

LONGITUDINAL EXAMINATION OF HOT AND COLD EXECUTIVE FUNCTION:
RELATIONSHIPS WITH PARENTING QUALITY, HOUSEHOLD CHAOS, AND ACCESS
TO FAMILY RESIDENCY GREEN SPACE

BY

SAMANTHA JEAN IWINSKI

DISSERTATION

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Doctoral Committee:

Professor Kelly Bost, Chair
Associate Professor Aaron Ebata
Professor Brent McBride
Associate Professor Dina Izenstark, San Jose State University

Abstract

Executive function (EF) is crucial for a child's cognitive development, influencing various life outcomes, including academic success, emotional regulation, and physical health throughout an individual's lifetime. This dissertation examines the relationships between environmental factors and EF among children from two to five years of age, utilizing data from the STRONG Kids2 longitudinal birth cohort study. This dissertation extends existing research on EF and integrates multidisciplinary perspectives, including developmental psychology, environmental studies, and public health, to elucidate the complex interactions that shape cognitive development in early childhood. There are several research areas in this study besides EF, including (1) access (e.g., family residency green space and economic hardship), (2) household environments, and (3) parent-child relationships. By addressing gaps in the literature regarding the simultaneous impacts of multiple environmental factors on EF, this study advances our understanding of the ecological dynamics contributing to cognitive outcomes in children. Methodologically, the dissertation employs structural equation modeling to analyze EF development from ages two to five, assessing how variables like parenting quality, household chaos, and green space access influence these associations. The studies include direct assessments of model variables and detailed environmental audits using tools like Google Earth to quantify green space. The expected outcomes of this research include more comprehensive insights into the modifiable aspects of a child's environment that could be targeted in early childhood interventions aimed at promoting optimal development over time.

This research first examines access to green spaces within and around family residences, household chaos, and how economic hardships influence EF. Theoretical frameworks such as Ecological Systems Theory, Attention Restoration Theory, and the concept of nature play

underscore the potential of green spaces to enhance attention, reduce stress, and subsequently improve EF. The results of this study suggest that early access to green spaces and the experience of economic hardships may influence children's EF development. While access to green spaces did not consistently enhance executive functioning as expected, the presence of these spaces alongside specific demographic and environmental factors could still play a significant role. Involving household environments, the dissertation explores how household chaos, characterized by noise, crowding, and lack of routine, relates to hot and cold EF among children. It was hypothesized that chaotic home environments disrupt children's ability to focus and regulate emotions, impairing EF development. The findings from the study indicate that the household environment significantly impacts children's executive function across early childhood. Higher levels of household chaos were generally associated with poorer executive function skills, suggesting that environments characterized by noise, disorganization, and lack of routine can hinder cognitive and emotional development. However, the dynamic nature of these effects, with some indications of resilience in response to early chaos, highlights the complexity of how children adapt to their immediate surroundings over time.

For parent-child relationships, we focused on how parent-child behavioral synchrony, mutual (dyadic) orientation, and smooth attachment affect the development of EF. Drawing from Attachment Theory, Kopp's model of self-regulation, and the Dynamic Systems Perspective, the study posits that high-quality, synchronous relationships enhance children's EF by providing a relational base for developing self-regulation skills. The study highlights the critical role of parent-child relationships, specifically attachment and synchrony, in developing children's executive functions. Higher smoothness in interaction in attachment relationships and certain levels of synchrony were associated with better executive function outcomes. These findings

emphasize the importance of responsive, coordinated, and emotionally positive interactions between parents and children and underscore the significance of nurturing parent-child interactions for developing early childhood cognitive and emotional regulation skills.

Collectively, the results of this study illustrate the intricate interplay between environmental factors, parent-child relationships, and household dynamics in shaping the development of children's executive function. Access to green spaces, economic conditions, and the quality of parental interactions (attachment, synchrony) each play distinct roles, with their influences sometimes yielding unexpected outcomes, such as potentially developing resilience in response to early hardships. Additionally, the significant impact of household chaos on cognitive growth emphasizes the need for stable and structured home environments. These findings underscore the importance of a holistic approach in early childhood interventions and policies, considering the diverse aspects of children's environments to support optimal development.

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Chapter 1: Integrated Introduction

Starting at an early age, individuals develop executive function (EF) abilities, which play a critical role in everyday life. EF can influence a myriad of factors, including academic success, physical health, financial instability, and the ability to regulate oneself (Blair & Razza, 2007; Diamond, 2013). Within the literature, we see the importance of EF throughout the lifespan; however, developmentally, there may be a critical period between two and seven years of life when many of these abilities develop more rapidly (Zelazo & Carlson, 2012; Zelazo & Müller, 2011). These abilities allow individuals to plan, regulate thoughts and behaviors, and create meaning (Collins & Koechlin, 2012; Diamond, 2013; Garon et al., 2008; Hughes & Devine, 2019; Hughes & Ensor, 2009; Lehto et al., 2003; Lunt et al., 2012; Miyake & Friedman, 2012). Therefore, studying these capacities when children grow is crucial while their lifestyle, parent-child relationships, and environments also change.

Many factors may influence developing EF capabilities, and experiences in the family context are proximal and crucial for cognitive and socioemotional development. In particular, parent-child relationships may influence EF abilities over time, especially those aspects that help shape capacities for regulation, including parent-child synchrony, attachment, and dyadic mutual orientation. Parent-child synchrony encompasses the dynamic process of exchanging hormonal, physiological, and behavioral cues between a parent and child during social contact (Feldman, 2012). The experience of behavioral synchrony in the first months of a child's life may influence attachment patterns and how children regulate themselves (Feldman, 2012; Feldman et al., 2010). Researchers have found that higher levels of synchrony were related to better performance on EF play tasks and school-age performance (Jirout et al., 2022; Treyvaud et al., 2016).

In addition to aspects of the parent-child relationship, characteristics of the environments in which children live, play, and interact may influence EF abilities in children. With respect to household environments, the literature and our past publications show consistent associations between household chaos and EF. High levels of household chaos have been associated with several subscales of EF, possibly due to the environment distracting, limiting, or altering a child's EF abilities (Dumas et al., 2005; Iwinski et al., 2021; Wachs, 1993). In the broader physical environment, nature contact has also been shown to be essential for children (Taylor & Kuo, 2006) and can potentially influence their cognitive abilities. Researchers have found that green space can affect children's mental health (Chawla, 2015; McCormick, 2017), well-being (Chawla, 2015; McCormick, 2017), and cognitive or academic skills (Browning & Rigolon, 2019; Ernst & Burcak, 2019). This might be due to the children's ability to explore nature, develop their creative thinking, and allows them to establish routines and memories with family and friends. Family-based nature activities may create a pathway for positive family functioning, allowing children to restore and develop their attention and inhibition abilities (Izenstark & Ebata, 2016; Izenstark & Ebata, 2017).

This dissertation will extend the literature by understanding the associations between several environmental and relational influences on children's EF from a developmental perspective. The data used in this analysis are from families participating in the STRONG Kids2 longitudinal birth cohort study in the Midwestern United States (Fiese et al., 2019). It is designed to examine multi-level predictors of weight trajectories, dietary habits, and family relationships over the first seven years of life. Some aims of this dissertation will involve longitudinal analyses, while others will involve cross-sectional examinations. The dissertation is divided into papers. Paper one examines cold and hot EF in early childhood and how family residency green

space, household chaos, perceived economic hardship, and other predictors influence EF over time (N = 250). Paper two examines several forms of parenting quality (e.g., smooth attachment, motion energy, and mutual responsiveness) and household environment and how these factors influence EF over time within a smaller sample (N = 109). These findings will help illustrate the importance of early life factors and how they may influence early childhood cognitive abilities.

Chapter 2: Family Residency Green Space, Household Chaos, and EF (Paper 1)

Executive Function (EF)

There are numerous ways researchers have conceptualized and measured EF. They may use three general core dimensions (e.g., inhibitory control, working memory, and cognitive flexibility) or examine each facet of EF separately (e.g., inhibition, shifting, emotional control, working memory, and planning/organizing). Some researchers also use the terms “hot” and “cold/cool” for different subsets of EF. Cool EF abilities refer to purely cognitive information processing and can be measured with inhibitory control, working memory, and cognitive flexibility subscales or tasks. Hot EF refers to processing reward, emotion, and motivation information, including the ability to regulate one’s emotions (Salehinejad et al., 2021; Zelazo & Carlson, 2012; Zelazo & Carlson, 2020).

The development of EF occurs early in life and can be shaped by social interactions, environments, and relationships with adults. EF development occurs during multiple sensitive periods when the brain is particularly receptive to learning new skills and behaviors (Thompson & Steinbeis, 2020). From an evolutionary perspective, these sensitive periods enable individuals to become more specialized and adapt to their environments (Fawcett & Frankenhuis, 2015). This specialization is directly tied to brain development, allowing children to utilize context clues, social interactions, and exploratory behaviors to understand and navigate societal norms (Knudsen, 2004). By identifying the specific times when children are most responsive to certain types of learning and support, educators and caregivers can tailor their approaches to maximize developmental outcomes.

Cold Executive Functions

Inhibitory Control. Inhibitory control refers to controlling one's attention, behaviors, and thoughts. This can include doing what may be appropriate in a given situation, which may involve overriding internal predispositions (Diamond, 2013; Fiske & Holmboe, 2019; Garon et al., 2008). Similar to attention regulation, inhibitory control of attention allows us to selectively attend and focus on what we choose while suppressing awareness of additional stimuli (Diamond, 2013). For example, a child may be assigned to read a paragraph aloud and told to stop when they reach the end. It may be difficult for some children to stop reading because they are unable to override their internal predispositions of reading aloud to the class. Researchers have found that the ability to inhibit improves throughout childhood and then is slightly diminished throughout adulthood (Williams et al., 1999). The literature suggests that rapid development and improvement in inhibitory control occurs during the toddler and preschool years (ages 2-5) and increases at a more steady pace during middle childhood (ages 6-12) (Best & Miller, 2010; Fiske & Holmboe, 2019; Garon et al., 2008; Garon et al., 2014; Miyake & Friedman, 2012). Specifically, with various lab tasks, multiple researchers found that the development of inhibitory control is more rapid between the ages of 3.5 and 5 years and then steadily increases between the ages of 5 and 6 years old (Dennis et al., 2007; Klenberg et al., 2001; Lengua et al., 2015). After this age, more complex inhibition characteristics keep improving until around seven years of age. Another critical component of EF, often paired with inhibition, is the ability to shift, which refers to the ability to move freely from one situation or aspect of a problem to another. For a child, this may be thinking about different verb tenses or changes within reading environments (e.g., reading quietly at school vs. aloud at home).

Working Memory. Working memory taps into the capacity to hold information in memory for goals or plans and allows individuals to work with the information they possess (Diamond, 2013). Working memory is critical to a child's ability to see connections, use one's knowledge to make decisions and formulate one's creativity. Working memory and inhibitory control may support and work together in most situations. For example, inhibitory control can assist one's working memory by keeping our mental workspace from becoming overwhelmed or cluttered. This ability can help our mind resist irrelevant information and suppress specific thoughts that may allow the mind to wander. These abilities form over time and may shift depending on the developmental period. Similar to inhibitory control, working memory begins in infancy. However, this development is much slower and shows a more prolonged developmental progression, with the most significant growth occurring between 5 and 12 years of age (Cowan et al., 2002; Crone et al., 2006; Diamond, 2013; Pelphrey et al., 2004; Reynolds & Romano, 2016). Researchers also propose a steady improvement in working memory from age 4 to 15 (Cowan, 2016; Panesi et al., 2022).

Cognitive Flexibility. Cognitive flexibility builds upon inhibitory control and working memory to enable a person to shift between different tasks or goals (Buttelmann & Karbach, 2017; Diamond, 2013). Planning/organizing skills may also stem from a child's cognitive flexibility. This may involve the child's ability to manage current or future tasks in an array of situations. In a given situation, children may need to change their perspectives, potentially inhibiting a current response and using their working memory to activate a different perspective.

Regarding development, cognitive flexibility may improve as a child develops, and skills may decline during aging (Cepeda et al., 2001; Kray, 2006). This ability is influenced by the situation or how one uses their capabilities (e.g., response to environmental demands vs. using

EF abilities proactively) (Diamond, 2013). Studying this dimension over time is essential to understanding how cognitive flexibility changes as children develop.

Hot Executive Functions

Emotion Regulation or Emotional Control. Emotion regulation is similar to many EF components, and some researchers may refer to emotion regulation as hot EFs, as discussed above. According to Diamond and Aspinwall (2003), emotion regulation refers “to the internal and transactional processes through which individuals consciously or unconsciously modulate one or more components of emotion, by modifying either their own experience/behavior/expression or the emotion-eliciting situation (p. 3)” (Eisenberg et al., 2000; Gross, 1999). In addition, Thompson (1994) discussed emotion regulation as, “the extrinsic and intrinsic processes responsible for monitoring, evaluating, and modifying emotional reactions, especially their intensive and temporal features, to accomplish goals (pp. 27-28)” (Thompson, 1994). This definition and conceptualization can be influenced by how it is measured (e.g., laboratory vs. observational tasks) and where this research is conducted (McRae & Gross, 2020). For example, among young adults, researchers have found that individuals from cultures who value self-reflection tend to use their ability for reappraisal more frequently, which is often used to study one’s emotion regulation. Furthermore, individuals who value open expression of emotion within their culture tend to suppress their emotions less frequently (Haga et al., 2009; Matsumoto et al., 2008; McRae et al., 2011; McRae & Gross, 2020; Su et al., 2015; Yih et al., 2019). This may also change depending on the developmental period and how parents teach their children about emotions (Lozada et al., 2016).

Researchers have also found connections between attention and emotion regulation, highlighting that the development of biological and behavioral attributes of attentional control

may influence emotion regulation in childhood (Graziano et al., 2011). Across development, there is a transition from reliance on the caregivers for co-regulation to higher levels of independent regulation from the child (Perry & Calkins, 2018; Sameroff, 2010). Children between the ages of two and three begin to manage emotional states and influence mechanisms often included in EF, including attention and behavior.

Conceptualizing Green Space and Family

Similar to EF, nature, green space, and the natural environment are often studied together and used as the same phenomenon. This may be due to the difficulty of conceptualizing nature across living locations (e.g., urban vs. rural) and varying access to natural areas. In a review article, researchers found that less than half of the 125 articles reviewed defined what green space was in their study (Taylor & Hochuli, 2017). Their research suggests that researchers may have different definitions and understandings of green space and how to examine it. This paper will examine green space using a combination of their suggestions and Drs. Ebata and Izenstark's work. Family residency green space involves all greenspaces within the participants' living arrangements, including rural and urban locations. Critical conditions that are included: being outdoors, varying levels of greenness (e.g., from trees, grass, and other vegetation), and various levels of builtness, amounts of grass, and tree cover in the family's residency green space (Izenstark & Ebata, 2016; Taylor & Hochuli, 2017). Family behaviors and identities provide the first groundwork for growth and development for children and individuals over time (Kapur, 2023; Sharma, 2013). The term "family" may provide different implications in social, biological, or cultural settings; however, it is also important to allow participants to provide input into who is their chosen family (Hodgson & Birks, 2002; Kapur, 2023; Sharma, 2013). For this study, family is referred to as a broad term encompassing the STRONG Kids2 study, which is focused

on children and their families; however, it is essential to note that many of the surveys are solely completed by the mother.

Theoretical Frameworks

Ecological systems theory emphasizes the importance of development in varying systems or environments in which individuals interact (Bronfenbrenner, 1979; Darling, 2007; Duerden & Witt, 2010; Wells & Evans, 2003). When adopting an ecological approach to studying nature, the microsystem (e.g., immediate environment) and mesosystem (e.g., connections between microsystems) are key components that may influence these associations. For example, nature and natural environments can be a part of a child's microsystem, providing regular exposure to the family's green space. Nature also offers social interaction contexts, allowing children to expand their social environment (e.g., playing with peers outdoors or participating in community events surrounding nature). Ecological theory also includes broader systems, such as policies related to child development. Policies surrounding environmental education, nature play, and urban planning incorporating the natural environment can all influence a child's growth and relationship with nature. Every child has aspects of nature within their environmental system, which may have implications for their EF abilities.

In addition, the link between nature and attention has been studied, and many researchers use Attention Restoration Theory (ART) to highlight this connection. ART examines the interaction between the natural environment and mental and behavioral functioning (Kaplan, 1995; Kaplan & Kaplan, 1989). ART originated in environmental psychology and was built upon James's theory of attention in 1962. According to these theories, humans may have two modes of using their attention: directed and involuntary. Directed attention involves paying attention and excluding distractions from your thoughts and environment. A child may be working on their

homework and start to think about playtime. Then, they hear the TV turn on and wonder what might be playing. To use their directed attention, they will focus on their homework and limit or exclude the surrounding distractions (e.g., wanting to play and listening to the TV). Involuntary attention allows an individual's inhibitory control and capacity to relax and potentially restore their directed attention. ART advises that natural settings are essential for restoration, and four components need to be involved in creating a restorative environment (Izenstark & Ebata, 2016; Kaplan, 1995; Kaplan & Kaplan, 1989; Ohly et al., 2016). These four components are (1) "be away" from stressors, which could be a mental or physical separation; (2) "extent," which involves experiencing rich and expansive spaces; (3) "soft fascination," allowing one's attention to recover while providing an opportunity to explore and reflect, and (4) compatibility between the environment and individuals purpose within the space (Izenstark & Ebata, 2016; Kaplan, 1995; Kaplan & Kaplan, 1989; Ohly et al., 2016). This study could offer several possibilities for children to use ART within their family residency green space. For example, "extent" could include visiting a nearby park, an open backyard that they can run through, or exploring their deck. This could further interplay and fascinate with items in the backyard, including a sandbox, watching butterflies, and listening to the wind. Each component of ART highlights how the environment may have implications for restoring attention and other EF abilities.

Izenstark and Ebata (2016) integrated ART with a routines and rituals framework to understand family functioning through Family-Based Nature Activities (FBNA). This framework combines the idea that routines and rituals may influence family functioning through meaningful interactions and how outdoor family leisure may benefit children and families (Izenstark & Ebata, 2016). While I am not directly measuring family-based nature activities, this theory highlights how nature activities and restoration can improve EF abilities and how essential

routines are for family functioning and other outcomes. By analyzing families' access to their residency green space, I examined how much access or potential families may have for outdoor activities and time spent together outdoors for daily access. Family residency green space may provide a familiar and approachable environment for the family, especially when public green spaces are not present, difficult to travel to, or unsafe.

Household Chaos

Household chaos describes an environment that is high in noise and crowding and low in regularity and routines (Vernon-Feagans et al., 2016). Routines and rituals provide predictable structures that may support early development and guide behaviors throughout childhood and adulthood (Fiese & Schwartz, 2008; Spagnola & Fiese, 2007). Routines (e.g., mealtime and bedtime) provide a structural space and can supply individual family members with a shared identity (Fiese & Schwartz, 2008; Fiese et al., 2002; Spagnola & Fiese, 2007). However, household chaos may create a challenging and unpredictable environment for a child and may influence their development. Researchers have found that household chaos is associated with less effective parental discipline, behavior problems, limited attentional focusing, reduced ability to understand and act in social situations, and decreased accuracy and efficiency (Dumas et al., 2005). This high noise level and chaos may result in lower caregiver attentiveness, responsivity, and verbal stimulation (Wachs, 1993; Wachs & Camli, 1991). Direct research also examines the relationship between household chaos and EF at specific time points.

Household Chaos and EF

Researchers have found a direct association between elevated levels of household chaos and poor performances on tasks that are related to core components of executive functioning, such as inhibitory control, cognitive flexibility, working memory, attention, and effortful control

(Andrews et al., 2021; Berry et al., 2016; Chen et al., 2014; Hughes & Ensor, 2009; Hur et al., 2015; Martin et al., 2012; Vernon-Feagans et al., 2016). A recent meta-analysis examining 35 articles found evidence that household chaos is significantly and negatively associated with child executive function, including completed questionnaires and direct assessments (Andrews et al., 2021). In addition, within the STRONG Kids2 sample, we found associations between household chaos and children's executive function abilities at 24 months, including Inhibitory Self-Control, Flexibility, and Emergent Metacognition (Iwinski et al., 2021).

