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# Attentional Control in Infancy: The Role of Sociodemographic Risk, Cortisol, and the Home Environment

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# ATTENTIONAL CONTROL IN INFANCY: THE ROLE OF SOCIODEMOGRAPHIC RISK, CORTISOL, AND THE HOME ENVIRONMENT

DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Arts and Sciences
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2020



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ABSTRACT OF DISSERTATION

ATTENTIONAL CONTROL IN INFANCY: THE ROLE OF SOCIODEMOGRAPHIC RISK, CORTISOL, AND THE HOME ENVIRONMENT

Infants' ability to channel their cognitive resources by controlling their visual attention allows them to be active agents in their learning and development. Individual differences in attentional control have been linked to a wide variety of developmental outcomes including disparities between social classes in cognitive functioning. However, it is yet unknown when in development differences in attentional control related to sociodemographic factors emerge, or how factors of the home environment and the infant's stress response relate to this effect. Accordingly, Experiment 1 examined whether certain sociodemographic factors, such as socioeconomic and minority status, predict 3.5-month-old infants' ($N$ = 102) ability to control their attention, as indexed by their average fixation durations. The results of this study not only suggest that average fixation duration is a viable metric for studying individual differences in cognitive development early in life, but are also, to my knowledge, the first demonstration of associations between sociodemographic risk and attentional control as early as 3.5 months of age. Next, in Experiment 2, an additional sample of 3.5-month-olds ($N$ = 96) was recruited to determine the roles of home stability (i.e., home chaos and adherence to routines) and infant's physiological response to stress (i.e., cortisol) in the relationship between attentional control and sociodemographic factors. A sub-sample of these infants were tested again at 5 months of age ($N$ = 60) to examine changes over time in the relationship between sociodemographic risk, cortisol, and home stability. Two theoretical models were tested, the first being that instability in the home and maladaptive child rearing practices cause dysregulation of infants' stress responses (indexed by heightened basal cortisol levels), which, in turn, disrupts their attentional control abilities. No empirical support for this model was found. The second model tested assumed that attentional control serves as a protective factor such that infants with more robust attentional control abilities show a less pronounced association between instability in the home and cortisol levels. Support for this model was found whereby only infants with poorer attentional control, indexed via average fixation durations, showed elevated cortisol levels in the context of poorer adherence to routines. The results of this project indicate that associations between attentional control and sociodemographic factors emerge very early in life. Therefore, intervention efforts aiming to reduce the gap in developmental outcomes between minority and low-SES infants and children and their peers may be beneficial beginning in early infancy. Furthermore, attentional control may be useful as a screening tool to determine which infants may be more susceptible to adverse home environments, and training attentional control may be one pathway to promote resilience early in life.

KEYWORDS: Cognitive development, attentional control, sociodemographic risk, cortisol, home environment

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______May 05, 2020________
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# Chapter 1: Introduction

Associations between social inequality and developmental outcomes have been documented throughout the lifespan. Most commonly discussed is the recurring finding of lower academic performance and attainment in childhood and adolescence in socially disadvantaged groups, such as children growing up in lower socioeconomic status (SES) or racial/ethnic minority homes (e.g., McKown, 2013; Reardon, 2013). However, deficits associated with sociodemographic factors can be found long before children enter school. In fact, as early as at 6 months of age, children from more disadvantaged backgrounds show deficits on a variety of cognitive metrics (e.g., Clearfield & Jedd, 2013; Lipina, Martelli, Vuelta, & Colombo, 2005). Furthermore, early social context appears to have lingering effects on development as it has been found that lower childhood socioeconomic status (SES) is associated with steeper rates of cognitive decline in late adulthood (Melrose et al., 2014). Therefore, understanding when deficits associated with social inequality emerge and what factors mediate or moderate the association is critical if future outreach programs hope to foster positive development in disadvantaged groups.

It has been suggested that negative outcomes in the context of lower SES are related to deficits in effortful control (Lengua, 2012). For instance, effortful control has been found to buffer the negative effects economic hardship has on the development of efficient coping strategies (Taylor, Widaman, & Robins, 2018), which has implications for children's mental health. Moreover, infancy may be a critical period for the development of executive functions such as effortful control given that risk in infancy predicts self-regulation difficulties in preschool (Mistry, Benner, Biesanz, Clark, & Howes, 2010). Thus, the present investigation aims 1) to determine whether social context is associated with attentional control at 3.5 months of age, which would be, to my knowledge, the earliest documentation of associations between sociodemographic variables and any aspect of effortful control, and 2) to examine the role of relevant physiological and environmental factors, namely basal cortisol, home chaos, and adherence to routines, at 3.5 and 5 months of age to gain a more holistic picture of how and when sociodemographic risk relates to developing attentional control.

**Social Status and Attentional Control**

Effortful control encompasses the ability to control one's emotions and behaviors through inhibition of typically reflexive, sub-optimal responses in favor of often reflective, more adaptive responses (Lengua, 2012), and it has been found to mediate the relationship between SES and school achievement (Sektnan, McClelland, Acock, & Morrison, 2010) and between SES and interpersonal problems at school (Miech, Essex, & Goldsmith, 2001). Effortful control also serves as a protective factor against the increased prevalence of antisocial behaviors found in disadvantaged youth (Veenstra, Odehinkle, DeWinter, Lindenburg, & Ormel, 2006), and children with higher effortful control are more likely to be classified as resilient, rather than vulnerable (Eisenburg et al., 2004).

One critical component of effortful control that has been associated with a wide range of developmental outcomes in its own right is attentional control. Attentional control is paramount to human development because the human visual processing system is continuously presented with a functionally infinite amount of information. Without efficient mechanisms to control such a massive influx of data we would be unable to perform even the most basic of tasks. Thus, it is not surprising that children who exhibit higher levels of attentional control have been found to display increased social competence (Lengua, 2003) and higher academic achievement (Welsh, Nix, Blair, Beirman, & Nelson, 2010). Furthermore, attentional control varies systematically between individuals even by 3 months of age (Libertus & Needham, 2014). Critically, by 6 months of age attention to objects and faces systematically varies with SES (Clearfield & Jedd, 2013), suggesting that deficits in attentional control may be an early manifestation of the previously mentioned deficits in effortful control that are associated with economic disparity later in life. However, it is important to note that the study by Clearfield and Jedd (2013), involved live social interaction and object manipulation, and therefore the results may not be entirely due to differences in attentional control.

One way to disentangle attentional control from other abilities (i.e., social competence or gross motor control), is by focusing on the *quality* rather than the *quantity* of attention. In other words, focusing on the efficiency with which attention is deployed within a viewing period rather than just the overall amount of time the individual attended to a stimulus. Attentional quality can be measured using average fixation duration. Fixation duration is an index of how long the viewer focused their foveal visual attention (opposed to parafoveal or peripheral) toward a specific locus on a visual stimulus. The fovea is the region containing the highest density of cones and therefore the best able to detect fine-grained detail. Consequently, foveated stimuli benefit from a deeper level of cognitive processing. For any given look to be considered a fixation, it must surpass a certain threshold (determined by duration, dispersion, or some combination thereof) that separates fixations from other types of looks (i.e., saccadic or smooth pursuit; Salvucci & Goldberg, 2000). Average fixation duration has been found to be a reliable measure of attentional control that shows within-participant stability across tasks (Castelhano & Henderson, 2008; Rayner, Williams, Cave, & Well, 2007) and time (Colombo, Mitchell, Coldren, & Freeseman, 1991). Longer average fixation durations are thought to result from deficits in the inhibitory processes necessary to disengage from a specific region of a stimulus to continue scanning the array (Niebur, & Koch, 1996), and slower processing speeds (Nuthmann, Smith, Engbert, & Henderson, 2010). Documenting an association between sociodemographic factors and this critical component of attentional control would expand on previous findings and suggest that the relationship between attentional control and social status is robust early in life, which raises the question of which physiological and environmental factors mediate or moderate the association.

**The Role of Cortisol**

Persistent stress, and the resulting frequent activation of the body's stress responses, can result in excessive wear-and-tear on the body and brain known as allostatic load (McEwen, 2000). Allostatic load can manifest in multiple ways including 1) frequent physical stressors (i.e., blood pressure surges) that can result in adverse health events, 2) failed habituation to a recurring stressor, 3) an inability to terminate the autonomic and neuroendocrine responses to stress, and 4) dysregulated physiological systems (e.g., the Hypothalamic-Pituitary-Adrenal/HPA axis), resulting in an inability to adequately respond to stressful events (McEwen & Gianaros, 2010). Thus, allostatic load can be thought of as a cycle through which excessive or persistent stress leaves an individual less capable of mitigating stress in the future.

The prolonged stress leading to and resulting from allostatic load has the potential to dramatically impact cognitive development by modulating the activity of the prefrontal cortex (PFC). Namely, periods of stress have been found to reduce prefrontal cortex connectivity and subsequent performance on attentional control tasks in animal and human studies (Liston, McEwen, & Casey, 2009). Specifically, experimentally induced chronic stress has been found to reduce apical dendritic arborization (branching/connectivity of pyramidal cells which serve to excite the PFC) in rodents which is consistent with the findings of reduced dorsolateral PFC (DSLPFC) functional connectivity to regions within and beyond the PFC in humans after a period of psychosocial stress. The DSLPFC has been found to be strongly associated with top-down attentional control processes. Thus, the association between social status and attentional control may be mediated by the effect of stress on the PFC. This would be consistent with findings that lower-SES 7-12-year-olds utilize the PFC less when completing an oddball task (novelty detection) than their higher-SES peers (Kishiyama, Boyce, Jimenez, Perry, & Knight, 2009). Interestingly, performance accuracy and speed on the oddball tasks did not differ between the two groups, suggesting that lower-SES children are adapting by using less sophisticated and potentially higher cognitive load strategies when completing even simple tasks.

