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INTERPERSONAL RELATIONS AND GROUP PROCESSES

Cognitive Adaptations to Stressful Environments: When Childhood Adversity Enhances Adult Executive Function

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Can growing up in a stressful childhood environment enhance certain cognitive functions? Drawing participants from higher-income and lower-income backgrounds, we tested how adults who grew up in harsh or unpredictable environments fared on 2 types of executive function tasks: inhibition and shifting. People who experienced unpredictable childhoods performed *worse at inhibition* (overriding dominant responses), but performed *better at shifting* (efficiently switching between different tasks). This finding is consistent with the notion that shifting, but not inhibition, is especially useful in unpredictable environments. Importantly, differences in executive function between people who experienced unpredictable versus predictable childhoods emerged only when they were tested in uncertain contexts. This catalyst suggests that some individual differences related to early life experience are manifested under conditions of uncertainty in adulthood. Viewed as a whole, these findings indicate that adverse childhood environments do not universally impair mental functioning, but can actually enhance specific types of cognitive performance in the face of uncertainty.

Keywords: life history theory, stressful childhood environments, uncertainty, cognitive adaptations, executive function

Can growing up in a stressful environment enhance certain cognitive functions? The evidence thus far suggests the answer is no. People who grow up in stressful environments tend to score lower on tests of intelligence, memory, and other important cognitive abilities (e.g., Ayoub et al., 2009; Fernlad et al., 2011; Goodman et al., 2010; Hostinar et al., 2012; Mani et al., 2013; Rieder & Cicchetti, 1989). This reduced performance is often assumed to imply that exposure to early life stress impairs general mental functioning. It is commonly presumed that experiencing an adverse childhood environment compromises cognitive competencies and prevents people from fully developing their cognitive potential.

Although these findings are important, they might not tell the whole story. Rather than *impairing* cognitive functioning, we suggest that childhood adversity *shapes* cognition in adaptive ways. According to evolutionary models of behavior, the minds of individuals who are reared in stressful environments should be specialized to perform tasks that are adaptive in such environments (Belsky et al., 1996; Ellis & Del Giudice, 2014; Frankenhuis & Del Giudice, 2012; Glover, 2011; Hawley, 2011; Nederhof & Schmidt, 2012). If, for example, a person grows up in an unpredictable and constantly changing environment, he or she ought to develop cognitive tendencies that help him or her function adaptively in this type of challenging environment.

The notion that stressful early life conditions might adaptively shape rather than impair cognition raises an important question: Might experiencing a stressful childhood environment actually *improve* specific types of cognitive performance (Frankenhuis & de Weerth, 2013)? In this research, we investigate how two dimensions of early life environmental stress—exposure to an unpredictable or a harsh childhood environment—influence cognitive functioning in adults. We test how people who grew up in environments that differed in harshness or unpredictability fare on two types of executive function tasks: inhibition and shifting. We do not find consistent effects of harsh childhood environments on either type of executive function. However, we demonstrate that people who had more unpredictable childhoods perform *worse at inhibition* (overriding dominant responses), but perform *better at shifting* (efficiently switching between different tasks). The final experiment was conducted with a socioeconomically disadvantaged sample of adults on whom we had detailed, longitudinal childhood environment data. This unique experiment allowed us to replicate the novel findings regarding shifting using prospective and more objective measures of childhood environments. The

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results confirm that improved shifting ability is linked to being exposed to a more unpredictable childhood environment.

Importantly, we also document that the effects of childhood unpredictability on adult executive function emerge only when people are tested under conditions of uncertainty. When current adult conditions are not characterized by uncertainty, individuals who experienced more unpredictable childhoods do *not* perform better or worse in our experiments. However, when tested in conditions of uncertainty—conditions reminiscent of their early life environments—adults exposed to more unpredictable childhood environments outperform those exposed to more predictable childhood environments on the executive function of shifting. These findings are important because they suggest that some individual differences related to early life experiences are manifested specifically under conditions of uncertainty later in life.

To our knowledge, these experiments are the first to document that stressful childhood environments do not universally impair mental functioning, but may actually enhance certain cognitive functions in the face of uncertainty. These findings, therefore, suggest that the cognitive functioning of adults reared in more unpredictable environments may be better conceptualized as *adapted* rather than impaired (Frankenhuis & de Weerth, 2013).

Influence of Stressful Childhood Environments

The predominant view in psychology suggests that children raised in supportive, well-resourced environments tend to develop normally, whereas those who encounter psychosocial adversity such as poverty or high levels of family conflict typically have impaired development (Ellis et al., 2012; Frankenhuis & de Weerth, 2013). Consistent with the notion that childhood adversity impairs the development of cognitive functioning, much research has found that people who grow up in more stressful environments tend to score lower on tests of intelligence, language, memory, and other cognitive abilities (e.g., Ayoub et al., 2009; Fernlad et al., 2011; Goodman et al., 2010; Hostinar et al., 2012; Mani et al., 2013; Rieder & Cicchetti, 1989).

These past findings are valid and important. An evolutionary perspective, however, suggests that they might be missing a key part of the story. Whereas the predominant view in psychology emphasizes that childhood stress compromises cognitive competencies and promotes dysfunctional behavior, the evolutionary framework of life history theory maintains that an individual's development and cognitive competencies should adjust to environmental stressors in ways that were adaptive in ancestral environments (Belsky et al., 1991; Del Giudice et al., 2012; Ellis et al., 2012; Frankenhuis & de Weerth, 2013; Nettle, 2010; Simpson & Belsky, in press).

For instance, people who are reared in harsh and unpredictable environments prefer smaller immediate rewards over larger future rewards, such as taking $10 now instead of receiving $20 next year (Brezina, Tekin, & Topalli, 2009). Although many psychologists describe this tendency as dysfunctional (e.g., shortsightedness, impulsivity, poor delay of gratification), this tendency is likely to be beneficial in harsh and unpredictable environments. Because future rewards are much more uncertain in dangerous and constantly changing environments, a preference for immediate over delayed rewards in these environments is actually more adaptive (see Daly & Wilson, 2005; Fawcett, McNamara, & Houston, 2012).

According to life history theory, a preference for immediate over delayed rewards can be either adaptive or maladaptive, depending on the nature of the early life environment to which a person has been exposed. Natural selection should, therefore, favor different cognitive and behavioral tendencies, contingent on the specific, reliable, and valid cues present in people's early life environments. The critical question to which we now turn is: What types of reliable, valid environmental cues guide this process?

Harsh and Unpredictable Environments

In an extensive cross-species analysis, Ellis, Figueredo, Brumbach, and Schlomer (2009) identified two dimensions of environmental stress central to human development: harshness and unpredictability. *Harshness* refers to age-specific rates of morbidity—mortality in the local environment. In modern Western societies, harshness is indexed by socioeconomic status (SES), given that lower SES is linearly related to nearly all forms of morbidity-mortality. *Unpredictability* refers to fluctuations in the harshness of environmental conditions across space and time. Unpredictability is indexed by changes in the family ecology that directly affect parents and/or their children, such as people moving in and out of the house, frequent changes in residence, and changes in parents' job/work status.

According to life history theory, our brains and bodies have been shaped by natural selection to respond adaptively to cues of harshness and unpredictability (Belsky et al., 1991; Chisholm, 1993, 1999; Ellis, Figueredo, Brumbach, & Schlomer, 2009; Quinlan, 2007). Consistent with this premise, recent longitudinal analyses of the National Longitudinal Study of Adolescent Health, the National Institute of Child Health and Human Development Study of Early Child Care and Youth Development, and the Minnesota Longitudinal Study of Risk and Adaptation support this prediction (Belsky, Schlomer, & Ellis, 2012; Brumbach, Figueredo, & Ellis, 2009; Simpson, Griskevicius, Kuo, Sung, & Collins, 2012). These studies find that experiencing greater unpredictability or harshness in early life has unique effects on opportunistic behaviors, such as increased risk-taking, earlier sexual debut, aggression, and sexual promiscuity.

In general, harsh and unpredictable environments motivate people to devalue the future and instead promote short-term opportunism to take advantage of immediate benefits. Although these outcomes are often considered socially undesirable, life history theory contends that they are adaptive responses to uncertain and rapidly changing environments. In what follows, we use this adaptive logic to derive hypotheses about which cognitive functions should be enhanced or diminished by exposure to different types of stressful childhood environments.

Executive Function: Inhibition and Shifting

We propose that stressful childhood environments should adaptively shape executive (cognitive) functioning. Considered central to intelligent behavior, executive function refers to the management of cognitive processes that guide complex behavior (Banich, 2009; Miller & Cohen, 2001). Executive function is critical for activating, maintaining, and selecting different courses of action needed to carry out complex behaviors to achieve different goals (Miyake & Friedman, 2012). Although executive function was once believed to reflect a single cognitive ability, recent research shows that executive function involves an array of distinct abilities. Even though a single source of variance accounts for some general executive functioning ability, distinct types of executive functioning consistently emerge as separate factors (Friedman & Miyake, 2004; Friedman et al., 2008; Garon, Bryson, & Smith, 2008; Miyake et al., 2000; Schmeichel & Tang, 2015).

Two of the most widely studied types of executive functioning are inhibition and shifting. *Inhibition*, also known as inhibitory control, is the deliberate overriding of dominant responses. It reflects the ability to exert active, intentional control to maintain and pursue a single goal. Inhibition is central to many behaviors that involve self-control, willpower, and self-regulation (Hall, Fong, Epp, & Elias, 2008; Pronk, Karremans, & Wigboldus, 2011; Young et al., 2009).

