ADVERSITY AND BIOLOGY: AN EXAMINATION OF THE RELATIONSHIP BETWEEN ADVERSE CHILDHOOD EXPERIENCES AND RESPIRATORY SINUS ARRHYTHMIA

by

FIONA BYRNE

A THESIS

Presented to the Department of Family and Human Services
and the Robert D. Clark Honors College
in partial fulfillment of the requirements for the degree of
Bachelor of Arts

June 2018

An Abstract of the Thesis of

Fiona Byrne for the degree of Bachelor of Arts
in the Department of Family and Human Services to be taken June 2018

Title: Adversity and Biology: An Examination of the Relationship Between Adverse Childhood Experiences and Respiratory Sinus Arrhythmia

Approved: _____

Dr. Elizabeth Skowron

Approved: _____

Dr. Shoshana D. Kerewsky

Exposure to adversity in childhood is shown to be a significant risk factor for negative physical and mental health outcomes in adulthood. What remains to be explored is the impact of adverse childhood experiences on adult parasympathetic nervous system activity as indexed by respiratory sinus arrhythmia (RSA). RSA describes the pattern of variability in heart rate across the respiration cycle, which provides an index of the parasympathetic nervous system influence on heart rate. The present study examines the relationship between Adverse Childhood Experiences Survey (ACES) scores and resting RSA within a sample of adult female caregivers (n = 64) who are involved with the child welfare system, and tests the hypothesis that greater adversity assessed via ACES scores will be associated with lower PNS influence on heart rate at rest, or lower resting RSA scores. No significant correlation was found between women's ACES scores and resting RSA within the sample ($r = -0.0091$, $p = 0.45$). Future studies should further explore the relationships between ACEs, resting RSA, and other risk and protective factors within larger samples and employ longitudinal designs to learn more about how early adverse experiences may 'get under the skin' and have long-term implications for health and physiological functioning.

Acknowledgements

I would like to thank Dr. Elizabeth Skowron for her support of this project and for allowing me to explore a portion of the fascinating wealth of data that is being collected in the NIDA-funded CAPS Study. Thank you also to Dr. Shoshana D. Kerewsky for helping me throughout the writing process with encouragement, perspective, and editorial expertise. I am also grateful to Dr. Dan Rosenberg for supporting this thesis as a representative of the Clark Honors College. I am beyond grateful to have had the mentoring guidance of Maria Schweer-Collins, who helped make my first venture into writing a research paper of this nature less intimidating and far more accessible, an opportunity for growth rather than a very high hurdle. Thank you for all of the hours and energy you put into this project, this thesis is what it is because of your support.

I would also like to thank the researchers in Dr. Skowron's FABB Lab for the years of work they have done collecting this data and more with the ultimate motive of helping families and children, and to the families and children for offering their time to support this project. Thank you to Lisa Shimomaeda and Felicia Gutierrez for making a STEM space profoundly accessible, for trusting me, and for challenging me to trust myself.

I would like to thank the Family and Human Services program for being a major unlike any other, through which students learn about the field by being in the field, while learning from professors with years of experience who encourage them to think critically every step of the way.

Finally, I would like to thank my family not only for the opportunity to pursue higher education, but also for being the safety net that enabled me to take risks.

