

October 2018

Influence of Household Chaos on Associations Between Physiology and Behavior

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<https://doi.org/10.7275/12527634> https://scholarworks.umass.edu/masters_theses_2/718

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INFLUENCE OF HOUSEHOLD CHAOS ON ASSOCIATIONS BETWEEN
PHYSIOLOGY AND BEHAVIOR

A Thesis Presented

by

SARAH A. MCCORMICK

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment

Of the requirements for the degree of

MASTER OF SCIENCE

September 2018

Psychology

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ABSTRACT

INFLUENCE OF HOUSEHOLD CHAOS ON ASSOCIATIONS BETWEEN PHYSIOLOGY AND BEHAVIOR

SEPTEMBER 2018

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Internalizing behaviors, or behaviors related to behavioral inhibition and the tendency to withdraw from novelty or uncertainty, are stable over time. There is substantial evidence indicating the association between greater resting right lateralized frontal EEG alpha asymmetry and negative affect as well as internalizing behaviors (Coan & Allen, 2003; Henderson, Fox, & Rubin, 2001; Fox, 1991). Further, right frontal asymmetry has been shown to be a stable marker of the presence of psychosocial risk (e.g. child maltreatment; see Peltola, Bakermans-Kranenburg, Alink, Huffmeijer, Biro, & van IJzendoorn, 2014 for meta-analyses). However, little is known about the influences of the home and family environment on the link between EEG asymmetry and behavior. The current study examines the associations between resting frontal EEG asymmetry, temperament, and internalizing behaviors in the context of household chaos, as well as additional models. Participants included 247 6-year-old children recruited as part of a larger study on emotion regulation. Results suggest that while household chaos is marginally associated with concurrent internalizing behaviors, the association does not differ depending on patterns of hemispheric asymmetry. Methodological considerations and future directions are discussed. By understanding the physiological mechanisms

underlying risk for internalizing problems as well as potential moderators of this link we can better inform the development and timing of effective prevention strategies.

TABLE OF CONTENTS

	Page
ABSTRACT.....	iii
LIST OF TABLES.....	vi
LIST OF FIGURES.....	vii
CHAPTER	
1. INTRODUCTION.....	1
Overview.....	1
Behavioral Indicators of Internalizing.....	2
Neurobiological Indicators of Behavior.....	4
Intergenerational Influences.....	6
The Role of the Environment.....	7
Current Study.....	9
2. METHOD.....	11
Participants.....	11
Procedure.....	11
Measures.....	12
3. RESULTS.....	15
Data Analysis.....	15
Descriptive Statistics and Correlations.....	15
Planned Analyses.....	16
Exploratory Analyses.....	17
4. DISCUSSION.....	20
BIBLIOGRAPHY.....	29

LIST OF TABLES

Table	Page
1. Descriptive Statistics for All Variables.....	26
2. Correlations Among Variables.....	26
3. Model 1: Associations between Variables when Chaos is the Grouping Variable: Total Sample (Groups not Different).....	27
4. Model 2: Associations between Variables when Frontal EEG Asymmetry is the Grouping Variable: Total Sample (Groups not Different).....	27
5. Model 3: Associations between Variables when EEG Asymmetry and Child Sex are the Grouping Variables: Total Sample (Groups not Different).....	27

LIST OF FIGURES

Figure	Page
1. Associations between Variables when Chaos is the Grouping Variable: Total Sample (Groups not Different).....	28

CHAPTER 1

INTRODUCTION

Overview

Temperament generally refers to the innate and distinct patterns of behavior and emotion that are present early in development and are stable over time (Kagan, 1989). Various psychopathologies have their roots in individual differences in temperament and behavior. One example of this is internalizing behaviors, which are characterized as tendencies to withdraw from novelty, and inhibition or extreme caution in the face of uncertainty (Schwartz, Snidman, & Kagan, 1999) as well as behavioral symptoms of depression and anxiety (Achenbach, 1991; Chorpita, Albano, and Barlow, 1998). Internalizing behaviors are moderately stable over time with a persistence rate of 37.8% (Briggs-Gowan, Carter, Bosson-Heenan, Guyer, & Horwitz, 2006), meaning that children rated high on internalizing behaviors by their parents are likely to continually display these behaviors later in development. Further, children exhibiting internalizing behaviors at an early age are at a higher risk of developing an anxiety or mood disorder (Chronis-Tuscano et al., 2009; Mesman & Koot, 2001). It is important to note that most children display behavior that may fall into the internalizing domain but does not occur often enough or intensely enough to be considered a significant psychopathology (Carter & Briggs-Gowan, 2005). The current study focused on the presence of non-clinically significant internalizing behaviors. Understanding developmental precursors and physiological indicators of early internalizing behaviors could help us determine which children are at the highest risk of developing internalizing problems that are clinically significant, and in turn develop more effective treatment strategies and early intervention.