Shifting, also known as task-switching, involves flexibly switching between different tasks or mental sets. Whereas inhibition entails the ability to exert intentional control to pursue a single goal, shifting is the ability to shift between goals or strategies. Shifting facilitates efficiently adapting to changing situations. People who are good at shifting are better at allowing their responses to be guided by the current situation rather than by an internal goal. Shifting is a core component of cognitive flexibility, which underlies important abilities such as creativity (Diamond, 2013). Cognitive flexibility plays an important role in academic achievement (Blair & Razza, 2007; Bull & Lee, 2014), and it correlates positively with math and reading abilities, even when controlling for IQ (Yeniad, Malda, Mesman, van Ijzendoorn, & Pieper, 2013).[1]

We propose that exposure to more stressful childhood environments should influence executive function outcomes in adulthood. Specifically, we test whether experiencing a harsher or a more unpredictable environment in childhood influences performance on inhibition and shifting tasks in adults. There is reason to believe that harsh and/or unpredictable early life environments might have *specific and opposing* effects on inhibition and shifting. If such early life environments shape the mind toward short-term opportunism, they ought to reduce inhibition. Inhibition is essential for pursuing long-term goals and delaying gratification, which makes it adaptive in stable and predictable environments in which long-term investments are more likely to pay off. Inhibition can be costly, however, in constantly changing, unpredictable environments because it prevents people from taking advantage of important, fleeting short-term opportunities (Daly & Wilson, 2005). Harsh or unpredictable early life environments might, therefore, especially impair inhibition.

In contrast to the predictions for inhibition, exposure to harsh or unpredictable early life environments should enhance shifting. The ability to shift between tasks flexibly, rapidly, and efficiently is essential for adapting to constantly changing environments (Nederhof, Ormel, & Oldehinkel, 2014). Because opportunities in such environments are fleeting, individuals who can adapt to change by rapidly identifying new patterns and associations should be in a better position to take advantage of new opportunities before they vanish. Consistent with this logic, low self-restraint in early childhood predicts better shifting in adolescence (Friedman et al., 2011). Moreover, studies of children living in orphanages, who tend to be exposed to more unpredictable environments, indicate that although these children display impaired inhibition, they do *not* always show impairment in shifting (Pollak et al., 2010). It is possible, therefore, that exposure to harsh or unpredictable early life environments could actually enhance the executive function of shifting.

The Critical Role of Current Uncertain Contexts

The current research investigates the contexts in which adults raised in stressful environments display enhanced or diminished executive functioning compared with adults raised in less stressful environments. Drawing on animal behavior research, we further hypothesize that a person's early life environment is most likely to influence his or her executive functioning later in life when he or she encounters uncertain situations.

Research with nonhuman animals has documented that adult rats reared in adverse environments can outperform those reared in nonadverse environments on learning tasks, but only when they are tested in stressful contexts (e.g., Bagot et al., 2009; Champagne et al., 2008). For example, rats that experienced more difficult early life environments (lower levels of maternal licking and grooming early in life) show enhanced performance on contextual fear conditioning tasks—but only when the tasks were conducted in a stressful context. When the tasks were conducted in low-stress contexts, adult rats reared in adverse conditions did *not* perform better than those reared in nonadverse environments. Thus, it is only when they are tested in stressful contexts that rats reared in adverse conditions show superior performance. These studies also suggest that early life environments influence neural development and functioning, which in turn enhances adult cognitive processes in stressful and uncertain contexts—that is, when organisms are in contexts similar to their early life environments (Bagot et al., 2009; Champagne et al., 2008).

Recent studies with humans lend additional support to the critical role of uncertain contexts. Experiments with college students indicate that individual differences associated with early life experiences are often contingent on environmental contexts later in life. When comparing the behavior of college students from higher-SES versus lower-SES childhoods, experimental studies have found that expected differences in responding emerge primarily when behavior is assessed in experimentally induced uncertain contexts (e.g., Griskevicius et al., 2011a, 2011b; 2013; Hill et al., 2013; White et al., 2013). For instance, students who report growing up in lower-SES conditions tend to take more risks and behave more impulsively, but *only after* they read a news article that elicits a sense of uncertainty (Griskevicius et al., 2011b, 2013; Mittal & Griskevicius, 2014).

[1] Inhibition and shifting are also related to a different region of the prefrontal cortex. Inhibition is related to the dorsolateral prefrontal cortex and subthalamic nucleus (Klein, Rauh, & Biscaldi, 2010; McDowell, Dyckman, Austin, & Clementz, 2008; Schaeffer et al., 2013), whereas shifting is tied to the anterior cingulate cortex and posterior parietal cortex (Aron, Robbins & Poldrack, 2004; Barber & Carter, 2005). Inhibition and shifting are likewise differentially influenced by particular neuromodulators. For instance, dopamine and norepinephrine enhance shifting performance, but norepinephrine decreases inhibition functioning (Robbins & Arnsten, 2009; Robbins & Roberts, 2007).

Viewed together, findings in both humans and rats suggest that a current uncertain context may be critical for eliciting the types of cognitive and behavioral tendencies associated with one's childhood environment. Accordingly, we predict that individuals who grew up in harsher and/or more unpredictable childhood environments should show the hypothesized differences in executive function *primarily* when they are confronted with current uncertainty.

Experiment 1: Inhibition and Shifting

Experiment 1 tested the performance of adults who were reared in harsh and/or unpredictable childhood environments on two executive function tasks: inhibition and shifting. Performance was compared in two experimental contexts (conditions): control and uncertainty. We predicted that individuals who reported being reared in more unpredictable and/or harsh environments would perform *worse on inhibition*, but *better on shifting*, compared with people who reported growing up in more predictable, less harsh environments. We also predicted that this specific pattern would emerge only when people were tested in the context of uncertainty.

Method

Participants. One-hundred and three people (45 males, 57 females, one declined to state his or her sex) participated in exchange for course credit or $10. Participants were university students or members of the general public, most of whom were employees at the local university. Participants' mean age was 22.8 years (SD = 7.95), ranging from 18- to 64-years-old. Data collection was conducted in two stages. The first stage involved data collection from an initial sample of 75 participants. After data analyses were performed on this initial sample, more data were collected from an additional 28 participants, which were combined with the initial sample.

Study design. The study had a 2 (Type of Task: Inhibition vs. Shifting) × 2 (Condition: Uncertainty vs. Control) mixed-factorial design. Type of task was a within-subjects factor, meaning that all participants completed both an inhibition task and a shifting task. Condition was a between-subjects factor, meaning that participants were randomly assigned to either an uncertainty or a control condition. All participants provided information about their childhood environments, indicating the level of environmental unpredictability and the level of harshness (their family's socioeconomic status) while they were growing up.

Procedure overview. All participants came to the lab in small groups and were seated at computers in separate rooms or at work stations separated by partitions. The procedure had six key parts. First, participants familiarized themselves with the inhibition and the shifting tasks by practicing a few trials of each task. Second, they read one of two news stories that constituted the experimental condition manipulation. Third, participants did the full inhibition task (90 trials), which was the first dependent measure. Fourth, all participants then underwent an experimental manipulation "booster" to ensure they were still in an uncertainty or a control frame of mind. Fifth, participants then did the full shifting task (48 trials), which was the second dependent measure. Finally, participants provided information about their childhood environments and demographic information.

To minimize suspicion, a cover story was used based on previous research using similar manipulations (see Griskevicius et al., 2011a, 2011b, 2013; Hill et al., 2012; Mittal & Griskevicius, 2014). Participants were told that the session had several different tasks related to visual perception and memory. Consistent with this cover story, the condition manipulation was presented as a memory task and the two executive function tasks were described as visual perception tasks. Specifically, participants were told they would read a recent news article and then answer some questions about it based on their memory of the article. After reading the news article, participants were told that some time needed to pass before the memory questions could be answered to allow for memory decay. In the meantime, they would work on the inhibition task. Following this, participants recalled aspects of the news article they read earlier (to be consistent with the cover story), which served as the experimental manipulation booster. Finally, they did the shifting task before providing information on their childhood environment and demographics.

Uncertain context manipulation. Participants were randomly assigned to one of two experimental context conditions: control or uncertainty. In both conditions, participants read a news article that, they were told, recently appeared in a Sunday section of the *New York Times.* The articles were formatted to look like a web-article featuring the newspaper's logo, font, and style. The articles used in Experiment 1 were based on previous research (Griskevicius et al., 2013; Hill et al., 2012; Mittal & Griskevicius, 2014), which has used these same articles to create uncertain experimental contexts.

In the uncertainty condition, the article was titled *Tough Times Ahead: The New Economics of the 21st Century*. It described the last economic recession and the highly uncertain economic climate. In the control condition, participants read an article that was similar in length and style. The control article described a person looking for lost keys at home. As in the uncertainty condition, the control article was intended to elicit some sense of worry and negative affect. However, the uncertainty article was intended to elicit a significantly greater sense of environmental uncertainty.

Pretest. To test whether the two articles elicited a different amount of uncertainty, a separate group of 69 participants read one of the two articles and indicated the extent to which they felt uncertain about the environment. Specifically, after reading one of the two articles, participants responded to the following four items: (a) How uncertain is the world? (b) How uncertain is the economy? (c) How unpredictable is the world? (d) How unpredictable is the economy? Responses to each item were provided on a 7-point scale anchored at 1 = *not at all* and 7 = *extremely*. The four items were aggregated into an *uncertainty index* (α = .95).

The results confirmed that participants felt a significantly greater sense of uncertainty after reading the uncertainty article than the control article ($M_{\text{uncertainty}} = 5.88$, $M_{\text{control}} = 4.64$; $p < .001$).

We also checked whether the uncertainty article elicited a different amount of uncertainty depending on the level of participants' childhood unpredictability or childhood SES. To do this, we regressed participants' uncertainty ratings on their childhood environment ratings. Participants' childhood unpredictability did not differentially influence how uncertain the article made them feel ($\beta = .19$, $p = .30$). Similarly, participants' childhood SES did not differentially influence how uncertain the article made them feel

($\beta = -.07$, $p = .69$). The uncertainty manipulation, therefore, elicited similar levels of uncertainty, regardless of the type of childhood environment that people experienced.