Given that allostatic load is theoretically a byproduct of the entire human stress response, which encompasses many systems, it is difficult to quantify. Thus, researchers often use the end-product of one system as a proxy (e.g., Blair et al., 2011a; 2011b; 2013; Finegood et al., 2017; Piccolo, Grassi-Oliveira, & Fumagalli de Salles, 2014). In the infant literature, this is almost exclusively cortisol which is instrumental in the activation of the autonomic nervous system via the HPA axis, and as such is a necessary component of the human stress response. Cortisol also has direct links to executive functions in its own right, not just as a proxy for allostatic load, such that elevations in cortisol have been found to cause neuronal death in the hippocampus and thus disrupt connectivity between the hippocampus and the PFC (for review, see Belanoff, Gross, Yager, & Schatzberg, 2001), a link thought to be critical for executive function (Godsil, Kiss, Spedding, & Jay, 2013). Furthermore, elevated basal cortisol levels in response to persistent stress have been implicated in the disruption of executive functions, such as effortful control, through a reduction of synaptic activity in the prefrontal cortex (Mizoguchi, Ishige, Takeda, Aburada, & Tabira, 2004) and impaired inhibitory control (Braunstein-Bercovitz, Dimentman-Ashkenazi, & Lubow, 2001; Lupien, Gillin, & Hauger, 1999).

Economically disadvantaged infants show increased basal cortisol levels at 7 months of age (Blair et al., 2011b), which suggests that SES related deficits in effortful/attentional control could also be present at this time point. While there is some support for this hypothesis such that increased basal cortisol levels at 7 and 15 months of age are associated with lower scores on the Mental Development Index of the Bayley Scales of Infant Development at 15 months of age (Finegood, et al., 2017), it is unknown whether certain aspects of effortful control that develop early, such as attentional control, are specifically impacted. As previously described, effortful control is often proposed as a mediator of the link between social disadvantage and negative developmental outcomes later in life. Thus, determining how cortisol levels relate to sociodemographic factors and an early analog of effortful control (attentional control) in infancy would provide valuable insight into the biological mechanisms that underlie the negative outcomes associated with social inequality. The reviewed literature would suggest that cortisol may mediate the association between sociodemographic variables and attentional control, possibly reflecting a rapid effect of stress on PFC development. However, it is also possible that the association between cortisol and attentional control is reversed, such that better attentional control is associated with lower levels of cortisol. This would be consistent with findings that, even by 4 months of age, infants are able to direct their attention away from an aversive stimulus resulting in a decrease in their outward signs of distress (Rothbart, Ziaie, & O'Boyle, 1992). Therefore, it is also possible that attentional control serves as a protective factor and moderates the association between cortisol levels and sources of stress in the environments faced by disadvantaged infants.

**The Role of the Home Environment**

Unlike children and adults for whom social inequality can directly lead to stress through social comparisons (e.g., Adler, Epel, Castellazzo, & Ickovics, 2000; Ursache, Noble, & Blair, 2015) or internalized racism (e.g., Speight, 2007), infants are unaware of their own SES and race/ethnicity; thus, neither can serve as a direct stressor. Therefore, it is important to examine aspects of the home environment, especially stability, that may have a substantial potential to impact their stress levels and subsequent allostatic load. Data from the National Longitudinal Survey of Youth suggests that the home environment accounts for one third to one half of the variability in developmental outcomes between low-SES youth and their higher-SES peers (Korenman, Miller, & Sjaastad, 1995). Thus, it is not surprising that certain factors of the home environment are associated with resting cortisol even by 7 months of age (Blair et al., 2011b), and the quality of home environment has been found to mediate the association between SES and cognitive development at 6 months of age (Rubio-Codina, Attanasio, Grantham-McGregor, 2016).

However, it is unclear from the extant literature if similar associations between home stability and cortisol exist within the first six months of life. Moreover, it is unknown whether stability in the home mediates the association between sociodemographic factors and basal cortisol levels. One metric of home stability that appears to be critical in quantifying infant stress is chaos, which is characterized as high levels of disorder and confusion. A longitudinal study demonstrated that both low-SES and higher levels of household chaos (measured from 2-48 months of age) were associated with increased cortisol levels at 48 months of age (Blair et al., 2013). Furthermore, increased consistency and predictability regarding routines in the home is associated with better emotion regulation in 4-year-olds, and this relationship is moderated by cortisol levels (Miller et al., 2017). Thus, home chaos and adherence to routines are important to consider when examining potential sources of socially disadvantaged infants' stress that could be mediating the relationship between sociodemographic factors and basal cortisol levels, not only to help explain the emergence of such a relationship but also to determine if home stability is a promising direction for future interventions.

As with the relationship between cortisol and attentional control, two major possibilities emerge. First, a serial-mediation model is possible whereby sociodemographic risk predicts more instability in the home which, in turn, results in elevations in infant cortisol and a subsequent disruption in attentional control (longer average fixation durations). In other words, home stability may be a source of stress for disadvantaged infants that begins the cascade culminating in disrupted attentional control. Second, it is possible that attentional control moderates the association between home stability and cortisol such that infants with strong attentional control abilities (short average fixation durations) show a less pronounced association between instability in the home and cortisol. This would indicate that robust attentional control may be a protective factor against infant stress due to instability in the home regardless of social strata.

**The Current Study**

As mentioned above, the first goal of this dissertation is to determine whether social context is associated with attentional control at 3.5 months of age. Accordingly, in Experiment 1, a retrospective data analysis was conducted to determine whether 3.5-month-old infants' average fixation durations are predicted by their estimated family income. A significant association between average fixation duration and SES would extend the findings of previous studies (Clearfield & Jedd, 2013) to demonstrate that not only the *quantity* of attention, but also the *quality* of attention varies systematically with sociodemographic variables in infancy, but also that such associations are present earlier in life than previous reports suggest.

The second goal of this dissertation is to examine how relevant physiological and environmental factors relate to sociodemographic risk and attentional control early in life. Thus, in Experiment 2, a new sample of 3.5-month-olds were recruited and their attentional control, indexed via quality (average fixation duration) and quantity (stimulus preference) of attention, was examined in the context of their cortisol levels, home chaos, and adherence to routines. A sub-sample of these infants were also tested at 5 months of age to examine how the relationships documented at 3.5 months of age change over time, and to allow for longitudinal analyses to aid in disambiguating between the competing hypotheses outlined above (i.e., poor attentional control as the end point in a developmental cascade through instability in the home and elevated cortisol vs. attentional control as a protective factor against elevations in cortisol due to instability in the home). Taken together, the results of this study should provide useful insight into the processes through which social inequality can shape developmental pathways and thus inform the development of future interventions.

## Chapter 2: Experiment 1

As noted above, average fixation duration quantifies the *quality* of attention given to a stimulus by indexing the extent to which a viewer is able to disengage after orienting to and processing information presented at a specific region of a stimulus. Smaller average fixation durations are often interpreted as more sophisticated processing as the viewer is better able to move about the visual scene to take in additional information (Niebur & Koch, 1996; Nuthmann et al., 2010). Systematic differences based on sociodemographic risk would be consistent with the finding that the markers of the *quantity* of attention vary with SES by 6 months of age (Clearfield & Jedd, 2013) and would, to our knowledge, be the earliest demonstration of sociodemographic individual differences in attention early in life. Such a finding would further reinforce the need for early interventions to improve cognitive development in at-risk children. This would also be the first investigation to document associations between average fixation durations and sociodemographic variables at any age group. Given that, as previously discussed, average fixation durations have been utilized into adulthood, further validation of this metric would be useful for studies of lifespan development.

### Method

#### Participants

Data were collected by collapsing across several studies conducted at the University of Kentucky Infant Memory Lab. Some of the data from these studies have been previously published (White, Hock, Jubran, Heck, & Bhatt, 2018; White, Jubran, Heck, Chroust, & Bhatt, 2019), but not those pertaining to average fixation durations. Participants were originally recruited through birth announcements and from the local hospital and must have participated in one of the included eye-tracking studies, described below, at 3.5 months of age. The final sample included 102 infants (mean age in days = 104.94, *SD* = 8.62, 47 female). Two participants' data were excluded for eye-tracking data that did not include a valid fixation and two participants' data were excluded for an average fixation duration classified as an outlier (more than 1.5 X the interquartile range beyond the 75th percentile). Participants were predominantly from middle class families. 78.43% of participants were identified by their parents as White, 8.82% were Black, 2.94% were Asian, and 9.80% were multiracial. 5.88% of the participants were Hispanic.

**Measures**

*Sociodemographic Risk*

Given that sociodemographic risk factors are often correlated, a common approach to avoiding issues with collinear predictors is to create a single aggregate score that is a sum of the number of dichotomous risk factors (for review, see Evans, Li, and Whipple, 2013). Accordingly, for the current study, a sociodemographic risk variable was calculated by summing each infant's number of risk factors. One point each was added for being a racial/ethnic minority (the majority in the area where the current studies were conducted is White, Non-Hispanic), below the median maternal education of the sample (less than a college degree), or below median estimated family income of the sample (less than $59,891.95). Parents reported infant race/ethnicity, maternal education (1 = less than a high-school degree, 2 = junior high school/9th grade, 3 = partial high school/10th or 11th grade, 4 = high school graduate, 5 = partial college or specialized training, 6 = college graduate, 7 = graduate professional training; Hollingshead, 1975), and their address, which was used to estimate family income via publicly available tax return data for each postal code. The method of estimating income through addresses has been used in previous research (e.g., Adelman, Morley, Schenzler, & Warning, 1994; Suruda, Burns, Knight, & Dean, 2005), and the association between maternal education and income was marginally significant and in the expected direction in the current study, $r$ (100) = .19, $p$ = .051, giving confidence in the validity of the metric.

*Attentional Control*

*Stimuli.* The present analyses included data from studies in which infants were shown human bodies ($n$ = 42) or faces and objects ($n$ = 60), see Figure 1. In the human body condition across infants two different types of body stimuli were used. In the first set, infants sequentially viewed one male and one female body (White et al., 2018; 2019); and in the second, infants were shown one typical and one distorted female body (e.g., arms on hips or elongated torso). On average, bodies subtended horizontal and vertical visual angles of 10.20° and 15.00°, respectively.

