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Adaptation in the face of adversity: Decrements and enhancements in children's cognitive control behavior following early caregiving instability

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Abstract

Cognitive control is typically described as disrupted following exposure to early caregiving instability. While much of the work within this field has approached cognitive control broadly, evidence from adults retrospectively reporting early-life instability has shown more nuanced effects on cognitive control, even demonstrating enhancements in certain subdomains. That is, exposure to unstable caregiving may disrupt some areas of cognitive control, yet promote adaptation in others. Here, we investigated three domains of cognitive control in a sample of school-age children ($N = 275$, $Age = 6$-12 years) as a function of early caregiving instability, defined as the total number of caregiving switches. Results demonstrated that caregiving instability was associated with reduced response inhibition (Go/No-Go) and attentional control (Flanker), but enhanced cognitive flexibility (Dimensional Change Card Sort Task Switching). Conversely, there were no statistically significant associations with group (i.e., institutional care versus foster care) or maltreatment exposure and these patterns. These findings build on the specialization framework, suggesting that caregiving instability results in both decrements and enhancements in children's cognitive control, consistent with the hypothesis that cognitive control development is scaffolded by early environmental pressures.

Keywords

Stress; Parenting; Executive Function; Development; Specialization

Introduction:

Early caregiving instability is a potent stressor for children. Broadly defined, caregiving instability comprises separations from a caregiver followed by semi-permanent or permanent changes to another, and is commonly experienced within the context of foster care and

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adoption (Almas et al., 2020). Unfortunately, many individuals are exposed to unstable early environments, with estimations that children in the United States experience an average of 1.2 changes in caregiver by the age of 18 years old (Raley et al., 2019). Unstable caregiving creates significant uncertainty and unpredictability (Dickerson et al., 2019), disrupts the learning processes fundamental to establishing a secure relationship with a primary caregiver (Bowlby, 1982), and is a dominant feature in the lives of children who experience parental separations. Given that unpredictability can serve as a powerful stressor itself (Baram et al., 2012; Gunnar et al., 1984), caregiving instability may have a particularly strong impact on children's development beyond the influence of other adverse early experiences, including changes at both the neurobiological and behavioral level (Casanueva et al., 2014; Davis et al., 2019; Fisher et al., 2013; Lewis et al., 2007; McGuire et al., 2018; Pears et al., 2010; Roy et al., 2004).

The negative consequences of caregiving instability have been posited to have an outsized impact on the development of cognitive control (Fisher et al., 2013). Cognitive control is an umbrella term describing processes that modulate and execute goal-directed behavior and is comprised of several subdomains including inhibitory control (e.g., response inhibition, attentional control), cognitive flexibility (e.g., task switching), and working memory (Davidson et al., 2006). Mastery of these skills is critical for achieving short term goals and has also been linked to academic achievement (Blair, 2002), emotion regulation (Carlson & Wang, 2007), and social competence in children (Riggs et al., 2006).

Cognitive control processes may be particularly susceptible to instability, as brain regions underlying these behaviors, such as the prefrontal cortex, undergo protracted development throughout childhood leaving them vulnerable to early environmental pressures (Casey et al., 2005; Pechtel & Pizzagalli, 2011). Consistent with this hypothesis, research has indicated that exposure to institutional care or foster care, environments defined by caregiving instability, is a significant risk factor for poor cognitive control (Fry et al., 2017; Hostinar et al., 2012). Moreover, children who experience multiple caregiving placements demonstrate lower cognitive control performance than children with more stable placement histories (Lewis et al., 2007; Roos et al., 2016). This work suggests that instability may be associated with worsened cognitive control, perhaps in a dose-dependent fashion, with greater instability linked to larger deficits in behavior. Importantly, the majority of research in this area has either examined cognitive control in a domain-general fashion, collapsing across subdomains of behavior (Fry et al., 2017; Pears & Fisher, 2005; Roos et al., 2016), focused the investigation on a single subdomain (e.g., inhibitory control; Lewis et al., 2007), or examined differences at the group level (Hostinar et al., 2012).