Inhibition task. After reading one of the two randomly assigned news articles, all participants completed a standard executive function task assessing inhibition. Inhibition tasks include the Stroop task (Stroop, 1935), the stop signal task (Logan, 1994), and the antisaccade task (Roberts, Hager, & Heron, 1994). Each of these tasks has high convergent validity, with factor analyses showing that responses to them load on one factor with loadings ranging from .75 to .82 (Friedman et al., 2008).

The current experiment measured inhibition using the antisaccade task. The task had 90 trials. A single trial included the following rapid sequence of images: (a) a centered fixation point, (b) a bright flash, (c) a picture of a block arrow, (d) a mask for the arrow image, and (e) a question asking the participant to indicate which direction the arrow was pointing. See Figure 1 for a visual depiction of the task, which is described in more detail below.

First, a white fixation cross appeared in the center of a black computer screen. Earlier, participants had been instructed to orient their attention toward the fixation cross each time it appeared on the screen. The cross measured 1.05 × 1.05 in. (1.67 × 1.67 cm). The cross was displayed on the screen for a varying amount of time, appearing for between 1,500 and 3,500 ms that varied in 250-ms intervals. The display time of the fixation cross was intentionally varied to ensure that participants could not settle into a predictable routine.

Second, a flash appeared on either the left or the right side of the cross. The flash was a yellow box measuring 1.05 × 1.05 in. (1.67 × 1.67 cm), and it appeared 4.19 in. (10.64 cm) to the left or the right of the cross. The flash always appeared for 150 ms. The flash served as an attention-grabbing visual stimulus that oriented each participant's attention toward the flash. It appeared on the right side of the fixation point on some trials, and on the left side on other trials.

Third, as the flash disappeared, a block arrow appeared on the *opposite side* of the screen from the flash. For example, if the flash appeared on the left side of the fixation point, the arrow would always appear on the right side of the fixation point. The white block arrow measured 1.05 × 1.05 in. (1.67 × 1.67 cm), and it appeared 4.19 in. (10.64 cm) from the fixation cross. The arrow always appeared for 175 ms. Importantly, *one of four different arrows* appeared on a given trial: The arrow was either pointing up, down, right, or left. The arrow was the target image that each participant needed to correctly identify in the trial.

Fourth, a box appeared in the same spot as the arrow, masking the arrow image. The mask was a gray cross-hatched box measuring 1.05 × 1.05 in. (1.67 × 1.67 cm). The use of a mask is standard procedure in these kinds of tasks. The function of the mask is to hide the image of the arrow, making it impossible to identify the arrow once it is hidden.

For each trial, participants were asked to identify the correct direction of the arrow image using the directional keypad on the keyboard. The dependent measure was the percentage of responses that participants answered correctly (out of 90 trials). On average, participants got the correct response 54.45% ($SD = 20.05$) of the time. Experiment 1 tested whether performance on this task differed as a function of people's childhood environment and the current testing context (i.e., control vs. uncertainty manipulation).

This executive function task measures inhibition because doing well on it requires *not* looking at the yellow flash. People who look at the yellow flash have a more difficult time correctly identifying the arrow because their attention is oriented to the wrong side of the screen. Thus, doing well on this task requires inhibiting one's dominant response, which is to orient toward the yellow flash and, instead, to effortfully direct one's attention to the opposite side of the screen. Consistent with previous executive function research using this task (Friedman et al., 2008; Roberts et al., 1994), participants could take as long as they wanted to provide their response on each trial. After a response was made for a given trial, the fixation cross for the next trial appeared on the screen.

Experimental manipulation booster. After participants finished the inhibition task, we wanted to ensure they were still in an uncertain or a control state of mind. To do this, we used a "booster" of the experimental manipulation. Consistent with the cover story, participants were asked to: "Please think back to the short story you read earlier. Think of a visual image that best describes the story. If you were to draw a picture or take a photo, what image best captures the emotions and descriptions felt in the story? Please take a few minutes to describe in detail the visual image that encapsulates the article." They were then instructed to spend a few minutes recalling and writing about the news story.

Shifting task. Immediately after the booster, participants completed a standard executive function task assessing shifting. Shifting tasks include the number–letter task (Rogers & Monsell, 1995), the color–shape task (Miyake, Emerson, Padilla, & Ahn, 2004), and the category switch task (Mayr & Kliegl, 2000). Each of these tasks has reasonable convergent validity, with factor analyses showing that responses to them load on one factor with loadings ranging from .50 to .62 (Friedman et al., 2008).

We measured shifting using the color–shape task (see Figure 2). The task had 48 trials. At the beginning of a given trial, the word "shape" or the word "color" appeared in light gray font at the top of a black screen. The word was 0.75 in. (1.90 cm) tall. The specific word that appeared on a given trial indicated whether the

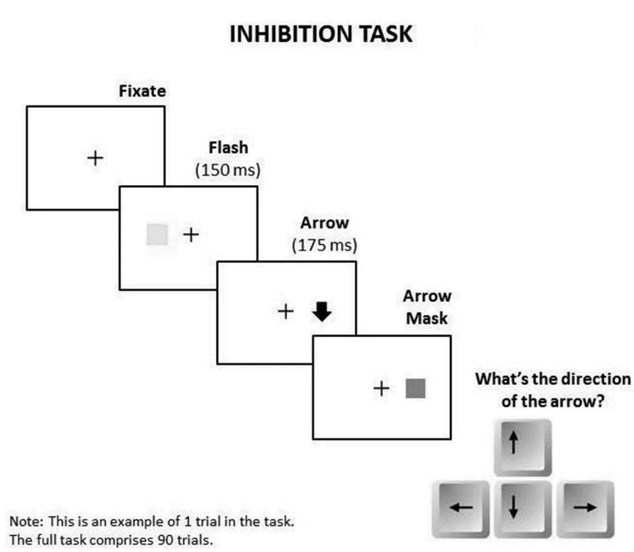

Figure 1. Inhibition task.

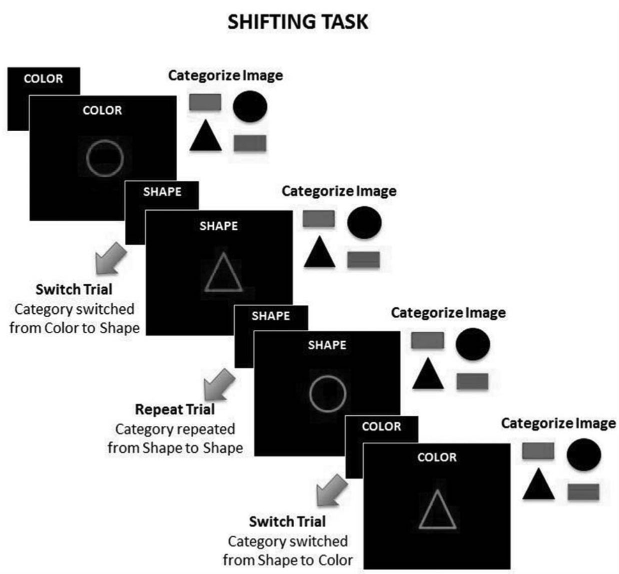

Figure 2. Shifting task.

current trial involved categorizing a color or categorizing a shape. The word remained on the screen for the entire trial.

After the word "shape" or "color" had been on the screen for 150 ms, another image of a colored shape appeared on the screen. The image was always one of two colors (red or green) and one of two shapes (triangle or circle). The triangle was approximately 2.96 in. (7.51 cm) tall and 3.07 in. (7.79 cm) wide; the circle was approximately 3.07 in. (7.79 cm) in diameter.

For each trial, participants were asked to categorize the image as quickly and as accurately as possible. For example, if the image was a red circle and the word on the screen was "shape," the correct categorization is circle. However, if the image was a red circle and the word on the screen was "color," the correct categorization is red. Two keys on the keyboard were used to categorize the image. Specifically, we glued small visual images (triangle, circle, red box, green box) on two keys on the keyboard (the "Z" key was red or circle; the "?" key was green or triangle). After a response was made, the next trial began after 600 ms.

Following established procedures for this task, only responses from trials on which participants made correct categorizations were used in the analysis. Participants provided the correct response on an overwhelming majority of trials, correctly categorizing the image 94.1% of the time. Specifically, out of the 48 trials, participants got an average of 45.15 correct responses ($SD = 3.29$). There were no differences in accuracy between the control and the uncertainty condition ($M_{\text{control}} = 45.5$, $M_{\text{uncertainty}}$ 44.7; $p = .22$).

Measuring shifting. This task has two types of trials: repeat and switch. *Repeat* trials involve the same categorization word as in the previous trial. For example, if the previous trial asked participants to categorize "shape," the current trial also asked them to categorize "shape"—the category *repeated* from one trial to the next. In contrast, *switch* trials involve a different categorization word than the previous trial. For example, if the previous trial asked participants to categorize "shape," the current trial asked them to categorize "color"—the category *switched* from one trial to the next (see Figure 2).

Of the 48 total trials, 24 were repeat trials and 24 were switch trials. Participants did not know in advance whether a given trial would be a repeat or a switch trial. In fact, the sequence was randomly generated. On average, participants were similarly accurate on the repeat trials and the switch trials ($M_{\text{Accuracy\_Switch}} = 94.5\%$, $M_{\text{Accuracy\_Repeat}} = 93.6\%$; $p = .79$). For both the repeat and the switch trials, there were no differences in accuracy as a function of either childhood unpredictability or experimental condition, and there were no interactions between experimental context and childhood unpredictability (all $ps > .16$). However, accuracy on the switch trials was associated with childhood SES ($\beta = -.22$, $p = .025$), with participants from poorer backgrounds having higher accuracy on the switch trials. There was no association between childhood SES on accuracy for repeat trials ($p = .13$). Additionally, there were no significant interactions between experimental context and childhood SES predicting accuracy (all $ps > .065$).

