 4, children's reward-oriented and visual problem-solving were measured.

Results—Path analyses revealed early environmental harshness and children's hawk temperament traits predicted worse visual problem-solving. Results showed a significant two-way interaction between children's hawk temperament traits and environmental harshness on reward-oriented problem-solving. Simple slope analyses revealed the effect of environmental harshness on reward-oriented problem-solving was specific to children with higher levels of hawk traits.

Correspondence: Jennifer H. Suor, Department of Clinical & Social Sciences in Psychology, University of Rochester, Rochester, NY 14627, USA; Jennifer.suor@rochester.edu.

Jennifer H. Suor, Melissa L. Sturge-Apple, and Patrick T. Davies, Department of Clinical and Social Sciences, University of Rochester; Dante Cicchetti, Institute of Child Development, University of Minnesota, and Mt. Hope Family Center.

Conflict of interest statement: No conflicts declared.

Conclusions—Results suggest early experiences of environmental harshness and child hawk temperament traits shape children’s trajectories of problem-solving in an environment-fitting manner.

Keywords

Human Ecology; adversity; temperament; cognitive development

Introduction

One of the most ubiquitous findings in the developmental literature is early stress undermines children’s cognitive abilities (e.g., Farah et al., 2006; Noble, Norman, & Farah, 2005). However, a long tradition of researchers have argued that standardized intelligence measures likely have low motivational salience for children growing up in stressful socioeconomic environments, and thus might not adequately capture their cognitive abilities (e.g., Hamers, Hessels, & Pennings, 1996). This proposal is consistent with recent evolutionary psychology approaches (e.g., Frankenhuis, Panchanathan, & Nettle, 2016), which assert what appears as impairments might reflect a reprioritization of developmental strategy. These frameworks suggest natural selection has selected for developmental plasticity, such that individuals tailor their cognition in an ‘environment-fitting’ manner in order to promote survival and success (Frankenhuis & de Weerth, 2013; Frankenhuis et al., 2016). Within high-risk contexts, children preferentially shift cognition to salient fitness-enhancing stimuli while minimizing attention and efforts on stimuli providing little gain. By virtue of their de-contextualized nature, standardized tests likely fail to capture the full repertoire of problem-solving behaviors that children develop within risky environments. However, evolution-informed research testing these provocative hypotheses in young children has been lacking. Towards this, the present study applied a process-oriented approach to elucidate how stressed children might develop specialized abilities to solve ecologically significant problems.

Life history theory and children’s problem solving

Life history theory (LHT) provides an elegant heuristic for understanding why resource-poor environments may predict enhanced problem-solving for rewards with the trade-off of less developed abstract problem-solving skills, as the latter would have limited adaptive value in those ecological contexts. Specifically, LHT proposes that harshness within the early caregiving environment is fundamental to shaping human development (e.g., Ellis, Figueredo, Brumbach, & Scholmer, 2009). Harshness has been conceptualized as factors with high probabilities of causing early mortality and morbidity (Ellis et al., 2009). Thus, within harsh rearing contexts characterized by limited caregiver investment and resources, individuals are likely to shift toward here-and-now survival and early reproduction strategies (Belsky, Schlomer, & Ellis, 2012), defined as a ‘fast’ life-history approach. Behavioral studies have documented associations between environmental harshness and increased risk-taking behavior, including aggression (e.g., Doom, VanZomeren-Dohm, & Simpson, 2015), lower inhibitory control (e.g., Mittal, Griskevicius, Simpson, Sung, & Young, 2015), and greater orientation towards immediate rewards (Humphreys et al., 2015; Sturge-Apple, et al.,

2016). In the present study we examined whether early exposure to harsh environments (e.g., low maternal investment and economic resources) positively predicts enhanced problem-solving for rewarding stimuli, consistent with a ‘fast’ life-history strategy. We also examined whether harsh environments negatively predicted performance on an abstract/decontextualized visual problem-solving task, as the latter abilities would be more advantageous within contexts favoring a ‘slow’ life-history approach.

The moderating role of hawk temperament traits

Although harsh environments have been associated with ‘fast’ life-history strategies, not all children follow similar developmental trajectories within these ecological niches. Drawing on Game theory and observations from animal studies, Korte and colleagues (2005) propose natural selection maintains a balance of two broad, phenotypic temperament dimensions—hawk and dove—which are underpinned by genetic variation and physiological mechanisms that coordinate life-history-related traits. Differences in behavioral traits are maintained in a frequency-dependent manner, conferring different advantages and costs depending on the environmental context (Ellis, Jackson, & Boyce, 2006). Specifically, the hawk temperament dimension is characterized by a constellation of interrelated traits including heightened levels of aggressiveness, boldness, activity, and approach—traits observed to cluster together in human research on personality and temperament (e.g., MacDonald, 2012), and associated with increased reward sensitivity (e.g., Depue & Collins, 1999).