Researchers have also found that household disorganization, in general, may negatively influence working memory, attention shifting, and other forms of inhibitory control (Berry et al., 2016). Higher levels of household chaos may also interfere with a child's competency levels, creating a lack of control within their environment (Evans & Stecker, 2004). More chaotic environments may prohibit some children from being able to predict events or interactions in their home environment, which could potentially influence their behavior in school, neighborhood, and other social environments.

Green Space, EF, and Household Chaos

Neighborhood greenness and green spaces may affect a multitude of health behaviors and outcomes. For example, several reviews found that physical activity, weight status, mental health, developmental outcomes, cardiovascular health, sleep, and mortality can all be associated with or affected by neighborhood greenness (De Keijzer et al., 2020; James et al., 2015).

Additional researchers have found that access to green spaces is linked to various health benefits, including reduced obesity rates, cardiovascular mortality, and improved mental health outcomes such as decreased stress and enhanced mood states (Twohig-Bennett & Jones, 2018). Moreover, green spaces are critical enablers of physical activity, offering aesthetically pleasing

environments that encourage walking, cycling, and recreational activities. This is particularly vital in densely populated urban areas, where natural landscapes can significantly impact physical activity levels and, by extension, overall public health (Kondo et al., 2018). From a social perspective, green spaces serve as communal areas that foster interactions among residents, thereby building stronger community bonds and improving social cohesion (Villeneuve et al., 2019). Environmental benefits of residential green spaces include enhancing urban biodiversity, improving air quality, reducing urban heat through cooling effects, and managing stormwater runoff. These ecological advantages underscore the critical role of green spaces in sustainable urban planning and climate change mitigation strategies (Rigolon et al., 2018). This comprehensive understanding of green spaces' value extends into children's health and development.

Access and exposure to nature have also been shown to be essential for children (Taylor & Kuo, 2006) and can potentially influence their cognitive abilities and health. Children who spend more time outdoors may experience improved cognitive capabilities, reduced stress, and enhanced social skills (Dockx et al., 2022; Strife & Downey, 2009). Specifically, research has shown that green (e.g., trees, grass, forests, parks, etc.) and blue spaces (e.g., lakes, rivers, and coastal waters) are associated with better mental health conditions, which could lead to less stress, distress, or physiological symptoms (Bowler et al., 2010; Chawla, 2015; Gascon et al., 2015, 2017; McCormick, 2017; Völker & Kistemann, 2015; Wheeler et al., 2012). This may be explained by ART and the ability to restore oneself. Regarding cognitive skills, researchers have found that nature play (e.g., freely chosen, unstructured, and open-ended, playful interactions in nature) can also increase curiosity, creative thinking, and resilience (Erickson & Ernst, 2011;

Ernst & Burcak, 2019). This research may also extend to school green space, which has been shown to positively influence academic performance (Browning & Rigolon, 2019).

Playing in nature can promote children's cognitive, social, and physical development, so playgrounds may be an essential resource for children to develop and grow, especially natural playgrounds (Dankiw et al., 2020; Luchs & Fikus, 2013; Torkar & Rejc, 2017; Zuo et al., 2020). In a recent review, researchers found that higher greenness exposure during childhood was related to a lower risk of obesity and higher levels of physical activity (Barton & Pretty, 2010; Dzhambov et al., 2014; Herrington & Brussoni, 2015; Islam et al., 2020; Lovasi et al., 2011; Sanders et al., 2015). This may also expand a child's social environment, allowing children to explore and learn from their natural environment while interacting with peers.

Green spaces may affect children and their families before and after birth and contain many sensitive periods. Researchers found that green space is positively associated with brain volume development, specifically in regions related to memory, attention, and emotional well-being and regulation (Balseviciene et al., 2014; Dadvand et al., 2018; Islam et al., 2020). Research also displays that prenatal and postnatal exposure to greenness may influence children's intelligence quotient at six years old in South Korea (Lee et al., 2021). Therefore, early exposure to green spaces may affect hot and cold EF abilities.

As discussed above, green spaces also help families and children interact and may promote trust and safety. Researchers have found that green public settings encourage all ages to interact and can decrease crime and increase positive perceptions within a community (Kuo et al., 1998). As indicated in the FBNA framework, time in nature may also influence a family dynamic and provide a pathway for positive family functioning (Izenstark & Ebata, 2016). This might be due to the children's ability to explore nature and develop their creative thinking while

allowing them to establish routines and memories with family and friends. Family-based nature activities may create a pathway for positive family functioning, allowing children to restore and develop their attention and inhibition abilities (Izenstark & Ebata, 2016; Izenstark & Ebata, 2017; Izenstark et al., 2021).

While there is no literature on the relationship between household chaos and green spaces, green spaces may provide an opportunity for increased family functioning and routines within the household. It may also offer a restorative environment, which is essential if the child may be in a more chaotic home environment. Using family residency green space can potentially help children restore their attention and cope with challenges within a chaotic home environment. This relationship may also depend on access to green space and an emotional connection to nature, which differs by each family.

Access to Green Space(s)

Even though we know nature is essential for child development, research shows that children's experiences in nature are rapidly declining (Kahn Jr & Weiss, 2017; Strife & Downey, 2009; Taylor & Kuo, 2006). This may result from environmental generational amnesia, technological advances, safety and crime in neighborhoods, or increases in indoor programming for children (Hartig & Kahn Jr, 2016; Kahn Jr & Weiss, 2017). This may also stem from the inequalities regarding access to green space and health. New research emerged during the past few years that found connections between nature inequality and COVID-19 rates. Researchers found that communities with the majority of persons of color had higher case rates and less greenness available to them (Spotswood et al., 2021). This is alarming, especially when other researchers found that nature may play a key role in helping mental health outcomes during the COVID-19 pandemic (Soga et al., 2021; Soga et al., 2021). In addition, researchers have used

consensus data to highlight the inequalities in nature further. Researchers found that people of color are more likely than white people to live in nature-deprived areas, and low-income communities are also more likely to experience nature deprivation (Landau et al., 2020). In Illinois, these researchers found the percentage of white people living in nature-deprived areas is 21%, and for people of color is 77% (Landau et al., 2020). Similar results were found for other Midwestern States. Other researchers have highlighted that green space might be a tool to advance health equity and address health disparities worldwide (Browning & Rigolon, 2019). These findings highlight the inequalities involving green space and health and need to be considered while examining family residency green space access.

Depending on their safety and comfort in the natural environment, it may also change how caregivers socialize their children with nature and its emotional connection (Collado et al., 2015). Over the years, nature and its importance to a family may become diminished, or the value of it may shift. Children may not be aware of this shift and accept the current norms within their system, which could lead to less nature throughout generations (Hartig & Kahn Jr, 2016; Kahn Jr & Weiss, 2017). However, some families use their family residency to allow their children to explore nature. Researchers have found that residential green space in childhood may have implications on mental health in adulthood, indicating that more prolonged exposure to green space in childhood is associated with better mental health (Engemann et al., 2019).

This research has significant implications for future researchers, practitioners, and policymakers, providing valuable insights into how to encourage families to engage with nature. By highlighting the benefits of early outdoor exposure, this research can guide and push policymakers to develop equitable laws and policies that increase access to nature for all families. These policies may encompass nature-based interventions, community programs, and

educational initiatives emphasizing the critical importance of connecting with the natural environment. Such efforts can foster healthier, more engaged communities and promote overall well-being.

The Present Study

This study examines the relation(s) between children's hot and cold EF abilities, household chaos, and access to family residency green space. Since executive function rapidly develops in early childhood, I will explore children's EF at 2, 4, and 5 years of age, and each research question will have two models for hot and cold EF dimensions. The first goal is to understand the associations between household chaos, access to family residency green space, and children's hot and cold EF abilities. I hypothesized that lower levels of household chaos and more access to family residency green space indicators would be associated with better EF abilities across all domains.

The second goal is to use a structural equation modeling (SEM) framework to test each pathway. Access to family residency green space indicators will be the early predictor (e.g., before two years of age), and household chaos and EF will be modeled over time. I hypothesized that more access to family residency green space (e.g., greenness, tree cover, and amounts of grass) would be associated with better EF abilities (e.g., hot and cold) and less household chaos. The model was tested with three economic hardship variables, income, race, sex at birth, and education levels, as statistical controls. Upon completing these aims, we will have significantly advanced the understanding of how family residency green space, household chaos, and demographic factors (e.g., economic hardship, sex at birth, education levels, race) impact children's developing hot and cold EF abilities in early childhood. Conceptual models are depicted in Figures 1 and 2.

Figure 1

Conceptual Model of Cold EF

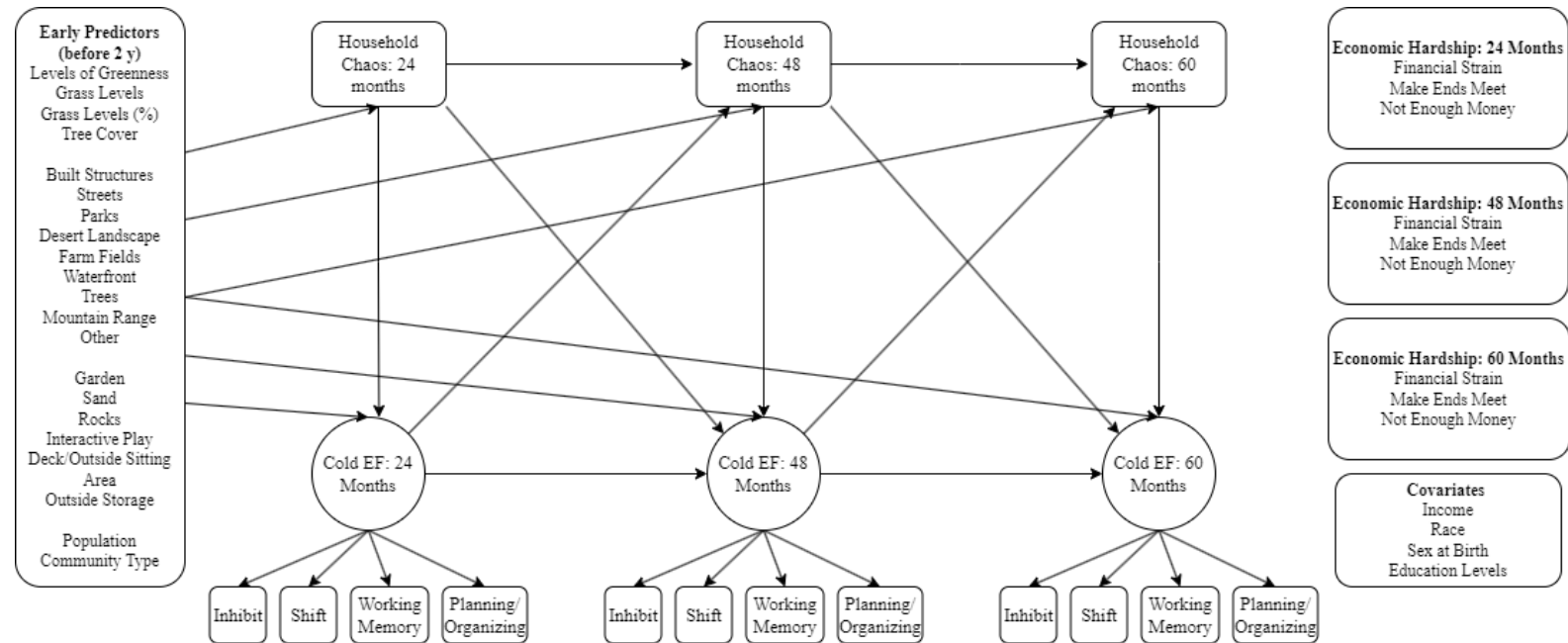
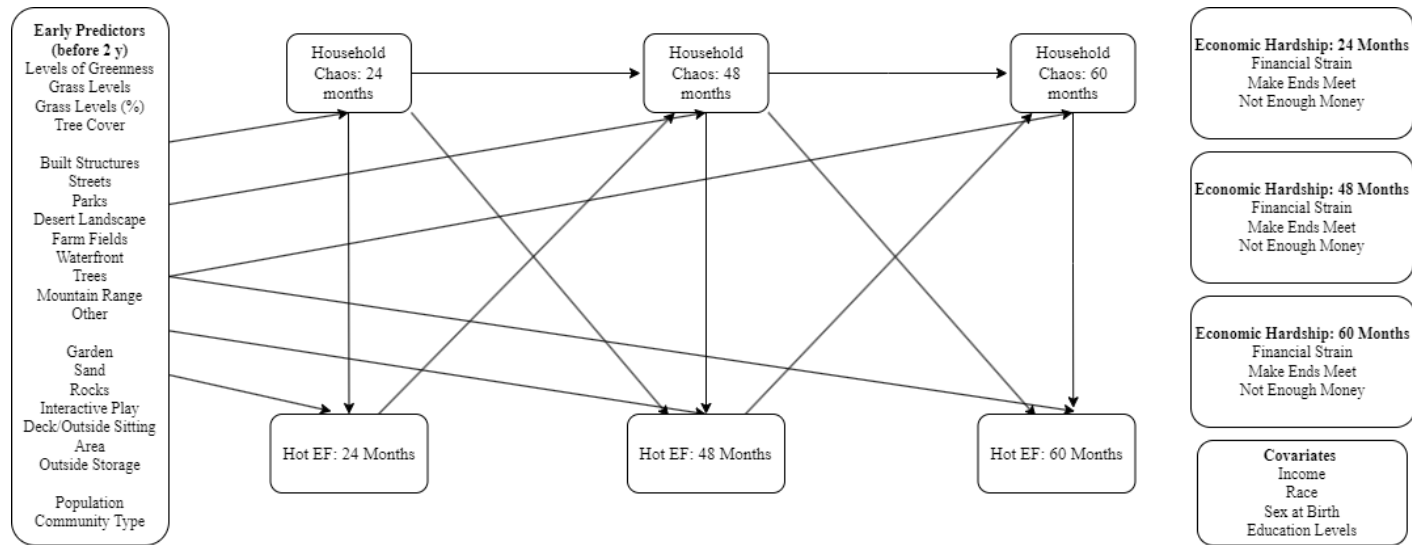


Figure 2

Conceptual Model of Hot EF



Methods

Participants

The data in this analysis are from families participating in a longitudinal birth cohort study in the Midwestern United States ($N = 468$; Table 1). It is designed to examine multi-level predictors of weight trajectories and dietary habits over the first seven years of life (Fiese et al., 2019). Participants were enrolled during their third trimester of pregnancy through outreach at medical centers and prenatal classes within the east-central region of Illinois. Additionally, advertisements were posted on a university-affiliated website. The study excluded those who delivered prematurely (before 37 weeks), infants with conditions that interfered with standard feeding practices (such as phenylketonuria), and infants with a birth weight under 2.5 kilograms—the recruitment period extended from May 2013 through January 2017. As part of the more extensive study, caregivers completed questionnaires regarding household chaos, child EF behaviors, and parent and child demographics. This study was approved by the University Institutional Review Board.

Table 1
Descriptive Statistics

	N	%	M	SD	Range
Child Sex at Birth					
Male	232	50.5			
Female	227	49.5			
Monthly income					
\$3,000 and under	77	23.8			
\$3,001-\$5,000	91	28.1			
\$5,001 and above	156	48.1			
Parent race/ethnicity					
American Indian/Alaska Native	2	0.5			
White	338	82.2			
Asian	28	6.8			
Black	21	5.1			
Prefer not to say	6	1.5			
Biracial	16	3.9			
Parent education level					
Some high school	2	0.6			
High school graduate	16	4.5			
Some college or technical school	59	16.5			
College graduate	120	33.5			
Post-graduate work	161	45.0			
Inhibit: 24 months (T scores)	304		49.83	10.29	34.00 – 85.00
Shift: 24 months (T scores)	320		48.61	8.27	37.00 – 74.00
Emotional Control: 24 months (T scores)	323		48.73	8.97	35.00 – 79.00
Working Memory: 24 months (T scores)	306		51.82	11.55	36.00 – 82.00
Planning/Organizing: 24 months (T scores)	315		49.59	11.09	32.00 – 78.00
Inhibit: 48 months (T scores)	317		52.37	10.57	36.00 – 91.00
Shift: 48 months (T scores)	323		51.50	9.13	38.00 – 83.00
Emotional Control: 48 months (T scores)	322		52.92	10.97	36.00 – 93.00
Working Memory: 48 months (T scores)	311		53.07	10.80	38.00 – 85.00
Planning/Organizing: 48 months (T scores)	317		52.33	11.50	34.00 – 100.00
Inhibit: 60 months (T scores)	290		52.31	10.58	36.00 – 89.00
Shift: 60 months (T scores)	288		50.92	9.74	38.00 – 84.00
Emotional Control: 60 months (T scores)	288		53.17	11.59	36.00 – 89.00
Working Memory: 60 months (T scores)	286		52.65	11.60	38.00 – 98.00
Planning/Organizing: 60 months (T scores)	292		52.23	11.91	34.00 – 90.00
Household Chaos: 24 months	365		26.86	7.07	13.00 – 48.00
Household Chaos: 48 months	335		28.65	7.19	10.00 – 51.00
Household Chaos: 60 months	301		28.68	7.07	15.00 – 53.00

Measures

Executive Function. EF was assessed using the Behavior Rating Inventory of Executive Function- Preschool Version (BRIEF-P; (Isquith et al., 2005)). This survey assesses multiple components of EF, including inhibition, shifting, emotional control, working memory, and planning/organizing. Parents are asked to complete this questionnaire based on how often each behavior has been a problem in their child's life during the last six months. These items are ranged from 1 (never) to 3 (often). Example questions include: "is easily overwhelmed or overstimulated by typical daily activities," "gets out of control more than playmates," and "talks or plays too loudly." Five subscales (listed above), three broad index scores (Inhibitory Self-Control, Flexibility, and Emergent Metacognition), and one global composition score are also derived from the BRIEF-P. Two validity scales (Inconsistency and Negativity) can also be derived. T-scores were used to account for additional child characteristics, including child sex at birth and age. Higher scores on the BRIEF-P indicate worse performance on EF abilities.

Access to Family Residency's Green Space. Access to family residency's green space was examined using historical Google Earth. Google Maps and Street View have become valuable resources for social scientists to understand the built and social environment, including green and urban spaces (Vandeviver, 2014; Zhang et al., 2021). Google Earth allows researchers to examine historical imagery, which is essential when investigating specific years. Researchers assess the overall greenness of the family's residence, the amount of tree cover in their yard, the amount of grass in their yard, what is near the home (e.g., built structures, streets, parks, farm fields, waterfront, trees, and mountain ranges), what is within the home yard (e.g., garden, sand, rocks, interactive play, deck or sitting area, and outside storage), and type of community (e.g., a large city (4.8%), medium city (28.9%), towns and semi-dense areas (46.3%), and rural areas

(19.9%)). Only photos before the children were two years of age were used to understand this factor as an early predictor. Photos ranged from 4/1/2013 to 4/20/2019, and seasons may have included spring, summer, and fall. Using guidance from past studies, overall greenness, grass quantity, and tree cover were rated on a 5-point Likert scale (Taylor et al., 2001). The grass quantity percent was on a 4-point Likert scale (1 = 25% to 4 = 100%). The primary coder, myself, was assigned to code all the photos, serving as a gold standard. Two reliability coders were each randomly assigned to code 38% of the images. Inter-rater reliability was established for each subscale, with ICC values of .88 for greenness, .66 for grass quantity, .68 for grass quantity percent, and .93 for tree cover, indicating acceptable reliability.

Household Chaos. Household chaos and environmental levels were assessed using the Confusion, Hubbub, and Order Scale (CHAOS; (Matheny Jr et al., 1995)). The questionnaire consists of 15 statements surrounding their household environment, and each question is on a 4-point Likert scale, ranging from very much like your home to not at all like your own home. Example questions include, “It’s a real zoo in our home,” “Our home is a good place to relax,” and “First thing in the day, we have a regular routine at home.” CHAOS measures two facets of household chaos. The first facet is routines and organization, and the second is disorganization, confusion, and noise. A single score is obtained by summing the items, with the highest possible score of 60. A higher score indicates a higher level of chaos within the home.