The executive function of shifting is defined as the time it takes to switch from one task to another *relative to* the time it takes to repeat the same task (Friedman et al., 2008; Miyake et al., 2004; Meiran et al., 2000). Better shifting means that a person is quicker to shift from one task to the other, whereas worse shifting means a person is slower to shift. Shifting is thus operationalized as the difference between the average RTs of the trials that required a switch and the average RTs of the trials in which no switch was necessary (Friedman et al., 2008; Miyake et al., 2004; Meiran et al., 2000).

Following established procedures for assessing shifting performance (Friedman et al., 2008; Meiran et al., 2000; Miyake et al., 2004), the dependent measure was the "switch cost," which is the difference between the average response time of switch trials *relative to* the average response time of repeat trials. Thus, we calculated response times for the switch trials ($M = 910.7$ ms, $SD = 262.79$) and for the repeat trials ($M = 868.11$ ms, $SD = 311.05$). As noted earlier, only accurate responses were used when calculating the dependent measure.

Conceptually, this task measures shifting ability because doing well on it requires individuals to efficiently shift between different categories. People who become fixated on one category have more difficulty correctly categorizing the image when the category changes. Hence, doing well on this task requires adapting to changing situations rapidly *and* efficiently. On average, the switch cost was 42.55 ms ($SD = 161.08$ ms). Thus, it took people an average of 42.55 ms longer to correctly categorize the switch trials than the repeat trials. Lower switch costs indicate a person is good at shifting; higher switch costs indicate a person is poor at shifting.

Childhood unpredictability. To assess exposure to an unpredictable childhood environment, participants were instructed to: "Think back to your life when you were younger than 10. This time includes preschool, kindergarten, and the first few years of elementary school." Participants then answered three questions (developed for the present Experiment) that assessed the extent to which they lived in an unpredictable environment. Specifically: "When I was younger than 10 . . .: (a) things were often chaotic in my house, (b) people often moved in and out of my house on a pretty random basis, and (c) I had a hard time knowing what my parent(s) or other people in my house were going to say or do from day-to-day."

Responses were made on 7-point scales with endpoints labeled *strongly disagree* and *strongly agree*. The items were aggregated into a childhood unpredictability index ($\alpha = .62$). The mean childhood unpredictability in this university/community sample was relatively low ($M = 2.02$), but the measure had considerable variability ($SD = 1.13$). There was no significant difference in childhood unpredictability between the control and uncertainty conditions ($M_{\text{uncertainty}} = 1.93$, $M_{\text{control}} = 2.09$; $p = .47$).

Childhood socioeconomic status. We also assessed participants' childhood SES as a proxy measure for harshness. We used established measures to assess childhood SES (see Griskevicius et al., 2011, 2013; Mittal & Griskevicius, 2014; White et al., 2013). Specifically, participants answered four items: (a) "My family usually had enough money for things when I was growing up," (b) "I grew up in a relatively wealthy neighborhood," (c) "I felt relatively wealthy compared to the other kids in my school," and (d) "What was your yearly household income when you were growing up (with eight response options: $15,000 or less; $15,001–$25,000; $25,001–$35,000; $35,001–$50,000; $50,001–$75,000; $75,001–$100,000; $100,001–$150,000; $150,000 or more). Responses to these four items were averaged and combined into a childhood SES index ($\alpha = .86$).

The correlation between the measure of childhood SES and the measure of childhood unpredictability was very low ($r = .013$), indicating that the two measures were uncorrelated.

Results and Discussion

We hypothesized that individuals who reported being raised in more unpredictable and/or harsher environments would perform worse on inhibition, but better on shifting, compared with people who reported growing up in more predictable, less harsh environments. Critically, we also hypothesized that this pattern would emerge primarily when people were tested in an uncertain context.

We first tested for a three-way interaction with type of task (inhibition vs. shifting, within-subjects), context (uncertainty vs. control, between-subjects), and childhood environment (unpredictability *or* SES as a mean-centered continuous variable). To account for nonindependence between performance on inhibition and shifting for a given person, we used a mixed modeling approach.

The analysis with childhood SES (harshness) did not reveal a significant three-way interaction with childhood SES, type of task, and context ($p = .087$). However, the analysis with childhood unpredictability did reveal a significant three-way interaction with type of task, context, and childhood unpredictability, $F(1, 99) = 11.23$, $p < .001$. We probed this interaction by using regression to analyze the specific findings for inhibition and for shifting.

Inhibition. We first examined inhibition as a function of childhood SES. Regression analyses did not yield any significant findings, including no main effect of childhood SES ($\beta = -.05$, $p = .64$) and no childhood SES by uncertainty interaction ($\beta = -.57$, $p = .16$). Thus, childhood SES (harshness) did not affect inhibition outcomes.

We next examined inhibition as a function of childhood unpredictability. This analysis did not yield a main effect of childhood unpredictability ($\beta = -.038$, $p = .70$). However, it did produce a childhood unpredictability by uncertain context interaction ($\beta = -.34$, $p = .011$), which indicated that performance on inhibition differed depending on a person's level of childhood unpredictability and whether or not the current context was uncertain.

As shown in Figure 3, in the control condition, there was no relation between childhood unpredictability and performance on inhibition ($\beta = .20$, $p = .14$). In the uncertainty condition, however, experiencing greater unpredictability in childhood predicted significantly *worse* performance on the inhibition task ($\beta = -.29$, $p = .042$).

Considered together, these findings indicate that experiencing a more unpredictable childhood environment affects inhibition in uncertain contexts. Although people who had more unpredictable childhood backgrounds exhibited no significant difference on the inhibition task in the control condition, when the current environment was uncertain, they were significantly worse at inhibition compared with people who had more predictable childhood backgrounds.

Shifting. We next examined shifting as a function of childhood SES. This analysis revealed a marginally significant main effect of childhood SES ($\beta = -.19$, $p = .053$), with the trend showing that higher childhood SES predicted better shifting. However, the analysis did not show a childhood SES by uncertainty interaction ($\beta = -.39$, $p = .32$).

We next examined shifting as a function of childhood unpredictability. This analysis yielded a marginally significant main effect of childhood unpredictability ($\beta = -.178$, $p = .072$), with greater childhood unpredictability predicting better performance on switching. More importantly, the analysis revealed a significant childhood unpredictability by uncertain context interaction ($\beta = -.28$, $p = .035$), which indicated that performance on the shifting task differed depending on a person's level of childhood unpredictability and whether or not the current environmental context was uncertain.

As presented in Figure 4,[2] in the control condition, there was no relation between childhood unpredictability and shifting ($\beta = .00$, $p = .99$). In the uncertainty condition, however, experiencing greater unpredictability during childhood predicted significantly *better* performance on shifting ($\beta = -.31$, $p = .026$). This indicates that even though people who had more unpredictable childhood backgrounds exhibited no difference on the shifting task in the control condition, when the current environment was uncertain, they were significantly better at shifting than people who had more predictable childhood backgrounds.

Finally, it is important to note that even though people who reported being raised in more unpredictable environments performed faster on the shifting task when the current context was uncertain, there were no differences in accuracy across the conditions (all $ps > .16$; see the Method section). Thus, in the uncertain experimental condition, people who had more unpredictable childhoods performed faster on the shifting task *without any decrease in accuracy*.

In summary, Experiment 1 reveals that individuals who recalled having a more unpredictable childhood performed *worse* on an inhibition task, but performed *better* on a shifting task. Importantly, these effects were observed only when people were tested

[2] Figure 4 plots the reverse of the switch cost, which is the "switch benefit" (i.e., the average response time on repeat trials minus the average response time on switch trials). We have plotted the findings as a switch benefit (rather than a switch cost) to avoid confusion about higher values indicating worse performance. When plotted as a switch benefit, higher values indicate better performance on the shifting task. The pattern of findings and the statistical analyses are identical in each case, regardless of whether shifting is calculated as a switch cost or switch benefit.

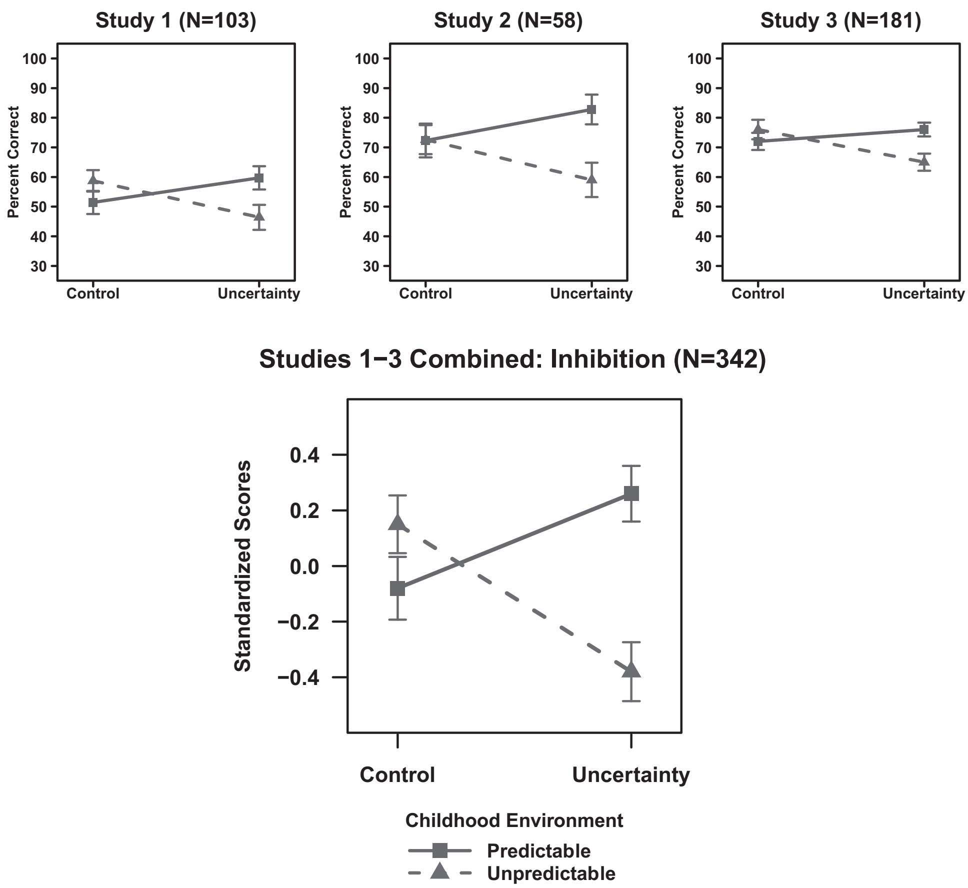

Figure 3. Inhibition findings. College and community samples.

in an uncertain current environmental context. To our knowledge, this is the first experiment demonstrating the conditions under which exposure to an unpredictable childhood environment leads to *improved* adult cognitive functioning on a major task.