One common goal in the field of developmental psychology is to identify biomarkers that show reliable associations to children's vulnerability to emotional and behavioral problems. A frequently utilized tool for this is electroencephalogram (EEG), which measures cortical electrical activity on surface of the scalp. In particular, a large body of research uses the measurement of frontal EEG alpha-band asymmetry. Frontal EEG asymmetry is shown to be a particularly stable marker of patterns of behavior (Mathersul, Williams, Hokinson, & Kemp, 2008), temperament (Coan & Allen, 2003), and motivation (Harmon-Jones, 2004). The current study seeks to replicate the known association between frontal alpha EEG asymmetry and behavioral outcomes while exploring familial influences and environmental moderators to provide a better understanding of this relationship.

Behavioral Indicators of Internalizing

There is a lack of consensus among researchers on which behavioral indicators are the most informative in predicting later pervasive internalizing problems, one of the most common of which is anxiety (31.1% lifetime prevalence in the United States; NIMH). Whereas some research points towards temperamental indicators (e.g., behavioral inhibition, shyness, and negative affect) primarily, other research points to the presence of internalizing symptoms in early childhood as the core indicator of later clinically significant internalizing disorders. Behavioral inhibition in early toddler and preschool years has been shown to be a significant predictor of generalized anxiety disorders in adolescence (Rapee, 2014; Schwartz et al., 1999). Another aspect of temperament, shyness, has also been shown to be a strong predictor of anxiety disorders (Perez-Edgar & Fox, 2005), especially in social anxiety disorders (Chronis-Tuscano et

al., 2009; Rapee & Spence, 2004). Negative affect, characterized by sadness, discomfort, frustration, fear, and difficulty to soothe, is also postulated to be another significant predictor of developing an internalizing disorder (Kagan & Snidman, 1991; Chorpita, 2002). Taken together, high levels of arousal or negative affectivity that are inadequately regulated may be indicative of greater risk for internalizing psychopathology.

Given the association between temperament and development of later internalizing disorders such as anxiety, it is important to understand the associations between temperament and internalizing dimension behavior in early childhood. Many internalizing disorders are not diagnosed clinically until later in childhood and adolescence, and young toddlers are more likely to display internalizing symptomology, though not always at clinically significant levels. Internalizing behaviors are common in childhood and tend to increase into adolescence (Buck & Dix, 2012; Degnan, Almas, & Fox, 2010). Specific aspects of internalizing behaviors, such as withdrawn and anxious behavior, are associated with behavioral inhibition (Klein, Dyson, Kujawa, & Kotov, 2012). Research does indeed show that the developmental pathway of internalizing behaviors and disorders is influenced by child temperament.

There is some disagreement about the best way to measure temperamental and behavioral constructs in childhood. A substantial amount of the current research utilizes maternal report measures of both temperament and internalizing problems through questionnaires. Alternatively, many studies use behavioral observation measures either instead of or in addition to parent-report. Research has shown that associations between the two methods are only modest (Gartstein & Marmion, 2008; Stifter, Willoughby, & Towe-Goodman, 2008). Particularly in the absence of multi-informant measures,

psychophysiological correlates of reported behavior aid in understanding the processes underlying development and individual differences in behavior. Neurobiological measurements of temperament and behavior are crucial to strengthening developmental research and provide us with an objective and direct measure of the neural activity underlying behavior that is critical for answering questions involving temperamental and behavioral constructs.

Neurobiological Indicators of Behavior

There is a considerable body of literature that indicates that frontal EEG asymmetry is a reliable marker of vulnerability for behavioral and emotional problems (see Peltola et al. 2014 for meta-analyses). EEG asymmetry is thought to reflect hemispheric differences in signals from the dorsolateral prefrontal cortex (PFC; Davidson, 2004) and it is further thought that regions of the dorsolateral PFC may modulate activity in the amygdala, shaping emotion and motivational behavior (Dixon, Thiruchselvam, Todd, and Christoff, 2017). This phenomenon relates to the well-established model of approach-avoidance motivational systems. In this model, greater relative right frontal activity has been shown to indicate avoidance or withdrawal motivational tendencies (Davidson, 1992), and may in fact be representative of a trait associated with internalizing behaviors (Allen & Cohen, 2010). The theory behind this model is that the motivational physiological system associated with the tendency to approach or withdraw impacts an individual's behavior to approach or withdraw (Harmon-Jones, Gable, & Peterson, 2010).

One frequently researched band of EEG activity is the alpha band. Power in this band has been shown to be inversely related to cortical activation during emotion

reactivity and regulation (Fox, 1994). To calculate frontal EEG alpha asymmetry, researchers subtract power at left frontal sites from power at right frontal sites. Therefore, a negative asymmetry score reflects greater right frontal activation. EEG asymmetry scores typically result from paradigms recording electrocortical activity during resting state measures or emotion reactivity and regulation tasks. Of particular relevance to the current study, greater resting right frontal alpha asymmetry is a strong indicator of behavioral inhibition and a fearful temperament (see Saby & Marshall, 2012 for a review; Schaffer, Davidson, & Saron, 1983).