In the faces and objects condition infants were presented with videos consisting of a face on one side of the screen and an object on the other side. Objects came from the Novel Object and Unusual Name (NOUN) database (Horst & Hout, 2016), and faces came from the Radboud Faces Database (Langner et al., 2010). Because the data analyzed in this study were obtained from an ongoing project examining social referencing, each video began with a still image of a neutral face in profile. After one second an object would appear on the screen and the face would switch to a still image displaying happiness. The same actor was used for both the neutral and happy expressions in any given video. Half of the actors were male, and half were female. Each infant saw one female face paired with an object and one male face paired with a different object. Across infants, a total of 16 faces and six objects were used in this study. On average, faces and objects subtended horizontal and vertical visual angles of 13.28° and 11.94° and 11.73° and 7.28°, respectively.

Figure 1

Examples of stimuli used in Experiment 1.

*Apparatus and Procedure.* In all studies, infants were seated on their parent's lap in a darkened chamber, approximately 60 cm in front of a 58 cm computer monitor. Parents wore opaque glasses to prevent them from seeing test images and potentially biasing their infant's looking patterns. In the human body condition, infants viewed one image on the screen at a time for 8 trials lasting 12 seconds each. In the faces and objects condition trials lasted 15 seconds, however, data were only analyzed for the 14 seconds when both the face and the object were on the screen. In both conditions between each trial, a colorful shape appeared to redirect infants' attention to the center of the screen.

Data were collected using a Tobii TX300 eye-tracker. The eye-tracker's cameras record the reflection of an infrared light source on the cornea relative to the pupil from both eyes at a frequency of 300 Hz. According to the manufacturer, the average accuracy of this eye-tracking system is in the range of 0.5 to 1 degree, which approximates to a 0.5-1 cm area on the screen with a viewing distance of 60 cm. When both eyes cannot be measured (e.g., due to movement or head position), data from one eye were used to determine the gaze coordinates. When both eyes are measured data is averaged to compute one fixation location and duration. The eye-tracker compensates for robust head movements, which typically result in a temporary accuracy error of approximately 1 degree and a 100 ms recovery time to full tracking ability after movement offset.

Prior to data collection, each infant's eyes were calibrated using a 5-point infant calibration procedure in which a 23.04 $cm^2$ red and yellow rattle coupled with a rhythmic sound was presented sequentially at five locations on the screen (i.e., the four corners and the center). An experimenter controlled the calibration process with a key press to advance to the next calibration point after the infant was judged (via a live video feed) to be looking to the current calibration point. The calibration procedure was repeated if calibration was not obtained for both eyes in more than one location. Eye-tracker calibration and stimulus presentation were controlled by Tobii Studio 3.3.1 software (Tobii Technology AB; www.tobii.com).

Fixations were classified using the velocity threshold identification (I-VT) filter in Tobii Studio (for detailed description, see Olsen, 2012). This filter works by first discarding saccades (identified as two or more consecutive gaze positions which are separated by a velocity of more than 30° per second). All remaining looks are potential fixations. Given that noise in the data can occasionally cause long fixations to be artificially divided and saccades to be incorrectly labeled as fixations, fixations that are separated by less than 75 ms and 0.5° are merged. Finally, fixation durations under 60 ms are discarded. Identical or similar filters have been used in many previous infant eye-tracking studies (e.g., Heck, Hock, White, Jubran, & Bhatt, 2016; Hunnius et al., 2011; Papageorgiou et al., 2014; White et al., 2018; 2019; Xiao et al., 2014; Wass, Smith, & Johnson, 2013).

A limitation of I-VT (and other) fixation filters is that all looks are classified as saccades or fixations. This means that smooth pursuit looks are sorted into one category or the other depending on the threshold selected. Additionally, it has been found that changing thresholds can reverse the direction of between-group differences in average fixation durations (e.g., typically developing children compared to children with autism spectrum disorder; Shic, Chawarska, & Scassellati, 2008). Thus, in order to examine whether the findings from the current study were similarly subject to the parameters used to define fixation duration, we conducted sensitivity analyses with a more conservative set of fixation criteria (12°/sec velocity threshold and 100 ms minimum fixation) which are analogous to those used in some studies of infant fixation durations (Papageorgiou et al., 2014; Wass, Smith, & Johnson, 2013). The results of the present investigation were virtually identical across both sets of criteria. Thus, the findings from the current studies do not seem to be a function of the specific parameters used to define fixation durations.

An area of interest (AOI) was created to encompass each stimulus. For the human bodies on average the AOI occupied 18.40% of the screen. For the faces and objects condition on average the stimuli AOIs encompassed 20.38% of the screen each. The dependent measure for this study was the average fixation duration to the stimulus AOI collapsed across all images a given infant saw and across all trials.

**Results and Discussion**

Descriptive statistics are presented in Table 1 and bivariate correlations are presented in Table 2. Average fixation duration was significantly, positively correlated with sociodemographic risk, $r$ (100) = .43, $p$ <.001, indicating that sociodemographic risk explains approximately 18% of the variance in average fixation duration at 3.5 months of age. The association held when controlling for infant age in days, stimulus type (faces and objects or bodies), total looking time, and sex, $\beta$ = .39, $t$ (96) = 5.18, $p$ <.001.

Table 1. *Descriptive Statistics for Experiment 1*

| | Sociodemographic Risk Score | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 |
| *N* | 35 | 43 | 15 | 9 |
| Female (%) | 42.86 | 39.53 | 66.67 | 55.56 |
| Age in Days, *M (SD)* | 103.06 (8.78) | 107.20 (8.37) | 105.60 (8.14) | 100.33 (7.70) |
| White, Non-Hispanic (%) | 100.00 | 81.40 | 26.67 | 0.00 |
| Maternal Education, *M (SD)* | 6.60 (0.50) | 6.37 (0.69) | 5.60 (1.06) | 4.44 (0.73) |
| Estimated Family Income [$1000s, *M (SD)]* | 82.18 (17.86) | 57.00 (18.97) | 50.93 (11.66) | 43.91 (8.68) |
| Total Looking Time (s), *M (SD)* | 55.18 (24.13) | 55.39 (22.94) | 54.40 (21.38) | 58.51 (26.23) |
| Fixation Count, *M (SD)* | 143.23 (81.02) | 139.60 (76.16) | 135.20 (59.13) | 146.00 (78.71) |
| Average Fixation Duration (s), *M (SD)* | 0.19 (0.06) | 0.20 (0.09) | 0.25 (0.10) | 0.33 (0.08) |

Table 2. *Experiment 1 Bivariate Correlations*

| Variable | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1. White, Non-Hispanic$^{\#}$ | -- | -- | -- | -- |
| 2. Estimated Family Income | .21$^{*}$ | -- | -- | -- |
| 3. Maternal Education | .32$^{***}$ | .19$^{\dagger}$ | -- | -- |
| 4. Sociodemographic Risk Score | -.71$^{***}$ | -.59$^{***}$ | -.63$^{***}$ | -- |
| 5. Average Fixation Duration | -.57$^{***}$ | -.12 | -.28$^{**}$ | .43$^{***}$ |

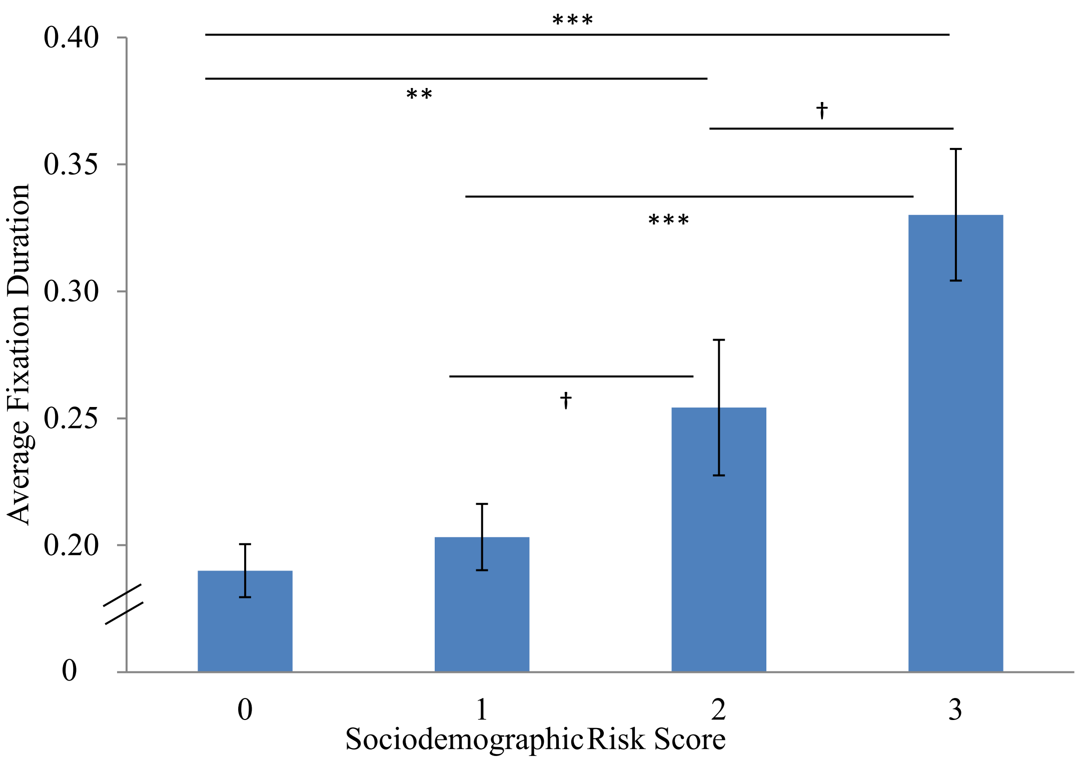
$^{\#}$White, Non-Hispanic = 1, Non-White or Hispanic = 0

$^{\dagger}p$<.10, *$p$<.05, **$p$<.01, ***$p$<.001

Furthermore, as seen in Figure 2, planned follow-up independent samples *t*-tests revealed significant differences between the mean average fixation durations of infants with risk scores of zero compared to two, $t$ (48) = -2.73, $p$ = 0.009, $d$ = 0.75, and three, $t$ (42) = -5.76, $p$ < .001, $d$ = 2.00, and infants with risk scores of one compared to three, $t$ (50) = -4.10, $p$ < .001, $d$ = 1.55. There were marginally significant differences between infants with risk scores of one compared to two $t$ (56) = -1.88, $p$ = 0.07, $d$ = 0.54, and risk scores of two compared to three, $t$ (22) = -1.90, $p$ = 0.07, $d$ = 0.83. The difference between infants with risk scores of zero versus one was not significant, $t$ (76) = -0.76, $p$ = .45, $d$ = 0.18.