Experiment 2: Direct Replication #1

Experiment 2 was designed to directly replicate the findings of Experiment 1.

Method

Participants. Fifty-eight students (41 males, 17 females) from a large North American university participated in Experiment 2 in exchange for course credit. Participants' mean age was 20.6 years (SD = 1.58).

Procedure overview. Participants were randomly assigned to either a control or an uncertainty condition. The procedures and materials were identical to those used in Experiment 1. This included using the same design, the same manipulations, the same cover story, and the same items to measure childhood unpredictability and childhood socioeconomic status. Finally, the same tasks used in Experiment 1 were also used to assess inhibition and shifting ability.

Inhibition and shifting. The exact same tasks and procedures used in Experiment 1 were used in Experiment 2. For the inhibition task, the average accuracy was 72.57% (SD = 21.2). For the shifting task, the average switch cost was 29.10 ms (SD = 103.18). Average accuracy on shifting was 45.15 out of 48 (SD = 2.54). There were no differences in accuracy between the repeat trials and the switch trials ($M_{\text{Accuracy\_Switch}}$ = 93.0%, $M_{\text{Accuracy\_Repeat}}$ = 95.1%; p = .64). Comparing between conditions, participants were more accurate in the control experimental condition than in the uncertain condition (M_{control} = 46.0, $M_{\text{uncertainty}}$ = 44.2; p = .01). Accuracy was also associated with childhood unpredictability (β = −.38, p = .026). Although there was no differences in accuracy in the control condition (β = .18, p = .354), those who reported more predictable childhood environments were more accurate in the uncertainty condition (β = −.37, p = .049).

Results and Discussion

To test our predictions, we first conducted a three-way analysis with type of task (inhibition vs. shifting, within-subjects), context (uncertainty vs. control, between-subjects), and childhood environment (unpredictability *or* SES, mean-centered continuous variable). As before, we used a mixed model approach to test for a three-way interaction. The analysis with childhood SES (harsh-

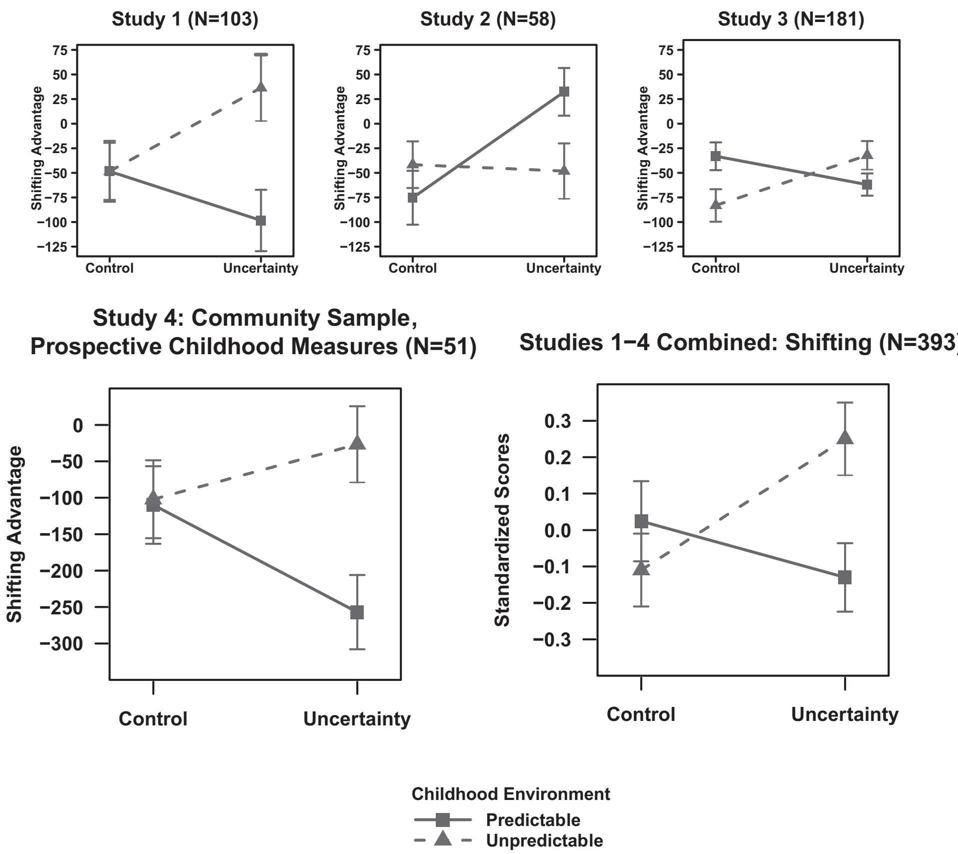

Figure 4. Shifting findings. College and community samples.

ness) did not reveal a significant interaction (p = .363). Furthermore, the analysis containing childhood unpredictability also did not reveal a significant three-way interaction, $F(1, 54) = .01$, p = .975. To probe the pattern of results in order to compare with this the findings from Study 1, we examined performance on each of the two tasks separately.

Inhibition. We first examined inhibition as a function of childhood SES. This analysis did not reveal either a main effect of childhood SES (β = −.12, p = .356), or a childhood SES by uncertainty interaction on inhibition (β = .21, p = .322). Thus, there was no effect of childhood SES on performance on the inhibition task.

We next examined inhibition as a function of childhood unpredictability. This analysis yielded a main effect of childhood unpredictability (β = −.26, p = .050), with people from more unpredictable backgrounds performing worse on the inhibition task. More importantly, analyses revealed a childhood unpredictability by uncertain context interaction (β = −.39, p = .030), which indicated that performance on inhibition differed as a function of a person's level of childhood unpredictability and current environmental context.

As shown in Figure 3, in the control condition, there was no relation between childhood unpredictability and performance on inhibition (β = .01, p = .975). In the uncertainty condition, however, experiencing greater unpredictability in childhood predicted significantly *worse* performance on the inhibition task (β = −.53, p = .003).

In sum, consistent with Experiment 1, Experiment 2 revealed that experiencing a more unpredictable childhood environment affects inhibition in uncertain contexts. Although people who had more unpredictable childhood backgrounds once again showed no difference on the inhibition task in the control condition, when the current environment was uncertain, they were worse at inhibition compared with people who had more predictable childhood backgrounds. Thus, the findings for inhibition replicate Experiment 1.

Shifting. We next examined shifting as a function of childhood SES. There was neither a main effect of childhood SES (β = *.19,* p = .156) nor a childhood SES by uncertainty interaction (β = .06, p = .781). Thus, there was no effect of childhood SES on shifting.

We next examined shifting as a function of childhood unpredictability. This analysis did not yield a main effect of childhood unpredictability (β = .14, p = .305). However, there was a significant childhood unpredictability by uncertain context interaction (β = .38, p = .033). As seen in Figure 4, in the control condition, there was no relation between childhood unpredictability and shifting (β = −.18, p = .356). However, contrary to findings in Experiment 1, people who experienced less unpredictability during childhood performed *better* on shifting in the uncertainty condition in this study (β = .38, p = .042).

In summary, Experiment 2 partly replicated the results from Experiment 1. The findings from Experiment 2 provide a direct replication of the *inhibition* findings from Experiment 1 in that individuals who recalled having a more unpredictable childhood performed *worse* on the inhibition task when conditions were uncertain. However, Experiment 2 did not replicate the *shifting* findings from Experiment 1. The lack of replication may be attributable to the relatively small sample size in Experiment 2 ($N = 58$). Small sample sizes can produce unreliable effects and sometimes even opposite patterns of results (see Button et al., 2013; Ioannidis, 2005). To resolve this concern, we conducted a second direct replication with a substantially larger sample.

Experiment 3: High-Powered Direct Replication #2

Experiment 3 once again tested how childhood environments affect performance on inhibition and shifting tasks depending on current uncertainty using identical methods as in Experiments 1 and 2. To determine the sample size for the study, before starting data collection, we conducted a power analysis based on effect sizes from Study 1. We calculated two different effect sizes, one for each of the two executive function tasks—inhibition and shifting. The effect size in Study 1 for inhibition was partial eta-squared = .064; the effect size for shifting was partial eta-squared = .044. To be conservative, we chose the smaller effect size as the standard. With an alpha of 0.05 and power = 0.8, the projected sample size needed to obtain the effect was $N = 173$. To get this sample size, for Experiment 3 we posted 200 participant slots, which allowed for some no-shows. Data collection ceased after all participants who signed-up for the study completed it. Our final sample for Experiment 3 was 181 participants, which is substantially higher than the 58 participants in Experiment 2.

Method

Participants. One-hundred and 81 university students (93 males, 88 females) participated in exchange for course credit. Participants' mean age was 20.0 years ($SD = 1.15$), ranging from 18- to 25-years-old. Participants were randomly assigned to either a control condition or an uncertainty condition. The methods, procedures, and tasks were identical to those used in Experiments 1 and 2.