This research has been widely replicated in studies with adults and children (i.e. Allen & Cohen, 2010; Diego, Field, Jones, & Hernandez-Reif, 2006) and across cultural contexts (Moss, Davidson, & Saron, 1985; McLaughlin, Fox, Zeanah, & Nelson, 2011). However, some research exists where these findings are not as strongly replicated (see Thibodeau, Jorgensen, and Kim, 2006 for meta-analyses). This variability may be due to task and measurement differences. Additionally, it has been shown that the stability of this asymmetry pattern predicts the presence of both internalizing and externalizing behaviors later in life, suggesting that EEG asymmetry may be a useful early physiological indicator even in preverbal infants (Smith & Bell, 2010).

Recent research utilizing alternative methodologies further illuminates the pattern of hemispheric differences associated with behavior. In an fNIRS study of 7-month-old infants, Ravicz and colleagues (2015) measured oxyhemoglobin (oxyHb) responses to happy faces, and found that only the infants low on negative emotionality (i.e. less inhibited and more approach oriented, measured by parent report) showed relatively greater activation in the left hemisphere (Ravicz, Perdue, Westerlund, Vanderwert, &

Nelson, 2015). This finding suggests that hemispheric activity is a robust indicator of temperament, regardless of whether it is measured using EEG or fNIRS techniques.

Intergenerational Influences

Developmental and family research has long considered how parental (most often maternal) psychopathology may influence children's risk for similar symptomology. There is a body of research detailing the effects of parent psychopathology on both child behavior problems and child frontal EEG asymmetry. This research largely shows that children of depressed mothers display greater right relative frontal EEG asymmetry compared to children whose mothers were not depressed (see Field & Diego, 2008 for a review; Jones, Field, & Davalos, 2000). It has also been shown that infants of depressed mothers are more likely to be behaviorally inhibited in addition to having a greater right frontal asymmetry (Jones, Field, & Almeida, 2009). Lopez-Duran and colleagues found that frontal asymmetry moderated the effects of stressful life events on internalizing symptoms in children with a family history of depression (Lopez-Duran, Nusslock, George, & Kovacs, 2012). Their findings suggest that children who were at a higher risk of developing internalizing symptoms, both because of their family history of depression and the presence of significant life stressors, were significantly more likely to develop internalizing problems if they displayed concurrent greater relative right frontal asymmetry.

A developmental perspective can help us better understand the underlying mechanisms of such findings. In their 1999 article, Goodman and Gotlib introduce a model for better understanding the mechanisms and moderators that might underlie transmission of risk for psychopathology. Though specific to depression, they broadly

theorize a complex model through which many different mechanisms and moderators may potentially influence child risk. In this, they stress the importance of including additional contextual variables (such as details on home environment, income level, or severity of parent diagnosis) when possible which can provide a more comprehensive and integrative picture of the transmission of risk from parent to child (Goodman & Gotlib, 1999).

As another example, parental characteristics are thought to be a potential influencing factor of child internalizing symptomology (Biederman et al., 2001). Behaviorally, research has shown that maternal inhibition is related to child internalizing behaviors (Kiel & Maack, 2012) and that maternal negativity is associated with greater stability in infant and child temperamental traits longitudinally (Degnan, Henderson, Fox, and Rubin, 2008). One potential confound in the extant literature is the wide use of mother-report questionnaires for both the mother's own behaviors and those of her child, which may reflect biases in reporting of behavior. Measures of physiology are crucial to strengthening research with this particular confound (in the absence of multi-informant measures of behavior), as they provide us with an objective and direct measure of the neural activity underlying behavior that is critical for answering questions involving temperamental and behavioral constructs.

The Role of the Environment

Taking a developmental perspective to these questions, it is hypothesized that the environment has an impact on biological indicators like EEG asymmetry (Bronfenbrenner & Morris, 2006). Some research exists demonstrating the role of psychosocial risk factors on developmental frontal EEG asymmetry patterns. Evidence

suggests that extreme conditions such as neglect, early institutionalization, and child maltreatment are all associated with a greater right relative frontal alpha asymmetry (McLaughlin et al., 2011; Curtis & Cichetti, 2007). Further, children who experience such extreme adversity in the form of neglect, maltreatment, or institutionalization are at a higher risk for developing emotion regulation and behavior problems (Kim & Cichetti, 2010).

Substantially less is known about the influence of the low-level, persistent, and environmentally salient stressor of household chaos. Chaos in the home is an indicator of a lack of routine, chronic uncertainty, and ever-present distractors. Indeed, research has shown that chaotic households impact socioemotional development (Bronfenbrenner & Evans, 2000; Evans & Wachs, 2009) and that household chaos is a chronic stressor often accompanying poverty and low socioeconomic status (Evans, Gonnella, Marcynyszyn, Gentile, & Salpekar, 2005). Two of the core domains of chaos, lack of routines and noise, are associated with poor psychosocial adjustment (Fiese et al., 2002) and increased psychological distress (Evans, 2006; Wachs & Corapci, 2003) respectively. Behaviorally, there is evidence that chaos and instability in the home environment is highly associated with child problem behaviors (Coley, Lynch, & Kull, 2015). However, there is very little, if any, research indicating the role that household chaos may play in the link between psychophysiological measures such as frontal EEG asymmetry patterns and child behavior problems. Research on this link will shed light on the disruptive nature of household chaos on the interactions between human physiology and behavior during development.