These associations between caregiving instability and poorer cognitive control performance are in line with predictions from theories postulating that repeated exposure to extreme stressors can ultimately result in deficits in developmental functions (McEwen, 2008; Sameroff et al., 1987). While these behavioral changes can be robust and concerning, they have also been hypothesized to reflect contextually appropriate adaptations to chronic environmental pressures in preparation for future conditions (Belsky, 2008; Callaghan & Tottenham, 2016; Ellis & Del Giudice, 2019; Frankenhuis & Ellis, 2017; Giudice et al., 2011; Nettle et al., 2013). Ellis and colleagues (2017) have further suggested that while understandable, a focus on deficits disregards the adaptive nature of developing systems and the specialization that can occur following stress exposure. Specialization has been defined by Frankenhuis and de Weerth (2013) within the realm of stress as a process that occurs when repeated developmental exposure to a stressor improves attention, perception, learning, memory, and problem-solving such that the resulting behavior is relevant to the particular stressor and can be applied across a variety of contexts.

Consistent with this adaptation view, research has identified domains of development that might show enhancements following exposure to early stressors (Ellis et al., 2020). Relatedly, recent work has indicated that children exposed to adverse conditions show improvements in working memory as compared to non-exposed children, a phenotype interpreted by the authors to have adapted in response to the environmental context (Nweze et al., 2020). Unpredictability has also emerged as an important aspect of early adversity in predicting enhancements in cognitive flexibility in adult samples. Adults who retrospectively reported unpredictable childhoods, operationalized as changes in parental employment status, residences, and adults in the household, demonstrated enhancements in cognitive flexibility (i.e., shifting behaviors) in the context of task uncertainty (Mittal et al., 2015). This last finding suggests that environmental unpredictability, a hallmark of unstable early caregiving, might promote the development of enhanced cognitive flexibility to meet the developmental challenges of the environment, and allow individuals to function most effectively in rapidly changing settings (e.g., new homes, schools, parenting practices, etc.). While adult retrospective reports of childhood adversity may not always adequately capture the veracity and/or timing of experiences (Danese & Widom, 2020), these data are important in that they demonstrate a link between childhood instability and enhancements in a relevant domain of cognitive control.

The current study sought to examine the association between caregiving instability and cognitive control processes in a sample of school-age children. We recruited children from heterogeneous backgrounds that were enriched for caregiving instability, including institutional care, domestic and international foster care, kinship care, and temporary/permanent separations from biological parents. To characterize instability, we measured the number of caregiving switches a child experienced from birth to the time of testing, as reported by primary caregivers. We hypothesized that an increased number of caregiving switches would be associated with decreased response inhibition and attentional control but increased cognitive flexibility, reflecting a process of specialization through environmental adaptation.

Methods:

Participants:

The present study included 275 children recruited from within the United States (*Mean Age (SD)* = 9.54 years (1.96)) who had experienced disruptions in caregiving (e.g., institutionalization, domestic and international foster care, temporary/permanent separations from parents) (N = 169) and a comparison group of children who had not (N = 106; Table 1 for demographic information and Supplemental Materials for exclusion criteria). Parents provided written consent, while children ages 7-years-old and older provided written assent and 6-year-olds provided verbal assent. The Institutional Review Board at Columbia University approved the protocol, and participants were compensated with a stipend. The protocol was designed to collect data in the following order (1. NIH Toolbox: Flanker, Dimensional Change Card Sort (DCCS); 2. Go/No-Go) to acclimate children to computerized testing prior to functional magnetic resonance imaging (fMRI; where the Go/No-Go was administered). Aside from rare deviations, tasks were presented in a fixed order, as is standard for individual differences research (Carlson & Moses, 2001). These tasks were obtained as part of a larger battery of assessments aimed at characterizing cognitive control behavior and negative valence systems (not included in the present work).

Caregiving Instability:

Caregiving instability was characterized by coding the number of switches in primary caregiving (*M* = 1.61, *Range* = 0-19), regardless of group. This information was obtained from the child's current legal guardian, who verbally provided a detailed timeline of their child's caregiving placements from birth-present. Caregiving switches were coded as changes in primary caregiver as reported by legal guardians, involving separations from biological parents (including those at, or shortly after birth to account for switches between the pre and postnatal environment), orphanage placements, foster care placements, kinship care placements, or moves from one biological parent's home to another (on-going co-parenting arrangements were not included). Changes to or from previous placements were counted as '1' switch, and switches were summed to create a total caregiving switch score. Children who experienced no switches in caregiving received a score of '0'. Due to a skewed distribution, (Supplemental Materials; *Skew* = 2.71), switches of 4 or greater were collapsed into one variable, and thus the transformed variable represented cases of 0, 1, 2, 3, and 4 or more caregiving switches (*Skew* = .51).