Inhibition and shifting. For the inhibition task, the average accuracy was 72.64% ($SD = 17.2$). For the shifting task, the average switch cost was 52.56 ms ($SD = 84.71$ ms). Average accuracy on the shifting task was 45.35 ($SD = 2.05$) out of 48. There were no differences in accuracy between the repeat trials and the switch trials ($M_{\text{Accuracy\_Switch}} = 93.2\%$, $M_{\text{Accuracy\_Repeat}} = 95.8\%$; $p = .28$). There also were no differences in accuracy between the two conditions ($M_{\text{control}} = 45.3$, $M_{\text{uncertainty}} = 45.4$; $p = .86$), and accuracy was not associated with childhood unpredictability ($\beta = .01$, $p = .889$).

Results and Discussion

To test our predictions, we first conducted a three-way analysis using a mixed model approach with type of task (inhibition vs. shifting, within-subjects), condition (uncertainty vs. control, between-subjects), and childhood environment (unpredictability *or* SES, entered as mean-centered continuous variables). The analysis containing childhood SES (harshness) did not reveal a significant three-way interaction ($p = .092$). However, there was significant three-way interaction with type of task, context, and childhood unpredictability, $F(1, 177) = 12.84$, $p < .001$. We probed this interaction by analyzing the specific findings for inhibition and for shifting.

Inhibition. We first examined inhibition as a function of childhood SES. This analysis did not reveal a main effect of childhood SES ($\beta = .13$, $p = .08$), but did reveal a marginal childhood SES by uncertainty interaction ($\beta = .19$, $p = .07$). Probing this interaction indicated there was no relation between childhood SES and performance on inhibition in the control condition ($\beta = -.002$, $p = .98$). However, there was a significant relation between childhood SES and performance on inhibition in the uncertainty condition ($\beta = .25$, $p = .012$). These results suggest that people from high SES backgrounds were better than those from low SES backgrounds at inhibition in an uncertain context.

We next examined inhibition as a function of childhood unpredictability. This analysis did not yield a main effect of childhood unpredictability ($\beta = -.11$, $p = .126$). However, as predicted, it revealed a significant childhood unpredictability by uncertain context interaction ($\beta = -.29$, $p = .017$), which indicated that performance on inhibition differed as a function of a person's level of childhood unpredictability and current environmental context.

As shown in Figure 3, in the control condition, there was no relation between childhood unpredictability and performance on inhibition ($\beta = .10$, $p = .368$). In the uncertainty condition, however, experiencing greater unpredictability in childhood predicted significantly *worse* performance on the inhibition task ($\beta = -.27$, $p = .007$).

In summary, consistent with Experiments 1 and 2, Experiment 3 indicated that experiencing a more unpredictable childhood environment affects inhibition in uncertain contexts. Although people who had more unpredictable childhood backgrounds once again exhibited no difference on the inhibition task in the control condition, when the current environment was uncertain, they were worse at inhibition compared to people who had more predictable childhood backgrounds. The findings for inhibition, therefore, replicated the pattern observed in Experiments 1 and 2.

Shifting. Next, we examined shifting as a function of childhood SES. There was no main effect of childhood SES ($\beta = .06$, $p = .399$) or a childhood SES by uncertain context interaction ($\beta = .06$, $p = .581$). Thus, there was no effect of childhood SES on shifting.

We next examined shifting as a function of childhood unpredictability. This analysis did not yield a main effect of childhood unpredictability ($\beta = .005$, $p = .942$), but it did produce the predicted childhood unpredictability by uncertain context interaction ($\beta = -.30$, $p = .011$).

As shown in Figure 4, in the control condition, there was a marginal relation between childhood unpredictability and shifting ($\beta = .19$, $p = .079$), indicating that people who had more unpredictable childhood environments performed marginally *worse* on shifting in the control condition. In the uncertainty condition, however, this pattern was reversed. When the current condition was uncertain, people who experienced more unpredictability during childhood performed marginally *better* on shifting ($\beta = -.18$, $p = .074$). Experiment 3, in other words, showed the same pattern for shifting as found in Experiment 1.

Finally, even though people who reported being raised in more unpredictable environments performed faster on the shifting task when the current context was uncertain, there were no differences in accuracy across the conditions (all *p*s $> .35$). Thus, in the uncertain experimental condition, people who had more unpredictable childhoods performed marginally faster on the shifting task *without any decrease in accuracy*.

In summary, Experiment 3 replicated the findings from Experiments 1 and 2 for inhibition. All three studies consistently showed that individuals who recalled having a more unpredictable childhood performed *worse* on an *inhibition* task in an uncertain context. For shifting, Experiment 3 revealed the same pattern found in Experiment 1. Both of these studies showed that individuals who recalled having a more unpredictable childhood performed *better* on a *shifting* task in an uncertain context. Although Experiment 2 did not replicate this pattern for shifting, it had the smallest sample size. Thus, we tested for the shifting effect once again, this time using a sample of people who have been studied longitudinally from birth into adulthood.

Experiment 4: Testing Shifting in a Longitudinal Sample

Experiment 4 sought to replicate and extend the findings regarding shifting. Similar to the first three experiments, participants in Experiment 4 were randomly assigned to either a control or an uncertainty experimental condition, after which they completed the same shifting task used in prior experiments. Experiment 4, however, differed from the previous experiments in two important ways. First, whereas the previous experiments were conducted mainly on college-based samples, Experiment 4 was conducted with an older, more socioeconomically disadvantaged group of participants. This difference enabled us to test for the shifting effect in two meaningfully different populations. Second, whereas participants in the previous experiments recalled their childhood environments (retrospectively), Experiment 4 was conducted with participants on whom we had detailed childhood data collected longitudinally across their development. Experiment 4, therefore, had excellent prospective measures of childhood unpredictability and childhood harshness (SES). These longitudinal measures allowed us to more precisely test whether and how shifting is impacted by childhood unpredictability versus harshness.

Method

Participants. Fifty-one individuals (all age 37; 27 males, 24 females) participated in Experiment 4. Participants came to the lab to complete a battery of measures routinely collected as part of the Minnesota Longitudinal Study of Risk and Adaptation (MLSRA) project (Sroufe et al., 2005). The MLSRA has followed a sample of initially socioeconomically disadvantaged individuals from before they were born into middle adulthood. It has excellent measures of environmental stressors that have been repeatedly assessed because participants were born in 1975–1976 to mothers who were receiving free prenatal health care in Minneapolis. The ethnicity breakdown of the participants in Experiment 4, all of whom were first-born children, was: 55.8% White, 9.6% African American, 26.9% mixed race, and 3.8% other. Data for one person was not available.

At initial recruitment, all mothers ($M_{\text{age}} = 20.6$) were low in socioeconomic status, 61% were single, and 60% had less than 12 years of education. Although the mothers were initially selected because their income was below the poverty line in 1975–1976, many of them experienced substantial increases in SES across time. For example, by the time the mothers' first-born children (the study participants) were 10-years-old, more than 50% of the sample was above the poverty line. Furthermore, at the start of the study, the mean prenatal Duncan Socioeconomic Index score in the sample was 20.4 with a *SD* was 10.5, but by the time participants were age 16, it was 30.5 with a *SD* of 16.2. Thus, within the sample as a whole, both the mean and the variance of SES increased notably across time.

At the time of Experiment 4, participants were 37-years-old. Their current mean monthly household income was \$5,232 (minimum = \$0; maximum = \$12,583; *SD* = \$3,117). In terms of their educational attainment, 5.9% had not graduated from high school, 18.6% had either graduated from high school or had a GED, 56.9% had technical school, some college, or a 2-year college degree, 13.7% had a 4-year college degree, and 5.9% had a postbaccalaureate or professional degree.

Experiment 4 was part of a larger data collection effort for which participants were paid \$100 to complete a lab session that lasted 2.5 to 3 hr. Experiment 4 was allotted 10 min within this longer lab session. These 10 min were used to conduct the experimental manipulation and the shifting task. Participants did not perform an inhibition task due to time constraints. The other measures collected as part of the longer session are not reported here because they are not relevant to the current hypotheses. The sample size in Experiment 4 reflects all of the MLSRA participants who came into the lab during the first year of the age 37 data collection.

Childhood environment. Unlike in the first three experiments, each participant's childhood environment in Experiment 4 had been assessed at multiple time-points on the dimensions of unpredictability and harshness (Ellis et al., 2009). Consistent with the previous experiments, in which participants were instructed to "Think back to your life when you were younger than 10," Experiment 4 assessed childhood harshness and unpredictability between the ages of 0 to 10. Because both environmental stress dimensions were assessed at multiple time-points, we used all of the available time-points to create individual difference measures of exposure to unpredictability and harshness, which are described in greater detail below.

Unpredictability. We operationalized and measured unpredictability using items similar to those used in previous research assessing this construct (e.g., Belsky et al., 2012; Simpson et al., 2012). Specifically, unpredictability was assessed by three items from the Life Stress Inventory (Cochrane & Robertson, 1973) that measured mothers' life stress stemming from three sources: (a) changes in employment status during the prior year (e.g., periods of unemployment); (b) changes in residence during the prior year (e.g., moving to a different house/apartment); and (c) people moving in and out of the house during the prior year (e.g., mother's romantic partners moving in or out; an immediate family member receiving a jail sentence). Trained coders read each mother's interview responses to these three items and then rated the total number of stressful events mentioned along with the intensity of disruption associated with each item on the following scale: 0 (*no disruption due to changing life event*), 1 (*some disruption*), 2 (*much disruption*), 3 (*severe disruption*). Thus, the childhood unpredictability measure tapped both the frequency and the intensity of disruption of stress stemming from these unpredictable life events.

The three unpredictability items were measured at eight time-points between ages 0 to 10: When each child was 12, 18, 48, and 54 months old, and then in Kindergarten and in Grades 1, 2, and 3. To create the childhood unpredictability measure, scores on these items were first summed within each assessment period and then aggregated (averaged) over the eight time-points (when children were 0 to 10-years-old), adjusting for the number of assessments completed by each mother at each assessment period. On average, participants were exposed to moderate levels of disruption (M = 1.42; SD = 0.91) as indexed by the stressful changes at each assessment period between ages 0 to 10. The unpredictability measure had a reasonable amount of variation, ranging from 0.13 to 3.38.