It is possible that the chronic uncertainty of household chaos may be particularly harmful for those who have a psychophysiological system that is oriented more towards withdrawal and avoidance of uncertainty, which is characteristic of the behavioral inhibition system. Children already prone to withdraw from novelty and uncertainty (as indexed by a greater right frontal EEG alpha band asymmetry) may be at an even higher risk of developing internalizing behaviors if the context of their household environment is consistently chaotic and uncertain. Further, as Evans and colleagues postulate in their 2005 article, it is possible that chaos interferes with the proximal processes that occur continuously between the child and their immediate environment throughout human development. The decreased predictability of the environment and social exchanges with caregivers may negatively impact the developing child's ability to self-regulate. A lack of consistent response from the environment and social partners may impede a child's ability to learn appropriate skills to interact with and respond to their immediate environment. Should research provide evidence to support this theory, it would suggest that we should consider the role of the home environment in developing behavioral interventions. Interventions aimed at reducing household chaos would be substantially easier to implement and likely more effective than those aimed at addressing aspects of the home environment that chaos is an indicator of (i.e. poverty, low SES).

Current Study

The present study seeks to better understand the role of the environment on the link between neurophysiological patterns, temperament, and childhood internalizing behaviors. Currently, there is a substantial gap in the literature for examining the particular role of household chaos, a potentially salient stressor for many families. The

first aim of the current study was to examine the associations between physiology and temperament. It is hypothesized that greater relative right frontal alpha asymmetry, temperamental negative affect, and internalizing behavior will all be positively correlated with each other. The second aim of the current study was to examine how these associations might differ depending on environmental context. Household chaos might be so salient that it disrupts normative social exchanges with caregivers and influences those already prone to inhibited behavior (as indexed by greater relative right frontal alpha asymmetry) to further withdraw and display more internalizing behavior. It is hypothesized that household chaos will influence the associations between greater relative right frontal alpha asymmetry, negative affect, and internalizing behaviors, such that the associations between frontal asymmetry, child temperament, and child internalizing problems will be stronger for those living in the context of high compared to low household chaos.

CHAPTER 2

METHOD

Participants

Participants for this study were recruited as part of a larger study examining emotion regulation and cognitive integration. Children and their mothers were recruited from a rural town in Virginia and a mid-size city in North Carolina. For the current study, participants were 6-years old. The overall sample contained 247 children. Of children enrolled, approximately 51% of the sample was female. Approximately 94% of the sample was Non-Hispanic, 77% White, 15% Black/African-American, 3% Multiracial, 3% Other, and 1% Asian. Racial and ethnic representation of the sample is representative of the Virginia town but not the city in North Carolina. Participants were recruited through a variety of established methods, including paper and online flyers, local community events, radio advertisements, and word-of-mouth.

Procedure

As a part of their participation in the larger study, parents completed number of questionnaires on themselves, their child, and their home environment. On the day of the assessment session the study details were described again to the participants and informed consent was obtained from parents and verbal assent was from the children.

Children were fitted with an electroencephalography (EEG) cap while seated in front of a computer with an experimenter nearby. They heard an experimenter give them directions for all tasks on the computer. Children completed a baseline task condition where they were instructed to sit still first with their eyes open and then eyes closed, each

for one minute. Then, they watched a video clip of the opening sequence from the movie *The Lion King* for two minutes.

Parents were thanked and provided with payment for participation. Parent-child dyads received \$20 compensation for participation in the study. Child participants also received a small toy. The Virginia Tech Institutional Review Board approved the protocol for this study.

Measures

Child Internalizing Behavior. Parents completed the Child Behavior Checklist (CBCL 6-18; Achenbach & Rescorla, 2001). The CBCL is a 132-item instrument designed to assess child behavior problems and adaptive behavior. The scales that are available through the questionnaire were empirically derived through factor analyses and are rated as consistent by experts from 16 different cultural contexts. One-week test-retest reliability has been reported to range from .80 to .94. (Naar-King, Ellis, & Frey, 2003). The raw broadband score for internalizing behaviors was used in analysis.

Child Negative Affect. Parents completed the Children's Behavior Questionnaires – Short Form (CBQ-SF; Putnam & Rothbart, 2006). The CBQ-SF is a 94-item instrument designed to assess a variety of temperament factors. Parents responded on a 7-point Likert scale. The broad factor scale for negative affect was used in analysis, which includes all sub-scales of frustration, fear, sadness, discomfort, and soothability. The previously published internal consistency alpha coefficient for the Negative Affect factor score was .72 (Putnam & Rothbart, 2006).