These results demonstrate that individual differences in average fixation durations are systematic and predictable based on sociodemographic factors at 3.5 months of age. Furthermore, the present findings are consistent with the cumulative risk hypothesis such that having multiple risk factors, as opposed to only one, was associated with longer fixation durations.

Figure 2




Average fixation durations exhibited by infants in Experiment 3 as a function of risk score. †$p$<.10, *$p$<.05, **$p$<.01, ***$p$<.001

## Chapter 3: Experiment 2

The results of Experiment 1 demonstrate that an association between attentional control, indexed via average fixation durations, and sociodemographic factors is present by 3.5 months of age. Experiment 2 aims to first replicate this effect in a prospective study. Namely, given the secondary nature of the Experiment 1, differences in the content and duration of the images infants saw was not prospectively controlled through counterbalancing and may have introduced enough noise into the data to result in a spurious effect. This is unlikely given that controlling for slight procedural differences did not impact the pattern of results. However, a prospective replication of the previous results would serve to give additional confidence in our claims. Experiment 2 will also examine a more global metric of attention (i.e., a preference for faces) to determine whether attention *quantity* and *quality* are similarly associated with sociodemographic risk in this age range. Furthermore, Experiment 2 will include infant cortisol as a proxy for allostatic load and metrics of stability in the home environment (chaos and adherence to routines) to examine how infant sensitivity to instability in the home relates to sociodemographic risk and attentional control.

The first major hypothesis that was tested is that the previously documented association between sociodemographic risk and attentional control at 3.5 months of age is explained by a cascading stress model through which sociodemographic risk predicts higher instability in the home which, in turn, is associated with elevated allostatic load and finally a disruption in attentional control. Given that the association between sociodemographic risk and attentional control has already been documented at 3.5 months of age in Experiment 1, indirect effects of the proposed model must also be significant at that age for the hypothesized mediation to be supported. Support for this model would be consistent with previous reports of deleterious effects of physiological responses to stress on cognition in at risk populations (Piccolo et al., 2014). Results inconsistent with this model would indicate that a different mechanism (e.g., prenatal stress or nutrition) may be driving the early association between sociodemographic factors and attentional control.

The second model that was tested posits that, rather than allostatic load being an intervening process through which attentional control is disrupted, attentional control serves as a protective factor against the accrual of allostatic load in the face of instability in the home. Specifically, I examined whether the *quality* or *quantity* of infant attention moderates the association between home chaos and adherence to routines suggesting that, consistent with previous reports (Rothbart et al., 1992), infants are able to modulate their attention to manage distress. It is possible that although sociodemographic risk is associated with attentional control by 3.5 months of age, the beneficial effects of robust attentional control do not manifest until later in development. Thus, a sub-sample of infants were retested at 5 months of age to determine whether attentional control at 3.5 months of age moderates the association between home instability and allostatic load later in development. Support for this model would provide guidance for future intervention efforts by indicating that attentional control could be useful as either a screening tool to determine which infants may be more susceptible to adverse experiences in the home or an ability that could be trained to help foster resilience.

# Method

## Participants

An a priori power analysis conducted with G*Power (Faul, Erdfelder, Buchner, & Lang, 2009), using effect sizes from pilot data and studies using similar measures (Blair et al., 2011b; Finegood et al., 2017; Libertus & Needham, 2014), indicated that 100 participants would give over 80% power to detect the smallest expected effect in the most complex model. The final sample included 94, 3.5-month-old infants (mean age in days = 104.81, SD = 9.83, 48 female). Fourteen additional infants participated but their data were excluded for contributing no useable eye-tracking data (*n* = 3), being an outlier (more than 3 X the interquartile range beyond the 75$^{th}$ percentile) on one of the variables of interest (cortisol, *n* = 1; average fixation duration, *n* = 1), missing data on one of the parent report questionnaires (*n* = 7), or declining to provide a saliva sample (*n* = 2). Participants were predominantly from middle class families. 77.66% percent of participants were identified by their parents as White, 8.51% were Black, 1.06% were Asian, and 12.77% were multiracial. 8.51% of the participants were Hispanic. Sixty infants were also tested at 5 months of age (mean age in days = 153.48, SD = 9.48, 30 female). Six additional infants participated at 5 months of age but their data were excluded for being an outlier on one of the variables of interest (cortisol, *n* = 5) or contributing no useable eye-tracking data (*n* = 1). Originally, all participants were going to be invited back for a second visit, however due to health concerns with COVID-19 data collection was abruptly terminated.

**Measures**

*Sociodemographic Risk*

As in Experiment 1, infants received a summed score reflecting their sociodemographic risk (i.e., one point each for being a racial/ethnic minority, below median maternal education, and below median income). In the present study, family income was directly reported by parents, rather than being estimated. Furthermore, below median subjective social status (less than 6 on the MacArthur Ladder; Adler & Ostrove, 1999) was added as an additional marker of sociodemographic risk (i.e., one point for being below median subjective social status). This scale is commonly used to study subjective social status and has been validated across multiple populations (e.g., Operario, Adler, & Williams, 2004; Giatti, do Valle Camelo, de Castro Rodrigues, & Baretto, 2012). Participants received a score from 1-9 reflecting the rung on the ladder that they indicate reflects where they feel they fall in their social hierarchy.

*Basal Cortisol*

Cortisol levels were assessed using saliva samples. This is considered an efficient and reliable procedure as studies show that cortisol levels in saliva have a high correlation with blood serum levels (Kirschbaum & Hellhammer, 1994). The procedure for cortisol collection and storage followed the protocol developed by Salmetrics to minimize sample contamination and degradation. A researcher placed a soft cotton swab (SalivaBio Infant's Swab produced by Salimetrics) in the infant's mouth for 60-90 second intervals until the bottom of the swab appeared to be saturated. The time of collection was recorded and the swab was be immediately placed in a sterile container and stored in a freezer until being sent to the Center of Clinical and Translational Science at the University of Kentucky for analysis using an enzyme-linked immunosorbent (ELISA) assay which is also produced by Salimetrics. Cortisol is a fairly robust chemical and can handle being frozen for up to 4 months without significant degradation (Salimetrics, 2018). Cortisol values cycle throughout the day, so to minimize noise in the data from differences in time of collection, infants' cortisol scores were regressed onto time of day and the unstandardized residuals were used for analysis, as has been done in previous research (Finegood et al., 2017). Cortisol levels are also impacted by eating and sleeping, therefore saliva was collected after the researcher verified that the infant has not been fed and has been awake and alert for at least 30 minutes. Resting cortisol levels, rather than increases in response to stress, were used as researchers have claimed that they are more consistent with the theoretical background of allostatic load (Blair et al., 2011b).

*Home Environment*

*Home chaos.* Parents completed the Confusion, Hubbub and Order Scale (CHAOS; Matheny, Wachs, Ludwig, & Phillips, 1995). CHAOS was chosen as it directly measures factors related to stress within the home and has been well validated (Dumas et al., 2005). The reliability of the scale in this sample was found to be sufficient, $\alpha = .89$.

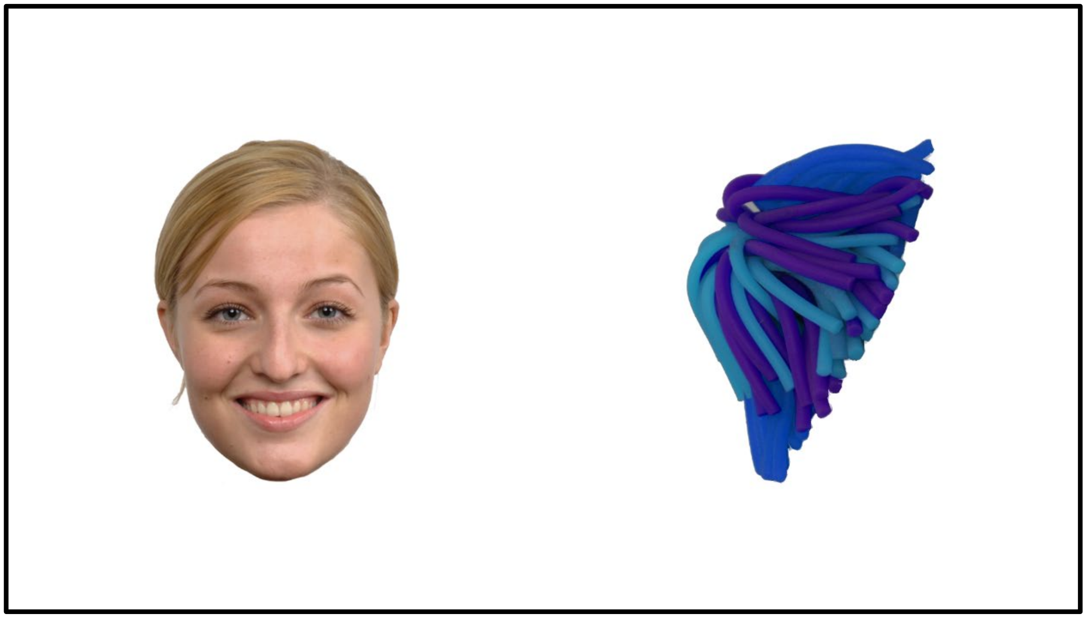
*Adherence to Routines.* To measure the extent to which infants are exposed to consistent routines, parents completed an adapted version of the Daily Living Routine subscale of the Child Routine Inventory (Sytsma, Kelley, & Wymer, 2001). This scale is a series of parent report questions pertaining to the consistency of meals, wake and bedtime, and morning and nightly rituals. Alterations were made to make the scale appropriate for use with infants, such as removing irrelevant items (e.g.., "My child brushes teeth before bed") and including an item pertaining to consistency of nap times. The reliability of the scale in this sample was found to be sufficient, $\alpha = .73$.