LHT proposes relevant cues within the rearing environment, such as resource availability and quality of parental investment (e.g., Ellis et al., 2009), calibrate individuals toward faster strategies, but this may manifest in different ways depending on an individual’s temperament characteristics (Korte et al., 2005). Research has shown when resources are sparse and threat is high, individuals higher on the hawk continuum increase their energy expenditure toward procuring resources, and exhibit bolder, more proactive coping strategies (Korte et al., 2005). For example, a recent study found harsh maternal discipline increased later vulnerability for aggression specifically among children with hawk characteristics (Sturge-Apple, Davies, Martin, Cicchetti, & Hentges, 2012). However, how early hawk traits in children interact with environmental harshness to shape later problem-solving skills has yet to be specified. Given how the hawk dimension is associated with increased sensitivity to rewarding stimuli and skillfulness in procuring resources under stressful conditions, we hypothesized that following early exposure to harsh environments children with higher levels of hawk traits might develop enhanced problem-solving for rewards. Furthermore, we hypothesized these children would display worse performance on a standardized visual problem-solving task with low motivational significance.

Present study

First, from a LHT framework we sought to examine whether environmental harshness, defined as maternal disengagement and low economic resources, predicts enhanced reward-oriented problem-solving on a task involving ecologically relevant stimuli, while predicting lower visual problem-solving on a standardized task with abstract stimuli. Second, we applied an evolutionary model of temperament to determine whether children’s hawk

temperament traits at age 2 moderated these effects. We tested our hypotheses within a prospective study of 201 mother-child dyads assessed across two years of early childhood.

Method

Participants

Participants included 201 children (46% girls) and their mothers. Mother-child dyads were living in a moderately sized Northeastern metropolitan area. Participants were recruited through community agencies (e.g., Women, Infant, and Children assistance offices, Temporary Assistance for Needy Families rosters from the Department of Human and Health system). Participant criteria included a) female caregivers were biological mothers, b) child participants were 27 months old (± 5 months), and c) child participants did not have any developmental disabilities or brain injuries. Reported median annual income among participants was \$18,300 (US). Thirty percent of mothers did not complete high school.

At wave 1, the mean age of children was 26 months ($SD = 1.69$). Majority of mother-child dyads identified as Black (56%), with smaller proportions of White (23%), Latino (11%), Multiracial (7%), and Other (3%). Mother-child dyads also visited the laboratory when children were 48 months old ($M = 48.56$, $SD = 2.11$). The cumulative retention rate was 87%. Tests of selective attrition were conducted via statistical comparisons between dyads that participated in both waves and those that dropped out along primary and demographic variables. No significant differences were identified.

Procedures

Mother-child dyads visited the laboratory when children were 2 and 4 years old. Informed consent was obtained at the beginning of each visit. Mothers and their children completed a battery of assessments relevant to the current study. The University's Institutional Review Board (IRB) approved research procedures prior to data collection.

Measures

Environmental harshness—Based on evolutionary models (e.g., Ellis et al., 2009), we utilized two indicators of environmental harshness. At wave 1, mothers reported earned annual household income ($M = 1.56$, $SD = 1.5$, Range = 0 – 4.52). Maternal disengagement was assessed via observational ratings of mothers while they assisted their children in completing a problem-solving paradigm (TUPS; Matas, Arend, & Sroufe, 1978). The tasks included a puzzle, a shape sorter task in which the child places plastic forms into holes matching their shapes, a reward-oriented seesaw problem that requires the child to gain access to an attractive toy on a lever encased in a transparent box by placing a wooden block on the other end of the lever, and a task where the child must use a piece of balsa wood to retrieve a ball stuck in a plastic tube. Coders rated the interactions using the Disengagement scale (Manning & Davies, 2011) adapted from prior coding schemes of relationship disengagement (e.g., Bascoe, Davies, & Cummings, 2012; Jacobvitz, Hazen, Curran, & Hitchens, 2004). The Disengagement scale assessed the extent to which the mother appeared uninterested and uninvolved with the child during the task. Displays of disengagement included behaviors that were lethargic, indifferent, and/or apathetic, or explicitly rejecting

behaviors. The subscale ranged from 1 (not at all characteristic) to 5 (*highly characteristic*) ($M = 1.70$, $SD = 1.08$, Range = 1 – 5). To evaluate reliability, a second coder independently rated 27% of the mother-child interactions. The intraclass correlation coefficient was acceptable ($r = .82$).

Earned income (reverse-scored) and maternal disengagement were significantly correlated ($r = .23$). They were also submitted to a principle component analysis and inspection of eigenvalues (>1) and scree plot supported a one-factor solution, which accounted for 61.40% of the variance. Given these results, earned income and maternal disengagement were standardized and averaged to create a single composite of environmental harshness. Higher scores indicated higher levels of environmental harshness.