Cognitive Control:

Response Inhibition: We adapted a Go/No-Go task (Durston et al., 2002) to assess response inhibition. Participants were instructed to press a button for every Pokemon character displayed ('go' trials), except for one character (Meowth), for which they were instructed to withhold presses ('no-go' trials). Go trials occurred more frequently (60% of trials) than no-go trials (40% of trials) to create a prepotent response to press. Two blocks of 50 trials were administered (100 trials total), except when only one block or partial blocks were completed due to participant non-compliance (*N* = 22). This task was completed during fMRI, except when participants did not scan and completed the task outside of the scanner on a laptop (*N* = 25). Response inhibition performance was calculated by subtracting the proportion of presses to 'no-go' trials (i.e., false alarms) from the proportion of presses to 'go' trials (i.e., hits). A score of 1 would indicate that participants always correctly pressed to 'go' trials (high hit rate) and never pressed to 'no-go' trials (low false alarm rate). A score of 0 would indicate that a participant's hit proportion was equivalent to their false alarm proportion. A score of −1 would indicate that a participant pressed to 'no-go' trials 100% of the time (high false alarm rate), and never pressed to 'go' trials (low hit rate). Thus, higher scores indicate better performance.

Attentional Control: The Flanker task was administered via the iOS version of the NIH Toolbox Cognitive Battery to assess attentional control (Gershon et al., 2013). Participants were instructed to press the button that matched the direction the middle arrow was pointing in a row of arrows. ‘Congruent trials’ were those in which the middle arrow pointed the same way as the rest of the arrows, and ‘incongruent trials’ were those in which the middle arrow pointed the opposite direction as the rest of the arrows. Attentional control performance was calculated by subtracting the mean reaction time (RT) for ‘incongruent trials’ from ‘congruent trials’, after removing outliers, determined as trials 3 SD above or below the mean RT of each trial type for each participant. A positive score would indicate that the mean RT for incongruent trials was less than the mean RT for congruent trials, or that participants were faster to press to incongruent trials than congruent trials. A score of 0 would indicate that participants pressed just as quickly to incongruent trials as congruent trials, on average. A negative score would represent incongruent interference, or that the mean RT for incongruent trials was greater than the mean RT for congruent trials (Mullane et al., 2009). This would indicate that participants were slower to press to incongruent trials than congruent trials. Thus, more positive scores indicate better performance (note: typically, the Flanker task is computed such that negative scores represent better performance; here, scores were inverted to keep the interpretation of higher scores consistent across tasks).

Cognitive Flexibility: The DCCS was administered via the iOS version of the NIH Toolbox Cognitive Battery to assess task switching (Gershon et al., 2013). Participants were instructed to sort cards based on two dimensions (shape, color), and were assessed during a mixed round in which the rule was the same as the initially-learned rule set (repeat) or switched from the initially-learned rule set (switch). Task switching performance was calculated by subtracting the mean RT for switch trials from repeat trials, after removing outliers, determined as trials 3 SD above or below the mean RT of each trial type, for each participant. A positive score would indicate that the mean RT for switch trials was less than the mean RT for repeat trials, or that participants were faster to press to switch trials than repeat trials. A score of 0 would indicate that participants pressed just as quickly to switch trials as repeat trials, on average. A negative score would represent switch cost, or that the mean RT for switch trials was greater than the mean RT for repeat trials. This would indicate that participants were slower to press to switch trials than repeat trials. Thus, more positive scores indicate better performance (note: typically, the DCCS task is computed such that negative scores represent better performance; here, scores were inverted to keep the interpretation of higher scores consistent across tasks).