*Children in the home.* Previous studies have found association between additional children in the home and various facets of the home environment (Garrett, Ng'andu, & Ferron, 1994; Luster, & Dubow, 1990). Accordingly, children in the home was included as a dichotomous control variable.

*Attentional Control*

*Stimuli.* Infants were presented with a static image of a face on one side of the screen and an object on the other side, see Figure 3. Objects came from the Novel Object and Unusual Name (NOUN) database (Horst & Hout, 2016), and faces came from the Radboud Faces (Langner et al., 2010) and the NimStim (Tottenham et al., 2009) stimulus banks. Half of the actors were male, and half were female. Each infant saw 16 face/object pairings. Trial types (i.e., female face on the left, female face on the right, male face on the left, and male face on the right) were counterbalanced and were presented in a random order. Across infants, a total of 48 faces and 48 objects were used in this study. On average, faces and objects subtended horizontal and vertical visual angles of 10.95° and 15.11° and 11.49° and 14.54°, respectively.

Figure 3



Example of stimuli used in Experiment 2.

*Apparatus and Procedure.* The apparatus and procedure were the same as those used in the previous studies with the exception that infants viewed 16 trials, each lasting 10 seconds. An area of interest (AOI) was defined around each stimulus and encompassed 21.72% of the screen.

*Face Over Object Preference (Attention Quantity).* The first measure of attentional control aimed to capture the extent to which infants resolve the conflict between two stimuli. Humans' proclivity to orient to and linger on faces early in life is well documented (Farroni et al., 2005; Gliga, Elsabbagh, Andravizou, & Johnson, 2009; Simion, Valenza, & Umiltà, 1998), thus heightened attention to faces (in real scenes or images) is interpreted as more sophisticated attentional control (Amso, Haas, & Markant, 2014; Libertus & Needham, 2014; Clearfield & Jedd, 2013). Proportional preferences for the face were calculated by summing fixations to the face AOI and dividing them by the total fixation to the face and object AOIs and multiplying this score by 100. Higher percentages are interpreted as higher levels of attentional control.

*Average Fixation Duration (Attention Quality)*. As in Experiment 1, infants' average fixation duration (collapsed across both AOIs across all trials) was also calculated. Shorter average fixation durations, indicating less difficulty disengaging after initiating a fixation, are interpreted as higher levels of attentional control.

## Results and Discussion

Descriptive statistics are presented in Tables 3 and 4 and bivariate correlations are presented in Tables 5 and 6. As in Experiment 1, average fixation duration was significantly, positively correlated with sociodemographic risk at 3.5 months of age, $r$ (92) = .30, $p$ = .004. However, the preference for faces was not significantly associated with sociodemographic risk, $r$ (92) = -.06, $p$ = .56.

Table 3. *Descriptive Statistics for 3.5-month-olds in Experiment 2*

| | Sociodemographic Risk Score | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 |
| *N* | 13 | 24 | 20 | 25 | 12 |
| Female (%) | 46.15 | 54.17 | 45.00 | 56.00 | 50.00 |
| Other child in home (%) | 46.15 | 37.50 | 65.00 | 48.00 | 58.33 |
| Age in Days, *M (SD)* | 102.77 (8.44) | 107.21 (11.26) | 104.30 (8.11) | 102.68 (9.46) | 107.50 (11.41) |
| White, Non-Hispanic (%) | 100.00 | 75.00 | 70.00 | 96.00 | 0.00 |
| Maternal Education, *M (SD)* | 7.00 (0.00) | 6.46 (0.59) | 5.95 (0.83) | 5.52 (0.71) | 4.92 (1.24) |
| Family Income ($1000), *M (SD)* | 147.31 (60.16) | 137.88 (72.52) | 86.95 (44.59) | 47.39 (20.74) | 33.50 (24.36) |
| Subjective Social Status, *M (SD)* | 7.12 (1.00) | 6.00 (0.83) | 5.75 (1.11) | 4.28 (0.97) | 3.96 (1.29) |
| Cortisol[a], *M (SD)* | -.11 (0.08) | .02 (0.27) | 0.01 (0.29) | -0.005 (.17) | -.03 (.21) |
| Home chaos, *M (SD)* | 27.15 (10.65) | 24.46 (8.13) | 27.80 (7.45) | 26.56 (8.82) | 26.42 (9.66) |
| Adherence to Routines, *M (SD)* | 30.31 (5.07) | 31.95 (5.07) | 31.75 (4.33) | 31.28 (4.37) | 30.33 (8.18) |
| Total Looking Time (s), *M (SD)* | 92.94 (41.09) | 82.36 (34.31) | 82.97 (43.90) | 74.88 (42.43) | 120.73 (15.34) |
| Fixation Count, *M (SD)* | 297.62 (145.03) | 239.21 (148.24) | 272.80 (232.20) | 200.64 (124.98) | 316.58 (47.39) |
| Average Fixation Duration (s), *M (SD)* | 0.20 (0.07) | 0.20 (0.08) | 0.19 (0.07) | 0.20 (0.10) | 0.33 (0.08) |
| Face Preference (%), *M (SD)* | 68.83 (10.76) | 55.89 (17.93) | 59.67 (18.88) | 54.28 (19.27) | 66.15 (14.43) |

[a] Cortisol concentrations (μg/dl) were regressed onto time of day (hours past midnight) to control for differences in time of collection

Table 4. *Descriptive Statistics for sub-sample of infants who participated at 5 months of age in Experiment 2*

| | Sociodemographic Risk Score | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 |
| *N* | 10 | 14 | 8 | 19 | 9 |
| Female (%) | 50.00 | 35.71 | 50.00 | 52.63 | 66.67 |
| Other child in home (%) | 60.00 | 35.71 | 75.00 | 47.37 | 33.33 |
| Age in Days, *M (SD)* | 151.70 (6.95) | 150.71 (8.77) | 153.34 (4.66) | 152.16 (9.44) | 162.67 (14.86) |
| White, Non-Hispanic (%) | 100.00 | 71.43 | 75.00 | 100.00 | 0.00 |
| Maternal Education, *M (SD)* | 7.00 (0.00) | 6.57 (0.51) | 5.50 (1.07) | 5.47 (0.61) | 4.67 (1.80) |
| Family Income ($1000), *M (SD)* | 146.50 (64.29) | 148.07 (66.95) | 79.81 (53.47) | 46.25 (20.53) | 42.89 (20.33) |
| Subjective Social Status, *M (SD)* | 7.05 (1.12) | 5.96 (0.93) | 6.38 (0.91) | 4.42 (0.82) | 3.67 (1.43) |
| Cortisol at 3.5-months [a], *M (SD)* | -0.10 (0.09) | 0.02 (0.29) | 0.01 (0.26) | -0.03 (0.12) | -0.04 (0.23) |
| Cortisol at 5-months [a], *M (SD)* | -0.15 (0.11) | -0.13 (0.22) | 0.22 (0.05) | -0.12 (0.17) | -0.07 (0.21) |
| Home chaos, *M (SD)* | 26.20 (6.73) | 25.62 (10.12) | 26.50 (7.35) | 27.89 (9.61) | 28.22 (11.33) |
| Adherence to Routines, *M (SD)* | 29.70 (5.17) | 32.14 (5.50) | 30.25 (5.06) | 30.63 (4.69) | 32.00 (8.01) |
| Total Looking Time (s), *M (SD)* | 85.46 (43.72) | 95.45 (20.47) | 95.90 (44.77) | 79.57 (41.63) | 120.87 (15.01) |
| Fixation Count, *M (SD)* | 275.40 (155.67) | 290.00 (153.21) | 319.50 (178.55) | 214.53 (124.68) | 303.50 (47.35) |
| Average Fixation Duration (s), *M (SD)* | 0.15 (0.07) | 0.17 (0.08) | 0.18 (0.09) | 0.16 (0.11) | 0.32 (0.03) |
| Face Preference (%), *M (SD)* | 70.93 (9.37) | 58.42 (15.14) | 58.81(15.05) | 56.29 (16.38) | 66.49 (13.24) |

*Notes*. Other than cortisol at 5 months and other children in the home, all variables were collected at 3.5-months; [a] Cortisol concentrations (µg/dl) were regressed onto time of day (hours past midnight) to control for differences in time of collection

Table 5. *Experiment 2 Bivariate Correlations at 3.5 months of age*

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1. White, Non-Hispanic[a] | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2. Family Income | -.07 | -- | -- | -- | -- | -- | -- | -- | -- |
| 3. Home Chaos | .11 | -.09 | -- | -- | -- | -- | -- | -- | -- |
| 4. Adherence to Routines | .14 | .10 | -.01 | -- | -- | -- | -- | -- | -- |
| 5. Cortisol | -.01 | -.09 | .09 | -.09 | -- | -- | -- | -- | -- |
| 6. Maternal Education | .16 | $.50^{***}$ | -.002 | -.07 | .17 | -- | -- | -- | -- |
| 7. Subjective Social Status | .13 | $.55^{***}$ | .002 | -.09 | -.17 | $.44^{***}$ | -- | -- | -- |
| 8. Sociodemographic Risk Score | $-.37^{***}$ | $-.65^{***}$ | .03 | -.02 | .06 | $-.66^{***}$ | $-.71^{***}$ | -- | -- |
| 9. Average Fixation Duration | $-.53^{***}$ | -.02 | -.11 | -.08 | -.07 | $-.21^{*}$ | -.16 | $.30^{**}$ | -- |
| 10. Face Preference | -.01 | .07 | .16 | $-.17^{\dagger}$ | .04 | .07 | .01 | -.06 | $.20^{\dagger}$ |

[a]White, Non-Hispanic = 1, Non-White or Hispanic = 0; $^{\dagger}p<.10$, $^{*}p<.05$, $^{**}p<.01$, $^{***}p<.001$