Hawk temperament—At wave 1, children were administered a series of temperament paradigms (e.g., Fox, Henderson, Rubin, Calkins, & Schmidt, 2001; Putnam & Stifter, 2005). Mothers were in the room during each episode but were instructed to complete questionnaires and only intervene with their children if they were concerned about their well-being. First, the experimenter escorted the child into a room containing several unusual objects (e.g., funnel, goggles). Following a brief period where the child was free to explore the objects and room, the experimenter instructed the child to manipulate the objects in different ways (e.g., windshield cover: ‘Poke it!’). Second, an unfamiliar experimenter dressed as a clown invited the child to play with different toys. In the third episode, the primary experimenter returned with a robot holding an attractive toy. The robot was operated from a different room with a remote control and alternated between periods of inactivity and movement. Each time the robot stopped moving, the experimenter encouraged the child to approach the toy. Lastly, the primary experimenter asked the child to imitate movements after she enacted them (e.g., reach behind a black curtain to pull out a doll).

Video recordings of children’s behavioral expressions of emotions during the unfamiliar episodes were rated independently by two coders who were randomly assigned to code 60% of the children, overlapping on approximately 26% of the cases in order to calculate reliability. Consistent with prior procedures (Davies, Sturge-Apple, & Cicchetti, 2011), coders rated indices of hawk temperament traits along five-point rating scales ranging from (0) no to (4) multiple, intense, and prolonged indications. The indices were; approach, indicated by physical movement toward the novel stimuli; dominant negative affect, as evidenced by aggressive, assertive, and behavioral responses to the novel events (vulnerable distress, sadness, crying, and fear were not coded); activity level, which measured children’s gross motor activity throughout the segment (e.g., Fox et al., 2001); and inhibition (reverse-scored), assessed tendency to restrain behavior. Intraclass correlations for all temperament codes across episodes were satisfactory ($r_s = .85 - 1.0$).

Ratings were averaged across episodes to obtain composites of the four temperament dimensions. Temperament dimensions were significantly correlated ($r_s = .19 - .27$). To test whether temperament dimensions reflect a single continuum of hawk temperament, a principal components analysis with varimax rotation was performed on the temperament composites. Inspection of the eigenvalues (>1) and scree plot supported a single factor solution, and accounted for 62.43% of the variance. The four temperament indices were

standardized and averaged to create a composite of hawk temperament. Higher scores reflected higher levels of hawk traits.

Visual problem-solving—At wave 2, children were administered the Block Design subtest from the Wechsler Preschool and Primary Scale of Intelligence-Third Edition (WPPSI-III; Wechsler, 2002). The child was required to view a constructed model or picture of a stimulus and use color blocks to re-create the design within a time limit. The task was discontinued after three consecutive trial failures. Mothers were not present during administration.

Reward-oriented problem-solving—At wave 2, children were also administered the Transparent Box task (Laboratory Temperament Assessment Battery; Goldsmith & Rothbart, 1996), which has been used previously to assess indicators of problem-solving (Dennis, Cole, Wiggins, Cohen, & Zalewski, 2009). Children picked out a prize before beginning the task. Then the experimenter brought the child into a room and placed the prize in a transparent plastic box. The experimenter locked the box with a set of keys and demonstrated how to open it to get the prize. Then, the experimenter gave the child an incorrect ring of keys and left the child alone in the room for four minutes to open the box independently while the experimenter was gone. Upon returning to the room, the experimenter explained she had given the child the wrong keys. The box was then opened and the child received their prize. Children's reward-oriented problem-solving behaviors were coded from video-recordings using a coding scheme developed for the current project. First, the Focused Attention subscale (e.g., Ruff & Capozzoli, 2003; Ruff, Capozzoli, & Weissberg, 1998) assessed the degree to which the child stayed focused on the lock box task. As defined by Ruff and colleagues (1998, 2003), focused attention consists of concentrated attention that involves an intent facial expression (e.g. furrowed brow, pursed lips), minimal extraneous bodily activity not relevant to the task, a posture that encloses the objects of interest and brings it closer to the eye, and either no talking or soft-talking directed to the self that indicates the child is focused and concentrated on the task. Ratings ranged from 1 (not at all characteristic) to 5 (mainly characteristic). The Strategy Use subscale (Dennis et al., 2009) assessed the extent to which the child exhibited behavior that was strategic across the entire episode, such as attempting to integrate multiple strategies to achieve the goal of opening the box to obtain their prize. Behavioral indicators of strategy use included using multiple keys in addition to other methods (e.g., trying different ways to open box with all available keys, use of extreme force to pull on lock by leveraging body position). Ratings ranged from 1 (child does not engage with objects) to 5 (multiple, patterned strategy use). Lastly, the Key Manipulation Behavior subscale was used to characterize the child's key manipulation behaviors during the paradigm (adapted from Valentino, Cicchetti, Toth, & Rogosch, 2011). Higher ratings were given to children who used all available keys in a functional manner, or in a creative-functional manner when traditional methods failed (e.g., attempted to use key as a screwdriver to unfasten screws). Ratings ranged from 0 (No manipulation) to 6 (Creative-Functional Manipulation). For all subscales, ratings were based on behaviors observed across the entire episode. In order to evaluate reliability of ratings, a second coder independently rated 23% of the cases. Intraclass correlation coefficients were acceptable: Focused Attention ($r = .81$), Strategy Use ($r = .88$), and Key Manipulation

Behavior ($r = .92$). Subscales were significantly correlated ($r_s = .58 - .72$) and were used as latent indicators of reward-oriented problem-solving.