Results:

After computing the scores for each cognitive control subdomain, scores were z-scored to allow for comparison between all three subdomains (Supplemental Materials for correlation table). A repeated measures ANCOVA was conducted to examine the association between caregiving switches and cognitive control measures (response inhibition, attentional control, cognitive flexibility), controlling for child sex and age. Mauchly’s Test of Sphericity was not violated ($p = .393$), so the assumption of sphericity was assumed. There was a significant interaction between caregiving switches and cognitive control subdomain ($F(8, 536) = 3.15$,

$p = .002$, $\eta_p^2 = .045$). To investigate this interaction, three separate linear regressions were performed on raw scores to examine the associations between caregiving switches and each cognitive control measure, with additional predictors of child sex and mean-centered age (Figure 1A).

For response inhibition (Go/No-Go), there was a negative association between caregiving switches and performance, such that a greater number of caregiving switches was associated with lower performance ($B = -.022$, $SE = .008$, $t = -2.65$, $p = .009$, $f^2 = .026$), driven by greater false alarm rate (Supplemental Materials). This association remained significant when controlling for task completion inside versus outside of the scanner ($B = -.023$, $SE = .008$, $t = -2.68$, $p = .008$, $f^2 = .027$). For attentional control (Flanker), there was a negative association between caregiving switches and performance, such that a greater number of caregiving switches was associated with reduced attentional control ($B = -.045$, $SE = .019$, $t = -2.35$, $p = .019$, $f^2 = .020$). This suggests greater incongruent interference or a larger difference between mean congruent RT and mean incongruent RT for children with more caregiving switches. For cognitive flexibility (DCCS task-switching), there was a positive association between caregiving switches and performance, such that a greater number of caregiving switches was associated with enhanced task-switching ($B = .037$, $SE = .013$, $t = 2.83$, $p = .005$, $f^2 = .030$). This suggests lower switch cost, or a smaller difference between mean repeat RT and mean switch RT for children with more caregiving switches (Figure 1B). Supplemental Materials provide exploratory modeling methods, and additional controls, which converge on the results here.

Discussion:

Here, we found that caregiving instability is associated with lower response inhibition and attentional control, but greater cognitive flexibility in school-age children. These findings support our hypothesis that children would show both decrements as well as domain-relevant enhancements in cognitive control following early caregiving instability. Importantly, our measure of caregiving instability was a quantitative sum of caregiving switches and was obtained during childhood, potentially avoiding biases of self-reporting and/or retrospective reporting. Additionally, statistical comparison of three separate tasks allowed for a nuanced characterization of cognitive control.

These findings replicate and extend initial work in both adults and rodent models that demonstrate enhancements in cognitive flexibility following early-life stress. Our results are conceptually consistent with the study by Mittal and colleagues (2015), showing that adults who reported experiencing high unpredictability in childhood demonstrated enhanced shifting performance in conditions of high uncertainty. Relatedly, adults raised in unstable early environments have also exhibited enhancements in working memory updating when tested following an uncertainty priming condition (Young et al., 2018). In rodent models, it has been shown that chronic stress exposure during adolescence produced more effective transitions to foraging patches to obtain rewards in adulthood when the animals were placed under threat (Chaby et al. 2015). Interestingly, these enhancements in behavior evident in adulthood were all contingent upon the task environment being uncertain or threatening. Although the current study administered the behavioral tasks in a controlled environment without any intended stress manipulation, we cannot rule out the possibility that participants experienced stress during the fMRI scan or the study session, giving rise to the pattern of obtained results. However, we did not observe a correlation between participants' self-reported post-MRI enjoyment and Go-No/Go performance ($r(243) = .004$, $p = .95$). Alternatively, adaptations in cognitive control, when studied in childhood, may manifest regardless of testing conditions, and become more ecologically-specific at older ages. These interpretations are only speculative and require additional research.

The field has increasingly aimed to characterize processes of adaptation to the early environment, diverging from longstanding theories of stress impairment (Frankenhuis & Ellis, 2017). Our work supports this framework, with a specific focus on the relevance of the enhanced behaviors. In the current study, we found enhancements only in the domain of cognitive flexibility in children who had experienced high levels of caregiving instability. Importantly, this improvement in task-switching may come at the cost of a decrease in inhibition performance, as has been suggested by Ellis and colleagues (2017), and previously demonstrated in a population of typically developing children (Blackwell et al., 2014). This tradeoff may also explain the lack of association previously reported between the number of caregiving placements and cognitive control when considered as a composite of both inhibitory control and task switching (Pears & Fisher, 2005).