Perceived Economic Hardship. The Perceived Economic Hardship Questionnaire measures financial strain, inability to make ends meet, and insufficient money for necessities (Barrera et al., 2001). For financial strain, an example question includes, “In the next three months, how often do you think that you and your family will experience bad times such as poor housing.” For making ends meet, an example question includes, “Think back over the past three

months and tell us how much difficulty you had with paying your bills.” For insufficient amounts of money, an example question includes, “We had enough money to afford the kind of car we need.” Participants responded to each item on a Likert-type scale, with options ranging from almost never to almost always, with no difficulty at all to a great deal of difficulty, and with strongly disagree to strongly agree. Scores were calculated by summing responses across items, with higher scores indicating greater perceived economic hardship.

Data Analysis Plan

This study used a comprehensive data analysis strategy that integrated both SPSS and R to examine the intricacies of the dataset, encompassing Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM). Initially, I utilized SPSS for data cleaning, preparation, and preliminary analyses, ensuring the dataset's readiness for advanced statistical examinations. This included checks for missing values, outliers, and the distribution normality of the variables under scrutiny. Following this preparatory stage, R, specifically the lavaan package, was used to execute CFA and SEM.

Results

Preliminary Analyses

Missing data analysis was conducted using Little's multivariate test of Missing Completely at Random. The results indicated that our data could be assumed to be missing completely at random, as the test did not reach statistical significance (24 months: $\chi^2(48) = 56.435$, $p = .189$; 48 months: $(\chi^2(28) = 37.114$, $p = .116$); 60 months: $(\chi^2(25) = 31.456$, $p = .174$)). This suggests that the missing data mechanism does not depend systematically on the observed data.

After this, bivariate associations between model variables were conducted. Greenness was positively associated with the ability to shift at 48 months ($r = .134$, $p = .038$) and 60 months ($r = .131$, $p = .030$) and planning and organizing at 48 months ($r = .138$, $p = .023$). Grass quantity was positively associated with planning and organizing at 48 months ($r = .143$, $p = .019$), shifting abilities at 60 months ($r = .154$, $p = .017$), and planning and organizing at 60 months ($r = .144$, $p = .024$). Lastly, tree cover was positively associated with the ability to plan and organize at 48 months ($r = .146$, $p = .016$). All correlations are found in Tables 2 to 5. A latent variable was created for cold EF to further understand these associations, and emotional control was used to examine hot EF.

Confirmatory Factor Analysis (CFA)

Starting with EF at 24 months, a CFA was performed to explore the structure of EF within a sample of 354 children, from a total of 415. The analysis, employing maximum likelihood estimation, converged normally after 81 iterations. The model evaluated the relationships between four observed variables—inhibition, shifting, working memory, and planning and organization—as being influenced by a single latent factor representing cold EF.

The results revealed significant loadings for all observed variables on the latent factor, with standardized loadings of 0.914 for inhibition, 0.610 for shifting, 0.917 for working memory, and 0.818 for planning and organization, indicating that these measures are highly indicative of the EF construct in this age group. A significant covariance was also observed and added to the model between working memory and planning and organization (Std. lv = 13.777, $p = 0.005$), suggesting a moderate relationship between these two aspects of EF. Intercepts for the observed variables were all significant, indicating the expected level of each variable when the latent factor was at zero. Model fit indices provided strong support for the model, with a Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) of 1.000, Root Mean Square Error of Approximation (RMSEA) of 0.000, and Standardized Root Mean Square Residual (SRMR) of 0.005, suggesting a perfect fit for the observed data. The Chi-square test of model fit yielded a value of $\chi^2(1) = 0.949$, $p = 0.330$, further corroborating the model's adequacy in capturing the structure of EF at 24 months.

At 48 months, a CFA was conducted to further understand EF development in a cohort of 346 children from an original sample size of 415. Utilizing maximum likelihood estimation, the analysis achieved convergence after 62 iterations. The findings from this assessment period highlighted significant factor loadings for all observed variables on the latent EF factor. Standardized loadings were observed at 0.831 for Inhibition, 0.589 for Shifting, 0.934 for Working Memory, and 0.900 for Planning and Organization. Model fit indices for the 48-month CFA presented exceptional support for the structural model, with excellent fit indices reported: a CFI and TLI of 1.000, RMSEA of 0.000, and SRMR of 0.005. Moreover, the Chi-square test of model fit returned a value of $\chi^2(2) = 0.016$, $p = 0.992$, providing further evidence of the model's effectiveness.

Transitioning to the assessment at 60 months, a CFA was conducted to investigate the structure of EF within a cohort of 313 children from the original sample of 415. Utilizing maximum likelihood estimation, the analysis achieved convergence after 60 iterations. The analysis illuminated significant and robust factor loadings for all observed variables on the latent EF factor, showcasing standardized loadings of 0.848 for Inhibition, 0.647 for Shifting, 0.929 for Working Memory, and 0.888 for Planning and Organization. The fit indices for the model strongly endorsed its structure, with a CFI and TLI of 1.000, an RMSEA of 0.000, and an SRMR of 0.005. Further, the Chi-square test of model fit resulted in a value of $\chi^2(2) = 0.658$, $p = 0.720$, reinforcing the model's capability to capture the nuanced structure of EF at 60 months.

A CFA with all time points in one model was also conducted before SEM analyses (Appendix B). The analysis, implemented through maximum likelihood estimation with the NLMINB optimization method, converged after 124 iterations with 27 model parameters. The measurement model across all three-time points indicated robust evidence that the latent cold EF variable was influencing the observed indicators. For instance, at 24 months, the standardized loadings were as follows: inhibition (Std. all = 0.864), shifting (Std. all = 0.610), working memory (Std. all = 0.985), and planning and organization (Std. all = 0.889). Similar patterns were observed at 48 and 60 months, underscoring stable factor structures. Notable covariances between the latent factors at each time point were also significant, for example, between cold EF at 24 and cold EF at 48 (Std. lv = 0.480, $p < 0.001$) and cold EF at 48 and cold EF at 60 (Std. lv = 0.764, $p < 0.001$), indicating moderate to strong correlations between these dimensions of EF across time. The model fit indices presented a moderate fit to the data, with a CFI of 0.875 and TLI of 0.838. The RMSEA was 0.160 with a 90% confidence interval ranging from 0.142 to 0.180, and the SRMR was 0.066, which alone suggested a good fit. The Chi-square test for the

model indicated a significant discrepancy between the hypothesized model and the observed data ($\chi^2(51) = 265.768$, $p < 0.001$). However, results yielded a less fitting model with emotional control ($\chi^2(86) = 752.798$, $p < 0.001$, and the following fit indices: CFI = 0.729, TLI = 0.691, RMSEA = 0.143, and SRMR = 0.171); therefore, it is appropriate to continue analyses with separate models regarding hot and cold EF.

SEM: Cold EF

SEM was conducted using the lavaan package 0.6.16 in R version 4.3.1, employing Full Information Maximum Likelihood (FIML) to handle missing data. The model included 246 parameters and was based on 210 observations out of a possible 552, accounting for missing data patterns across 35 distinct configurations. The estimation process converged normally after 1011 iterations, suggesting an acceptable fit between the model and the observed data. The model's goodness of fit was evaluated using several indices. The Chi-square test statistic for the model was significant ($\chi^2 = 782.779$, $df = 414$, $p < .000$), indicating a discrepancy between the observed and model-implied covariance matrices. However, the CFI and TLI values were 0.854 and 0.777, respectively, with the Robust CFI and TLI slightly higher at 0.857 and 0.783, suggesting a moderate fit to the data according to conventional thresholds. The RMSEA was 0.065, with a 90% confidence interval ranging from 0.058 to 0.072, and the SRMR was notably low at 0.034, indicating a reasonable fit.

The measurement model for EF at 24, 48, and 60 months demonstrated significant loadings for all indicators, confirming the assumed structure of the EF construct over time. Specifically, EF latent variables across all three time points significantly contributed to 'Inhibit,' 'Shift,' 'Working Memory,' and 'Planning and Organizing' tasks, with standardized loadings

ranging from 0.619 to 0.948, indicating strong relationships. All significant pathways are discussed below and in Figures 3 (e.g., cold EF) and 4 (e.g., hot EF).

Cold EF at 24 months

There were several significant predictors of cold EF at 24 months, including living near a park ($B = 4.696$, $SE = 2.334$, $p = .044$, $std. all = 0.144$) and household chaos at 24 months ($B = 0.374$, $SE = 0.093$, $p < .000$, $std. all = 0.290$). These results highlight that higher household chaos levels and living near a park are associated with worse cold EF abilities at 24 months. In addition, several races showed significant effects on cold EF at 24 months (African American: $B = -8.691$, $SE = 4.500$, $p = .053$, $std. all = -0.180$; Asian: $B = -10.992$, $SE = 4.046$, $p = .007$, $std. all = -0.283$; White: $B = -7.564$, $SE = 3.158$, $p = .017$, $std. all = -0.288$), indicating racial disparities in early EF.

Cold EF at 48 months

In addition, there were several predictors of better cold EF at 48 months, including living near trees ($B = -2.642$, $SE = 1.228$, $p = .031$, $std.all = -0.144$), higher levels of household chaos at 24 months ($B = -0.199$, $SE = 0.098$, $p = 0.042$, $std.all = -0.150$), having a sandbox ($B = -6.543$, $SE = 3.394$, $p = 0.054$, $std.all = -0.112$) or shed/outside storage ($B = -4.436$, $SE = 1.605$, $p = .006$, $std.all = -0.174$) within the family residency green space. Furthermore, several factors showed a worsening effect on cold EF, including having a garden ($B = 3.756$, $SE = 1.526$, $p = .014$, $std.all = 0.169$) and higher levels of household chaos at 48 months ($B = 0.390$, $SE = 0.098$, $p < .000$, $std.all = 0.311$). Cold EF at 24 months was also positively associated with cold EF at 48 months, suggesting consistency over time ($B = 0.458$, $SE = 0.074$, $p < .000$, $std.all = 0.445$). Sex at birth also significantly affected cold EF at 48 months, indicating sex at birth differences in cold EF at this stage ($B = -3.604$, $SE = 1.053$, $p = .001$, $std.all = -0.202$). Lastly, levels of

education were associated with cold EF at 48 months of age (Some college or technical school: $B = -20.474$, $SE = 7.991$, $p = .010$, $std.all = -0.731$; college graduate: $B = -19.215$, $SE = 7.972$, $p = .016$, $std.all = -1.042$; post-graduate work: $B = -18.135$, $SE = 7.980$, $p = .023$, $std.all = -1.016$).

Cold EF at 60 months

Moreover, for cold EF at 60 months, chaos at home continued to have a detrimental effect ($B = 0.260$, $SE = 0.094$, $p = .005$, $std.all = 0.200$) and earlier EF scores showing predictive value for later EF ($B = 0.753$, $SE = 0.078$, $p < .001$, $std.all = 0.773$). Perceived economic hardship at 24 months also displayed a significant negative association with cold EF at 60 months ($B = -1.797$, $SE = 0.699$, $p = .010$, $std.all = -0.193$), indicating that difficulty making money at 24 months may be related to better cold EF outcomes. Lastly, race (e.g., African American) was also associated with cold EF at 60 months ($B = 6.024$, $SE = 3.171$, $p = .058$, $std.all = .125$).

Household Chaos at 48 months

Both household chaos at 24 months ($B = .597$, $SE = .058$, $p = p < .000$, $std.all = 0.564$) and cold EF at 24 months ($B = .125$, $SE = .049$, $p = .011$, $std.all = .152$) were positively associated with chaos at 48 months. Perceived economic hardship at 48 months ($B = 1.989$, $SE = .609$, $p = .001$, $std.all = .256$) is also related to more chaos at 48 months.

Household Chaos at 60 months

Household chaos at 60 months was also associated with several important factors. The path coefficient between 48-month chaos and cold EF at 60 months was significant ($B = 0.673$, $SE = 0.050$, $p < .000$, $std.all = 0.716$), indicating higher chaos levels are associated with poorer outcomes. Levels of greenness ($B = -1.287$, $SE = 0.503$, $p = .011$, $std.all = -0.195$) and having sand or a sandbox within the home ($B = -4.010$, $SE = 2.030$, $p = .048$, $std.all = -0.092$) were

significantly associated with better chaos levels at 60 months. The path coefficient between cold EF at 48 months and chaos at 60 months was significant ($B = 0.103$, $SE = 0.044$, $p = .021$, $std.all = 0.137$), suggesting that more problematic EF abilities at 48 months are associated with more chaos later in life. Difficulty making ends meet at 48 months ($B = -1.155$, $SE = 0.590$, $p = .050$, $std.all = -0.158$) and financial strain at 60 months ($B = -1.441$, $SE = 0.590$, $p = .014$, $std.all = -0.133$) also showed significant effects, underscoring the nuanced role of financial conditions on child development outcomes.

SEM: Hot EF

SEM was conducted using the lavaan package 0.6.16 in R version 4.3.1, employing FIML to handle missing data. Ninety-one model parameters were estimated using data from 221 observations out of a possible 552, with seven missing patterns noted. The overall model fit was evaluated using several fit indices. The Chi-square test of model fit was significant ($\chi^2(38) = 80.608$, $p < .001$), indicating that the model did not fit the data perfectly. However, the CFI and TLI were .929 and .782, respectively, suggesting a good fit according to CFI but a less satisfactory fit based on TLI. The RMSEA was .071, with a 90% confidence interval ranging from .049 to .093, which is considered a reasonable approximation error. The SRMR was .029, indicating a good fit.

Hot EF at 24 Months

A higher level of chaos within the home at 24 months significantly predicted increased hot EF problems at 24 months ($B = 0.353$, $SE = 0.085$, $p < .001$, $Std.all = 0.284$), indicating early exposure to chaotic environments may negatively impact children's emotional control.

Hot EF at 48 Months

At 48 months, having a deck/patio was significantly associated with increased hot EF ($B = -3.198$, $SE = 1.385$, $p = .021$, $Std.all = -0.139$). A higher level of chaos within the home at 48 months significantly predicted increased hot EF problems at 48 months ($B = 0.367$, $SE = 0.116$, $p = .002$, $Std.all = 0.240$). A higher level of chaos within the home at 24 months significantly predicted increased hot EF abilities at 48 months ($B = -0.272$, $SE = 0.119$, $p = .023$, $Std.all = -0.173$), which indicates differences surrounding household chaos over time. Sex at birth also had a significant effect on hot EF at 48 months, suggesting sex at birth differences at this stage ($B = -6.153$, $SE = 1.258$, $p < .001$, $std.all = -0.280$). Higher levels of financial strain at 24 months were related to worse hot EF at 48 months ($B = 3.833$, $SE = 1.732$, $p = 0.027$, $std.all = 0.141$). Lastly, hot EF at 24 months strongly predicts hot EF at 48 months ($B = 0.502$, $SE = 0.079$, $p < .001$, $Std.all = 0.396$), suggesting group order stability in hot EF over time.

EC at 60 Months

Moreover, living near a farm was related to increased hot EF at 60 months ($B = -3.212$, $SE = 1.612$, $p = .046$, $Std.all = -0.099$). Hot EF at 48 months strongly predicts hot EF at 60 months ($B = 0.614$, $SE = 0.056$, $p < .001$, $Std.all = 0.563$). Higher chaos levels at 48 months led to better hot EF at 60 months ($B = -0.289$, $SE = 0.124$, $p = 0.019$, $std.all = -0.174$), and higher levels of chaos at 60 months were related to worse hot EF at 60 months ($B = 0.719$, $SE = 0.127$, $p < 0.001$, $std.all = 0.406$). Educational levels also were associated with hot EF (High school graduate: $B = 15.132$, $SE = 7.004$, $p = .031$, $Std.all = 0.250$; Some college or technical school: $B = 17.255$, $SE = 6.887$, $p = .012$, $Std.all = 0.480$; College graduate: $B = 15.114$, $SE = 6.853$, $p = .027$, $Std.all = 0.609$; Post-graduate work: $B = 16.245$, $SE = 6.823$, $p = .017$, $Std.all = 0.677$). We

also found that more financial strain at 24 months led to worse hot EF at 60 months ($B = 2.706$, $SE = 1.045$, $p = 0.010$, $std.all = 0.181$).

Chaos at 24 months

At 24 months, more financial strain was related to more chaos ($B = 2.291$, $SE = 1.205$, $p = 0.057$, $std.all = 0.133$).

Chaos at 48 months

Chaos at home shows a sustained negative impact, with chaos at 24 months predicting chaos at 48 months ($B = 0.601$, $SE = 0.056$, $p < .001$, $Std.all = 0.582$). More difficulty in making ends meet at 48 months was related to higher chaos ($B = 2.070$, $SE = 0.607$, $p = 0.001$, $std.all = 0.264$). Educational levels were also predictors of chaos (High school graduate: $B = 10.416$, $SE = 4.448$, $p = 0.019$, $std.all = 0.287$; Some college or technical school: $B = 12.671$, $SE = 4.328$, $p = 0.003$, $std.all = 0.587$; College graduate: $B = 12.432$, $SE = 4.341$, $p = 0.004$, $std.all = 0.834$; Post-graduate work: $B = 12.627$, $SE = 4.326$, $p = 0.004$, $std.all = 0.876$).

Chaos at 60 months

Similar to the above findings, chaos at 48 months predicted chaos at 60 months ($B = 0.699$, $SE = 0.046$, $p < .001$, $Std.all = 0.743$). Hot EF problems at 48 months related to higher chaos at 60 months ($B = 0.087$, $SE = 0.030$, $p = 0.004$, $std.all = 0.141$). More financial strain at 60 months is related to less chaos at 60 months ($B = -1.163$, $SE = 0.596$, $p = 0.051$, $std.all = -0.103$).