Results

Descriptive analyses

Means, sample sizes, standard deviations, ranges, and correlations among the primary variables in the analyses are presented in Tables 1 and 2. At the bivariate level, we observed a marginally positive correlation between reward-oriented and visual problem-solving ($p < .10$). To evaluate whether data were missing completely at random, we examined the pattern of missing data using Little MCAR's test (Little, 1988; Schlomer, Bauman, & Card, 2010). Results did not support rejecting the null hypothesis ($\chi^2 = 107.853$, $df = 88$, $p = .07$), suggesting data were missing completely at random. We utilized the missing data estimation function available in AMOS (e.g., FIML, Enders, 2001) and included the full sample in the final analyses. Predictor variables were centered to avoid issues with multicollinearity (Aikins & West, 1991). We created the interaction term by multiplying the centered predictor variables.

Primary analyses

Path analyses were performed within a structural equation modeling framework to test the hypothesized model using AMOS, Version 22.0 (SPSS Inc., Chicago, 2007). To test model fit, we calculated three model fit indices. The chi-square statistic tests the null hypothesis that the overidentified model fits the data as well as the fully saturated model (i.e., paths from each variable to the other). A nonsignificant chi-square ($p > .05$) would indicate that the fit between the specified model and the data is not significantly worse than the fit between the saturated model and the data (Hu & Bentler, 1999). Due to the stringency of the chi-square test and its sensitivity to sample size, additional fit indices were computed. The comparative fit index (CFI; Bentler, 1990) is a goodness of fit measure that compares the tested model to the fit of the independence model; CFI values above .90 suggest acceptable fit (Hu & Bentler, 1999). Lastly, the root-mean-square error of approximation (RMSEA; Steiger & Lind, 1980) is an absolute measure of fit based on the non-centrality parameter, values less than .08 suggest acceptable fit (Hu & Bentler, 1999). Model analyses were run in a step-wise fashion. First, we examined the main effect of environmental harshness at wave 1 (age 2) on children's reward-oriented and visual problem-solving at wave 2 (age 4). Child race (Black or Mixed Race versus White, including children identified as Other or non-Black Latino), gender, age (months), and maternal education were included as covariates. Model fit was acceptable, $\chi^2 = 22.89$, $df = 13$, $p = .04$, CFI = .97, RMSEA = .06, 90% CI [.01, .10]. Environmental harshness at age 2 predicted better reward-oriented problem-solving ($\beta = .19$, $SE = .12$, $p = .04$), but worse visual problem-solving at age 4 ($\beta = -.17$, $SE = .51$, $p = .04$). Results are presented in Table 3. In the next step, hawk temperament and the two-way interaction were entered into the model. Model fit was acceptable, $\chi^2 = 24.82$, $df = 17$, $p = .10$, CFI = .98, RMSEA = .05, 90% CI [.00, .09]. Results showed the main effects of hawk temperament and environmental harshness on reward-oriented problem-solving were qualified by a significant two-way interaction ($\beta = .20$, $SE = .22$, $p = .01$). Higher levels of

hawk temperament traits predicted worse visual problem-solving ($\beta = -.16$, $SE = .75$, $p = .04$). The interaction was not significant ($\beta = .07$, $SE = .95$, $p = .34$) (Table 3).

Next we probed the two-way interaction by plotting the simple slopes with hawk temperament as the moderator. We conducted simple slope analysis by using an online utilities program (Preacher, Curran, & Bauer, 2006; <http://www.quantpsy.org/interact.mlr2.htm>). Hawk temperament and environmental harshness were plotted at ± 1 SD from their means. Results showed the simple slope for children with high levels of hawk traits was significantly different than zero ($\beta = .46$, $t = 3.11$, $p = .002$), whereas the simple slope for children with low levels of hawk traits was not significantly different than zero ($\beta = -.09$, $t = -.496$, $p = .62$), indicating the influence of environmental harshness on reward-oriented problem-solving was specific to children who at age 2 were higher on the hawk continuum (Figure 1).

Discussion

The central aim of the present study was to demonstrate how Life History Theory (LHT) might enhance understanding of how proximal signs of early adversity shape children's problem-solving abilities in a manner that would benefit them within those contexts. We found early environmental harshness and children's hawk temperament traits predicted reduced abstract visual problem-solving. Interestingly, early experiences of environmental harshness predicted enhanced reward-oriented problem-solving at age 4 for children who displayed hawk traits at age 2.