Table 6. *Experiment 2 Bivariate Correlations at 5 months of age*

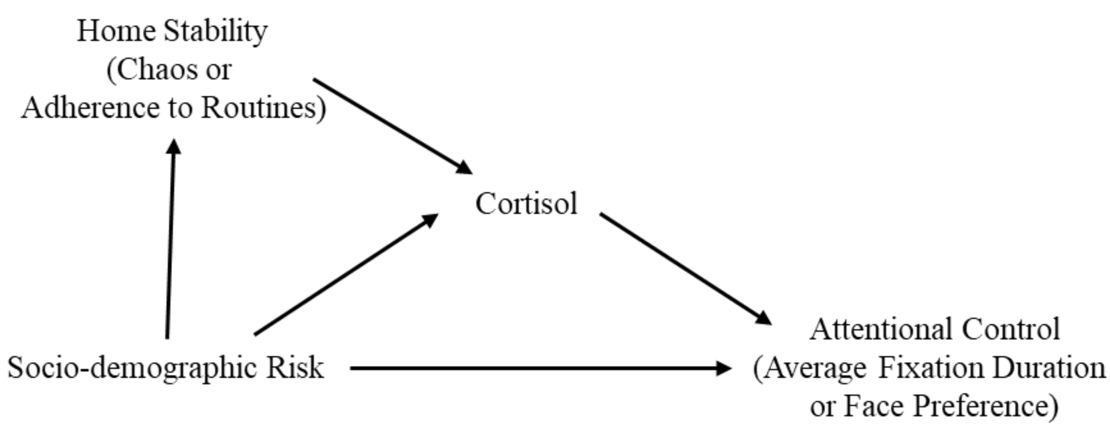
| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. White, Non-Hispanic[a] | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2. Family Income | -.09 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 3. Home Chaos | .03 | -.15 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4. Adherence to Routines | -.03 | .16 | -.14 | -- | -- | -- | -- | -- | -- | -- |
| 5. Cortisol at 3 Months | -.06 | -.01 | -.18 | -.13 | -- | -- | -- | -- | -- | -- |
| 6. Cortisol at 5 Months | -.16 | .08 | $.24^{\dagger}$ | -.05 | $.24^{\dagger}$ | -- | -- | -- | -- | -- |
| 7. Maternal Education | $.27^{*}$ | $.53^{***}$ | -.08 | -.09 | .17 | -.16 | -- | -- | -- | -- |
| 8. Subjective Social Status | .21 | $.54^{***}$ | -.13 | -.05 | -.10 | -.04 | $.49^{***}$ | -- | -- | -- |
| 9. Sociodemographic Risk Score | $-.38^{**}$ | $-.68^{***}$ | .11 | .05 | .03 | .10 | $-.66^{***}$ | $-.73^{***}$ | -- | -- |
| 10. Average Fixation Duration | $-.55^{**}$ | -.11 | -.05 | .05 | .04 | -.02 | $-.30^{*}$ | $-.33^{*}$ | $.40^{**}$ | -- |
| 11. Face Preference | -.07 | .13 | .15 | -.18 | -.01 | -.03 | -.09 | -.02 | -.13 | .16 |

[a] White, Non-Hispanic = 1, Non-White or Hispanic = 0; $^{\dagger}p<.10$, $^{*}p<.05$, $^{**}p<.01$, $^{***}p<.001$

*Cascading Stress Model*

To test the hypothesis that higher sociodemographic risk is associated with more instability in the home environment (lower chaos or adherence to routines) resulting in heightened infant cortisol and a subsequent disruption in attentional control (higher average fixation durations or a lower preference for faces (Figure 4), four mediation models were fit using the Process Macro in SPSS (Hayes, 2017). The results are presented in Table 7. No indirect effects were significant. Therefore, the results of the current study do not provide evidence for home stability or cortisol as mediating factors in the relationship between sociodemographic risk and attentional control at 3.5 months of age.

Figure 4




Cascading stress model tested in Experiment 2.

Table 7. *Results of Experiment 2 mediation models*

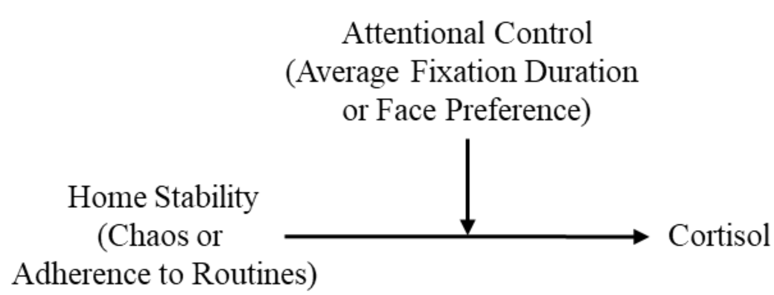
| | Model 1 | | Model 2 | | Model 3 | | Model 4 | |
|---|---|---|---|---|---|---|---|---|
| *Dependent Variable:* | Cortisol | | | | Average Fixation Duration | | Face Preference | |
| | ß | 95% CI | ß | 95% CI | ß | 95% CI | ß | 95% CI |
| **Direct Effects** | | | | | | | | |
| Sociodemographic Risk | 0.04 | [-0.03, 0.04] | 0.04 | [-0.03, 0.04] | 0.30** | [0.01, 0.04] | -0.07 | [-3.83, 2.00] |
| Cortisol | -- | -- | -- | -- | -0.12 | [-0.14, 0.04] | 0.05 | [-13.34, 20.50] |
| Home Chaos | -- | -- | 0.04 | [-0.005, 0.01] | -- | -- | -- | -- |
| Adherence to Routines | -0.06 | [-0.01, 0.01] | -- | -- | -- | -- | -- | -- |
| **Total Effect** | | | | | | | | |
| Sociodemographic Risk | 0.04 | [-0.03, 0.04] | 0.04 | [-0.03, 0.04] | 0.29** | [-0.07, 0.04] | -0.06 | [-3.79, 2.01] |
| **Indirect Effect** | | | | | | | | |
| Sociodemographic Risk | 0.001 | [-0.02, 0.03] | 0.0003 | [-0.02, 0.03] | -0.01 | [-0.06, 0.01] | 0.002 | [-0.04, 0.04] |
| *Mediator:* | Adherence to Routines | | Home Chaos | | Cortisol | | | |
| Sociodemographic Risk | -0.01 | [-0.89, 0.81] | 0.01 | [-1.34, 1.46] | 0.04 | [-0.03, 0.04] | 0.04 | [-0.03, 0.04] |

*Notes.* All Models control for age in days, sex (1 = Female/0 = Male), and children in the home (1 = one or more additional children in the home/0 = No additional children); Standardized coefficients are presented; The 95% CI for the indirect effect is the standardized result of 5,000 bootstrapped samples; ** $p < .01$

*Attentional Control as a Protective Factor*

To test the hypothesis that attentional control moderates the association between factors of the home environment and infant cortisol at 3.5 months of age (Figure 5), four multiple regression models were fit whereby cortisol was predicted by age in days, the presence of children in the home, sex, home stability (home chaos or adherence to routines), attentional control (average fixation duration or face preference), and the interaction of attentional control and the home environment. The results are presented in Table 8. None of the interaction effects were significant. Thus, no evidence was found to suggest that attentional control moderates 3.5-month-olds' cortisol levels in the context of instability in the home environment.

Figure 5




Model of attentional control as a protective factor tested in Experiment 2.

Next, data from the sub-sample of infants who were retested at 5 months of age were used to test the hypothesis that the beneficial effects of robust attentional control at 3.5 months of age take time to manifest. Again, four multiple regression models were fit whereby cortisol at 5 months was predicted by the number of days between test sessions, the presence of children in the home, sex, cortisol at 3.5 months, home stability at 3.5 months (home chaos or adherence to routines), attentional control at 3.5 months (average fixation duration or face preference), and the interaction of attentional control and the home environment. The results are presented in Table 9. Unlike the results at 3.5 months of age, the adherence to routines by average fixation duration, $\beta = -0.31$, $t$ (51) = -2.01, $p$ = .049, and adherence to routines by face preference $\beta = -0.27$, $t$ (51) = -2.05, $p$ = .046, interactions were significant at 5 months. Follow-up analyses of the adherence to routines by average fixation duration interaction using the Johnson-Neyman technique within the Process Macro in SPSS (Hayes, 2017) revealed a discrete region of significance, see Figure 6. Specifically, there was only an association between reduced stability in the home and increased basal cortisol in the context of very high fixation durations. Recall that fixation durations are meant to capture the *quality* of attention; therefore, this result indicates that the relationship between predictability and stability in the home, indexed via parent endorsement of routines, may only be present for infants with less efficient attentional patterns  Similar analyses of the adherence to routines by face preference interaction failed to document any regions of significance, therefore, it is unclear whether attention *quantity* is similarly impacted. However, the results of this study do provide some evidence that attentional control (especially indexed by average fixation durations) can in fact moderate the association between home stability and infant cortisol at 5 months of age.