Behavioral enhancements may be specific to ecologically relevant aspects of one's experience, rather than overarching group labels. That is, specific experiences common across groups (e.g., institutional care versus foster care) may be the relevant agent for predicting individual differences in cognitive control behaviors. In support of this theory, we did not observe a statistically significant difference between groups in task switching (Supplemental Materials). Caregiving switching, as measured in the present work, is likely more directly related to cognitive flexibility than other experiences of adversity, in that children who have experienced many caregiving settings must learn to effectively shift between changing environments and new house rules. In support of this distinction, while paternal transitions have been associated with improved effortful control in three-year-old children, a self-regulatory construct integral to managing behavior across changing contexts, harsh parenting was associated with diminishments (Warren & Barnett, 2020). Though experiences of harsh parenting or maltreatment may interfere with the child/caregiver relationship, they may not involve any changes in caregiving. In this way, maltreatment represents a qualitatively different experience than the metric of caregiving switches captured in the current study, which may explain the previous inconsistency in findings in regards to the association between maltreatment and cognitive flexibility (Harms et al., 2018; Kirke-Smith et al., 2014) and the lack of association between maltreatment exposure and cognitive control behavior in the current sample (Supplemental Materials). Comparatively, childhood maltreatment has been linked to alterations in reward processing (Dillon et al., 2009; Guyer et al., 2006; Harms et al., 2019), perhaps due to less positive parenting (Hanson et al., 2017; McCrory et al., 2017) and hypervigilance to threat (Teicher & Samson, 2016)—experiences which may be more directly linked to growing up in a dangerous environment. Additional recent work has also observed that behavioral enhancements occurred only within a domain posited as relevant to the specific population (Nweze et al., 2020), with no group differences noted in task switching behavior. Taken together, this work highlights the importance of capturing not only the type but also the characteristics of the caregiving environment when disentangling the developmental consequences of early adversity.

There are several limitations to acknowledge within the current study. First, caregiving transitions are not always random—instead, factors like age and child behavior can influence the number of caregiving placements a child experiences (Fisher et al., 2013; Proctor et al., 2011). Past work has suggested that older children and those who demonstrate more behavioral problems are more likely to experience a greater number of caregiving placements (Aarons et al., 2010; Barth et al., 2007; Chamberlain et al., 2006). Understanding the mechanisms leading to increased caregiving switches is an important task; however, the current study did not seek to identify such factors. Instead, our work suggests that children adapt to their present environment in light of the potential causes that lead to increased disruption. Though we attempted to capture an unbiased metric of caregiving instability, these data were obtained from current legal guardians, some of whom may not have been privy to the full caregiving history of their adopted children. Additionally, while the Flanker and DCCS were obtained under standardized settings, the Go/No-Go was completed during an MRI scan, which might result in differences in response inhibition performance than if participants were tested outside of the scanner. Further, task administration was not counterbalanced; however, given the general order of tasks (Flanker, DCCS, Go/No-Go), it is unlikely that order effects would explain the observed patterns of behavior. Finally, we had a large number of participants with 0 caregiving switches, and substantially fewer within the greater caregiving switch groups.

Despite these limitations, our study adds to the growing body of evidence for the specialization theory, indicating that disruptions to the caregiving environment can modulate children's cognitive control behavior in domain-specific ways. Investigating specific attributes of the environment, rather than broad group designations, allowed us to gain a comprehensive understanding of the way early adversity impacts, rather than impairs, cognitive control. By continuing to examine how behaviors might be differentially altered in response to early pressures, we may better understand the influential role of early experience during development.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Data availability statement:

The data and analysis code that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Research Highlights:

- Caregiving instability is associated with reduced response inhibition and attentional control but enhanced cognitive flexibility in 6-12-year-old children.
- Caregiving instability was more effective in explaining these patterns than was group (e.g., institutional care versus foster care).
- Caregiving instability demonstrates domain-specific associations with children’s cognitive control, possibly reflecting a process of adaptation to meet the developmental challenges of an unstable environment.