Harshness. We operationalized and measured harshness using items similar to those used in previous research assessing this construct (e.g., Belsky et al., 2012; Simpson et al., 2012). Harshness was assessed by SES, which was indexed by household income, mothers' educational attainment, and the revised version of the Duncan Socioeconomic Index (Duncan, 1961; Stevens & Featherman, 1981), which measures occupational prestige. SES was computed by first calculating z-scores for all the items at each assessment period. Using standard procedures, these z-scores were then transformed to t-scores to remove negative values, which generated positively scaled scores. SES was assessed six times between ages 0–10: prenatally (just before each mother's child [the participant] was born), at 42 months, at 54 months, and when the child was in Grades 1, 2, and 3. To create the measure of childhood harshness, we averaged the SES t-scores scores over all six assessment periods (α = .83).

A t-score of 50 reflects the mean response in the current sample. The harshness measure had a reasonable amount of variation (M = 50.50; SD = 6.27), ranging from 36.92 to 66.18. As mentioned earlier, although all participants were living below the poverty line before birth, by age 10 more than 50% of them were living above the poverty line.

Uncertain context manipulation. As in Experiments 1–3, Experiment 4 had two between-subjects conditions that experimentally manipulated the current context (control vs. uncertain). The uncertainty manipulation once again involved a news story. However, given the variability in the reading ability of participants in Experiment 4, instead of having them read a news article, they viewed a slideshow of a news story. This manipulation was based on previous research that has used a news story slideshow to experimentally manipulate uncertain contexts (Griskevicius et al., 2013; Hill et al., 2012; Mittal & Griskevicius, 2014).

The slideshow had five images, each of which was accompanied by a brief written caption. In the uncertainty condition, the slideshow depicted worsening economic conditions, highlighting increasing economic uncertainty. In the control condition, it depicted serene nature scenes accompanied by generic descriptions of each scene.

Shifting task. Immediately after the experimental manipulation, participants completed the same shifting task used in Experiments 1–3. Similar to the previous experiments, participants provided the correct response in the overwhelming majority of trials, correctly categorizing the image 91.2% of the time. Specifically, out of the 48 trials, participants got an average of 43.78 correct responses (SD = 4.07). Furthermore, there were no differences in accuracy as a function of experimental condition, childhood harshness, childhood unpredictability, or the interactions of these variables (all $ps > .38$).

Participants were also similarly accurate on the repeat trials and the switch trials ($M_{\text{Accuracy\_Switch}}$ = 89.8%, $M_{\text{Accuracy\_Repeat}}$ = 92.6%; p = .62). There were no differences in accuracy in either type of trial as a function of experimental condition, childhood harshness, childhood unpredictability, or the interactions of these variables (all $ps > .36$).

Results and Discussion

The executive function of shifting is defined as the time it takes to switch from one task to another *relative to* the time it takes to repeat the same task. Our switching dependent measure, therefore, assessed how quickly participants correctly categorized images for switch trials *relative to* repeat trials. We first calculated response times for the switch trials (M = 1171.57, SD = 383.85) and for the repeat trials (M = 1047.08, SD = 341.27). As in the previous experiments, we followed established procedures for assessing shifting performance (Friedman et al., 2008; Miyake et al., 2004; Meiran et al., 2000), whereby the dependent measure was the switch cost (i.e., the difference between the average response time of switch trials *relative to* the average response time of repeat trials).

On average, the switch cost was 124.49 ms (SD = 203.83 ms). In other words, it took participants an average of 124.49 ms longer to correctly categorize the switch trials than the repeat trials. The purpose of Experiment 4 was to test whether shifting performance differed as a function of individuals' childhood environments and whether the current experimental context was uncertain versus not.

We performed two separate regression analyses for the two individual difference measures of childhood harshness and childhood unpredictability. The analysis of childhood harshness did not reveal any significant effects. That is, performance on the shifting task did not differ as a function of childhood harshness, experimental condition, or the interaction of these variables (all $ps >$ .52). Childhood harshness, therefore, did not significantly influence performance on the shifting task in Experiment 4.

The analysis of childhood unpredictability, however, revealed that greater childhood unpredictability predicted *better* performance at shifting ($\beta = -.34$, p = .016). The more unpredictable a person's childhood environment was, the better his or her performance on the shifting task. This main effect, however, was once again qualified by the hypothesized childhood unpredictability by uncertain context interaction ($\beta = -.42$, p = .038). As shown in Figure 4, in the control condition, there was no relation between childhood unpredictability and shifting ($\beta = -.03$, p = .89). In the uncertainty condition, however, experiencing greater unpredictability in childhood predicted significantly better performance on the shifting task ($\beta = -.48$, p = .016).

Even though individuals who experienced more unpredictable environments early in life performed faster on the shifting task in the current uncertainty condition, there was no decrease in their accuracy (all $ps > .36$; see the Method section). In sum, similar to Experiments 1 and 3, when faced with uncertainty, people who had more unpredictable childhoods performed faster on the shifting task *without any decrease in accuracy*.

So far, the analyses of Experiment 4 have focused on the influence of the childhood environment from ages 0–10, which is consistent with the retrospective measures in Experiments 1–3. Prior longitudinal research using the MLSRA sample, however, has also considered the influence of childhood environments for earlier versus later time-periods (e.g., examining the influence of unpredictability and harshness between ages 0–5 vs. ages 6–16; see Simpson et al., 2012). Thus, for purposes of completeness, we also analyzed the current findings for shifting using the same early versus later childhood distinction and the same categorization methods as employed by Simpson and colleagues.

In general, the effects of childhood harshness and unpredictability were very similar for both the early period (ages 0–5) and the later period (ages 6–16). For harshness, we once again did not find any significant effects for either time period. For unpredictability, we found the same pattern for both early and late childhood. Specifically, for ages 0–5, there was a significant interaction between condition and unpredictability ($\beta = -.72$; $p = .031$). In the control condition, there was no relation between unpredictability and shifting ($\beta = -.01$, $p = .96$). In the uncertainty condition, however, experiencing greater unpredictability between ages 0–5 predicted significantly better performance on shifting ($\beta = -.52$, $p = .009$). For ages 6–16, there was a significant interaction with condition and unpredictability ($\beta = -.50$; $p = .046$). In the control condition, there was no relation between unpredictability and shifting ($\beta = -.09$, $p = .66$). In the uncertainty condition, however, experiencing greater unpredictability between ages 6–16 predicted significantly better performance on shifting ($\beta = -.43$, $p = .037$). These results suggest there might not be a "sensitive period" during development that is uniquely associated with our primary hypothesized effects.

In summary, Experiment 4 replicated the novel superior-shifting effect found in Experiments 1 and 3 using an older and somewhat more socioeconomically disadvantaged sample. Because we had longitudinal measures of childhood unpredictability and harshness for these unique participants, Experiment 4 also confirmed that the superior-shifting effect is tied to experiencing an unpredictable childhood environment between ages 0–16 rather than merely experiencing a harsh environment during this broad time-period.

Meta-Analysis of Findings Across All Studies

Meta-analytic approaches have been recommended to test for the reliability of an effect across different studies (Maner, 2014). We therefore performed a meta-analysis for inhibition (Experiments 1–3, $N = 342$) and for shifting (Experiments 1–4, $N = 393$). In the meta-analysis, we sought to assess the reliability of three types of effects: (a) the interaction effect of childhood unpredictability and experimentally manipulated uncertainty on inhibition and on shifting; (b) the simple effect of experimentally manipulated uncertainty on inhibition and on shifting, testing the performance in the control condition versus the uncertainty condition by people at +/− 1 *SD* from the mean of childhood unpredictability; and (c) the effect of childhood unpredictability on inhibition and on shifting within the control conditions and within the uncertainty conditions across the studies.

Following established procedures to conduct meta-analyses (see Maner et al., 2003; Rosenthal, 1991), we first converted the two-tailed p values into one-tailed p values. We then converted these values into z-scores to obtain a weighted overall significance. We also calculated an overall effect size, weighting each study by its degrees of freedom (see Appendix for all z-standardized significance levels, *df*, and effect size r).

The meta-analytic findings for *inhibition* revealed a significant childhood unpredictability by uncertainty condition interaction, $r = .23$, $z = 3.77$, $p < .001$. Results showed that people from unpredictable childhood environments (1 *SD* above the mean of childhood unpredictability) were significantly *worse* at inhibition in the uncertainty condition compared with the control condition, $r = .19$, $z = 3.38$, $p < .001$. In contrast, people from predictable childhood environments (1 *SD* below the mean of childhood unpredictability) were significantly *better* at inhibition in the uncertainty condition compared with the control condition, $r = .12$, $z = 2.05$, $p = .02$. Furthermore, within the control conditions across the studies, there was only a small association between inhibition and childhood unpredictability, $r = .12$, $z = 1.49$, $p = .068$, with the pattern showing that people who experienced greater unpredictability in childhood performed marginally better at inhibition in the control condition. However, within the uncertainty conditions across the studies, experiencing greater unpredictability in childhood predicted significantly *worse* performance on inhibition, $r = .32$, $z = 3.94$, $p < .001$. Thus, the meta-analyses confirmed that childhood unpredictability is associated with worse inhibition under conditions of uncertainty.