Table 2*Correlations among model variables with 24-month EF*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 Greenness	----																
2 Grass Quantity	.78***	----															
3 Grass Quantity Percent	.09	0.1	----														
4 Tree Cover	.19***	.15**	.18**	----													
5 Month 24: PEH financial strain	-.01	.00	.01	0.11	----												
6 Month 24: PEH make ends meet	-.03	.03	-.02	.08	.45***	----											
7 Month 24: PEH not enough money	-.01	.01	-.08	.07	.45***	.68***	----										
8 Month 48: PEH financial strain	-.03	-.04	-.03	.01	.42***	.19***	.31***	----									
9 Month 48: PEH make ends meet	-.07	-.02	-.08	.05	.29***	.64***	.55***	.36***	----								
10 Month 48: PEH not enough money	-.01	.05	-0.11	.03	.33***	.53***	.61***	.38***	.66***	----							
11 Month 60: PEH financial strain	-.04	-.02	-.02	-.03	.26***	.12*	.27***	.37***	.32***	.34***	----						
12 Month 60: PEH make ends meet	-0.11	-.09	-.03	.07	.25***	.54***	.48***	.19**	.71***	.58***	.37***	----					
13 Month 60: PEH not enough money	.01	.00	-0.12	.05	.21***	.45***	.60***	.24***	.60***	.65***	.41***	.65***	----				
14 Month 24: Inhibit	.03	.01	.05	-.03	.18**	.15*	.14*	.05	.09	.05	-0.13	-.02	.04	----			
15 Month 24: Shift	-.01	-.05	.08	.03	0.1	0.11	.07	.01	.02	-.08	-.08	.01	.03	.58***	----		
16 Month 24: Emotional Control	.01	.01	.02	-.02	.16**	.13*	.12*	.14*	.06	-.04	-.15*	-.06	.02	.69***	.57***	----	
17 Month 24: Working Memory	.05	.03	0.11	.05	0.1	.04	.05	.05	.02	-.04	-0.11	-.05	.04	.84***	.56***	.64***	----
18 Month 24: Planning and Organizing	.03	.05	.06	.04	0.1	.15**	.07	.04	.07	.04	-0.12	.00	.07	.75***	.49***	.56***	.85***

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 3*Correlations among model variables with 48-month EF*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 Greenness	----																
2 Grass Quantity	.78***	----															
3 Grass Quantity Percent	.09	0.1	----														
4 Tree Cover	.19***	.15**	.18**	----													
5 Month 24: PEH financial strain	-.01	.00	.01	0.11	----												
6 Month 24: PEH make ends meet	-.03	.03	-.02	.08	.45***	----											
7 Month 24: PEH not enough money	-.01	.01	-.08	.07	.45***	.68***	----										
8 Month 48: PEH financial strain	-.03	-.04	-.03	.01	.42***	.19***	.31***	----									
9 Month 48: PEH make ends meet	-.07	-.02	-.08	.05	.29***	.64***	.55***	.36***	----								
10 Month 48: PEH not enough money	-.01	.05	-0.11	.03	.33***	.53***	.61***	.38***	.66***	----							
11 Month 60: PEH financial strain	-.04	-.02	-.02	-.03	.26***	.12*	.27***	.37***	.32***	.34***	----						
12 Month 60: PEH make ends meet	-0.11	-.09	-.03	.07	.25***	.54***	.48***	.19**	.71***	.58***	.37***	----					
13 Month 60: PEH not enough money	.01	.00	-0.12	.05	.21***	.45***	.60***	.24***	.60***	.65***	.41***	.65***	----				
14 Month 48: Inhibit	.03	.05	-.08	.06	.14*	0.11	.06	.13*	.11*	.07	.03	.02	.08	----			
15 Month 48: Shift	.14*	0.12	.00	.03	.12*	.03	.08	.13*	.08	.12*	.15*	.03	.13*	.49***	----		
16 Month 48: Emotional Control	.04	.04	-.10	.03	.15*	.04	0.1	.12*	.07	.07	.04	.02	.10	.60***	.61***	----	
17 Month 48: Working Memory	0.11	0.11	-.02	.09	.18**	.15*	0.11	.15**	.09	.13*	.06	.04	0.12	.77***	.53***	.50***	----
18 Month 48: Planning and Organizing	.16*	.14*	-.03	.15*	.21***	.13*	.07	.18**	.07	.12*	.07	.00	.10	.74***	.54***	.57***	.83***

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 4*Correlations among model variables with 60-month EF*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 Greenness	----																
2 Grass Quantity	.78***	----															
3 Grass Quantity Percent	.09	0.1	----														
4 Tree Cover	.19***	.15**	.18**	----													
5 Month 24: PEH financial strain	-.01	.00	.01	0.11	----												
6 Month 24: PEH make ends meet	-.03	.03	-.02	.08	.45***	----											
7 Month 24: PEH not enough money	-.01	.01	-.08	.07	.45***	.68***	----										
8 Month 48: PEH financial strain	-.03	-.04	-.03	.01	.42***	.19***	.31***	----									
9 Month 48: PEH make ends meet	-.07	-.02	-.08	.05	.29***	.64***	.55***	.36***	----								
10 Month 48: PEH not enough money	-.01	.05	-0.11	.03	.33***	.53***	.61***	.38***	.66***	----							
11 Month 60: PEH financial strain	-.04	-.02	-.02	-.03	.26***	.12*	.27***	.37***	.32***	.34***	----						
12 Month 60: PEH make ends meet	-0.11	-.09	-.03	.07	.25***	.54***	.48***	.19**	.71***	.58***	.37***	----					
13 Month 60: PEH not enough money	.01	.00	-0.12	.05	.21***	.45***	.60***	.24***	.60***	.65***	.41***	.65***	----				
14 Month 60: Inhibit	.00	.07	-.08	.02	.00	.07	.05	.06	.05	.02	.07	.06	.09	----			
15 Month 60: Shift	.13*	.15*	-.08	-.01	.07	.06	.13*	0.1	.04	.04	.17**	.07	.13*	.55***	----		
16 Month 60: Emotional Control	.05	.10	-.10	.03	.07	.07	.15*	.06	.02	.02	.09	.05	0.11	.68***	.65***	----	
17 Month 60: Working Memory	.12*	0.13*	-.10	.04	0.11	.10	.09	0.1	.07	.07	0.11	.07	.16**	.79***	.63***	.61***	----
18 Month 60: Planning and Organizing	.07	.14*	-.07	.08	0.1	0.11	.14*	.06	0.11	.10	.13*	.09	.18**	.76***	.58***	.62***	.82***

*p < .05, **p < .01, ***p < .001.

Table 5

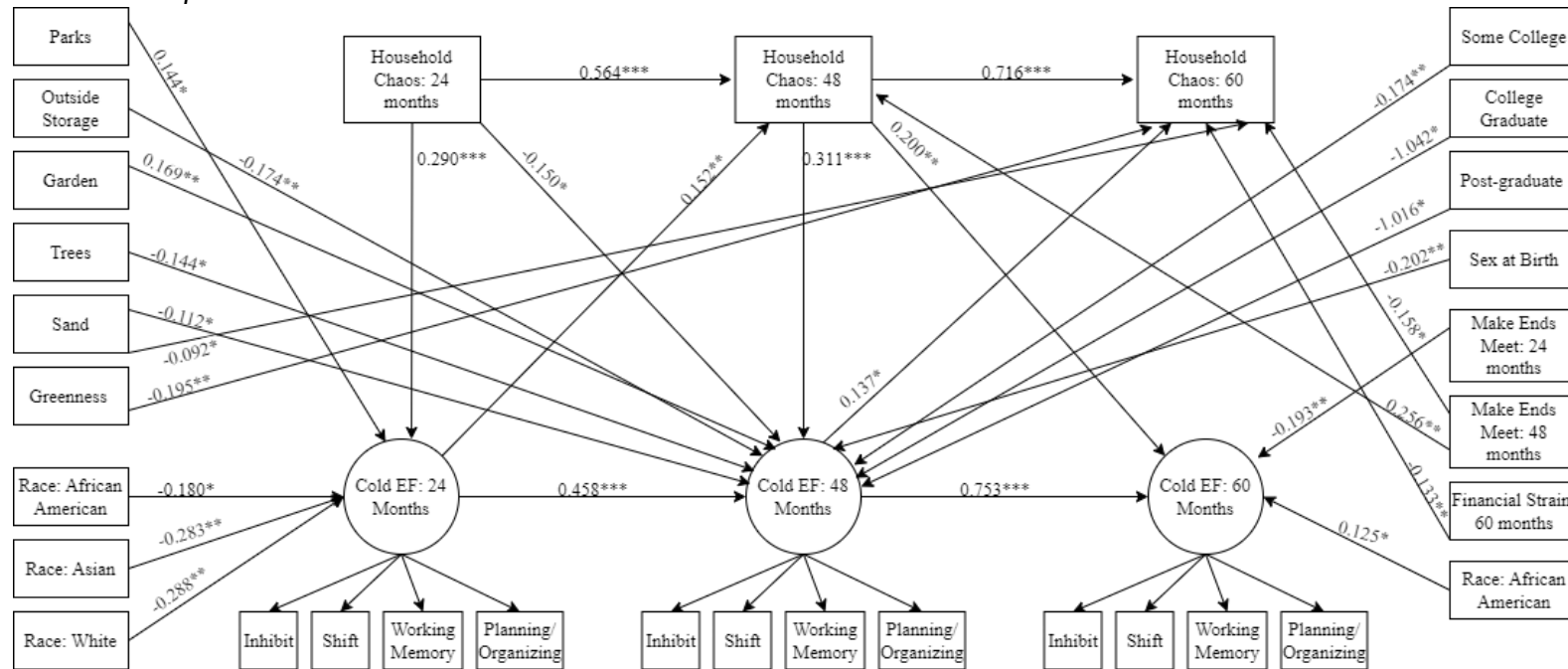
Correlations among model variables with EF and additional variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Month 24: Inhibit	----																		
2	Month 24: Shift	.58***	----																	
3	Month 24: Emotional Control	.69***	.57***	----																
4	Month 24: Working Memory	.84***	.56***	.64***	----															
5	Month 24: Planning and Organizing	.75***	.49***	.56***	.85***	----														
6	Month 48: Inhibit	.46***	.20***	.29***	.37***	.40***	----													
7	Month 48: Shift	.25***	.34***	.23***	.24***	.20**	.49***	----												
8	Month 48: Emotional Control	.35***	.26***	.43***	.30***	.26***	.60***	.61***	----											
9	Month 48: Working Memory	.42***	.18**	.28***	.45***	.46***	.77***	.53***	.50***	----										
10	Month 48: Planning and Organizing	.37***	.20**	.28***	.43***	.45***	.74***	.54***	.57***	.83***	----									
11	Month 60: Inhibit	.43***	.18**	.26***	.34***	.39***	.72***	.32***	.42***	.55***	.56***	----								
12	Month 60: Shift	.31***	.38***	.27***	.25***	.20**	.37***	.65***	.45***	.38***	.39***	.55***	----							
13	Month 60: Emotional Control	.36***	.25***	.48***	.31***	.27***	.50***	.43***	.66***	.38***	.46***	.68***	.65***	----						
14	Month 60: Working Memory	.34***	.18**	.25***	.34***	.31***	.55***	.39***	.36***	.60***	.62***	.79***	.63***	.61***	----					
15	Month 60: Planning and Organizing	.40***	.23***	.32***	.40***	.43***	.54***	.37***	.38***	.55***	.62***	.76***	.58***	.62***	.82***	----				
16	Population Size	.01	.05	.02	.01	.01	.10	.07	.13*	.01	.01	.03	.13*	.08	.05	.07	----			
17	Community Size	.00	-.06	.00	.00	.01	.03	-.01	-.05	.01	.02	.00	-.09	-.04	-.01	-.03	-.43***	----		
18	Near the home (SUM)	-.03	.07	.03	.01	.02	.01	.13*	0.11	-.01	-.04	-.04	.10	.05	-.04	-.01	-.01	.02	---	
19	Within the home (SUM)	.02	.02	.02	.03	.03	-.03	-.05	-.06	-.01	-.01	-.07	-.05	-.08	-.06	-.06	-.08	.19***	-.10	--

*p < .05, **p < .01, ***p < .001.

Figure 3

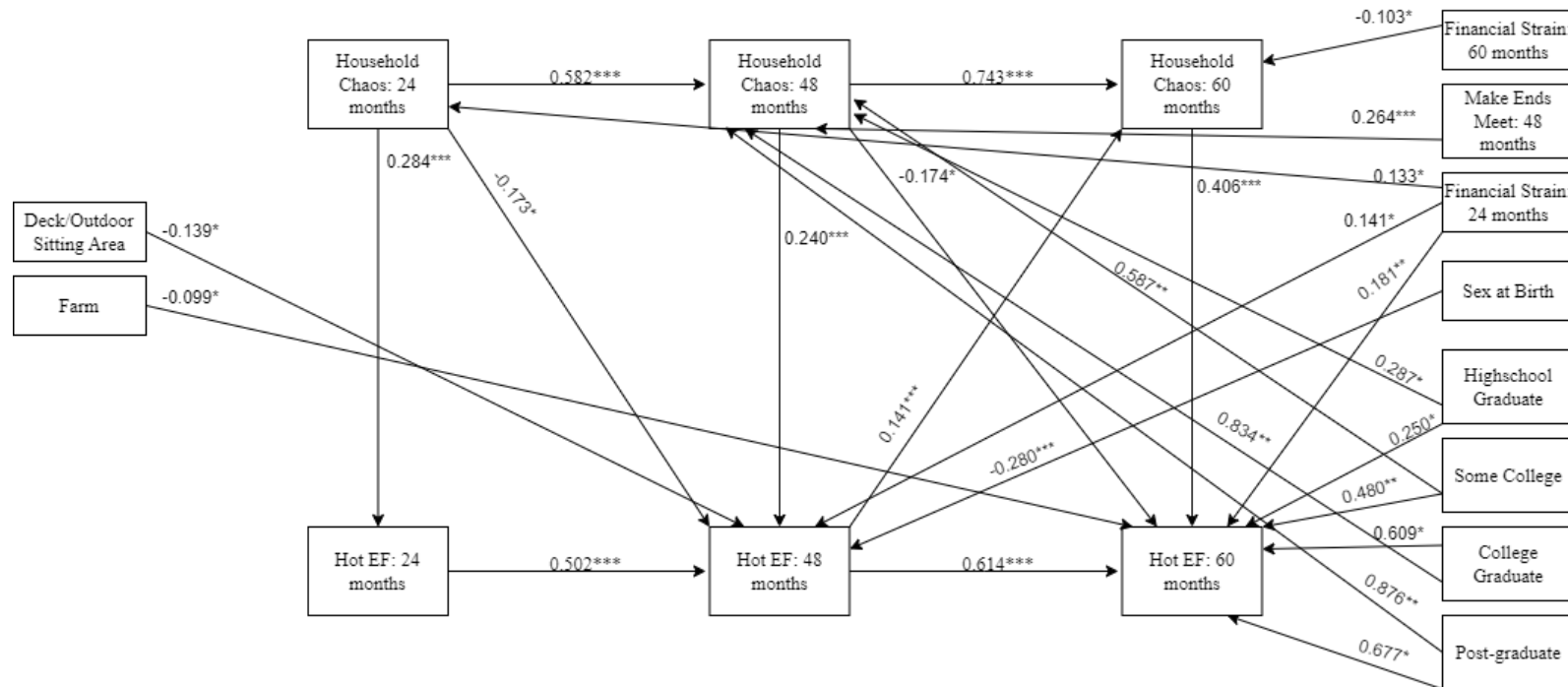
SEM model of cold EF with all variables



Note. * $p < .05$. ** $p < .01$. *** $p < .001$. The results above contain standardized values.

Figure 4

SEM model of hot EF with all variables



Note. * $p < .05$. ** $p < .01$. *** $p < .001$. The results above contain standardized values.

Discussion

This study displays the complex structure of EF across early childhood and what factors may influence developing EF. Our findings indicate significant associations between environmental factors—such as exposure to green/outdoor spaces, financial factors, and varying levels of household chaos—and executive functioning, emphasizing the intricate associations between a child’s physical environment and cognitive development. These findings support the implementation of targeted interventions that modify environmental factors to support cognitive development. Specifically, policies promoting access to natural environments and interventions designed to reduce household chaos are potential strategies to enhance executive function in young children. Such interventions could be particularly impactful if implemented at sensitive periods of child development, as suggested by the temporal variations in the influence of these factors.

The study’s findings reveal distinct patterns between hot and cold executive functions in early childhood, underscoring how different environmental factors influence these domains. Cold EF, which encompasses cognitive processes like planning and inhibitory control, showed significant associations with environmental stability factors such as household chaos, proximity to green spaces, and items for outdoor exploration. In contrast, hot EF, similar to emotional control, appeared to be influenced by different social environments and economic conditions, including living near a farm and having an outdoor sitting area. Financial strain was found to have a notable impact on hot EF, indicating that economic hardships could affect a child’s ability to manage emotions and social interactions. Notably, higher levels of household chaos simultaneously were associated with poorer cold and hot EF outcomes, suggesting that a more structured and predictable environment might support the development of hot and cold EF. These

differences highlight the necessity for targeted interventions that address specific environmental conditions to support the respective domains of EF.

Overall, this research establishes an understanding of the environmental influences on hot and cold executive functions across developmental periods. Future research should explore the longitudinal effects of specific types of environmental exposures, such as the duration and quality of greenness exposure, and how these interact with socio-economic factors to influence cognitive development. Additionally, further studies might investigate the mechanisms through which environmental factors exert their effects. Additional research could provide more targeted insights for developing interventions that mitigate risks and enhance cognitive and emotional development in early childhood.

Chapter 3: Parent-Child Relationships, Household Chaos, and EF (Paper 2)

Executive Function (EF)

There are numerous ways researchers have conceptualized and measured EF. They may use three general core dimensions (e.g., inhibitory control, working memory, and cognitive flexibility) or examine each facet of EF separately (e.g., inhibition, shifting, emotional control, working memory, and planning/organizing). Some researchers also use the terms “hot” and “cold/cool” for different subsets of EF. Cool EF abilities refer to purely cognitive information processing and can be measured with inhibitory control, working memory, and cognitive flexibility subscales or tasks. Hot EF refers to processing reward, emotion, and motivation information, including the ability to regulate one’s emotions (Salehinejad et al., 2021; Zelazo & Carlson, 2012, 2020).

The development of EF occurs early in life and can be shaped by interactions, environments, and relationships with adults. EF development occurs during multiple sensitive periods when the brain is particularly receptive to learning new skills and behaviors (Thompson & Steinbeis, 2020). From an evolutionary perspective, these sensitive periods enable individuals to become more specialized and adapt to their environments (Fawcett & Frankenhuis, 2015). This specialization is directly tied to brain development and attachment, allowing children to utilize context clues, social interactions, and exploratory behaviors to understand and navigate societal norms (Knudsen, 2004). By identifying the specific times when children are most responsive to certain types of learning and support, educators and caregivers can tailor their approaches to maximize developmental outcomes.

Cold Executive Functions

Inhibitory Control. Inhibitory control refers to controlling one's attention, behaviors, and thoughts. This can include doing what may be appropriate in a given situation, which may involve overriding internal predispositions (Diamond, 2013; Fiske & Holmboe, 2019; Garon et al., 2008). Similar to attention regulation, inhibitory control of attention allows us to selectively attend and focus on what we choose while suppressing awareness of additional stimuli (Diamond, 2013). For example, a child may be assigned to read a paragraph aloud and told to stop when they reach the end. It may be difficult for some children to stop reading because they are unable to override their internal predispositions of reading aloud to the class. Researchers have found that the ability to inhibit improves throughout childhood and then is slightly diminished throughout adulthood (Williams et al., 1999). The literature suggests that rapid development and improvement in inhibitory control occurs during the toddler and preschool years (ages 2-5) and increases at a more steady pace during middle childhood (ages 6-12) (Best & Miller, 2010; Fiske & Holmboe, 2019; Garon et al., 2008, 2014; Miyake & Friedman, 2012). Specifically, with various lab tasks, multiple researchers found the development of inhibitory control is more rapid between the age of 3.5 and 5 years, and the increase remains at a steadier pace between the ages of 5 and 6 years old (Dennis et al., 2007; Klenberg et al., 2001; Lengua et al., 2015). After this age, more complex inhibition characteristics keep improving until around seven years of age. Another critical component of EF, often paired with inhibition, is the ability to shift, which refers to the ability to move freely from one situation or aspect of a problem to another. For a child, this may be thinking about different verb tenses or changes within reading environments (e.g., reading quietly at school vs. aloud at home).

Working Memory. Working memory taps into the capacity to hold information in memory for goals or plans and allows individuals to work with the information they possess (Diamond, 2013). Working memory is critical to a child's ability to see connections, use one's knowledge to make decisions and formulate one's creativity. Working memory and inhibitory control may support and work together in most situations. For example, inhibitory control can assist one's working memory by keeping our mental workspace from becoming overwhelmed or cluttered. This ability can help our mind resist irrelevant information and suppress specific thoughts that may allow the mind to wander. These abilities form over time and may shift depending on the developmental period. Similar to inhibitory control, working memory begins in infancy. However, this development is much slower and shows a more prolonged developmental progression, with the most significant growth occurring between 5 and 12 years of age (Cowan et al., 2002; Crone et al., 2006; Diamond, 2013; Pelphrey et al., 2004; Reynolds & Romano, 2016). Researchers also propose a steady improvement in working memory from age 4 to 15 (Cowan, 2016; Panesi et al., 2022).

Cognitive Flexibility. Cognitive flexibility builds upon inhibitory control and working memory to enable a person to shift between different tasks or goals (Buttelmann & Karbach, 2017; Diamond, 2013). Planning/organizing skills may also stem from a child's cognitive flexibility. This may involve the child's ability to manage current or future tasks in an array of situations. In a given situation, children may need to change their perspectives, potentially inhibiting a current response and using their working memory to activate a different perspective.

Regarding development, cognitive flexibility may improve as a child develops, and skills may decline during aging (Cepeda et al., 2001; Kray, 2006). This ability is influenced by the situation or how one uses their capabilities (e.g., response to environmental demands vs. using

EF abilities proactively) (Diamond, 2013). Studying this dimension over time is essential to understanding how cognitive flexibility changes as children develop.

Hot Executive Functions

Emotion Regulation or Emotional Control. Emotion regulation is similar to many EF components, and some researchers may refer to emotion regulation as hot EFs, as discussed above. According to Diamond and Aspinwall (2003), emotion regulation refers “to the internal and transactional processes through which individuals consciously or unconsciously modulate one or more components of emotion, by modifying either their own experience/behavior/expression or the emotion-eliciting situation (p. 3)” (Eisenberg et al., 2000; Gross, 1999). In addition, Thompson (1994) discussed emotion regulation as, “the extrinsic and intrinsic processes responsible for monitoring, evaluating, and modifying emotional reactions, especially their intensive and temporal features, to accomplish goals (pp. 27-28)” (Thompson, 1994). This definition and conceptualization can be influenced by how it is measured (e.g., laboratory vs. observational tasks) and where this research is conducted (McRae & Gross, 2020). For example, among young adults, researchers have found that individuals from cultures who value self-reflection tend to use their ability for reappraisal more frequently, which is often used to study one’s emotion regulation. Furthermore, individuals who value open expression of emotion within their culture tend to suppress their emotions less frequently (Haga et al., 2009; Matsumoto et al., 2008; McRae et al., 2011; McRae & Gross, 2020; Su et al., 2015; Yih et al., 2019). This may also change depending on the developmental period and how parents teach their children about emotions (Lozada et al., 2016).