Frontal EEG Asymmetry. Electroencephalogram data were collected during a baseline interval where children were instructed to remain still and calm while viewing a

two-minute clip from the opening sequence of the movie, *The Lion King* and during one minute each of eyes open/eyes closed. Continuous scalp EEG was recorded using a cap (Electro-Cap, Inc.; Eaton, OH; E1-series cap) with tin electrodes along the international 10/20 system (26 scalp locations [frontal pole (Fp1, Fp2), frontal (F3, F4, Fz, F7, F8), central (C3, C4), frontal central (FC1, FC2, FC5, FC6), temporal (T7, T8), parietal (P3, P4, Pz, P7, P8), central parietal (CP1, CP2, CP5, Cp6), occipital (O1, O2)] and two additional left and right mastoid sites) that was connected to a James Long Company Bioamps (James Long Company; Caroga Lake, NY) and referenced online to Cz. Channel impedances were kept at or below 20 kOhms and EEG was digitized online at 512 samples per second for each channel to eliminate the effects of aliasing. The acquisition software used was Snapshot-Snapstream (HEM Data Corp., Southfield, MI).

EEG data were analyzed using EEG Analysis software developed by the James Long Company (Caroga Lake, NY). Average reference EEG data were then artifact scored for eye movements greater than 100uV and motor movements greater than 200 uV. Epochs containing artifact were eliminated from analyses, and data were analyzed with a discrete Fourier transform with a Hanning window of one-second width and 50% overlap. Alpha band activity is dominant in the 6-9 Hz range for children (Marshall, Fox, & BEIP Core Group 2004; Tarullo, Garvin, & Gunnar 2011). Power in the alpha band is expressed as mean square microvolts and the data are transformed using the natural log (ln) to normalize the distribution.

Frontal EEG asymmetry values were computed by subtracting ln power at left frontal (F3) from ln power at right frontal (F4). Power in this band has been shown to be inversely related to cortical activation during emotion reactivity and regulation (Fox,

1994). Therefore, a negative asymmetry score reflects greater right frontal activation. An average asymmetry score between the eyes open and baseline video condition ($r = 0.62$, $p < .001$) was used in analysis, because they were so strongly correlated.

Household Chaos. Parents completed a modified version of the Chaos, Hubbub, and Order Scale (CHAOS: Matheny, Wachs, Ludwig, & Phillips, 1995). The modified scale includes six Likert-type scale items that assess the home environment. The six items are: ‘You can’t hear yourself think in our home’, ‘It’s a real zoo in our home’, ‘There is usually a television turned on somewhere in our home’, ‘We are usually able to stay on top of things’ (reverse scored), ‘I have a regular morning routine’ (reverse scored), and ‘The atmosphere in our house is calm’ (reverse scored). Scores on the CHAOS scale have been shown to reliably measure environmental processes distinctly different from sociodemographic measures (Matheny et al., 1995). One-year test-retest reliability has been reported to range from .70 to .80 (Deater-Deckard et al., 2009).

CHAPTER 3

RESULTS

Data Analysis

Structural Equation Modeling (SEM) was used to measure the influence of household chaos on the associations between negative affect, frontal EEG alpha asymmetry, and internalizing behaviors. The software Mplus was used to fit the SEM models (Muthén and Muthén, 1998).

Descriptive Statistics and Correlations

The current study examines the participants from the larger study with data available for all variables ($n = 179$). Full-information maximum likelihood (FIML) could not be used to account for missing data as many participants were missing data on all variables. Descriptive statistics for the final sample with usable EEG data are presented in Table 1. Correlations among variables are presented in Table 2. The distribution of frontal asymmetry showed a mean at 0 and a wide range of negative and positive scores spanning asymmetry toward the right and left hemispheres, respectively ($M = 0.001$, $SD = .165$). Chaos was widely distributed ($M = 2.305$, $SD = 0.659$), with a mean score near the middle of the measure's Likert scale (1 – 5). The distribution of raw internalizing ($M = 4.793$, $SD = 4.614$) is significantly skewed to the left ($p < .001$), with 12.3% of children showing scores that were borderline or above the clinical cutoff for internalizing (Achenbach, 1991). Negative affect was normally distributed ($M = 3.907$, $SD = 0.723$), with a mean score close to middle of the measure's Likert scale (1 – 7). Turning to correlations, only two were significant. Negative affect was positively associated with internalizing behaviors ($r = .462$, $p < .001$) and household chaos ($r = .265$, $p < .001$).

Planned Analyses

Model 1. Analysis was carried out in two stages. First for aim one, correlations between frontal EEG alpha asymmetry, negative affect, and internalizing behaviors were run. Then for aim 2, household chaos was split into high ($n = 92$) and low ($n = 87$) groups by median split. Using the grouping command in Mplus, the correlations between frontal EEG alpha asymmetry, negative affect, and internalizing behaviors were estimated. The model was run twice, first where all correlations between variables were constrained to be equal between the two groups and then where the path of interest was unconstrained (EEG asymmetry and internalizing) and allowed to be estimated freely between the two groups, in order to test if the unconstrained model was a significant improvement in fitting the data.

Model 1 Results. Model fit was tested using the $\Delta\chi^2$ test. The $\Delta\chi^2$ test examines whether the more complicated model (in this case, the unconstrained model) is a significantly better fit to the data than the simpler model, despite the loss in degrees of freedom. The $\Delta\chi^2$ between the constrained and unconstrained models was not significant ($\Delta\chi^2(1) = 1.29, p = 0.26$), indicating that the simpler constrained model is superior because it is more parsimonious and not significantly different in terms of fitting the data. This suggests that the groups (high and low chaos) are not significantly different from each other. The association between internalizing behavior and negative affect is significant ($B = 1.40, SE = 0.27, p < .001$) though this association does not differ between the high and low chaos groups. The associations between EEG asymmetry and internalizing and EEG asymmetry and negative affect are not statistically significant.