Recent evolutionary-developmental studies have provided compelling insights into how young children may be capable of calibrating their reward-oriented decision-making based on information from their early caregiving environments (e.g., Humphreys et al., 2015). Specifically, if early rearing contexts are characterized by the presence of unresponsive caregivers and limited material resources children may develop the mindset to favor a small immediate reward over a larger future reward they perceive as having a small probability of being delivered (Sturge-Apple et al., 2016). This burgeoning research has suggested viewing stressed children as impulsive or lacking self-control ignores how environments guide what strategies children select, and furthermore, how committing to one strategy that is consistent with early environmental expectations may pose fewer survival risks than changing strategies across different contexts (Frankenhuis et al., 2016). The present study extends this work by suggesting early harsh environments may orient children toward developing specialized abilities to secure immediate rewards.

The present findings evoke the question of 'how' children exposed to environmental harshness develop enhanced reward-oriented problem-solving. In fact, current evidence suggests reward salience tends to impair attention and planning during early development (Zelazo, Qu, & Kesek, 2010), until adulthood where it enhances task performance (Locke & Braver, 2008). However, as LHT emphasizes, previous findings with middle-income samples may reflect how cognition develops when resources are abundant and caregivers are available to insulate children from environmental pressures. Children from high stress environments may need to develop certain cognitive skills at a faster pace so they can

effectively cope with the ecological demands of stressful contexts (Frankenhuis & de Weerth, 2013). The brain has two primary motivational circuits (fear and appetitive), which evolved to promote survival. The appetitive motivational circuit reacts to stimuli that is rewarding and potentially survival enhancing, stimulating attention-visual processing and strategic action toward securing resources (Lang & Bradley, 2013). Compelling evidence from the animal and human literature indicates harsh environments may accelerate development in 'survival' motivational systems toward more adult-like functioning (e.g., Callaghan & Tottenham, 2016). For example, recent empirical evidence from neuroimaging studies using reward paradigms has suggested early childhood adversity may alter developmental trajectories in reward circuitry (Boecker et al., 2014; Gonzalez et al., 2016), and enhance reward-oriented visual processing and motor preparedness (e.g., Gonzalez et al., 2016). Based on previous and presenting findings, one tentative hypothesis may be disengaged caregiving and limited resources regulate development of appetitive and other cognitive systems in a way that facilitates an individual's ability to secure environmental resources at an early age. By the same token, this reorganization of affective-cognitive neurocircuitry to meet survival demands may eventuate in fixed patterns of responding that detracts from the development of abstract problem-solving abilities (e.g., Frankenhuis & de Weerth, 2013). It is important to note that the marginally positive correlation between reward-oriented problem-solving and visual problem-solving in the present study does not provide decisive support for the operation of a strong developmental tradeoff.

Although research in this area is still in its infancy, neuroimaging studies have been inconsistent with respect to direction of effects (hyper- versus hypo-responsivity in reward pathways), suggesting individual differences may moderate effects. This seems to converge with our finding that environmental harshness predicted enhanced reward-oriented problem-solving only among children with heightened hawk traits at age 2. Korte et al.'s (2005) hawk temperament model offers a set of hypotheses for how individual's neuropsychological systems respond to environmental stress and how this organizes behavior around specialized life history strategies (Davies et al., 2011). For individuals higher on the hawk continuum, harsh environments are thought to up-regulate sympathetic reactivity and down-regulate adrenocortical and parasympathetic activity, which facilitates higher levels of activity and approach in challenging contexts, while down-regulations in dopaminergic and serotonin pathways fosters greater exploration and securement of resources (Korte et al., 2005). Following experiences of risk, children with hawk traits may be uniquely positioned to acquire enhanced skills for securing rewards in challenging situations in comparison to others with different traits. We did not detect a significant interaction between hawk traits and environmental harshness on our standardized assessment of visual problem-solving, rather only observed main effects. Children with more hawk traits might have increased difficulties with abstract visual problem-solving regardless of the degree of harshness within their early environments. This is not entirely unexpected given children characterized by heightened appetitive motivation often prefer high-intensity stimuli, which makes them prone to boredom and experience greater difficulty inhibiting competing sources of attention when completing abstract tasks (e.g., Depue & Collins, 1999).

Despite the novelty of findings, several limitations should be discussed. First, our study was correlational; therefore, interpretations regarding causality are highly speculative.

Furthermore, we did not find definitive evidence of a developmental tradeoff, which is difficult to observe in correlational research (Metcalf, 2016). Nonetheless, present findings may serve as a conceptual blueprint for future work. Second, even though there was some variability in income the sample was still relatively high risk. Future research should test hypotheses across a wider continuum of environmental experiences. Third, even though both tasks tapped similar problem-solving processes (e.g., concentration, visual-motor coordination, planning), differences in format limit direct comparisons. One future direction may be to examine whether stressed children's performance on standardized visual problem-solving tasks improves with positive reinforcements, or if using objects stressed children are potentially more familiar with is key to assessing cognition. Fourth, we focused on hawk temperament traits and it would be interesting to examine alternative traits (e.g., dove) that may lead to different outcomes. Fifth, our maternal disengagement measure was based on observations of caregiving behaviors across reward and non-reward tasks, so it is possible that further insights may be garnered by using fine-grained assessments of caregiving. Lastly, our goal was to prospectively examine how early environmental experiences and hawk temperament traits differentially shape cognition in an environment-fitting manner. Future work should test transactional processes across multiple time points and utilize additional environmental assessments.