Table 8. *Results of Experiment 2 moderation models predicting cortisol at 3.5 months of age*

| | Model 1 | | Model 2 | | Model 3 | | Model 4 | |
|---|---|---|---|---|---|---|---|---|
| | ß | 95% CI | ß | 95% CI | ß | 95% CI | ß | 95% CI |
| Intercept | -0.40 | [-0.93, 0.12] | -.41 | [-0.93, 0.11] | -0.36 | [-0.88, 0.15] | -.36 | [-0.88, 0.15] |
| **Control Variables** | | | | | | | | |
| Sex [a] | -0.02 | [-0.10, 0.09] | -0.01 | [-0.10, 0.09] | -0.03 | [-0.11, 0.08] | -0.03 | [-0.11, 0.09] |
| Children in the Home [b] | 0.22* | [-0.00, 0.19] | 0.22* | [0.01, 0.19] | 0.23* | [0.003, 0.20] | 0.21* | [0.01, 0.19] |
| Age in days | 0.13 | [-0.002, 0.01] | 0.13 | [-0.002, 0.01] | 0.12 | [-0.002, 0.01] | 0.12 | [-0.02, 0.01] |
| Sociodemographic Risk | 0.07 | [-0.03, 0.05] | 0.08 | [-0.02, 0.05] | 0.06 | [-0.03, 0.05] | 0.05 | [-0.03, 0.05] |
| **Direct Effects** | | | | | | | | |
| Home Chaos [c] | 0.04 | [-0.01, 0.01] | -- | -- | -0.04 | [-0.01, 0.01] | -- | -- |
| Adherence to Routines [c] | -- | -- | -0.04 | [-0.01, 0.01] | -- | -- | -0.03 | [-0.01, 0.01] |
| Average Fixation Duration [c] | -0.11 | [-0.78, 0.27] | -0.12 | [-0.79, 0.25] | -- | -- | -- | -- |
| Face Preference [c] | -- | -- | -- | -- | 0.06 | [-0.002, 0.003] | 0.04 | [-0.002, 0.003] |
| **Interactions** | | | | | | | | |
| Average Fixation Duration X Home Chaos | 0.08 | [-0.04, 0.09] | -- | -- | -- | -- | -- | -- |
| Average Fixation Duration X Adherence to Routines | -- | -- | -0.09 | [-0.12, 0.06] | -- | -- | -- | -- |
| Face Preference X Home Chaos | -- | -- | -- | -- | 0.14 | [0.00, 0.001] | -- | -- |
| Face Preference X Adherence to Routines | -- | -- | -- | -- | -- | -- | -0.07 | [-0.001, 0.00] |
| **Adjusted Model $R^2$** | .01 | | .01 | | .003 | | -.01 | |

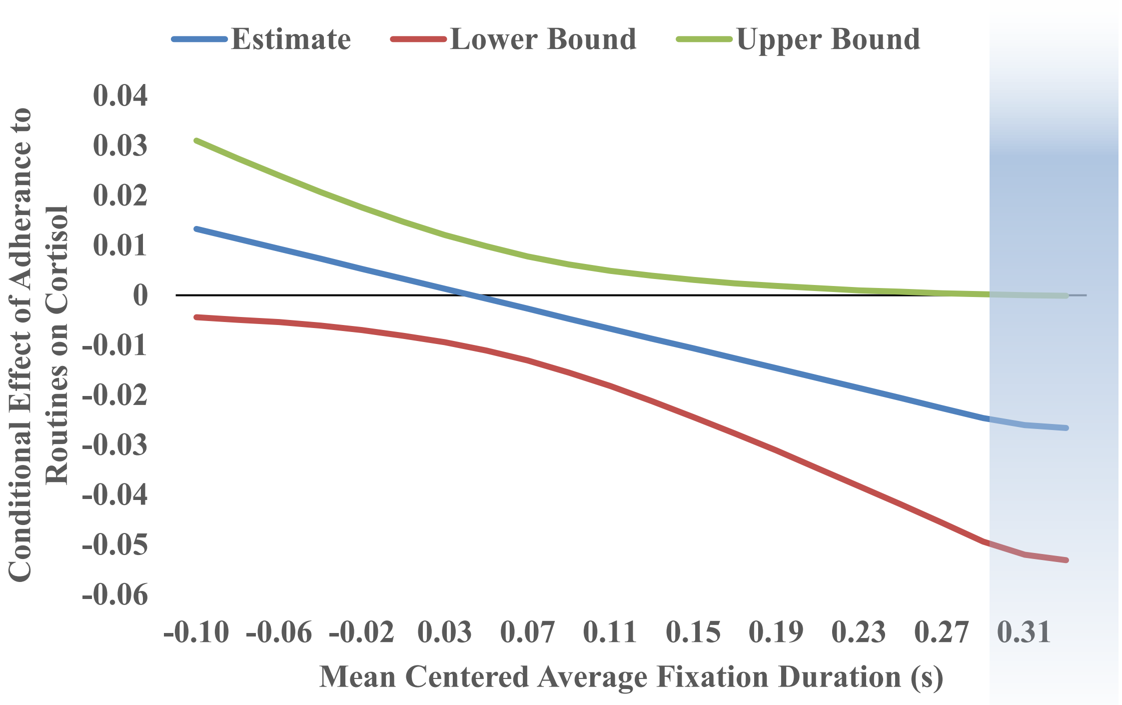
*Notes.* [a] 1 = Female/0 = Male; [b] 1 =one or more additional children in the home/0 = No additional children; [c] Mean centered;
$^{\dagger}p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Table 9. *Results of Experiment 2 moderation models predicting cortisol at 5 months of age*

| | Model 1 | | Model 2 | | Model 3 | | Model 4 | |
|---|---|---|---|---|---|---|---|---|
| | ß | 95% CI | ß | 95% CI | ß | 95% CI | ß | 95% CI |
| Intercept | -0.11 | [-0.43, 0.22] | -0.14 | [-0.46, 0.17] | -0.11 | [-0.43, 0.21] | -0.14 | [-0.45, 0.18] |
| **Control Variables** | | | | | | | | |
| Sex[a] | -0.08 | [-0.15, 0.09] | -0.05 | [-0.14, 0.10] | -0.08 | [-0.16, 0.09] | -0.06 | [-0.15, 0.10] |
| Children in the Home[b] | 0.09 | [-0.08, 0.16] | 0.22 | [-0.03, 0.21] | 0.13 | [-0.07, 0.18] | 0.20 | [-0.04, 0.20] |
| Days Between Visits | -0.02 | [-0.01, 0.01] | -0.03 | [-0.01, 0.01] | -0.02 | [-0.01, -0.01] | -0.03 | [-0.01, 0.01] |
| Cortisol at 3.5 Months | 0.17 | [-0.13, 0.48] | 0.15 | [-0.15, 0.45] | 0.16 | [-0.14, 0.47] | 0.17 | [-0.12. 0.48] |
| Sociodemographic Risk | 0.12 | [-0.03, 0.06] | 0.17 | [-0.02, 0.07] | 0.09 | [-0.03, 0.06] | 0.14 | [-0.02. 0.07] |
| **Direct Effects** | | | | | | | | |
| Home Chaos [c] | 0.20 | [-0.002, -0.01] | -- | -- | 0.14 | [-0.004, 0.01] | -- | -- |
| Adherence to Routines [c] | -- | -- | 0.10 | [-0.01, 0.02] | -- | -- | 0.002 | [-0.01, 0.01] |
| Average Fixation Duration [c] | -0.06 | [-0.74, 0.50] | 0.01 | [-0.60, 0.63] | -- | -- | -- | -- |
| Face Preference [c] | -- | -- | -- | -- | -0.02 | [-0.004, 0.004] | -0.001 | [-0.004, 0.004] |
| **Interactions** | | | | | | | | |
| Average Fixation Duration X Home Chaos | -0.09 | [-0.09, 0.05] | -- | -- | -- | -- | -- | -- |
| Average Fixation Duration X Adherence to Routines | -- | -- | -0.31* | [-0.19, -0.003] | -- | -- | -- | -- |
| Face Preference X Home Chaos | -- | -- | -- | -- | 0.09 | [0.00, 0.001] | -- | -- |
| Face Preference X Adherence to Routines | -- | -- | -- | -- | -- | -- | -0.27* | [-0.001, 0.00] |
| **Model $R^2$** | -0.01 | | .03 | | -0.02 | | 0.03 | |

*Notes.* [a] 1 = Female/0 = Male; [b] 1 =one or more additional children in the home/0 = No additional children; [c] Mean centered;
[†] $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 6




Johnson-Neyman Region of Significance for the average fixation duration by adherence to routines interaction. The shaded region depicts where the conditional effect of adherence to routines on cortisol reaches statistical significance at the average fixation duration of 0.31, ß = -0.03, 95% CI [-0.05, 0.00], *p* = .05.

# Chapter 4: General Discussion

Recall that the goals of the present investigation were 1) to determine whether associations between sociodemographic factors and attentional control are present at 3.5 months of age, and 2) to examine how cortisol levels and factors of the home environment relate to these associations. Experiment 1 accomplished the first goal by revealing a significant association between sociodemographic risk and average fixation duration in 3.5-month-old infants. This finding is, to my knowledge, the earliest demonstration of associations between any facet of social inequality and attentional control. Moreover, the current study is the first to establish average fixation duration as a sensitive metric to examine sociodemographic differences in cognitive development at any point of the lifespan. Experiment 2 addressed the second goal and expanded on the previous results by first replicating the association found between sociodemographic risk and average fixation durations early in life and then documenting that average fixation duration moderates the association between factors of the home environment (specifically, adherence to routines) and elevations in infant cortisol. Specifically, only infants with higher average fixation durations (indicating poorer attentional control) recorded at 3.5 months of age showed an association between home chaos or adherence to routines and cortisol (a proxy for allostatic load) at 5 months. This finding suggests that strong attentional control abilities may be a protective factor against adverse effects resulting from home instability. Taken together, these results suggest that sociodemographic factors are associated with cognitive development very early in life and demonstrate a complex interplay between attentional control and infant susceptibility to environmental stressors.

Developmental psychologists have long understood that social contexts can have pronounced impacts on developmental trajectories (Bronfenbrenner, 1979). One important contribution of the present investigation is the demonstration that social factors that infants are not yet aware of or able to comprehend (i.e., race and socioeconomic status) are associated with attentional control very early in life. This finding is significant because attentional control is central to various theories of development (Gibson, 1966; Heyselaar, Hagoort, & Segaert, 2016; Moore, Dunham, & Dunham, 2014) and associated with a host of developmental outcomes (Lengua, 2003; Welsh, Nix, Blair, Beirman, & Nelson, 2010). This suggests that intervention programs aimed at closing academic achievement gaps may be most effective well before children enter school.

Although the finding of early sociodemographic differences in attentional control should be useful in the targeting of future intervention efforts, it will also be critical to understand the mechanism driving this association. Theorists have posited that sociodemographic risk factors lead to negative child outcomes through an accrual of allostatic load and a subsequent disruption of executive functions (Lengua, 2012). Some empirical studies have found support for such a model later in infancy (Finegood, et al., 2017; Blair et al., 2011b). Thus, an unexpected finding of the present investigation was that cortisol did not mediate the link between sociodemographic risk and attentional control. Therefore, it is yet unclear what intervening process, or processes, result in a disruption of attentional control in higher-risk young infants. While it is possible that the proxy for allostatic load in the present study was merely not sensitive enough to demonstrate the hypothesized mediation (see discussion below), it is also possible that the cascading stress model described above does not manifest until later in development, as infants accrue more exposure to stressful environments related to social inequality; therefore, a different mechanism is likely driving the effects early in life. One such alternative mechanism is that prenatal stress experienced by the mother disrupts fetal PFC development to a sufficient extent as to manifest as poorer attentional control 3.5 months after birth. Studies demonstrating associations between prenatal stress and various morphological changes in the brain of the offspring (for review, see Scheinost et al., 2017), including a reduction of PFC volume in children of mothers with high levels of anxiety during pregnancy (Buss, Davis, Muftuler, Head, & Sandman, 2010), are consistent with this hypothesis. Thus, future work should include prenatal experiences, including nutrition which has also been linked to cognitive development (Fuglestad, Rao, Georgieff, & Code, 2008), as additional possible explanatory factors.