Researchers have also found connections between attention and emotion regulation, highlighting that the development of biological and behavioral attributes of attentional control

may influence emotion regulation in childhood (Graziano et al., 2011). Across development, there is a transition from reliance on the caregivers for co-regulation to higher levels of independent regulation from the child (Perry & Calkins, 2018; Sameroff, 2010). Children between the ages of two and three begin to manage emotional states and influence mechanisms often included in EF, including attention and behavior.

Parent-child Behavioral Synchrony

Synchrony collectively forms a relationship unit that examines the matching of behavior, affect, and biological states over time (Davis et al., 2018; Feldman, 2007). There are various types of synchrony, including motion, behavioral, bio-behavioral, and physiological, and all have been associated with parent-child relationships and developmental outcomes for children (Davis et al., 2018). Synchrony allows researchers to examine the dyad, implying a bidirectional influence for both parties involved (Davis et al., 2018; Feldman, 2007; Feldman, 2012). This co-regulation process facilitates synchronous parent-child interactions, allowing children to practice their regulatory skills (Davis et al., 2017). Similar to synchrony, mutually responsive orientation (MRO) also allows us to examine dyadic interactions, specifically mutual responsiveness and shared positive affect. This includes the degree to which the dyad demonstrates coordinated interactions, mutual cooperation, harmonious communication, and emotional ambiance (Kochanska et al., 2008). These dimensions encompass smooth communication, enjoyment of each other's company, and shared expectations (Kochanska et al., 2008). Nonverbal synchrony, also used in this study, provides an alternative to manual observer ratings, which can offer another level of behavioral synchrony within the parent-child relationship.

Researchers may also explore attachment, sensitivity, and responsiveness when examining parent-child relationships to understand the bond between the parent and child.

The relationship between behavioral synchrony and attachment is closely intertwined and essential for a child's development. During infancy, the attachment relationship may contribute to the development of behavioral synchrony (Beebe & Lachmann, 2013; Bretherton, 1992; Feldman, 2007). For example, suppose a child feels more securely attached to their parent. In that case, they may be more likely to engage in synchronous behaviors, including modeling their behaviors and movements after the caregiver. In turn, the caregiver may be more responsive to the child's needs and cues, creating a sense of safety and connectedness. Behavioral synchrony may promote, strengthen, and reinforce the attachment bond. These behaviors may assist with shared social understanding and a sense of security and promote a child's emotional and cognitive well-being.

Theoretical Frameworks

There are several frameworks and perspectives that also explain the importance of these early experiences and how they may relate to hot and cold EF. According to Bowlby's attachment theory, all infants are born with a behavioral attachment system that leads infants to seek proximity to adult caregivers when activated in times of distress or need (Ainsworth, 1978; Bretherton, 1992). The nature and quality of the attachment relationship are determined by caregiving responses to a child's bids for proximity, support, or help in times of distress. Individuals develop internal working models of themselves and others based on past experiences with caregivers. Within this, there may be expectations that a child has of their parent, including responsiveness, strategies to regulate themselves, and interpreting attachment-related information (Edelstein et al., 2006). Children's secure base behavior, or seeking proximity to the caregiver when distressed and otherwise feeling safe to explore, may influence a child's ability to be flexible, pay attention, and concentrate, which are core features of EF and regulation (Pallini et

al., 2019). Bowlby also proposed that the biological function of attachment involved protection, which may include adaptations from the environment (Ainsworth et al., 2015). Using attachment theory in combination with synchrony allows researchers to understand the bidirectional influence parents and children may have on one another and how it can further influence cognitive abilities and regulation.

In addition, many social-emotional developmental theories suggest that early co-regulatory experiences may influence children's development of self-regulatory capacities (Feldman, 2007). For example, Kopp's model (1982) incorporates a developmental perspective for socio-emotional development, indicating that self-regulation may differ and evolve from three months to 3 years. Children begin with parent-infant coordinated interactions, allowing them to learn and adapt to the environment while modeling their parent(s). Between the ages of 2 and 3, children may begin testing their self-control and self-regulation (Kopp, 1982). This perspective utilizes a developmental approach that further displays how children may adapt and model their regulation based on their caregivers and environment.

Furthermore, the dynamic systems perspective explains that expressive and communicative actions are within the same system and may influence children's physiology, cognition, behavior, and social environment (Fogel, 1993; Fogel, 1987). This perspective assumes that developmental processes are multicausal, nonlinear, and complex while highlighting that it might include stability and change. One of the main, and sometimes steady, environments for a child and family is mealtime. Therefore, this may be an early environment that regularly involves parent-child interaction and helps the child to understand societal cues while developing self-regulation and EF capacities. By adopting a dynamic systems and developmental perspective, coupled with tenets of attachment theory, researchers can better

understand these complex processes while acknowledging these systems' dyadic and interconnected nature.

Parent-child Relationships and EF

The parent-child relationship and synchrony may affect behavior, attention, and control across development. Researchers have found associations between the quality of parent-child relationships and EF, and the overall caregiving environment is thought to be critical in promoting the development of children's EF and regulation (Bernier et al., 2015; Diamond et al., 2007; Fay-Stammbach et al., 2014). Consistent and sensitive parenting is thought to influence EF through biobehavioral regulation (Antonucci et al., 2018; Feldman, 2017; Ulmer-Yaniv et al., 2022). For example, the attachment relationship has important implications for biobehavioral stress regulation, including a child's ability to develop capacities to regulate emotion, behavior, and attention – all essential aspects of EF. Early life attachment disruptions may negatively impact EF, including behavioral inhibition and emotion regulation (Blair et al., 2018). Researchers have also proposed that the affective bond that characterizes secure attachment relationships may provide children with a safe relational context. This may then help children gradually learn to self-regulate actions defined by EF (Bernier et al., 2015; Kochanska & Aksan, 1995; Lewis & Carpendale, 2009).

Previous studies suggest that children who are more securely attached to their mothers show better performance on EF tasks (Bernier et al., 2015; Meuwissen & Englund, 2016). Parent-child relationships may specifically affect a child's working memory, emotion regulation, and cognitive flexibility. Bernier et al.'s (2010, 2015) results suggested that scores of child attachment and parenting behaviors (18-26 months and 15 months to 3 years old) were related to child performance on working memory and cognitive flexibility tasks. If the parent-child

relationship was strong, the child was more likely to have better working memory or cognitive flexibility abilities over time (Bernier et al., 2015; Bernier et al., 2010).

In addition to child attachment security, others have examined parent-child relationships using assessments of maternal sensitivity and parenting styles. Bernier et al. (2010) assessed this relationship using maternal sensitivity during interactions, maternal mindfulness, and maternal autonomy support. The researchers found that all three parenting dimensions (maternal sensitivity, mind-mindedness, and autonomy support) were positively related to the child's EF scores (Bernier et al., 2010). In addition, while longitudinally examining children (aged 36 to 60 months), researchers found that parenting sensitivity and responsiveness predicted more significant positive changes in EF, and EF may bidirectionally predict a shift in parenting quality. This link provides insight into the importance of caregiving relationships at a young age and the transactional relations between early experiences and EF (Blair et al., 2014). Furthermore, researchers have found that parental behaviors show associations with children's EF abilities, highlighting how positive and negative interactions within the parent-child relationship may influence children's cognitive skills (Hughes & Devine, 2019). In a meta-analysis, researchers found associations between parental behaviors and EF moderated by child age, with results in younger children showing a more substantial effect size. Additionally, positive (warmth, responsiveness, sensitivity) and negative (control, detachment, intrusiveness) parental behaviors had a stable association with EF across various age groups (0-8 years) (Valcan et al., 2018). These results indicate that early parent-child relationships, experiences, and exposures may influence children's developing EF in all domains, including hot and cold EF abilities.

Furthermore, positive and interactive synchrony has been linked with better self-control outcomes for children. This includes children who experience more mutually positive and prosocial interactions with their caregivers and may demonstrate better behavioral (e.g., potentially cold EF) and emotional control (e.g., hot EF) (Davis et al., 2017; Kim & Kochanska, 2012; Lengua et al., 2007; Lindsey et al., 2009; Scholtes et al., 2021). Early patterns of interactions may also influence how children behaviorally inhibit, which may impact their social relationships over time (Anaya et al., 2021; Guyer et al., 2018; Jarcho & Guyer, 2018). Examples may include making eye contact, starting conversations, and understanding social cues in various environments. Regarding emotion regulation, researchers have found that mother-child synchrony may predict children's self-regulation capacities, including emotion regulation (Bell, 2020; Feldman, 2012; Feldman, 2015). Parent-child synchrony may also improve emotion regulation strategies during positive and negative emotions. This may also interplay with a caregiver's response to children's emotions, which can influence their emotional regulation and response to specific situations (Ju et al., 2024). By having more positive interactions and synchrony, children may be better equipped to manage and perform particular tasks, including understanding their feelings, shifting their attention, and adjusting their behaviors.

Engaging in synchronized interactions and activities can provide a rich context for development and allow children to develop their EF skills. For example, there may be more social engagement within the parent-child dyad and other environments (e.g., playing in various settings, team sports, or after childcare programming). This engagement allows children to adapt and alter their behavior over time, strengthening the bond between the parent and child and the child with their peers (Van Puyvelde et al., 2013). Researchers have also suggested in adults that behavioral and social synchrony may be associated with neural synchronization, indicating that

brain activity may become synchronized (Nummenmaa et al., 2012; Uhlhaas et al., 2009). This synchronization could then facilitate communication between brain regions involved in EF abilities and assist with the development process. While the research is often broad and focuses on older children or adults, there are clear benefits from greater levels of synchrony in a parent-child relationship.

However, limited research examines the direct relations between parent-child behavioral, motion synchrony, and children's hot and cold EF. However, some researchers compare EF to self-regulation and illustrate that these abilities may overlap and influence one another. Reasons for this may include (1) EF may support mechanisms in an individual's self-regulatory goals and plans, (2) cold EF (e.g., working memory, inhibitory control, and cognitive flexibility) may be implicated in hot EF (e.g., emotion regulation, motivation processing), and (3) improvements or worsening of EF may also influence regulatory capacities (Barkley, 2001; Baumeister et al., 2007; Becker et al., 2014; Hoffman et al., 2012; McClelland & Tominey, 2014; Montroy et al., 2016; Ponitz et al., 2009). While there is no detailed research studying synchrony and EF, there is research to support the notion that EF tendencies (e.g., self-control) and abilities have been linked to parent-child synchrony.

Children are building a bond with an adult or caregiver at a young age, and this relationship may shape how their brain develops and cognitive abilities structure themselves. Many proximal regulatory processes may influence a child's health and family systems (Fiese & Bost, 2016). Children with secure attachments have a history of experiences with trusting caregivers who provide sensitive and responsive care in response to their distress and needs. Regulatory capacities that develop through these experiences may impact the development of EF capabilities. Therefore, it is essential to understand how many different parenting techniques,

levels, and bonds may influence children's ability to regulate themselves, use their working memory, and make goals for their future(s). This study assessed motion and behavioral synchrony during a mealtime; therefore, these results may be specific to synchrony during this context and may not describe the synchrony levels in other environments. Studying this context, which may be a family routine, will shed light on how caregivers and child behaviors may match and how the mealtime environment can influence EF development.

Household Chaos

Household chaos describes an environment that is high in noise and crowding and low in regularity and routines (Vernon-Feagans et al., 2016). Routines and rituals provide predictable structures that may support early development and guide behaviors throughout childhood and adulthood (Fiese & Schwartz, 2008; Spagnola & Fiese, 2007). Routines (e.g., mealtime and bedtime) provide a structural space and can supply individual family members with a shared identity (Fiese & Schwartz, 2008; Fiese et al., 2002; Spagnola & Fiese, 2007). However, household chaos may create a challenging and unpredictable environment for a child and may influence their development. Researchers have found that household chaos is associated with less effective parental discipline, behavior problems, limited attentional focusing, reduced ability to understand and act in social situations, and decreased accuracy and efficiency (Dumas et al., 2005). This high noise level and chaos may result in lower caregiver attentiveness, responsiveness, and verbal stimulation (Wachs, 1993; Wachs & Camli, 1991). Direct research also examines the relationship between household chaos and EF at specific time points.

Household Chaos and EF

Researchers have found a direct association between elevated levels of household chaos and poor performances on tasks that are related to core components of executive functioning,

such as inhibitory control, cognitive flexibility, working memory, attention, and effortful control (Andrews et al., 2021; Berry et al., 2016; Chen et al., 2014; Hughes & Ensor, 2009; Hur et al., 2015; Martin et al., 2012; Vernon-Feagans et al., 2016). A recent meta-analysis examining 35 articles found evidence that household chaos is significantly and negatively associated with child executive function, including completed questionnaires and direct assessments (Andrews et al., 2021). In addition, within the STRONG Kids2 sample, we found associations between household chaos and children's executive function abilities at 24 months, including Inhibitory Self-Control, Flexibility, and Emergent Metacognition (Iwinski et al., 2021).

Researchers have also found that household disorganization, in general, may negatively influence working memory, attention shifting, and other forms of inhibitory control (Berry et al., 2016). Higher levels of household chaos may also interfere with a child's competency levels, creating a lack of control within their environment (Evans & Stecker, 2004). More chaotic environments may prohibit some children from being able to predict events or interactions in their home environment, which could potentially influence their behavior and relationships in school, neighborhood, and other social environments.

Benefits and Barriers of Mealtimes

Mealtimes can be a vital routine for the daily lives of families (Fiese et al., 2006). As a ritual, mealtimes can provide opportunities for symbolic gestures and can give individual family members a shared identity (Fiese et al., 2006). Furthermore, eating together is a routine focusing on mealtimes' structural and instrumental values, such as shared expectations about the role assignment and participation of different family members (de Wit et al., 2015). Family mealtimes may provide stability among family members, and the frequency of mealtimes may provide a sense of stability.

Thirty years of research have linked the frequency of family mealtimes with many positive childhood outcomes and protective factors, such as decreasing the likelihood of alcohol problems, cigarette use, and mental health problems (CASA, 2007; Fiese & Winter, 2010; Ju et al., 2024). Frequent family mealtimes have been linked to both fewer externalizing behaviors (e.g., substance use and violence) and internalizing behaviors (e.g., self-esteem, self-efficacy, depressive symptoms, and suicidal ideation) in children (Harrison et al., 2015) as well as greater academic achievement (CASA, 2007). Mealtimes may also assist with family functioning, allowing family members to communicate more effectively and accomplish tasks together (Smith et al., 2022). It is important to note that while much research has recognized the benefits of mealtimes among families of ethnically and socioeconomically diverse communities (Helton et al., 2023; Robson et al., 2020; Smith et al., 2022), few studies have examined disparities or barriers that may exist. For example, within Black families, researchers have found that caregivers valued family mealtimes and acknowledged the benefits; however, several barriers did not allow them to have regular family mealtimes (Jarrett et al., 2016). Research displays that structural inequalities may disproportionately create obstacles to family meals among different racial and ethnic groups (Skala et al., 2012).

Many barriers within and outside the family unit may limit the frequency of shared mealtimes (Jones, 2018). Disparities may exist based on socioeconomic status. Specifically, families in poverty may simultaneously struggle with eating meals together regularly (Neumark-Sztainer et al., 2003). Another example of social and economic inequality affecting mealtimes is access to certain foods due to financial hardships. Families may be unable to provide certain foods or an adequate amount for a family mealtime together, resulting in eating separately or at different times (Jarrett et al., 2016; Schuler et al., 2020). Financial hardships also produce a

scarcity of time. Family members often need to concurrently manage work and family responsibilities that require accommodating individuals' schedules to set a mutual time to engage in this routine (Jarrett et al., 2016; Jones, 2018). For instance, work shift characteristics of family members, such as having a night shift, may create a common barrier to holding frequent mealtimes (Jones, 2018). Additionally, age-related life transitions with the increase in a child's age, such as gaining autonomy and spending more time with peer groups, tend to reduce the family's mealtime frequency (Hammons & Fiese, 2011). In dual-earner families, having to negotiate between gendered norms and personal values to create shared expectations about who is responsible for organizing mealtimes and feeding children may impose an additional burden on having family mealtimes (Flagg et al., 2014). Overall, mealtimes have many benefits and barriers and can have lasting effects on the child and family functioning.

The Present Study

This study examines the relation(s) between children's EF abilities, parent-child dyadic (behavioral) synchrony, attachment, household chaos, and motion synchrony during a mealtime. Since executive function rapidly develops in early childhood, I explored children's EF at 2, 4, and 5 years of age, and each research question will have two models for hot and cold EF dimensions. I hypothesized that EF can be best conceptualized as two dimensions reflecting cold EF and hot EF. The second goal was to understand the associations between hot and cold EF, attachment and synchrony variables, and household chaos. It was hypothesized that more smooth attachments, lower chaos, and higher synchrony levels would be associated with better hot and cold EF abilities. The model was tested with three economic hardship variables, income, race, sex at birth, and education levels, as statistical controls. Conceptual models are depicted in Figures 5 and 6.