Exploratory Analyses

Rational. Correlations revealed that frontal EEG alpha asymmetry is not significantly associated with either negative affect or internalizing behaviors. Two additional exploratory models were run to explore further associations among study variables. First, Model 2 examined if the associations between household chaos, negative affect, and internalizing behaviors differed between EEG asymmetry groups. It is hypothesized that the associations between household chaos, internalizing behaviors, and negative affect will be stronger for those who have a greater relative right frontal asymmetry score. Further, literature suggests that these associations may differ based on child sex. This will be tested in Model 3. A recent meta-analysis (Peltola et al., 2014) showed that gender significantly moderated effects in studies examining both internalizing behaviors and psychosocial risk, such that studies with greater percentage of females than males in the sample resulted in the largest effect sizes. This suggests that girls who are already prone to withdraw (as indexed by greater relative right frontal EEG alpha asymmetry) might show larger associations between environmental risk factors and internalizing behaviors. It is hypothesized that in the current study, the associations between household chaos, negative affect, and internalizing behaviors will be strongly positively correlated for females who display a greater relative right frontal EEG alpha asymmetry score.

Model 2. In order to examine if correlations between household chaos, negative affect, and internalizing behaviors differed according to frontal EEG asymmetry lateralization, EEG asymmetry was coded into left ($n = 93$; positive asymmetry score) and right ($n = 86$; negative asymmetry score) groups. Using the grouping command in

Mplus, the correlations between household chaos, negative affect, and internalizing behaviors were estimated. The model was again run twice, first where all correlations between variables were constrained to be equal between the two groups and then where the relationship of interest (household chaos and internalizing) was unconstrained and allowed to be estimated freely between the two groups.

Model 3. In order to examine the potential role of child sex, four groups were created (Right – Male, $n = 39$; Right – Female, $n = 32$; Left – Male, $n = 33$; Left – Female, $n = 34$). Using the grouping command in Mplus, the correlations between household chaos, child temperament, and internalizing behaviors were estimated. The model was run twice, first where all correlations between variables were constrained to be equal between the two groups and then where the relationship of interest (household chaos and internalizing) was unconstrained and allowed to be estimated freely between the four groups.

Model 2 Results: Associations with EEG Asymmetry as Group. The $\Delta\chi^2$ between the constrained and unconstrained models was not significant ($\Delta\chi^2(1) = 0.19, p = 0.66$, indicating that the simpler constrained model is just as good a fit to the data as the more complex model where the relationship between household chaos and internalizing is allowed to vary between the groups. This suggests that the groups (left and right frontal EEG asymmetry) are not significantly different from each other. The associations between internalizing behavior and negative affect ($B = 1.54, SE = 0.28, p < .001$) and negative affect and chaos ($B = 0.13, SE = 0.04, p < .001$) are significant, though these associations do not differ between the EEG asymmetry groups. The association between

household chaos and internalizing was marginally statistically significant ($B = .41, SE = 0.23, p < 0.10$).

Model 3 Results: Associations with EEG Asymmetry and Child Sex as Group. The $\Delta\chi^2$ between the constrained and unconstrained models was not significant ($\Delta\chi^2(3) = 0.54, p = 0.91$), indicating that the simpler constrained model is just as good a fit to the data as the more complex model where the path between household chaos and internalizing is allowed to vary between the groups. This suggests that the four groups (right male, right female, left male, and left female) are not significantly different from each other. The associations between internalizing behavior and negative affect ($B = 1.17, SE = 0.27, p < .001$) and negative affect and chaos ($B = 0.14, SE = 0.04, p < .001$) are significant, though these associations do not differ between the four groups. The association between household chaos and internalizing was marginally statistically significant ($B = .37, SE = 0.19, p < 0.10$).

CHAPTER 4

DISCUSSION

The current study examined the associations between frontal asymmetry, temperament, and child internalizing behavior problems within the context of household chaos. Two additional exploratory models were run to examine similar questions looking at associations between household chaos, temperament, and child internalizing behaviors depending on frontal EEG asymmetry group (right or left) as well as associations between household chaos, temperament, and child internalizing behaviors depending on both frontal EEG asymmetry group and child sex. Additional exploratory models were tested due to questions that came up during the analysis process. More specifically, concerns about how to best interpret associations with frontal asymmetry scores were brought up after analyzing Model 1, as the variable ranges on a scale that includes both positive and negative values. To best combat this, additional models were tested that grouped participants into either left or right asymmetry groups, which is commonly done in the field (Jones et al., 2000; Smith & Bell, 2010). Further, research has shown that both greater relative right frontal alpha asymmetry and internalizing behaviors might be more common in girls than in boys (Peltola et al., 2014; Sterba, Prinstein, & Cox, 2007). To test the potential role of child sex, a third model was tested where four groups were created base on frontal asymmetry group (left or right) and child sex (male or female).