As others have argued (e.g., Frankenhuis et al., 2016), in order to move research, policy, and practice forward, we must push beyond conceptualizing stressed children as globally impaired, and instead view them as having developed in ways that allows them to effectively cope with the unique challenges they face. Collectively, the present findings illustrate how LHT approaches might offer important insights into the functional significance behind developmental adaptations in cognition and more ecologically relevant ways for assessing stressed children's capabilities (e.g., Frankenhuis & de Weerth, 2013). Standardized assessments that lack reward incentives, or direct ecological relevance, may fail to assess the specialized repertoire of cognitive skills children develop in stressful environments. Furthermore, children with high approach and dominant temperament characteristics might be especially poised for developing enhanced reward-oriented problem-solving following experiences of environmental harshness, though they may be at risk for worse cognitive outcomes on abstract, visual problem-solving tasks. From a public health perspective, these findings may inform how to tailor school-based interventions for high-risk children with particular temperament traits. Development of child-centered, dynamic assessments (e.g., computer/video games) that incorporate stressed children's experiences and interests may better capture their skillsets (e.g., Frankenhuis & de Weerth, 2013), and enhance feelings of mastery and engagement in early education settings. Given the importance of engaging children in early education for long-term success, developing creative classroom tools to match stressed children's needs may yield substantial payoffs.

Acknowledgments

This research was supported by grant R01 MH071256 from the National Institute of Mental Health awarded to Patrick T. Davies and Dante Cicchetti. The authors thank the families for their participation, and the staff and students who assisted on this project. The authors have declared that they have no competing of potential conflicts of interest in relation to this article.

References

- Aiken, L.S., West, S.G. Multiple regression: Testing and interpreting interactions. Thousand Oaks, CA: Sage; 1991.
- Bascoe SM, Davies PT, Cummings EM. Beyond warmth and conflict: The developmental utility of a boundary conceptualization of sibling relationship processes. *Child Development*. 2012; 83:2121–2138. [PubMed: 22862542]
- Belsky J, Schlomer GL, Ellis BJ. Beyond cumulative risk: distinguishing harshness and unpredictability as determinants of parenting and early life history strategy. *Developmental Psychology*. 2012; 48:662–673. [PubMed: 21744948]
- Bentler PM. Comparative fit indices in structural models. *Psychological Bulletin*. 1990; 107:238–246. [PubMed: 2320703]
- Boecker R, Holz NE, Buchmann AF, Blomeyer D, Plichta MM, Wolf I, et al. Impact of early life adversity on reward processing in young adults: EEG- fMRI results from a prospective study over 25 years. *PLoS ONE*. 2014; 9:e104185. [PubMed: 25118701]
- Callaghan BL, Tottenham N. The stress acceleration hypothesis: Effects of early-life adversity on emotion circuits and behavior. *Current Opinion in Behavioral Sciences*. 2016; 7:76–81.
- Davies PT, Sturge-Apple ML, Cicchetti D. Interparental aggression and children's adrenocortical reactivity: Testing an evolutionary model of allostatic load. *Development and Psychopathology*. 2011; 23:801–814. [PubMed: 21756433]
- Dennis TA, Cole PM, Wiggins CN, Cohen LH, Zalewski M. The functional organization of preschool-age children's emotion expressions and actions in challenging situations. *Emotion*. 2009; 9:520–530. [PubMed: 19653775]
- Depue RA, Collins PF. Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion. *Behavioral and Brain Sciences*. 1999; 22:491–517. [PubMed: 11301519]
- Doom JR, VanZomeren-Dohm AA, Simpson JA. Early unpredictability predicts increased adolescent externalizing behaviors and substance use: A life history perspective. *Development and Psychopathology*. 2015:1–12.
- Ellis BJ, Figueredo AJ, Brumbach BH, Schlomer GL. Fundamental dimensions of environmental risk. *Human Nature*. 2009; 20:204–268. [PubMed: 25526958]
- Ellis BJ, Jackson JJ, Boyce WT. The stress response systems: Universality and adaptive individual differences. *Developmental Review*. 2006; 26:175–212.
- Enders CK. The impact of nonnormality on full information maximum likelihood estimation for structural equation models with missing data. *Psychological Methods*. 2001; 6:352–370. [PubMed: 11778677]
- Farah MJ, Shera DM, Savage JH, Betancourt L, Giannetta JM, Brodsky NL, ... Hurt H. Childhood poverty: Specific associations with neurocognitive development. *Brain Research*. 2006; 1110:166–174. [PubMed: 16879809]
- Fox NA, Henderson HA, Rubin KH, Calkins SD, Schmidt LA. Continuity and discontinuity of behavioral inhibition and exuberance: Psychophysiological and behavioral influences across the first four years of life. *Child Development*. 2001; 72:1–21. [PubMed: 11280472]
- Frankenhuis WE, de Weerth C. Does early-life exposure to stress shape or impair cognition? *Current Directions in Psychological Science*. 2013; 22:407–412.
- Frankenhuis WE, Panchanathan K, Nettle D. Cognition in harsh and unpredictable environments. *Current Opinion in Psychology*. 2016; 7:76–80.
- Goldsmith, H., Rothbart, MK. Prelocomotor and locomotor laboratory temperament assessment battery (Lab-TAB; version 3.0, Technical Manual). Madison: University of Wisconsin, Department of Psychology; 1996.
- Gonzalez MZ, Allen JP, Coan JA. Lower neighborhood quality in adolescence predicts higher mesolimbic sensitivity to reward anticipation in adulthood. *Developmental Cognitive Neuroscience*. 2016; 22:48–57. [PubMed: 27838595]
- Hamers JH, Hessels MG, Pennings AH. Learning potential in ethnic minority children. *European Journal of Psychological Assessment*. 1996; 12:183.