Although, as outlined above, support for the cascading stress mediation model was not found in the current study, the findings are consistent with the alternative hypothesis that attentional control moderates the association between adverse home environments (i.e., high levels of chaos and low adherence to routines) and infant stress, at least in the context of HPA-axis indexed by basal cortisol. This result complements previous work demonstrating that infants can down-regulate attention to stressful stimuli (Rothbart et al., 1992) and has interesting implications for future intervention efforts. First, given the increasing affordability and accessibility of eye-tracking technology, it is possible that average fixation duration could be used to identify infants who may be more susceptible to instability in the home. This could aid in targeting families who may benefit most from an intervention aiming to improve the predictability and stability of the home environment. Second, the findings of this study suggest that training attentional control may help improve the resilience of children in riskier environments regardless of their social strata.

Relatedly, one result of the present investigation that may be especially useful for future work is the validation of a new, efficient measure of the home environment. Namely, the adherence to routines scale, adapted from the Child Routines Inventory (Sytsma et al., 2001), is, to my knowledge, the first attempt to quantify the predictability of routines in infancy. The scale was found to have a high level of reliability, and the fact that scores on the adherence to routines scale were related to infant stress, at least indexed by HPA-axis activity, suggests that the scale taps into more than parent perception and is in fact measuring something infants are sensitive to in their environment. If future work with this scale reveals long term impacts of routines established in the infant period, the scale could become a useful tool in the development and deployment of intervention programs. However, it will be important to consider the bidirectional effect that infants may have on the ability of their parents to enforce routines. Infants with more difficult temperaments or health concerns may be more volatile, thus making it more challenging for parents to establish predictable patterns. The lack of routine could then lead to an elevation in infant stress which exacerbates any underlying issues. Intensive longitudinal designs, such as a daily diary study, examining day to day changes in routines in the context of other parent and infant behaviors, would be a useful next step to further understand the nuances of routine regulation in young infants.

Another finding of note is that Experiment 2 examined both the *quality* (average fixation duration) and *quantity* (overall duration of face preference) of infants' attention and found distinct patterns of results. Namely, average fixation duration was associated with sociodemographic risk and more clearly moderated the association between factors of the home environment and infant cortisol than infants' preference for faces. The diverging results of the two metrics of attention could indicate that average fixation duration is an especially useful metric of attentional control in infancy. This conclusion is consistent with the finding in a previous study that examining more fine-grained attentional patterns (White et al., 2018), as opposed to overall stimulus preferences (Hock, Kangas, Zieber, & Bhatt, 2015), revealed relatively sophisticated body processing abilities at 3.5 months of age. It is also possible that the two metrics are tapping into different facets of attention, and the different facets differentially interact with the infant's developmental context. For instance, average fixation duration may more tightly map onto attentional control, whereas the preference for faces may encompass other tangential abilities, such as social competency. Given that different aspects of attention have been found to correspond to different neural circuits (Posner, 2012), future work utilizing neuroimaging could shed light on this issue.

Future studies should also examine additional markers of allostatic load. Although cortisol alone has been used in previous infant studies (Finegood, et al., 2017; Blair et al., 2011a; 2011b, 2013), and the significant associations documented in the present study suggest that a single basal cortisol measure was sufficiently sensitive to show variability in HPA-axis reactivity in the context of factors of the home environment, a more robust test of allostatic load would be ideal. It is possible that the failure of the present study to find support for the cascading stress model could be because the dynamic nature of cortisol (e.g., being affected by circadian rhythms; de Weerth, Zijl, & Buitelaar, 2003) clouded the results. Examination of additional markers of stress, including salivary amylase, which is often used as a proxy for sympathetic nervous system activity (for review, see, Nater & Rohleder, 2009) and/or the interaction between salivary amylase and cortisol (Keller, El-Sheikh, Granger, & Buckhalt, 2012), may provide a clearer picture of how stress-physiology may impact attentional control early in life.

Future research should also examine how the association between sociodemographic risk and attentional control found in infancy relate to downstream developmental outcomes. Specifically, it will be important to determine whether similar associations are present in different developmental periods, and whether attentional control measured in infancy predicts developmental outcomes later in life. Preliminary results from our lab indicate that average fixation duration, measured in college students, may be associated with high school grade point average, and that average fixation durations measured in infancy may predict parent reported Attention Deficit Hyperactivity Disorder at age five. The results of these ongoing projects will hopefully shed light on the persistence of the associations between sociodemographic risk and attentional control documented in the present study.

It is important to note that a limitation of the current study is the lack of diversity in the sample. The sample is predominantly white (reflective of the demographic make-up of Lexington, Kentucky where the data was collected), and relatively educated and affluent. That means that generalizing the present results to minority families living in more diverse areas and impoverished families is problematic. While the fact that significant associations were found even within a restricted range of risk suggests that the processes examined are likely to be quite robust, and therefore only more pronounced in higher-risk groups, it is impossible to know for certain how these results may generalize to different social contexts. Therefore, additional research in regions with different sociodemographic make-ups will be paramount. It will be especially important to examine differences among specific racial/ethnic minority groups given the pressures faced by distinct ethnic groups and multi-ethnic groups are unlikely to be homogenous (Greene, Way & Pahl, 2006; Tran, Lee, & Burgess, 2010).

Recruiting a large, representative sample would be ideal, not only to examine the nuances of the different sociodemographic factors included in the present study, but also to address an issue with power. The analysis of 3.5-month-olds' data in Experiment 2 was theoretically sufficiently powered based on the presented a priori power analyses. However, due to unforeseen complications with the second round of data collection, the 5-month-old sample was likely underpowered. This means that the failure to find robust moderation of the interaction between face preferences and cortisol should be interpreted with caution. Additional studies with larger samples and additional metrics of attention quantity should be conducted before any strong conclusions can be make.

Furthermore, it is important to note that while the results of the present investigation suggest that sociodemographic risk is associated with cognitive development very early in life, there is nothing in the present results to suggest that such effects are permanent. In fact, previous work has found that the effect of stress on the PFC and subsequent attentional control is largely reversible in animal models and human studies (Radley et al., 2004; Liston, McEwen, & Casey, 2009). Therefore, while the results of the present study suggest that intervention efforts may be effective very early in life, it is unlikely that effects that manifest in infancy are immutable. Thus, if the results of the present study are replicated at different developmental periods, training attentional control abilities at any age may be useful in reducing elevations of stress in less than ideal developmental contexts.

Finally, future studies should also examine the downstream impacts of the elevated allostatic load (indexed via basal cortisol) found in infants with poorer attentional control. It is possible that higher order cognitive functions are disrupted, reflecting a reciprocal relationship between cognition and stress. It is also likely that other domains of development are impacted. For example, stress has been found to have a pronounced effect on physical health (Gianaros & Wager, 2015). Thus, it is possible that negative effects of stress on the immune system begin in infancy and set the stage for health disparities documented between social groups later in life (House, 2002). Analysis of additional biomarkers, such as Interleukin-6, which can also be assayed from infant saliva (Sesso et al., 2014), could be a promising first step to answering this question.

In sum, the results of this dissertation demonstrate that cognitive development, specifically in the context of attentional control, varies by sociodemographic risk as early as 3.5 months of age. Additionally, it was found that attentional control moderates the association between instability in the home environment and elevations in infant cortisol reflecting a complex interplay between infant abilities and their home environments. These findings have implications for the development of intervention programs by highlighting attentional control, specifically average fixation duration, as a sensitive metric for documenting divergent pathways of development pertaining to sociodemographic risk, and a potential protective factor that could help promote resilience in the context of adverse home environments.

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## Education

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|---|---|
| Graduate Certificate | Biostatistics, May 2019<br>College of Public Health<br>University of Kentucky, Lexington, KY |
| M.S. | Experimental Psychology, May 2016<br>Thesis: "Categorical Perception of Species in Infancy"<br>University of Kentucky, Lexington, KY<br>Advisor: Dr. Ramesh S. Bhatt, Ph.D. |
| B.S. | Biology, May 2014<br>Psychology, December 2014<br>University of Kentucky, Lexington, KY<br>Magna Cum Laude |

## Awards and Honors

| | |
|---|---|
| 2019 | Ruth L. Kirschstein Research Service Award Predoctoral Fellowship |
| 2018 | American Psychological Association Dissertation Research Award |
| 2019 | Society for Research in Child Development Graduate Travel Award |
| 2018, 2019 | University of Kentucky Developmental Graduate Student Award |
| 2018 | Nominated for University of Kentucky A&S Dean's Graduate Fellowship |
| 2015-2018 | University of Kentucky Graduate Travel Award |
| 2015-2016 | University of Kentucky Graduate School Travel Award |
| 2014-2016 | Lipmann Fellowship |
| 2014-2015 | University of Kentucky Graduate Student Fellowship |

## Professional Positions

Graduate Research Assistant, Department of Psychology, University of Kentucky
(Fall 2015, Fall 2016, Spring 2017, Fall 2017, Fall 2018)

## Publications

**White, H.**, Chroust, A., Jubran, R., Heck, A., & Bhatt, R. S. (In Press). Waist-to-Hip ratio sensitivity in early infancy. *Infant and Child Development.*

**White, H.**, Jubran, R., Heck, A., Chroust, A., & Bhatt, R. S. (2019). Sex-Specific scanning in infancy: Developmental changes in the use of face/head and body information. *Journal of Experimental Child Psychology*, *182*, 126-143.

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