For the planned analyses Model 1, in the first aim it was expected based on prior literature that frontal EEG alpha asymmetry would be negatively associated with internalizing behaviors (Gatzke-Kopp, Jetha, & Segalowitz, 2014; Smith & Bell, 2010), such that a negative asymmetry score (indicating greater relative right frontal alpha

asymmetry) would be associated with higher internalizing behaviors. This association was not observed in the current study. It was further expected in the second aim that the association between internalizing behaviors and frontal EEG asymmetry would be stronger in the high household chaos group. This association was not found to be significant and overall the high and low groups were not found to be different.

Two additional exploratory analyses were run. In Model 2, it was expected based on prior literature (Deater-Deckard et al., 2009; Peltola et al., 2014) that the associations between household chaos and internalizing behaviors would be stronger for the relative right frontal asymmetry group. Results show that although household chaos is marginally positively associated with internalizing behaviors and significantly positively associated with negative affect, these associations do not vary between the left and right asymmetry groups. Finally, in Model 3 it was expected that associations between household chaos and internalizing behaviors would be strongest for female participants with greater relative right frontal asymmetry (Peltola et al., 2014; Sterba, Prinstein, & Cox, 2007). Once again, the groups were not found to be significantly different from each other. In all models tested, negative affect and internalizing were significantly associated with each other (all $ps < .001$), which was expected given the known relationship between negative affectivity and internalizing symptoms in youth (Ormel et al., 2013).

There are several methodological issues to consider in the current study. First, individual differences in frontal asymmetry are likely to be most pronounced during an emotionally evocative task rather than at baseline (Reznik & Allen, 2018). Further, while resting state measures are subject to noise, due to greater variations in what thoughts or processes participants will engage in when not constrained by the researchers, cognitive

and emotional asymmetry measures are greater impacted by cognitive ability (Reznik & Allen, 2018). In the current study, only resting state electrophysiological data was used. Future research may benefit from considering the use of both resting state and task-dependent measures of EEG activity. Additionally, care should be taken in determining what stimuli or prompts are used for resting state measures. Movie clips are very useful for research with young children, but may not be a true measure of baseline activity.

Resting-to-task reactivity difference scores of EEG asymmetry would likely be difficult to calculate reliably as it would be a “difference of a difference” score and would be further complicated by the interpretability of the sign of the value. A possible solution would be to first average power in frontal sites for resting and task measures and then calculate an asymmetry score from the average. This method may allow for a comprehensive assessment of neural information by utilizing both trait and state task measures. Alternatively, research predicting behavioral outcomes from task-related EEG asymmetry might benefit from controlling for resting state EEG asymmetry in statistical models (Diaz & Bell, 2012). Future research should carefully consider the importance of experimental conditions in the measurement of frontal asymmetry.

Another possible measurement issue to consider is the non-normal distribution of internalizing behaviors in our sample. Though the current study aimed to examine the normative range of internalizing behaviors in early childhood, our sample did not show substantial variability in internalizing, and was highly skewed towards fewer internalizing behaviors. SEM is generally robust to violations of the normality assumption and there is no clear consensus on regarding an acceptable degree of non-normality (Finney & DiStefano, 2006). Further estimation methods could be used to

accommodate non-normal data, such as the robust weighted least square estimation method (WLSM; Finney & DiStefano, 2006), which provides estimation and adjustments to the data that are more robust to non-normality than the maximum likelihood estimator used in the current study. This aside, it is noteworthy that the current study also fails to find an association between negative affect and frontal EEG asymmetry, even though negative affect was normally distributed. This raises questions about whether skewness is a contributing factor to the modest correlation with asymmetry.

Another issue is that the internalizing scale of the CBCL contains subscales that differentially assess symptoms of anxiety/depression, somatic complaints, and withdrawn behavior. It is possible that only some of these subscales, rather than the broad internalizing factor, are more associated with motivational withdrawal and greater relative right frontal EEG asymmetry (Peltola et al., 2014) and that this effect is diminished when the broader scale is used. Along the same lines, the subscales included within the broader negative affect scale should also be considered. The negative affect factor scale on the CBQ consists of the subscales of fear, shyness, frustration/anger and discomfort. Whereas fear and shyness are related to withdrawal motivation, anger has been shown to be associated with approach motivation and greater relative left frontal EEG asymmetry scores (Harmon-Jones & Allen, 1998, Harmon-Jones & Gable, 2017). Future research should consider variability in the broad factor scores as well as the narrow subscale facet scores when examining associations with avoidance/withdrawal motivation.