Figure 5

Conceptual Model of Cold EF

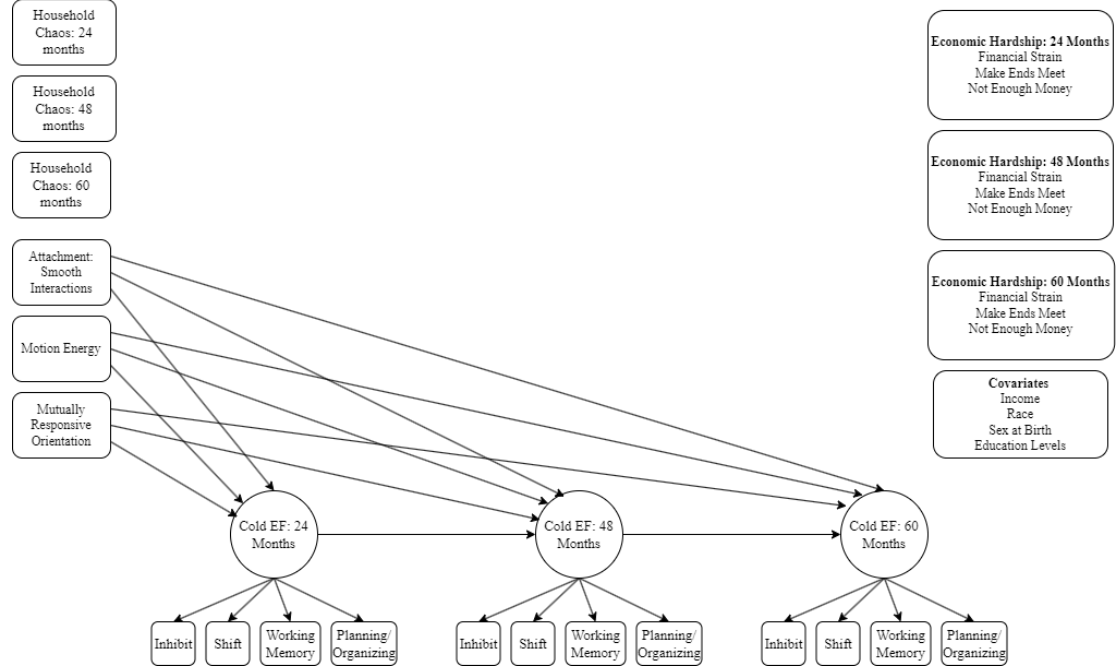
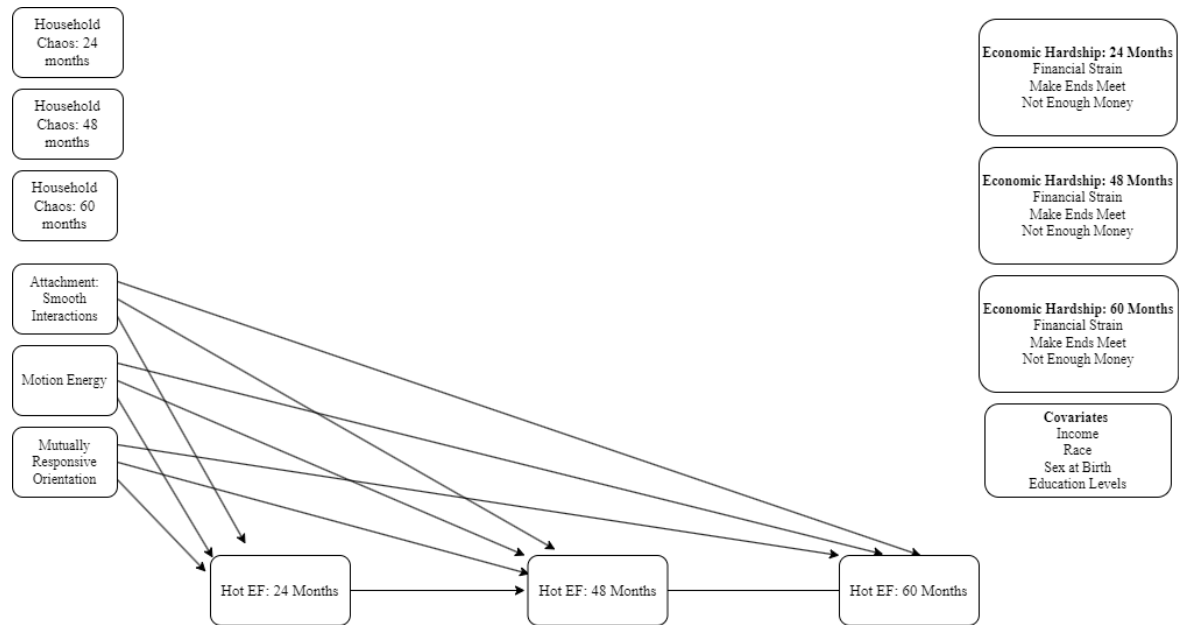


Figure 6

Conceptual Model of Cold EF



Methods

Participants

The data in this analysis are from families participating in a longitudinal birth cohort study in the Midwestern United States ($N = 468$; Table 6). It is designed to examine multi-level predictors of weight trajectories and dietary habits over the first seven years of life (Fiese et al., 2019). Participants were enrolled during their third trimester of pregnancy through outreach at medical centers and prenatal classes within the east-central region of Illinois. Additionally, advertisements were posted on a university-affiliated website. The study excluded those who delivered prematurely (before 37 weeks), infants with conditions that interfered with standard feeding practices (such as phenylketonuria), and infants with a birth weight under 2.5 kilograms—the recruitment period extended from May 2013 through January 2017.

As part of the more extensive study, caregivers completed questionnaires regarding household chaos, child EF behaviors, and parent and child demographics. They also indicated if they would be willing to participate in a home observation component of the study when children were 18 and 24 months of age. Parents willing to be contacted were recruited for the home observation, which included a videotaped mealtime and attachment assessment. Caregivers were compensated \$80 for their participation in the home visit. This study was approved by the University Institutional Review Board.

Table 6
Descriptive Statistics

	N	%	M	SD	Range
Child Sex at Birth					
Male	232	50.5			
Female	227	49.5			
Monthly income					
\$3,000 and under	77	23.8			
\$3,001-\$5,000	91	28.1			
\$5,001 and above	156	48.1			
Parent race/ethnicity					
American Indian/Alaska Native	2	0.5			
White	338	82.2			
Asian	28	6.8			
Black	21	5.1			
Prefer not to say	6	1.5			
Biracial	16	3.9			
Parent education level					
Some high school	2	0.6			
High school graduate	16	4.5			
Some college or technical school	59	16.5			
College graduate	120	33.5			
Post-graduate work	161	45.0			
Inhibit: 24 months (T scores)	304		49.83	10.29	34.00 – 85.00
Shift: 24 months (T scores)	320		48.61	8.27	37.00 – 74.00
Emotional Control: 24 months (T scores)	323		48.73	8.97	35.00 – 79.00
Working Memory: 24 months (T scores)	306		51.82	11.55	36.00 – 82.00
Planning/Organizing: 24 months (T scores)	315		49.59	11.09	32.00 – 78.00
Inhibit: 48 months (T scores)	317		52.37	10.57	36.00 – 91.00
Shift: 48 months (T scores)	323		51.50	9.13	38.00 – 83.00
Emotional Control: 48 months (T scores)	322		52.92	10.97	36.00 – 93.00
Working Memory: 48 months (T scores)	311		53.07	10.80	38.00 – 85.00
Planning/Organizing: 48 months (T scores)	317		52.33	11.50	34.00 – 100.00
Inhibit: 60 months (T scores)	290		52.31	10.58	36.00 – 89.00
Shift: 60 months (T scores)	288		50.92	9.74	38.00 – 84.00
Emotional Control: 60 months (T scores)	288		53.17	11.59	36.00 – 89.00
Working Memory: 60 months (T scores)	286		52.65	11.60	38.00 – 98.00
Planning/Organizing: 60 months (T scores)	292		52.23	11.91	34.00 – 90.00
Household Chaos: 24 months	365		26.86	7.07	13.00 – 48.00
Household Chaos: 48 months	335		28.65	7.19	10.00 – 51.00
Household Chaos: 60 months	301		28.68	7.07	15.00 – 53.00
Smooth Interactions (AQS)	108		5.84	1.21	2.65 – 7.94
Proximity Seeking (AQS)	108		5.59	1.46	1.92 – 8.13
Mutual Responsive Orientation	109		15.79	3.15	8.00 – 20.00
Motion Energy	81		0.11	0.03	0.05 – 0.36

Home Visit Procedures

Caregivers were invited to participate in a 2-hour home observation using a script with detailed information about the visit, and all participating families provided written informed consent. Researchers instructed caregivers to plan their dinnertime meals as they typically would. The trained researchers would arrive 30-45 minutes before the parent-arranged dinnertime to build rapport and set up video equipment. When families were ready to begin dinner, the researchers turned on the video equipment and left the home to prevent bias and avoid influencing behavior during the meal. Once the mealtime ended, the researchers returned to complete observations of parent-child interactions. These mealtime recordings were used to assess parent-child behavioral and motion synchrony.

Measures

Executive Function. EF was assessed using the Behavior Rating Inventory of Executive Function- Preschool Version (BRIEF-P; (Isquith et al., 2005)). This survey assesses multiple components of EF, including inhibition, shifting, emotional control, working memory, and planning/organizing. Parents are asked to complete this questionnaire based on how often each behavior has been a problem in their child's life during the last six months. These items are ranged from 1 (never) to 3 (often). Example questions include: "is easily overwhelmed or overstimulated by typical daily activities," "gets out of control more than playmates," and "talks or plays too loudly." Five subscales (listed above), three broad index scores (Inhibitory Self-Control, Flexibility, and Emergent Metacognition), and one global composition score are also derived from the BRIEF-P. Two validity scales (Inconsistency and Negativity) can also be derived. T-scores were used to account for additional child characteristics. Higher scores on the BRIEF-P indicate worse performance on EF abilities.

Child Attachment Security. Child attachment behavior was assessed with the Attachment Behavior Q-Set version 3.0 (AQS; (van IJzendoorn et al., 2004; Waters, 1995)). The AQS uses Q-methodology to describe a child's organization of secure base behavior and interactions around a caregiver in naturalistic settings. Trained observers sorted 90 behavioral items based on how descriptive they were of the child's behavior according to their detailed observations *after* the family mealtime. During the home visit, the observer took notes and asked the caregivers a series of questions regarding the behaviors outside of mealtime. After the visit, the observer sorted AQS items into three separate piles: most, moderately, and least like the child. Eventually, nine piles were created with ten items. The observer then used a rating scale from 1 (least like the child) to 9 (most like the child). Higher scores represented more attachment in the child-caregiver relationship. In this analysis, two subscales reflecting smoothness in caregiver-child interaction and proximity seeking were created using items from the AQS (Posada et al., 2013). The scales characterize the child's emotional tone, specifically when interacting with the caregiver (e.g., "Child easily becomes angry at caregiver"); trust and readiness to interact with the caregiver (e.g., "Child readily shares with caregiver or lets them hold things if asked"); and behaviors surrounding compliance (e.g., "Child follows caregiver's suggestions readily, even when they are suggestions rather than demands"). Together, the items reflect child behaviors around their caregivers that are defining features of secure base relationships, such as smooth transitions from exploration and proximity and child expectations of caregiver interference, intrusion, or unresponsiveness. Research has shown that when the attachment system may not be activated in naturalistic settings, secure attachment may be best described with items that reflect harmonious caregiver-child interaction (Cadman et al., 2018). Scale items from the AQS have been shown to have adequate internal consistency and are

associated with maternal adult attachment classifications (Kazui et al., 2000; Posada et al., 2013). The AQS has been shown to have ecological, discriminant, predictive, and convergent validity, and findings are consistent across cultural contexts (van IJzendoorn et al., 2004).

Household Chaos. Household chaos and environmental levels were assessed using the Confusion, Hubbub, and Order Scale (CHAOS; (Matheny Jr et al., 1995)). The questionnaire consists of 15 statements surrounding their household environment, and each question is on a 4-point Likert scale, ranging from very much like your home to not at all like your own home. Example questions include, “It’s a real zoo in our home,” “Our home is a good place to relax,” and “First thing in the day, we have a regular routine at home.” CHAOS measures two facets of household chaos. The first facet is routines and organization, and the second is disorganization, confusion, and noise. A single score is obtained by summing the items, with the highest possible score of 60. A higher score indicates a higher level of chaos within the home.

Parent-child Behavioral Synchrony. Parent-child behavioral synchrony was examined using the Mutually Responsive Orientation Scale (MRO; (Aksan et al., 2006; Kochanska, 1997)). MRO is a positive, mutually binding, and cooperative relationship between the parent and the child. Subscales include Coordinated Routines, Harmonious Communication, Mutual Cooperation, and Emotional Ambiance. Coordinated Routines is the extent to which the dyad displays coordinated activities and settles comfortably into routines. Harmonious Communication is the degree to which verbal and nonverbal communication flows smoothly. Mutual Cooperation is the extent to which the dyad effectively resolves conflict and how the partners are open to each other’s influence. Emotional Ambiance is the extent to which the dyad enjoys an emotionally positive atmosphere, indicating joy in each other’s company. Mealtime videos were coded for this analysis.

Three trained coders separately rated each subscale on a 5-point scale ranging from 1 (Very untrue of dyad) to 5 (Very true of dyad). The primary coder was trained with the coding schemes and assigned to code all the videos, serving as a gold standard. Two reliability coders were each randomly assigned to code 50% of the total number of videos. Inter-rater reliability was established for each subscale, with ICC values of .80 for Coordinated Routines, .79 for Harmonious Communication, .79 for Mutual Cooperation, and .78 for Emotional Ambiance, indicating acceptable reliability. An average score for the final scoring was calculated between the primary and reliability coders' scores for each subscale.

Parent-child Motion Synchrony. Parent-child motion synchrony was examined in a Motion Energy Analysis (MEA; (Ramseyer, 2020; Ramseyer & Tschacher, 2011)). MEA is an objective method to determine nonverbal synchrony, which provides an alternative to manual observer ratings. MEA can be automated to continuously monitor the amount of change occurring in pre-defined regions of interest. The prerequisites for MEA are a static camera position, stable light conditions, and digitized film material. Each home visit video was cropped and adjusted to fit the appropriate length for analysis by another HDFS graduate student, Sehyun Ju. This process involved excluding portions of the frame when a participant leaves the table. Detecting changes frame by frame makes quantifying any alterations in the specified regions of interest possible. After inserting each video, the software examines the pixel changes using time series analysis. After completing this process, it provided and calculated an overall synchrony score. Motion energy was calculated by reviewing the frame difference across the dyad.

Perceived Economic Hardship. The Perceived Economic Hardship Questionnaire measures financial strain, inability to make ends meet, and insufficient money for necessities (Barrera et al., 2001). For financial strain, an example question includes, "In the next three

months, how often do you think that you and your family will experience bad times such as poor housing.” For making ends meet, an example question includes, “Think back over the past three months and tell us how much difficulty you had with paying your bills.” For insufficient amount of money, an example question includes, “We had enough money to afford the kind of car we need.” Participants responded to each item on a Likert-type scale, with options ranging from almost never to almost always, no difficulty at all to a great deal of difficulty, and strongly disagree to strongly agree. Scores were calculated by summing responses across items, with higher scores indicating greater perceived economic hardship.

Data Analysis Plan

This study used a comprehensive data analysis strategy that integrated both SPSS and R to delve into the intricacies of the dataset, encompassing Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM). Initially, I utilized SPSS for data cleaning, preparation, and preliminary analyses, ensuring the dataset's readiness for advanced statistical examinations. This included meticulous checks for missing values, outliers, and the distribution normality of the variables under scrutiny. Following this preparatory stage, R, specifically the lavaan package, was leveraged to execute CFA and SEM.

Results

Preliminary Analyses

Missing data analysis was conducted using Little's multivariate test of Missing Completely at Random. The results indicated that our data could be assumed to be missing completely at random, as the test did not reach statistical significance (24 months: $\chi^2(48) = 56.435$, $p = .189$; 48 months: ($\chi^2(28) = 37.114$, $p = .116$); 60 months: ($\chi^2(25) = 31.456$, $p = .174$)). This suggests that the missing data mechanism does not depend systematically on the observed data. Correlations were conducted with all model variables, which include parenting quality variables, household chaos, perceived economic hardship, and EF (see Tables 7 to 10). All significant pathways are discussed below and in Figures 7 (e.g., cold EF) and 8 (e.g., hot EF).

Confirmatory Factor Analysis (CFA)

The structure of cold EF was examined in a CFA utilizing a sample of 99 observations from an initial total of 110. The analysis was implemented through maximum likelihood estimation and converged after 87 iterations. Significant factor loadings were observed, indicating robust associations between the latent factor and its indicators: inhibition (standardized loading = 0.979), shifting (standardized loading = 0.574), working memory (standardized loading = 0.792), and planning and organization (standardized loading = 0.726). A notable covariance between working memory and planning and organization (Std.lv = 31.322, $p = 0.003$) highlighted a moderate correlation between these dimensions of executive function and was added to the model. The model fit indices presented a perfect fit to the data, with CFI and TLI (CFI = 1.000, TLI = 1.016), RMSEA at 0.000, and SRMR at 0.008, supporting the model's structural validity. The Chi-square test further confirmed the model's adequacy with a test

statistic of $\chi^2(1) = 0.456$, $p = 0.500$, demonstrating a good fit between the proposed model and the observed data at 24 months.

In a Confirmatory Factor Analysis (CFA) at 48 months involving a sample of 96 children, the model displayed exceptional fit to the observed data, as indicated by a chi-square statistic of $\chi^2(2) = 0.693$, $p = 0.707$, and optimal fit indices: CFI = 1.000, TLI = 1.020, RMSEA = 0.000, and SRMR = 0.009. The analysis utilized maximum likelihood estimation and successfully converged after 62 iterations. The parameter estimates revealed significant factor loadings for all observed variables on the latent executive function factor, showcasing standardized loadings of 0.821 for inhibition, 0.526 for shifting, 0.921 for working memory, and 0.859 for planning and organization. These findings suggest that these measures effectively indicate executive function at this developmental stage.

Lastly, at the 60-month assessment, the model, executed through maximum likelihood estimation, successfully converged after 60 iterations, analyzing data from 90 participants out of a total sample of 110. Significant factor loadings were observed across all measured variables, indicating a robust association with the executive function construct: inhibition (standardized loading = 0.852), shifting (standardized loading = 0.650), working memory (standardized loading = 0.915), and planning and organization (standardized loading = 0.855). The model demonstrated excellent fit to the data, as evidenced by a chi-square test yielding a statistic of $\chi^2(2) = 0.636$, $p = 0.727$, alongside ideal fit indices: CFI = 1.000, TLI = 1.020, RMSEA = 0.000, and SRMR = 0.008.

A CFA with all time points in one model was also conducted (Appendix C). The analysis, implemented through maximum likelihood estimation with the NLMINB optimization method, converged after 109 iterations with 27 model parameters. Significant factor loadings across all

three time points indicated robust associations between the latent factors and their indicators. For instance, at 24 months, the standardized loadings were as follows: inhibition (Std.all = 0.860), shifting (Std.all = 0.565), working memory (Std.all = 0.975), and planning and organization (Std.all = 0.915). Similar patterns were observed at 48 and 60 months, underscoring stable factor structures. Notable covariances between the latent factors at each time point were also significant, for example, between cold EF at 24 and 48 months (Std.lv = 0.672, $p = 0.002$) and cold EF at 48 and 60 months (Std.lv = 0.747, $p = 0.001$), indicating moderate to strong correlations between these dimensions of executive function across time. The model fit indices presented a moderate fit to the data, with a CFI of 0.881 and a TLI of 0.846. The RMSEA was 0.149 with a 90% confidence interval ranging from 0.105 to 0.191, and the SRMR was 0.085, which suggested a good fit. The Chi-square test for the model indicated a significant discrepancy between the hypothesized model and the observed data ($\chi^2(51) = 100.541$, $p < 0.001$). However, results yielded a less fitting model with emotional control ($\chi^2(86) = 298.850$, $p < 0.001$, and the following fit indices: CFI = 0.700, TLI = 0.755, RMSEA = 0.152, and SRMR = 0.186); therefore, it is appropriate to continue analyses with separate models regarding hot and cold EF.

SEM: Cold EF

SEM was conducted using the lavaan package 0.6.16 in R version 4.3.1, employing Full Information Maximum Likelihood (FIML) to handle missing data. The model assessed the latent constructs of cold EF across three-time points, denoting measurements at 24, 48, and 60 months, respectively. The latent constructs had standardized loadings ranging from 0.574 to 0.975, all significant at the $p < 0.001$ level. Cold EF at 24 months showed a particularly strong relationship with inhibition (standardized loading = 0.975), suggesting that this task was a robust indicator of EF at 24 months. The chi-square test of model fit was significant ($\chi^2 = 244.416$, $df = 159$, $p <$

0.001), indicating that the model did not fit the data perfectly. However, additional fit indices were considered as the chi-square test is sensitive to sample size. The CFI was 0.848, and the TLI was 0.811, suggesting an acceptable fit to the data. The RMSEA was 0.094, with a 90% confidence interval ranging from 0.070 to 0.117, indicating a mediocre fit. The SRMR was 0.077, falling within the acceptable range of less than 0.08.

Cold EF

In the structural model, previous time points significantly predicted later executive function, with cold EF at 24 months predicting cold EF at 48 months ($B = 0.550$, $SE = 0.104$, $p = .001$, $Std.all = 0.550$), and cold EF at 48 months significantly predicting cold EF at 60 months ($B = 0.725$, $SE = 0.165$, $p < .001$, $Std.all = 0.725$). The model also revealed a significant association between smooth interactions and cold EF at 60 months ($B = -1.415$, $SE = 0.527$, $p = .007$, $Std.all = -0.228$), indicating that higher smoothness in parenting quality was associated with better executive function scores at 60 months. Parent-child behavioral synchrony was also shown to be related to later cold EF at 60 months ($B = 44.465$, $SE = 16.426$, $p = .007$, $Std.all = 0.218$), which indicated an importance of behavioral synchrony during a mealtime.

Household Chaos

Additionally, chaos at 24 months showed a significant positive relationship with cold EF at 24 months ($B = 0.65$, $SE = 0.016$, $p < 0.001$, $Std.all = 0.492$), suggesting that the chaos at home at 24 months is associated with a more problematic level of cold EF. The chaos at home at 60 months showed a significant positive relationship with cold EF at 60 months ($B = 0.616$, $SE = 0.154$, $p < 0.001$, $Std.all = 0.569$), indicating that a chaotic home environment at this time is associated with lower levels of executive function.

Financial Strain

Notably, financial strain in the home environment at 48 months was significantly negatively associated with cold EF at 60 months ($B = -22.351$, $SE = 9.442$, $p = 0.018$, $Std.all = -0.189$). Making ends meet in the home environment at 48 months significantly positively affected cold EF at 60 months ($B = 1.668$, $SE = 0.822$, $p = 0.042$, $Std.all = 0.206$). These results indicate the nuanced role of financial conditions on cold EF outcomes.