Using the same methodology, we next conducted meta-analyses for *shifting* using data from Experiments 1–4. The meta-analytic findings revealed a significant childhood unpredictability by uncertainty condition interaction, $r = .13$, $z = 2.98$, $p = .001$. Results showed that people from unpredictable childhood environments (1 *SD* above the mean of childhood unpredictability) were significantly *better* at shifting in the uncertainty condition compared with the control condition, $r = .14$, $z = 2.76$, $p = .003$. In contrast, people from predictable childhood environments (1 *SD* below the mean of childhood unpredictability) performed marginally *worse* at shifting in the uncertainty condition compared with the control condition, $r = .07$, $z = 1.55$, $p = .062$. Furthermore, within the control conditions across the studies, there was no significant association between shifting and childhood unpredictability, $r = .05$, $z = 1.11$, $p = .133$. However, within the uncertainty conditions, experiencing greater unpredictability in childhood predicted significantly *better* shifting performance, $r = .17$, $z = 2.45$, $p = .007$. Thus, the meta-analyses confirmed that childhood unpredictability is associated with better shifting under conditions of uncertainty.

General Discussion

Can growing up in a stressful childhood environment improve certain types of cognitive performance (Frankenhuis & de Weerth, 2013)? The answer appears to be yes—but only when current conditions are uncertain. We tested adults' performance on two major types of executive function—inhibition and shifting—in relation to whether they grew up in unpredictable or low-SES (harsh) childhood environments. No consistent effects for childhood SES (harshness) emerged. However, people who had more unpredictable childhoods were worse at inhibition (overriding dominant responses), but better at shifting (efficiently switching between different tasks) when tested in conditions of uncertainty.

The fact that exposure to more unpredictable childhoods had specific and opposite effects on two major types of executive functioning is consistent with the notion that shifting, but not inhibition, is more useful and adaptive in unpredictable environments (see Nederhof et al., 2014). To the extent that individuals have lived in, or anticipate living in, environments in which the source or location of rewards and costs change rapidly, being able to quickly shift should help them capitalize on currently available rewards or avert potential costs. For example, in unpredictable environments during our ancestral past, the location, availability, and quality of certain foods may have changed quickly due to unpredictable patterns of weather, competition (i.e., other foraging or hunting people), and other factors. Individuals who were "programmed" by unpredictable childhood experiences to identify new and better food sources more rapidly would have been more likely to survive and eventually reproduce in these arduous environments.

It is noteworthy that the effects of childhood unpredictability on executive function emerged only when people felt uncertain about the current environment. In the control condition of our experiments, individuals who had more stressful childhoods generally did not perform better on any task. It was only when they were tested in uncertain immediate contexts—conditions similar to their early life environments—that individuals who had been exposed to more unpredictable childhoods outperformed those who had more predictable childhoods on the shifting task. This context-specific pattern linking early life adversity to adult cognitive functioning in humans has analogies to findings with rats (see Bagot et al., 2009; Champagne et al., 2008). Viewed together, the current results support the premise that the expression of certain individual differences associated with unpredictable early life experiences is contingent on current levels of environmental uncertainty.

Experiment 4 tested shifting performance in individuals using longitudinal data that contained more objective measures of exposure to childhood unpredictability and harshness. This experiment allowed us to more directly link the "enhanced shifting effect" to exposure to a specific dimension of environmental stress. Only individuals who had been exposed to more unpredictable, rather than harsher, childhood environments performed better on the shifting task when confronted with current uncertainty.

Considered together, these experiments are the first to document that stressful childhood environments do not universally impair cognitive functioning, but may selectively *enhance* it under conditions of current uncertainty. Although past research has shown that adults who are currently living in low socioeconomic status conditions display greater empathic accuracy (Kraus, Piff, Mendoza-Denton, Rheinschmidt, & Keltner, 2012), research on how people's early childhood environments might enhance their mental functioning in adulthood is scarce. Previous research has primarily focused on children's cognition, revealing that maltreated or physically abused children are more attuned to threat-related information (e.g., orienting to angry faces, identifying angry expressions, recalling aggressive stimuli; Goodman et al., 2010; Pollak, 2008). In contrast, we find that adults exposed to more unpredictable childhood environments display better performance in uncertain contexts on a specific type of executive function—one that is a principle indicator of cognitive functioning in humans.

In summary, the vast majority of research to date has focused on various physical and mental deficits of people who have been exposed to higher levels of developmental stress and/or "disadvantaged" environments (see Ellis et al., 2012). We, on the other hand, have adopted an evolutionary life history approach, which proposes that exposure to certain kinds of stressful environments early in life may actually shape adult mental functioning in *adaptive ways* with respect to reproductive fitness in our ancestral environments. Using both higher-income and lower-income samples, we provide the first experimental evidence indicating that exposure to more unpredictable environments early in life, in combination with exposure to uncertainty in one's current adult environment, is associated with superior performance in shifting. This major executive function should have been valuable in unpredictable ancestral environments, in which the source or location of rewards and costs changed rapidly, often, and without forewarning.

Limitations, Implications, and Future Directions

An important contribution of the current research is that the predicted cognitive differences based on childhood environment emerged only when people were tested in current contexts of uncertainty. Our context-specific experimental findings may help to explain why past correlational studies with humans (e.g., Nederhof et al., 2014) have found small associations between childhood stress and shifting-like attentional style ($r = .07$). Our findings indicate that current contexts of uncertainty may be necessary to reveal superior shifting performance in adults exposed to unpredictable childhood environments.

Although past correlational research has found that people who had more stressful childhoods tend to perform worse on many cognitive tasks, we found such effects (e.g., performance on the inhibition task) only when individuals were confronted with current uncertainty. As noted earlier, this context-specific effect has analogies to past findings in rats (Bagot et al., 2009; Champagne et al., 2008) as well as multiple findings in humans (Griskevicius et al., 2011a, 2011b; 2013; Hill et al., 2013; White et al., 2013). Our findings, however, raise questions as to why we did not find differences between people who had different childhood environments in our control conditions.

One possible reason is that our participants did not have sufficient variability in stressful childhood environments. It is possible that sampling an even wider range of the population (including people who grew up in abject poverty or were severely maltreated or abused as children) would reveal effects in the control condition. Another possibility is that our control conditions did not reflect the normal, daily life of people who grew up in stressful childhood environments. Instead, such individuals may feel uncertain at many different points during a given day. If this is true, most prior correlational studies would probably have included some people who felt uncertain when they took part in the study. Indeed, the findings of our experiments suggest that the effects of early life environments in past correlational research may be driven by individuals who felt uncertain at the time of the study. A third possibility is that these patterns depend on the specific effect being examined. For example, previous research has shown that being maltreated or physically abused improves children's content-specific cognition by enhancing their recognition of specific emotions or their recall of specific memories (e.g., Pollak et al., 2010). Perhaps emergence of such effects does not require current uncertainty. However, perhaps other effects, such as improved executive function in shifting, do require some level of current uncertainty in order to emerge. Future research is needed to ascertain how, why, and when current uncertainty is necessary or unnecessary in order to observe effects stemming from stressful early life environments.

Another important issue for future research is determining what type of uncertainty brings out the impact of stressful childhood environments most strongly. We find that the effects of childhood unpredictability on executive functioning emerge when people are confronted with economic uncertainty. Future research needs to determine whether any kind of environmental uncertainty generates such findings, or whether only specific types of uncertainty unleash the effects of early childhood environments.

It is also important to note the limitations of the current research. In Experiments 1–3, childhood unpredictability was measured with a short self-report questionnaire. In the future, a better and more comprehensive retrospective measure of developmental exposure to stress should include more questions that tap different facets of developmental exposure to stress. Nevertheless, Experiment 4, which contained detailed information about each participant's childhood environment, allowed us to test more precisely for the influence of environment harshness and unpredictability. Future research should determine whether and how childhood unpredictability and harshness have similar or different influences on cognition and behavior.

Finally, it is important to note that the predicted effect for shifting did not emerge in Experiment 2. We believe this lack of replication is most likely attributable to the low statistical power of Experiment 2, given its small sample size ($N = 58$). Consistent with this inference, the meta-analysis of shifting across all four experiments ($N = 393$) found that childhood unpredictability is reliably associated with better shifting during times of uncertainty. Future research, however, is still needed to ascertain the magnitude and boundary conditions of this robust effect.

Conclusion

Our findings suggest that the psychological functioning of adults reared in more unpredictable early life environments may be better conceptualized as *adapted* rather than impaired (see also Frankenhuis & de Weerth, 2013). We are *not* in any way suggesting or implying that stressful childhoods are positive or good for people. Rather, we have presented an empirical case that identifies some of the conditions under which exposure to a particular type of stressful childhood—unpredictability—may shape cognitive functioning in adulthood to be specialized to certain types of environmental conditions.

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Appendix

Standardized *Z* Significance Levels, Degrees of Freedom (*df*), and Effect Size *r* Used in the Meta-Analysis

	Effect of uncertainty condition by childhood unpredictability interaction			Effect of uncertainty condition for +1 *SD* from mean childhood unpredictability			Effect of uncertainty condition for −1 *SD* from mean childhood unpredictability			Effect of childhood unpredictability in the control condition			Effect of childhood unpredictability in the uncertainty condition		
Study	*z*	*df*	*r*	*z*	*df*	*r*	*z*	*df*	*r*	*z*	*df*	*r*	*z*	*df*	*r*
Inhibition															
1	2.54	99	0.25	2.16	99	0.22	1.49	99	0.15	2.03	51	0.204	2.03	48	0.29
2	2.17	54	0.29	1.74	54	0.24	1.36	54	0.18	2.96	27	0.01	2.96	27	0.53
3	2.39	177	0.19	2.27	177	0.17	1.18	177	0.09	2.7	81	0.1	2.7	96	0.27
Shifting															
1	2.11	99	0.21	1.88	99	0.19	1.14	99	0.11	0	51	0	2.23	48	0.32
2	2.14	54	−0.29	0.18	54	−0.02	2.82	54	−0.37	0.92	27	−0.177	2.03	27	−0.38
3	2.54	177	0.16	2.07	177	0.15	1.58	177	0.12	1.76	81	0.194	1.79	96	0.18
4	2.08	47	0.30	1.11	47	0.15	1.97	47	0.28	0.15	25	−0.03	2.41	22	0.49

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