An additional concern is that all of the variables measured in the current study occur during a single time-point in early childhood. The nature of the questions addressed

in the current study would benefit from longitudinal data collection. Namely, previous work has shown that stability of greater relative right frontal EEG asymmetry patterns is predictive of internalizing behaviors over the first three years of life (Smith & Bell, 2010). Of note, Smith & Bell (2010) show that not all children show stability in their frontal EEG alpha asymmetry scores. In their study, while half of their sample changed asymmetry groups (left or right) between the two measurement time-points (10 months and 24 months) the other half showed group stability over this time, suggesting that stability in frontal EEG asymmetry scores may be particularly informative in predicting later behavior. However, the longitudinal study that Smith & Bell (2010) published from reports even lower stability in asymmetry scores between 24 months and 36 months of age ($\beta = .12, p = ns$) and 36 months of age and 48 months of age ($\beta = .01, p = ns$) (Horwath, Fettig, Curby, & Bell, 2016). This further suggests that single time-point measurements of EEG asymmetry may not be the most explanatory measures of behavior developmentally. Future work should aim to include multiple time-points of data collection when possible to tell a more comprehensive developmental story.

Future directions for research on influences of household chaos on associations between physiology and behavior should also consider using observational measures of behavioral variables to support parent-report measures. Of particular relevance, a measure relying exclusively on observations of household chaos, instead of parent-report, has recently been developed: the Descriptive In-home Survey of Chaos – Observer ReporteD (DISCORD; Whitesell, Teti, Crosby, & Kim, 2015). Though no research has yet compared the brief CHAOS measure used in the current study with the DISCORD measure, or other lab-based measures used to assess chaos (Vernon-Feagans,

Willoughby, & Garrett-Peters, 2016), research suggests that objective lab-based assessments of household chaos may be useful. When resources allow, future research should consider the use of lab or home-based observational measures of behavior and environmental context in addition to parent-report measures.

In conclusion, the current study fails to replicate that frontal EEG alpha asymmetry is concurrently associated with temperament or internalizing behavior in school-age children. Further, it fails to show that differences in household chaos at the group level influence associations between resting frontal alpha asymmetry and internalizing behaviors in young children at the same time points, nor do group differences in frontal alpha asymmetry influence associations between household chaos and internalizing behaviors. The study raises important methodological concerns and offers several directions for future work to consider.

Table 1. Descriptive Statistics for All Variables

	<i>M</i>	<i>SD</i>	Range
Frontal Asymmetry	0.001	0.165	-0.422 – 0.873
Household Chaos	2.305	0.659	1.00 – 4.67
Internalizing	4.793	4.614	0.00 – 38.00
Negative Affect	3.907	0.723	2.20 – 6.00

Table 2. Correlations between Variables

	1	2	3	4	5
1. Sex	–				
2. Internalizing	.004	–			
3. Negative Affect	.049	.462**	–		
4. Household Chaos	.055	.121	.265**	–	
5. Frontal Asymmetry	.033	.070	.002	.016	–

Note: ** $p < .001$; Sex was coded as 1 = male and 2 = female

Table 3. Model 1: Associations between Variables when Chaos is the Grouping Variable: Total Sample (Groups not Different)

Parameter	Unstandardized		Standardized	
	Estimate	SE	Estimate	SE
<u>Correlations</u>				
<u>Constrained</u>				
Frontal Asymmetry – Internalizing	0.032	0.054	0.050	0.083
Frontal Asymmetry – Negative Affect	-0.001	0.009	-0.005	0.068
Internalizing – Negative Affect	1.404***	0.267	0.463***	0.062

Note: *** $p < .001$

Table 4. Model 2: Associations between Variables when Frontal EEG Asymmetry is the Grouping Variable: Total Sample (Groups not Different)

Parameter	Unstandardized		Standardized	
	Estimate	SE	Estimate	SE
<u>Correlations</u>				
<u>Constrained</u>				
Chaos – Internalizing	0.410 [^]	0.226	0.122 [^]	0.066
Chaos – Negative Affect	0.132***	0.037	0.259***	0.065
Internalizing – Negative Affect	1.535***	0.278	0.465***	0.070

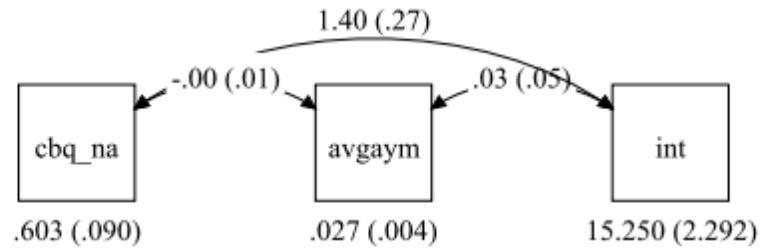
Note: *** $p < .001$, [^] $p < .1$

Table 5. Model 3: Associations between Variables when EEG Asymmetry and Child Sex are the Grouping Variables: Total Sample (Groups not Different)

Parameter	Unstandardized		Standardized	
	Estimate	SE	Estimate	SE
<u>Correlations</u>				
<u>Constrained</u>				
Chaos – Internalizing	0.369 [^]	0.194	0.176 [^]	0.092
Chaos – Negative Affect	0.141***	0.040	0.283***	0.077
Internalizing – Negative Affect	1.170***	0.266	0.513***	0.081

Note: *** $p < .001$, [^] $p < .1$

Figure 1. Associations between Variables when Chaos is the Grouping Variable: Total Sample (Groups not Different)



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