SEM: Hot EF

SEM was conducted using the lavaan package 0.6.16 in R version 4.3.1, employing FIML to handle missing data. The model achieved convergence after 63 iterations, indicating an adequate fit between the proposed model and the observed data. The model included 23 parameters and was assessed with 84 observations, encompassing a broad representation of the sample population. The Chi-square test of model fit produced a test statistic of 7.083 with 4 degrees of freedom, resulting in a p-value of 0.132. The CFI and TLI further supported the model's adequacy, with values of 0.971 and 0.848, respectively. The robust versions of these indices, which account for potential non-normality in the data, also indicated a good fit (RCFI = 0.976, RTLI = 0.872). The RMSEA stood at 0.096, with a 90% confidence interval ranging from 0.000 to 0.209. This index, coupled with its p-values for testing close fit ($RMSEA \leq 0.050$; $p = 0.210$) and not poor fit ($RMSEA \geq 0.080$; $p = 0.665$), suggests that the model's approximation of the data is reasonable. The Standardized Root Mean Square Residual (SRMR) value of 0.038 further corroborates the model's good fit.

Hot EF at 24 months

For hot EF at 24 months, the chaos score was a significant predictor ($B = 0.342$, $SE = 0.121$, $p = 0.005$, $std.all = 0.298$), indicating that higher levels of chaos were associated with

worse emotional control at this age. Smooth Interactions with the caregiver were related to better EF at 24 months ($B = -1.395$, $SE = 0.708$, $p = 0.04$, $std.all = -0.208$).

Hot EF at 48 months

The model revealed that both the chaos score at 24 months ($B = -0.691$, $SE = 0.226$, $p = 0.002$, $Std.all = -0.418$) and the chaos score at 48 months ($B = 0.693$, $SE = 0.224$, $p = 0.002$, $Std.all = 0.420$) significantly predicted emotional control in different ways. Hot EF at 24 months significantly predicted later hot EF at 48 months ($B = 0.813$, $SE = 0.141$, $p < 0.001$, $Std.all = 0.563$).

Hot EF at 60 months

For hot EF at 60 months, the model revealed that both the chaos score at 48 months ($B = -0.650$, $SE = 0.195$, $p < 0.001$, $Std.all = -0.438$) and score at 60 months emerged as a strong predictor ($B = 1.047$, $SE = 0.200$, $p < 0.001$, $Std.all = 0.659$). Additionally, hot EF at 48 months ($B = 0.539$, $SE = 0.072$, $p < 0.001$, $Std.all = 0.599$) strongly predicted hot EF at 60 months.

Table 7

Correlations among model variables with 24-month EF

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1 AQS Smooth Interaction	----																		
2 AQS Proximity to Mother	.10	----																	
3 Mutually Responsive Orientation	.12	.23*	----																
4 Month 24: CHAOS	.00	.00	-.21*	----															
5 Month 48: CHAOS	-.03	-.05	-.017	.61***	----														
6 Month 60: CHAOS	.08	-.14	-.018	.60***	.76***	----													
7 Month 24: PEH financial strain	.08	-.11	-.07	.25***	.09	.06	----												
8 Month 24: PEH make ends meet	-.01	.09	-.15	.28***	.22***	.19**	.45***	----											
9 Month 24: PEH not enough money	.02	.07	-.018	.30***	.23***	.14*	.45***	.68***	----										
10 Month 48: PEH financial strain	.06	.03	.04	.20***	.13*	.05	.42***	.19***	.31***	----									
11 Month 48: PEH make ends meet	.04	.09	-.11	.25***	.26***	.16**	.29***	.64***	.55***	.36***	----								
12 Month 48: PEH not enough money	-.01	0.18	-.09	.21***	.25***	.14*	.33***	.53***	.61***	.38***	.66***	----							
13 Month 60: PEH financial strain	.07	-0.19	-.24*	.07	.20***	.05	.26***	.12*	.27***	.37***	.32***	.34***	----						
14 Month 60: PEH make ends meet	.17	.14	-.13	.24***	.32***	.21***	.25***	.54***	.48***	.19**	.71***	.58***	.37***	----					
15 Month 60: PEH not enough money	.10	.08	-.25*	.23***	.36***	.26***	.21***	.45***	.60***	.24***	.60***	.65***	.41***	.65***	----				
16 Month 24: Inhibit	-.17	-.02	.01	.42***	.39***	.41***	.16	.09	.06	-.04	.05	.02	.04	-.12	.05	----			
17 Month 24: Shift	-.15	.09	-.02	0.18	.06	.02	.11	.08	.09	-.09	.09	-.04	.12	.04	.08	.59***	----		
18 Month 24: Emotional Control	-.16	-.05	-.06	.33**	.26*	.33**	-.03	.10	.06	.04	.10	.02	-.02	-.03	.17	.66***	.45***	----	
19 Month 24: Working Memory	.00	-.05	-.12	.38***	.37***	.39***	.12	-.07	-.04	-.07	.04	-.03	.12	-.07	.10	.77***	.45***	.54***	----
20 Month 24: Planning and Organizing	-.04	-.16	-0.19	.36***	.34**	.36**	.14	.13	.08	.02	.23*	.12	.09	.04	0.22	.71***	.40***	.57***	.82***

Note. *p < .05, **p < .01, ***p < .001.

Table 8*Correlations among model variables with 48 month EF*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1 AQS Smooth Interaction	----																		
2 AQS Proximity to Mother	.10	----																	
3 Mutually Responsive Orientation	.12	.23*	----																
4 Month 24: CHAOS	.00	.00	-.21*	----															
5 Month 48: CHAOS	-.03	-.05	-0.17	.61***	----														
6 Month 60: CHAOS	.08	-.14	-0.18	.60***	.76***	----													
7 Month 24: PEH financial strain	.08	-.11	-.07	.25***	.09	.06	----												
8 Month 24: PEH make ends meet	-.01	.09	-.15	.28***	.22***	.19**	.45***	----											
9 Month 24: PEH not enough money	.02	.07	-.18†	.30***	.23***	.14*	.45***	.68***	----										
10 Month 48: PEH financial strain	.06	.03	.04	.20***	.13*	.05	.42***	.19***	.31***	----									
11 Month 48: PEH make ends meet	.04	.09	-.11	.25***	.26***	.16**	.29***	.64***	.55***	.36***	----								
12 Month 48: PEH not enough money	-.01	0.18	-.09	.21***	.25***	.14*	.33***	.53***	.61***	.38***	.66***	----							
13 Month 60: PEH financial strain	.07	-0.19	-.24*	.07	.20***	.05	.26***	.12*	.27***	.37***	.32***	.34***	----						
14 Month 60: PEH make ends meet	.17	.14	-.13	.24***	.32***	.21***	.25***	.54***	.48***	.19**	.71***	.58***	.37***	----					
15 Month 60: PEH not enough money	.10	.08	-.25*	.23***	.36***	.26***	.21***	.45***	.60***	.24***	.60***	.65***	.41***	.65***	----				
16 Month 48: Inhibit	-.12	-.23*	-.14	.23*	.27*	.38***	.09	.06	.17	.01	.07	.07	.17	-.17	.12	----			
17 Month 48: Shift	.01	.00	.03	.07	.14	.08	.13	-.09	.04	-.12	-.09	-.08	.08	-.12	.06	.45***	----		
18 Month 48: Emotional Control	-.05	-.13	.00	.03	0.2	.26*	.04	-.13	.02	-.08	-.07	-.11	.07	-.14	.05	.58***	.66***	----	
19 Month 48: Working Memory	.05	-.08	-.06	.30**	.30**	.34**	.17	.12	.18	-.05	.07	.06	.15	-.11	.17	.76***	.46***	.46***	----
20 Month 48: Planning and Organizing	.02	-.12	-.14	.31**	.38***	.42***	.17	-.01	-.02	.11	-.04	-.01	.17	-.12	.08	.69***	.48***	.54***	.79***

*p < .05, **p < .01, ***p < .001.

Table 9*Correlations among model variables with 60-month EF*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1 AQS Smooth Interaction	----																		
2 AQS Proximity to Mother	.10	----																	
3 Mutually Responsive Orientation	.12	.23*	----																
4 Month 24: CHAOS	.00	.00	-.21*	----															
5 Month 48: CHAOS	-.03	-.05	-0.17	.61***	----														
6 Month 60: CHAOS	.08	-.14	-0.18	.60***	.76***	----													
7 Month 24: PEH financial strain	.08	-.11	-.07	.25***	.09	.06	----												
8 Month 24: PEH make ends meet	-.01	.09	-.15	.28***	.22***	.19**	.45***	----											
9 Month 24: PEH not enough money	.02	.07	-0.18	.30***	.23***	.14*	.45***	.68***	----										
10 Month 48: PEH financial strain	.06	.03	.04	.20***	.13*	.05	.42***	.19***	.31***	----									
11 Month 48: PEH make ends meet	.04	.09	-.11	.25***	.26***	.16**	.29***	.64***	.55***	.36***	----								
12 Month 48: PEH not enough money	-.01	0.18	-.09	.21***	.25***	.14*	.33***	.53***	.61***	.38***	.66***	----							
13 Month 60: PEH financial strain	.07	-0.19	-.24*	.07	.20***	.05	.26***	.12*	.27***	.37***	.32***	.34***	----						
14 Month 60: PEH make ends meet	.17	.14	-.13	.24***	.32***	.21***	.25***	.54***	.48***	.19**	.71***	.58***	.37***	----					
15 Month 60: PEH not enough money	.10	.08	-.25*	.23***	.36***	.26***	.21***	.45***	.60***	.24***	.60***	.65***	.41***	.65***	----				
16 Month 60: Inhibit	-.10	-.29**	-.12	0.22	.33**	.49***	-.03	-.10	.02	-.07	-.03	-.10	.11	-.04	.12	----			
17 Month 60: Shift	-.06	-.07	-.04	.16	0.19	.29**	.04	.06	.10	.02	.00	-.06	.13	.06	0.19	.55***	----		
18 Month 60: Emotional Control	.01	-.17	-.13	.18	0.19	.47***	.03	-.03	.11	.06	-.01	-.03	.12	-.03	.14	.70***	.59***	----	
19 Month 60: Working Memory	-.05	-0.21	-.08	.22*	.29**	.37***	.07	-.05	.03	-.06	-.04	-.08	0.2	-.02	.23*	.80***	.58***	.50***	----
20 Month 60: Planning and Organizing	-.07	-.07	-.13	.27*	.27*	.37***	.07	-.02	.12	-.11	.12	.04	.12	.01	.31**	.73***	.57***	.57***	.79***

*p < .05, **p < .01, ***p < .001.

Table 10

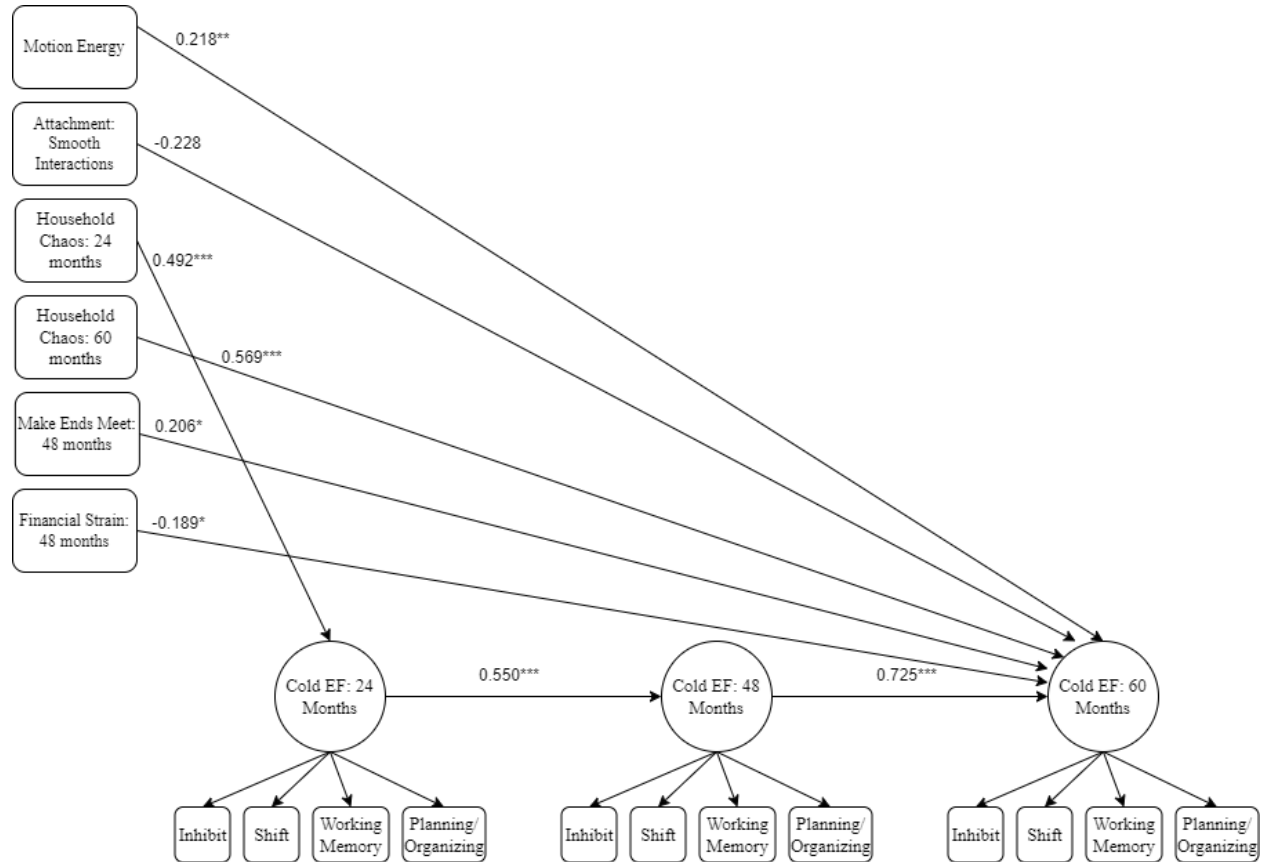
Correlations among model variables with EF and additional variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 Motion Energy	----															
2 Month 24: Inhibit	.05	----														
3 Month 24: Shift	.08	.59***	----													
4 Month 24: Emotional Control	.01	.66***	.45***	----												
5 Month 24: Working Memory	-.02	.77***	.45***	.54***	----											
6 Month 24: Planning and Organizing	-.08	.71***	.40***	.57***	.82***	----										
7 Month 48: Inhibit	.08	.54***	.17	.37***	.36**	.45***	----									
8 Month 48: Shift	.17	.29**	.35**	.23*	.23*	.16	.45***	----								
9 Month 48: Emotional Control	-.07	.35**	.17	.46***	.23*	0.21	.58***	.66***	----							
10 Month 48: Working Memory	.04	.52***	.16	.28**	.50***	.56***	.76***	.46***	.46***	----						
11 Month 48: Planning and Organizing	.00	.39***	.08	.24*	.46***	.51***	.69***	.48***	.54***	.79***	----					
12 Month 60: Inhibit	.09	.45***	.10	.38***	.36**	.43***	.71***	.31**	.46***	.59***	.54***	----				
13 Month 60: Shift	.11	.37**	.36**	.23*	.20	.18	.44***	.65***	.50***	.44***	.46***	.55***	----			
14 Month 60: Emotional Control	-.01	.33**	.11	.46***	.24*	0.21	.63***	.42***	.66***	.43***	.52***	.70***	.59***	----		
15 Month 60: Working Memory	.10	.39***	.08	0.19	.42***	.35**	.59***	.30**	.35**	.64***	.60***	.80***	.58***	.50***	----	
16 Month 60: Planning and Organizing	.19	.51***	.25*	.42***	.50***	.57***	.60***	.34**	.38***	.64***	.63***	.73***	.57***	.57***	.79***	----

*p < .05, **p < .01, ***p < .001.

Figure 7

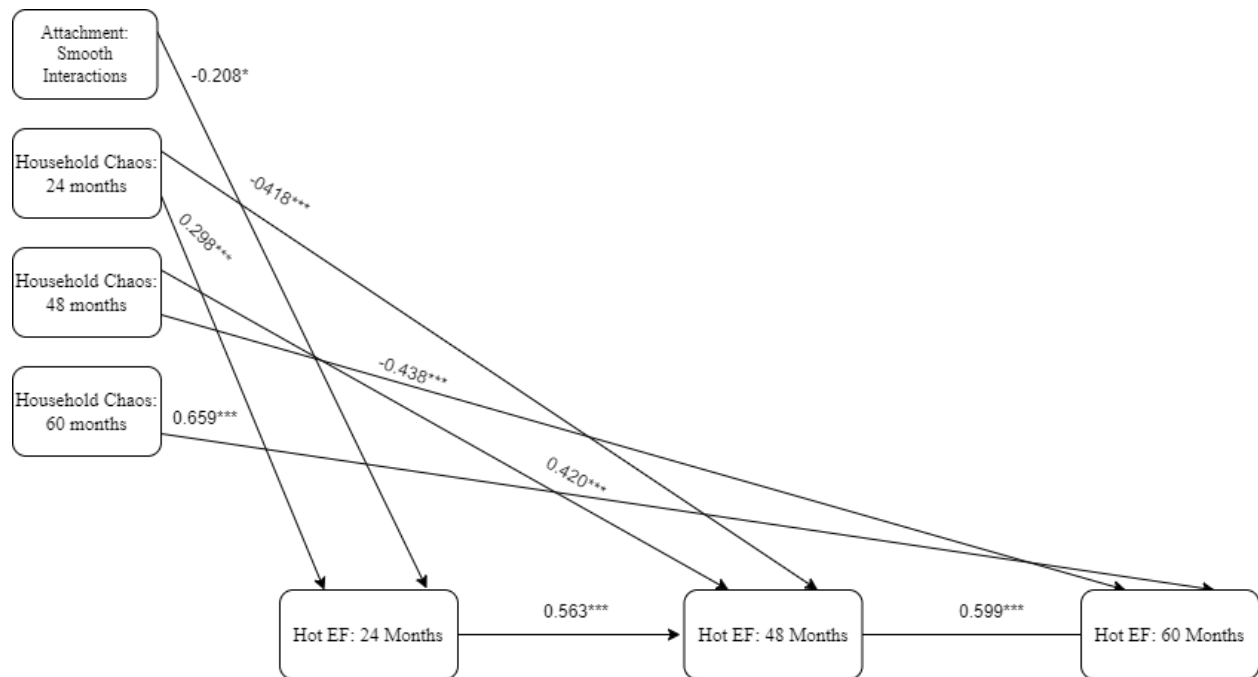
SEM model of cold EF with all variables



Note. * $p < .05$. ** $p < .01$. *** $p < .001$. The results above contain standardized values.

Figure 8

SEM model of hot EF with all variables



Note. * $p < .05$. ** $p < .01$. *** $p < .001$. The results above contain standardized values.

Discussion

The results from three critical early childhood periods—24, 48, and 60 months—reveal the influence of environmental stability and parenting quality on cognitive development. Notably, factors such as household chaos and financial strain have been identified as significant predictors, with their impacts continuing into the later stages of cold EF. Similar to the last paper, a stable environment may give children more space to learn and expand their cold or hot EF abilities. Another critical aspect highlighted in the study is the role of parenting quality, specifically the impact of smooth interactions between the caregiver and the child, which was shown to influence cold and hot EF at different time points. These results may indicate that smooth interaction with the parent may assist with early and later development, which may differ depending on the skill (e.g., regulating emotions vs organizing their toys). This suggests that smoother caregiver-child interactions may potentially buffer against other environmental stressors' negative impacts. Interestingly, motion energy also shows a strong positive effect on cold EF, pointing towards the possible benefits of synchronous engagements between a mother and child at a young age. Policymakers and practitioners might consider developing community-based programs that support families in creating nurturing and structured home environments. Such initiatives could involve providing parents with resources and training to improve household management and reduce stressors contributing to chaos. Additionally, the positive predictive value of earlier cold and hot EF on subsequent EF indicates developmental continuity at the group level. This suggests that interventions improving cold and hot EF at an earlier stage might yield benefits extending into later childhood.