- Hu LT, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*. 1999; 6:1–55.
- Humphreys KL, Lee SS, Telzer EH, Gabard-Durnam LJ, Goff B, Flannery J, Tottenham N. Exploration—exploitation strategy is dependent on early experience. *Developmental Psychobiology*. 2015; 57:313–321. [PubMed: 25783033]
- Jacobvitz D, Hazen N, Curran M, Hitchens K. Observations of early triadic family interactions: Boundary disturbances in the family predict symptoms of depression, anxiety, and attentiondeficit/hyperactivity disorder in middle childhood. *Development and Psychopathology*. 2004; 16:577–592. [PubMed: 15605626]
- Korte SM, Koolhaas JM, Wingfield JC, McEwen BS. The Darwinian concept of stress: benefits of allostasis and costs of allostatic load and the trade-offs in health and disease. *Neuroscience & Biobehavioral Reviews*. 2005; 29:3–38. [PubMed: 15652252]
- Lang PJ, Bradley MM. Appetitive and defensive motivation: goal-directed or goal-determined? *Emotion Review*. 2013; 5:230–234. [PubMed: 24077330]
- Little RJA. A test of missing completely at random for multivariate data with missing values. *Journal of the American Statistical Association*. 1988; 83:1198–1202.
- Locke HS, Braver TS. Motivational influences on cognitive control: Behavior, brain activation, and individual differences. *Cognitive, Affective, & Behavioral Neuroscience*. 2008; 8:99–112.
- MacDonald KB. Temperament and evolution. *Handbook of temperament*. 2012:273–296.
- Manning, LG., Davies, PT. Family systems processing coding system. 2011. Unpublished manuscript
- Matas L, Arend RA, Sroufe LA. Continuity of adaptation in the second year: The relationship between quality of attachment and later competence. *Child Development*. 1978; 49:547–556.
- Metcalf CJE. Invisible trade-offs: Van Noordwijk and de Jong and life-history evolution. *The American Naturalist*. 2016; 187:iii–v.
- Mittal C, Griskevicius V, Simpson JA, Sung S, Young ES. Cognitive adaptations to stressful environments: When childhood adversity enhances adult executive function. *Journal of Personality and Social Psychology*. 2015; 109:604–621. [PubMed: 26414842]
- Noble KG, Norman MF, Farah MJ. Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science*. 2005; 8:74–87. [PubMed: 15647068]
- Preacher KJ, Curran PJ, Bauer DJ. Computational tools for probing interaction effects in multiple linear regression, multilevel modeling, and latent curve analysis. *Journal of Educational and Behavioral Statistics*. 2006; 31:437–448.
- Putnam SP, Stifter CA. Behavioral approach–inhibition in toddlers: Prediction from infancy, positive and negative affective components, and relations with behavior problems. *Child Development*. 2005; 76:212–226. [PubMed: 15693768]
- Ruff HA, Capozzoli MC. Development of attention and distractibility in the first 4 years of life. *Developmental psychology*. 2003; 39:877–890. [PubMed: 12952400]
- Ruff HA, Capozzoli M, Weissberg R. Age, individuality, and context as factors in sustained visual attention during the preschool years. *Developmental psychology*. 1998; 34:454–464. [PubMed: 9597356]
- Schlomer GL, Bauman S, Card NA. Best practices for missing data management in counseling psychology. *Journal of Counseling Psychology*. 2010; 57:1–10. [PubMed: 21133556]
- Steiger, JH., Lind, J. Statistically based tests for the number of common factors. Paper presented at the Annual Meeting of the Psychometric Society; IA. 1980.
- Sturge-Apple ML, Davies PT, Martin MJ, Cicchetti D, Hentges RF. An examination of the impact of harsh parenting contexts on children's adaptation within an evolutionary framework. *Developmental Psychology*. 2012; 48:791. [PubMed: 22229853]
- Sturge-Apple ML, Suor JH, Davies PT, Cicchetti D, Skibo MA, Rogosch FA. Vagal tone and children's delay of gratification: Differential sensitivity in resource-poor and resource-rich environments. *Psychological Science*. 2016; 27:885–893. [PubMed: 27117276]
- Valentino K, Cicchetti D, Toth SL, Rogosch FA. Mother-child play and maltreatment: A longitudinal analysis of emerging social behavior from infancy to toddlerhood. *Developmental Psychology*. 2011; 47:1280–1294. [PubMed: 21744951]