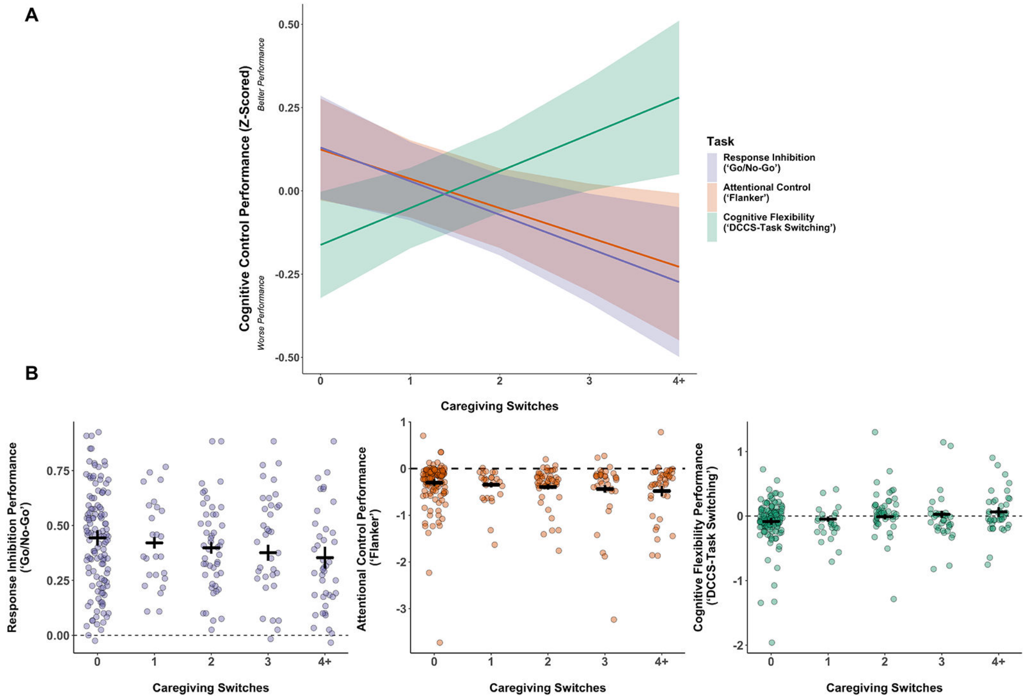

Figure 1A and 1B:

A. Fitted linear regression lines for z-scored response inhibition, attentional control, and cognitive flexibility performance at mean age and sex. Ribbons represent 95% confidence intervals. The y-axis represents z-scored performance metrics of hit – false alarm score for the Go/No-Go task, mean congruent trial RT – mean incongruent RT for the Flanker task, and mean repeat trial RT – mean switch trial RT for the DCCS task. The x-axis represents the number of caregiving switches, with all values greater than 4 represented in the 4+ bin. ***B.*** Raw individual data points of the association between caregiving switches and three measures of cognitive control performance. *(left panel)* The y-axis represents the proportion of hit trials - the proportion of false alarm trials on the Go/No-Go task. The dashed line represents a score in which the proportion of hits and the proportion of false alarms is equal. *(middle panel)* The y-axis represents the difference in mean RT between congruent and incongruent trials on the Flanker behavioral task. The dashed line represents when the mean RT for congruent trials is equal to that of incongruent trials. *(right panel)* The y-axis represents the difference in mean RT between repeat and switch trials on the DCCS task-switching behavioral task. The dashed line represents when the mean RT for repeat trials is equal to that of switch trials. The x-axes represent the number of caregiving switches, with all values greater than 4 represented in the 4+ bin. Black horizontal crossbars represent linear model fitted means for each task and black vertical bars represent 95% confidence intervals.

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Table 1:

Demographics

Measure	Descriptive Statistics
Child Age (years)	*M±SD:* 9.54±1.96
Child Sex	148F/127M
Child Race	
African-American/Black	37.8%
American Indian/Alaskan Native	1.8%
Asian-American	8.4%
Native Hawaiian/Other Pacific Islander	.40%
European-American/Caucasian	42.9%
Other	22.8%
Child Ethnicity	
Hispanic/Latinx	27.6%
Non-Hispanic/Latinx	70.2%
Missing	2.2%
Household Income	*Median*: $82,000

Note: Totals exceed 100% to account for individuals endorsing more than 1 race