Given these results, future research should delve deeper into these factors' longitudinal impacts and focus on how specific elements of financial strain can be mitigated to support

cognitive development. Moreover, studies could explore the interactive effects of synchrony (as indicated by motion energy) and parenting quality on EF outcomes. Understanding these relationships could lead to more comprehensive intervention programs that address socioeconomic and lifestyle factors to enhance cognitive development across the critical years of childhood development. These interpretations bring out the complex relationships of various environmental, socioeconomic, and interpersonal factors in shaping executive functions in young children, pointing towards multifaceted strategies for improving EF within multiple generations.

Chapter 4: Integrated Discussion

This longitudinal examination of cold and hot EF over time provided insights into how early family residency green space indicators, household chaos, synchrony, attachment, motion energy, and demographic factors influence EF during varying developmental periods. Exploring these ideas and topics allows us to further understand how executive function could be altered in early childhood. Specifically, in paper 1, we found that some early family residency green space indicators and household environments can influence cold or hot EF over time. For paper 2, we found that parent-child interactions and household environment may also influence cold and hot EF over time. However, we also found results that we would not expect and do not align with the literature involving several of these topics, which will need future research to shed light on the nature of these relations.

The CFAs conducted at 24, 48, and 60 months provide valuable insights into the development of executive functions during early childhood. The findings highlight the necessity of conceptualizing EF in terms of cold EF and hot EF. The CFAs revealed that a model excluding emotional control for cold EF demonstrated a better fit. The longitudinal CFA showed a strong fit to the data, with latent factors exhibiting significant correlations over time. The robust and significant loadings of observed variables on the latent EF factor at each time point underscore the validity of the measured constructs, and the consistently high fit indices confirm the stability and reliability of the EF construct across early developmental stages.

Paper 1

Regarding cold EF, family residency green space factors (before two years of age), household environment, economic hardship, demographic characteristics, and cold EF were tested to understand how different forms of access may influence cold EF over time. When the

children were 24 months, we saw that living near a park and higher levels of household chaos contributed to worse cold EF skills at 24 months. While the results with household chaos were hypothesized, living near a park was not expected to present these results. Living near a park may provide access to outdoor play, but we do not know if families use these facilities. In addition, parks may assist developmental periods differently. Having a park throughout childhood, instead of just before two years of age, could have a more pronounced effect on cold EF. Furthermore, cold EF at 24 months was also shown to differ by race (African American, Asian, and White), highlighting that cold EF may vary by demographic factors. When the children were 48 months, education levels and sex at birth were also related to cold EF, indicating the continued differences based on education and sex at birth.

Beyond demographic factors, green space variables were also shown to be associated with child EF. Early exposure to outdoor storage, sand, and trees within the vicinity of households was associated with better cold EF at 48 months. However, a garden was shown to be related to worse cold EF abilities, which does not align with the literature. We also found that higher levels of household chaos at 24 months and lower levels at 48 months were related to better cold EF skills at 48 months. The effects of household chaos become increasingly prevalent as children grow older, with significant impacts becoming more apparent over time. These results highlight a dynamic process that may be occurring. Household chaos in real time may hinder or limit cold EF abilities due to attention shifting and lack of routines. However, if a child has social support, then the levels of chaos may be mitigated and could potentially build resilience (Zhao et al., 2023). While this was not a focus of the present study, future studies that examine factors that might mitigate these associations or shed light on differential associations will help highlight more nuanced explanations.

Continuing with Paper 1 and cold EF, when the children were 60 months, higher household chaos at 48 months was related to worse cold EF skills, which was different from the relationship between household chaos at 24 months and cold EF at 48 months. Race was also an important factor when examining cold EF at 60 months. Perceived economic strain at 24 months was negatively associated with cold EF difficulties at 60 months, indicating that difficulty making money at 24 months may be related to better cold executive functioning outcomes. While these results were unexpected, they highlight the importance of early life and how malleable it is. Children may be affected by the household environment and financial strain early in life; however, other factors may allow this hardship to assist with cold EF at five years old. Results of household chaos also highlighted how cold EF may influence the household environment. Worse abilities in cold EF at 24 months and more difficulty in making ends meet at 48 months were related to higher household chaos at 48 months. These results indicate complex relationships between the early environment and EF.

Early greenspace predictors were also associated with household chaos at 60 months, including greater exposure to greenness and the presence of sand within the family residence, as well as better cold EF at 48 months. In addition, making ends meet at 48 months and financial strain at 60 months were negatively related, indicating that hardships might be related to lower chaos levels. Also, cold EF and household chaos demonstrated a strong positive continuity effect throughout all times, suggesting a group order stability of cold EF and household chaos over this period.

Analyses with hot EF resulted in different environmental and demographic factors impacting EF over time. Similar to the findings with cold EF, higher levels of chaos at each matching time point were related to worse EF abilities. Higher levels of chaos at 24 months

resulted in better hot EF abilities at 48 months, and higher chaos at 48 months led to better hot EF abilities at 60 months. These similar results highlight that while household chaos may hinder EF abilities simultaneously, there may be a different relationship between past chaos and future EF development. In addition, two family residency green space indicators were related to hot EF. Living near a farm was linked to better hot EF abilities at 60 months, and having a deck or outdoor sitting area was related to better hot EF skills at 48 months.

Furthermore, demographic factors (e.g., sex at birth and varying levels of education) were related to hot EF and household chaos, highlighting the importance of investigating different family types, races, genders, and socioeconomic statuses. We also found that financial strain at 24 months was related to worse chaos at 24 months, hot EF at 48 months, and hot EF at 60 months. Higher levels of difficulty making ends meet at 48 months were also related to higher levels of chaos simultaneously. Interestingly, financial strain at 60 months was linked to lower chaos levels at 60 months. Similarly, hot EF and household chaos demonstrated a strong positive continuity effect throughout all time points.

These findings point to a broader concept crucial for families: access. This encompasses access to green and outdoor spaces, improved socioeconomic status, and more stable, less chaotic home environments. These elements are consistent with Bronfenbrenner's ecological systems theory, which posits that a child's development is influenced by their various environmental systems. The microsystem, which includes direct environments such as home and school, significantly impacts early development. Access to green spaces, for example, encourages physical activity and reduces mental fatigue and stress, promoting better emotional regulation and cognitive abilities (Kaplan & Kaplan, 1989). Access to green and outdoor space, interactive items and locations (e.g., sand, outside storage, communal area), and living near more

outdoor opportunities may provide additional resources for a child to develop and learn from the natural environment. These spaces could have implications to assist with increased physical activity, more nature exposure, and dietary influences. Specifically, with hot EF, living near a farm and having an outdoor sitting area early in life are related to better hot EF at five years old. An outdoor sitting area may provide more opportunities to play outside and be exposed to more natural light, increased social interaction (e.g., places to gather), quality family time, sensory development, and exploration. Living near a farm may also provide these opportunities with a focus on community. Farming communities can provide early learning and routine responsibilities, which could impact how and when children develop particular EF abilities. Farm life often also involves strong community ties and collective activities, fostering social support and collaboration (Furness et al., 2022). Moreover, socioeconomic status is closely tied to educational opportunities and resources available to children, which has been shown to affect cognitive development and executive functioning skills (Bradley & Corwyn, 2002). Less chaotic home environments provide a stable setting for consistent learning and emotional growth, supporting cold and hot skills, which are critical for handling stress and making informed decisions (Evans & Kim, 2013). Over time, each system or form of access may contribute cumulatively to a child's development, underscoring the importance of holistic approaches in fostering an environment conducive to healthy growth and development.

Implications for Policy

The findings of this study have several policy implications that could help enhance the development of executive functioning in children. EFs developed in early childhood predict a wide array of life outcomes, including academic achievement, occupational success, health behaviors, and social relationships (Moffitt et al., 2011). For instance, enhanced EF in early

years, fostered by stable and enriched environments, can lead to better problem-solving skills and greater academic resilience during schooling, which correlates with higher educational attainment and more stable employment in adulthood (Diamond, 2013). Conversely, children experiencing high levels of household chaos and economic hardship without adequate support may face ongoing challenges that affect their educational and social trajectories, potentially leading to increased vulnerability to mental health issues and socioeconomic disadvantages (Evans & Kim, 2013). Given the positive impact of access to green and outdoor spaces on EF, urban planning policies should prioritize integrating accessible, high-quality green spaces within residential areas. Policymakers should also consider the benefits of designing family-friendly parks that encourage physical activity and social interactions, which are known to support cognitive development and emotional well-being (Izenstark & Ebata, 2022; Taylor & Kuo, 2006).

Furthermore, the influence of socioeconomic factors highlights the need for policies that address economic disparities, such as providing greater educational and developmental resources in underserved communities. These could include after-school programs and community centers that offer structured activities and support services, which have been shown to mitigate the effects of household chaos on cognitive outcomes (Evans & Kim, 2013). Additionally, given the complex interplay between demographic factors and EF, diversity-informed policies that tailor educational and health interventions to different communities' cultural and demographic contexts are crucial. Implementing these changes could improve childhood developmental outcomes and contribute to long-term societal benefits by fostering a more equitable distribution of cognitive and emotional resilience skills across populations (Bradley & Corwyn, 2002). By investing in early childhood environments that promote healthy EF development, societies can cultivate a

population that is more capable of achieving their goals and better equipped to contribute positively to the community.

Paper 2

While modeling was altered due to sample size and statistical approach, similar results were found regarding factors that may influence hot and cold EF over time. At 24 months, higher household chaos was related to more problematic EF abilities. This aligns with the literature indicating that chaotic environments can disrupt early cognitive processes by overwhelming children's limited coping capacities (Vernon-Feagans et al., 2016). In addition, several factors were related to worse cold EF abilities at 60 months, including difficulty making ends meet at 48 months and higher levels of household chaos at 60 months. These findings suggest prolonged economic hardship and environmental instability may negatively affect children's cognitive development. Moreover, a few factors were related to better cold EF at 60 months, including higher levels of smooth interactions at 18-24 months, motion synchrony, and higher levels of financial strain at 48 months. The association with smooth interactions and motion synchrony could reflect the benefits of early responsive caregiving and coordinated physical activities, which are known to support the development of attentional control and problem-solving skills (Feldman, 2012). Surprisingly, higher financial strain at 48 months associated with better cold EF at 60 months might suggest that children develop adaptive coping mechanisms in response to challenges, which can enhance resilience and executive functioning. This counterintuitive result warrants further investigation to understand if specific compensatory behaviors or environmental factors, such as increased community support or effective parenting strategies during times of strain, play a role.

For hot EF, higher levels of smooth interactions and lower levels of chaos were associated with better emotional control at 24 months. This aligns with research suggesting that stable and responsive environments are crucial for developing self-regulation in young children, as they provide the necessary support for learning how to manage emotions effectively. At 48 months, a pattern similar to the findings from the first paper was observed. Higher levels of chaos at 48 months were related to worse hot EF abilities. This could be explained by the disruption that high-chaos environments cause to children's daily routines and stress levels, potentially overwhelming their still-developing regulatory capacities (Evans & Wachs, 2010). However, an intriguing pattern emerged where higher levels of chaos at 24 months were associated with better hot EF at 48 months. This could indicate a form of resilience or adaptive response, where early exposure to moderate stressors teaches children coping mechanisms that enhance their ability to regulate emotions later in life, a concept supported by theories of stress inoculation (Seery, 2011). These results remained consistent for emotional control at 60 months, suggesting that while concurrent high chaos relates to poorer emotional function, earlier chaos might foster adaptive skills that benefit emotional regulation as the child matures.

Beyond household chaos and economic hardship, various contextual factors significantly impact children's cognitive and emotional development. Parental education levels are crucial, as more educated parents often provide supportive environments, engaging in activities that promote cognitive growth (Davis-Kean et al., 2021; Kalil & Ryan, 2020). Interventions should educate parents about effective child-rearing practices and the importance of a stable, nurturing home. In addition, cultural practices also shape parenting styles and children's experiences, influencing cold and hot EF (Roos et al., 2017). Interventions must be culturally sensitive, recognizing and respecting diverse practices while promoting supportive environments. Access

to community resources like healthcare, education, recreational facilities, and social services is also vital. Resource-rich communities offer structured play, social interaction, and educational enrichment, which are essential for developing cold and hot EF. Policymakers and community planners should prioritize creating and maintaining accessible resources to support families. These findings highlight the importance of structured, supportive home environments and responsive caregiving for parents and educators. Predictable routines help children feel secure, aiding cognitive and emotional regulation, while responsive caregiving fosters secure attachments and healthy development. Parents should establish routines, minimize chaos, and engage positively with their children. Educators can support this by providing guidance, resources, and workshops on effective parenting strategies and creating nurturing classroom environments. Integrating these insights into broader strategies requires collaboration across healthcare, education, and social services, creating comprehensive support systems for families. By addressing diverse contextual factors, researchers can develop effective, holistic interventions that promote resilience and optimal development, ensuring all children, regardless of background, can thrive and reach their full potential.

Limitations

While the findings are novel, the studies are not without limitations. For both studies, most participants were white and had higher socioeconomic status, education, and income. Therefore, the findings are not generalizable, and diverse and varied family contexts should be examined in the future. Regarding green spaces, it can change over time due to seasonal variations, development, or environmental degradation. Data collected at one point might not represent space at another time, affecting longitudinal studies. However, since this study wanted to examine early family residency green space factors, we were limited to pictures before age

two and what was available on Google Earth. This study also does not fully capture how, when, and why families use their outdoor spaces, which is a limitation. Access to family residency green space needs to incorporate multiple time points, use of the area from the family's perspective, and more advanced mapping to understand this effect in future research.

Chapter 5: Integrated Conclusion and Implications for Practice

The results have important implications for early childhood education and intervention strategies. They underscore the necessity of supporting the development of EF from a young age, as these cognitive abilities play a crucial role in academic achievement, social development, and adaptive behavior. This might include several avenues to assist children, including classroom activities, parental involvement, and community involvement. For example, more structured play, activities (e.g., memory matching games), and mindfulness practices (e.g., heartbeat exercises) targeted toward children's hot and cold EF abilities may provide more opportunities to test their abilities. The children may be able to understand their skills and how they may be different in various settings. To do this, teacher and parent workshops may be needed to model these practices and understand the importance of early development. Parent and teacher workshops focus on developing EF-based activities and creating supportive practices within the home or classroom (e.g., routines, discussing emotions, and cognitive flexibility). Parents developing home-based activities will assist and support children's development of EF capacities, especially within their home environment. In addition to this, parents and teachers can create more organized spaces, expectations, or solutions for when children might need to take a step away. Each of these suggestions can occur early in life and lead to better life outcomes for children and families.

One central finding of this dissertation is that families need access, which could include various options, including resources, calm environments, or nature. Increased access, awareness, and support can significantly influence children by fostering a coordinated support system that integrates schools, parents, and local organizations. This holistic approach ensures the effective sharing of resources, expertise, and knowledge, promoting educational equity and reducing

disparities. This can provide timely support for children who need it by facilitating early identification and intervention, leading to improved long-term outcomes. Enhanced parental engagement also empowers parents to actively support their children's development at home, creating a consistent and reinforcing environment. Additionally, community involvement could build strong networks that provide emotional and social support, expose children to positive role models, and foster mentoring relationships. This inclusive, resource-rich environment promotes sustainable development and continuous improvement, ultimately enhancing children's developmental prospects and future opportunities. Overall, increased access to education, health services, supportive environments, and community networks lay a solid foundation for future generations, leading to better social, economic, and environmental outcomes.

Future research should delve deeper into the environmental and biological factors that influence the development of EF. Researchers can design more targeted interventions to support children facing challenges in these areas by identifying the key variables contributing to EF development. Moreover, expanding the scope of these studies to include more longitudinal research that tracks a diverse cohort of children beyond their early years could provide invaluable insights. Such studies would better understand how early EF profiles predict long-term outcomes in various domains, including educational achievement, social interactions, and overall well-being. Investigating interventions' potential mediating and moderating effects on these associations could also shed light on the most effective strategies for fostering resilience and adaptability in young individuals. Ultimately, this research could inform policies and practices that aim to support children, contributing to a healthier, more equitable society.

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Appendix A: Access to Family Residency's Green Space Data Collection

1. How “green” is the area around the family residency?

1. Not green at all
2. Between not green at all and somewhat green
3. Somewhat green
4. Between somewhat green and very green
5. Very green

2. Try your best to trace the “property” lines. How much grass is within the family residency/property?

1. No grass at all
2. Small amount of grass
3. Medium amount of grass
4. Large amount of grass

3. Try your best to trace the “property” lines. How much grass is within the family residency/property? (e.g., you may need to compare what else is on the property to the grass. Is the house within all of the property, or do they have land?)

1. 25%
2. 50%
3. 75%
4. 100%

4. What do you see near the home (Y/N)?

- Built structures (nearby buildings)
- Desert landscape (little vegetation, mostly sand, rocks, etc.)
- Farm fields (crops, pasture, etc.)
- Waterfront (lake, ocean, river, etc.)
- Trees
- Mountain range or mountain side/hillside
- None of the above (please explain)

5. Select one of the labels below that best describes the type of community the participant lives in:

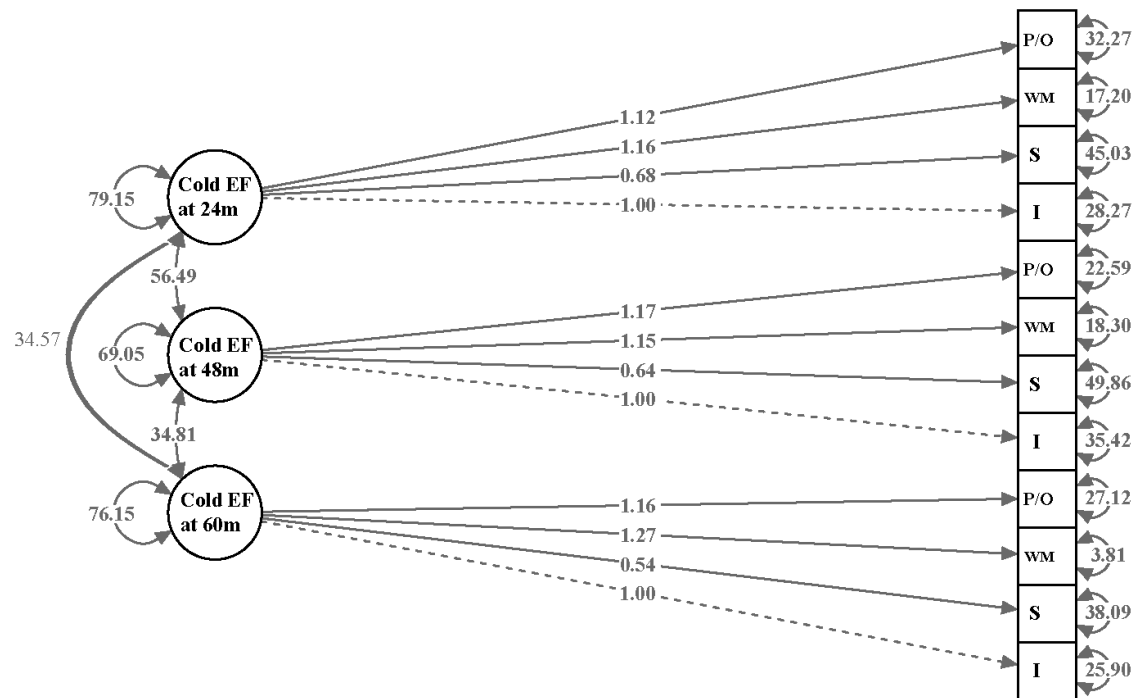
1. Large city (over 100,000)
2. Medium city (between 50,000 and 100,000)
3. Towns and semi-dense areas (between 5,000 and 49,999)
4. Rural areas (places with 5,000 people or fewer)

6. What do you see within the home yard (front or backyard)?

1. Garden (e.g., flowers, plants, or food)
2. Sand (e.g., could be like a natural playscape or sandbox)
3. Rocks (to play on)
4. Playset/Interactive play (e.g., pool, tennis court, basketball hoop)
5. Deck or outside sitting area
6. Shed or outside storage

7. What is the total population of the town/city?

Appendix B: CFA for all Time Points in Paper 1



Appendix C: CFA for all Time Points in Paper 2