Wechsler, D. Wechsler Preschool and Primary Scale of Intelligence-Third Edition. San Antonio, TX: Psychological Corporation; 2002.

Zelazo, PD., Qu, L., Kesek, AC. Hot executive function: Emotion and the development of cognitive control. In: Calkins, S., Bell, MA., editors. Child development at the intersection of emotion and cognition. Washington, DC: American Psychological Association; 2010. p. 97-111.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Key points

- Stressful environments are known to impair children's cognitive abilities.
- Life History Theory approaches might increase understanding of how children's cognitive skills are honed toward salient features within stressful environments.
- Environmental harshness and hawk temperament predicted worse visual problem-solving on a standardized assessment.
- Child hawk temperament moderated the association between environmental harshness and reward-oriented problem-solving; these effects were specific to children high on hawk traits.
- Findings may inform development of ecologically relevant assessments of children's cognition within contexts of risk and school-based interventions.

Figure 1.

Plot of simple slopes of the moderating role of hawk temperament on associations between environmental harshness and children's reward-oriented problem-solving. Solid line denotes simple slope significantly different from 0. High and low values are calculated at ± 1 standard deviation.

Table 1

Sample Sizes, Means, Standard Deviations, and Ranges for Primary Variables

Variable	N	Mean	Standard Deviation	Range
Environmental Harshness	201	-.02	.80	-1.56 – 2.04
Hawk Temperament	192	1.81	.50	.25 – 3.06
RO Strategy Use	164	3.19	1.11	1.0 – 5.0
RO Key Manipulation	164	4.76	1.20	0.0 – 6.0
RO Focused Attention	164	3.10	1.22	1.0 – 5.0
WPPSI Block Design	170	17.11	4.94	0 – 24

Note. RO = Reward-Oriented.

Table 2

Correlations Among Primary Variables in Analyses

	1	2	3	4	5	6	7
1. Male	–						
2. Age	–.05	–					
3. Black/Mixed Race	.05	–.18*	–				
4. Maternal Education	–.10	–.02	–.23**	–			
5. Environmental Harshness	.07	–.09	.34**	–.42**	–		
6. Hawk Temperament	.25**	.01	.10	–.13†	.20**	–	
7. Reward-Oriented Problem-Solving	.00	.11	.05	–.04	.17*	.19*	–
8. Visual Problem-Solving	–.22**	.17*	–.14†	.18*	–.25**	–.24**	.14†

Note.

† $p < .10$,* $p < .05$,** $p < .01$.

Table 3

Hierarchical Path Models Examining Main Effects of Environmental Harshness and Hawk Temperament Traits and their Interaction on Children's Reward-Oriented and Visual Problem-Solving

Independent Variables	β	B	SE	p-value
<i>Environmental Harshness Model → Reward-Oriented PS</i>				
Male	-.00	-.00	.17	.98
Black/Mixed Race	.03	.06	.20	.78
Age (months)	.13	.07	.04	.11
Maternal Education	.05	.05	.09	.59
Environmental Harshness	.19	.24	.12	.04*
<i>Moderating Effect of Hawk Temperament → Reward-Oriented PS</i>				
Male	-.05	-.10	.17	.56
Black/Mixed Race	.02	.04	.19	.83
Age (months)	.13	.06	.04	.11
Maternal Education	.06	.06	.08	.48
Environmental Harshness	.15	.19	.12	.11
Hawk Temperament	.18	.39	.17	.03*
Hawk Temperament × Environmental Harshness	.20	.55	.22	.01*
<i>Environmental Harshness → Visual PS</i>				
Male	-.18	-1.76	.72	.01*
Black/Mixed Race	-.03	-.29	.84	.73
Age (months)	.15	.34	.17	.05*
Maternal Education	.09	.39	.37	.29
Environmental Harshness	-.17	-1.06	.51	.04*
<i>Moderating Effect of Hawk Temperament → Visual PS</i>				
Male	-.15	-1.53	.73	.04*
Black/Mixed Race	-.02	-.18	.83	.83
Age (months)	.15	.35	.17	.04*
Maternal Education	.08	.37	.36	.31
Environmental Harshness	-.16	-1.00	.51	.05*
Hawk Temperament	-.16	-1.54	.75	.04*
Hawk Temperament × Environmental Harshness	.07	.90	.95	.34

Note. PS = Problem Solving.

*
p .05