Table of Contents

A THESIS I

PRESENTED TO THE DEPARTMENT OF FAMILY AND HUMAN SERVICES I

AN ABSTRACT OF THE THESIS OF II

APPROVED: _____ II

DR. ELIZABETH SKOWRON II

DR. SHOSHANA D. KEREWSKY II

ACKNOWLEDGEMENTS III

INTRODUCTION 1

BACKGROUND 2

THE COACHING ALTERNATIVE PARENTING STRATEGIES (CAPS) STUDY 2

LITERATURE REVIEW 3

HEART RATE VARIABILITY 3

RESPIRATORY SINUS ARRHYTHMIA 4

EMOTION REGULATION 7

THE ADVERSE CHILDHOOD EXPERIENCES (ACE) SURVEY 8

THE PRESENT STUDY 9

METHOD AND MATERIALS 10

Participants. *10*

Procedure. *11*

Measures. *11*

Analysis Plan. *13*

RESULTS 14

PRELIMINARY ANALYSES 14

MAIN STUDY ANALYSIS 14

FOLLOW-UP EXPLORATORY ANALYSES 14

DISCUSSION **15**

LIMITATIONS AND SOURCES OF ERROR 16

Sample size. *16*

Study design. *16*

ACE survey. *17*

FUTURE DIRECTIONS 17

APPENDIX A **23**

APPENDIX B **24**

REFERENCES **25**

Introduction

Although existing research in the field of psychology shows that lived experiences can influence an individual on the biological level, much remains to be discovered regarding the extent to which specific life events impact human physiology. In the realm of early childhood experiences in particular, researchers have found strong associations between retrospective adult reports of early adversity and numerous health impairments, including but not limited to heart disease, lung disease, cancer, and an array of mental health problems (Shonkoff, Boyce, & McEwen, 2009). Acute (single instance), complex (recurring), and chronic (prolonged) trauma, and even non-traumatic but nonetheless stressful events that occur during childhood, can all continue to impact an individual long into adulthood. Although stressful life events are profoundly unique and individualized, there are empirical methods of quantifying such experiences. One assessment tool is the Adverse Childhood Experiences Survey (ACES), which lists general types of adverse experiences and asks the respondent which, if any, they experienced before reaching the age of eighteen ("The Adverse Childhood Experiences Study," Felitti et al., 1998). If a respondent has endured many adverse experiences, their score is high. High ACE scores have been shown to strongly correlate to a wide range of both physical and mental health problems, including depression, heart disease, and cancer (Odgers & Jaffee, 2013; Hughes et al., 2017), but there is less literature on the link between adverse experiences and negative physiological outcomes. One biomarker that has linked stress with negative health outcomes is heart rate variability (HRV). HRV is the naturally occurring variation in the time interval between heartbeats. Lower HRV is associated with higher risk of all-cause mortality (Thayer et al., 2012). When

HRV is examined in conjunction with respiration, the increase in heart rate during inhalation and decrease during exhalation is referred to as respiratory sinus arrhythmia (RSA; Billman, 2011). HRV is a component of RSA, and RSA provides insight into the parasympathetic influence that the vagus nerve has on heart rate (Thayer, 2007). HRV and RSA are closely connected, and each measure has been empirically linked to physiological and psychological outcomes (Lampert et al., 2016; Porges, 1995, 2001; Thayer et al., 2012). This project examines individuals' resting RSA and ACE scores to determine whether the two measures are correlated, with the aim of exploring the potential link between stressful life experiences and physiological functioning.

Background

The Coaching Alternative Parenting Strategies (CAPS) Study

The CAPS study is a randomized-control trial for the efficacy of Parent-Child Interaction Therapy (PCIT) with families in which child maltreatment has occurred. Principal investigators Dr. Elizabeth Skowron and Dr. Phil Fisher run the project at the Prevention Science Institute at the University of Oregon. The program is funded by the National Institute on Drug Abuse, with the formal project title "Targeting Neurobiological and Behavioral Mechanisms of Self-Regulation in High-Risk Families." When participants come in to the laboratory for their scheduled assessments, assessors collect data on participant heart rate, brain activity and behavior, as well as psychological and physical health. Participants in the study are parent-child dyads who are recruited through the Department of Human Services Child Welfare and have founded cases of child maltreatment, which are either closed or ongoing. In the laboratory assessments, dyads complete a series of joint and individual tasks, some

delivered by research assistants and some administered through standardized computer measures. At the end of a two-visit baseline session, each dyad is randomized into either the control group or the treatment group. Those in the control group continue services as usual and return to the lab for a six-month session where they complete the same tasks that they did at the baseline visit. Those in the treatment group are assigned a PCIT therapist and attend weekly PCIT therapy sessions in addition to a mid-treatment and post-treatment assessment. The current study includes an analysis of parent baseline RSA data and ACE scores collected by undergraduate, graduate, and professional research assistants during CAPS research sessions. Dr. Skowron has provided consent for the use of CAPS data in this research project.

Literature Review

Heart Rate Variability

Heart rate variability (HRV) is a measure of the variation in time between heartbeats. Variation in heart rate shows that a heart is healthy, because it shows the capacity to respond to internal and external stimuli (Thayer et al., 2012). Decreased HRV predicts poor cardiovascular outcomes (Lampert et al., 2016) and is associated with a greater risk for all-cause mortality (Thayer et al., 2012). Low HRV has also been suggested as an indicator of disease (Thayer et al., 2012).

Research has established HRV as a sign of healthy heart function, but it is also considered to be linked to the brain's system for adaptive regulation. This system is the central autonomic network (CAN; Benarroch, 1993, 1997), a functional unit within the central nervous system (CNS; Thayer et al., 2012), and it supports adaptability and goal-directed behavior (Thayer, 2007). Within Thayer and Lane's model of

neurovisceral integration, HRV is used as an indicator of the overall functionality of the CAN, which includes more than ten connected neural structures (Thayer, 2007). Parasympathetic neurons mediate the CAN's primary output through the vagus nerve (Thayer, 2007). The resulting input to the cardiac sinoatrial node (specialized tissue that acts as a pacemaker for the heart) produces variability in heart rate (Saul, 1990), wherein lies the connection between the CAN and HRV.

This is significant because the immune system and several organs including the heart send sensory information back to the CAN, therefore HRV indicates that neural feedback is occurring and that the CNS and the autonomic nervous system (ANS, which is responsible for regulating bodily functions that we do not consciously control including heartbeat, breathing, and digestion) are integrated as they should be (Thayer, 2007). This is also important because, according to the neurovisceral integration theory, high resting HRV indicates greater prefrontal cortex activation, which in turn suggests a higher capacity for adaptive cognitive engagement (Thayer et al., 2012).

Respiratory Sinus Arrhythmia

Under normal conditions, heart rate increases during inhalation and decreases during exhalation. This pattern is called RSA, which can be used as a psychophysiological index of emotional regulation (Porges, 1995, 2001). Sinus arrhythmia, also called vagal tone, refers to activity of the vagus nerve. Specifically, RSA provides an approximation of the parasympathetic influence that the vagus nerve has on heart rate. While the sympathetic nervous system prepares the body for physical activity through what is often referred to as the "fight or flight" response, the parasympathetic nervous system is often called the "rest and digest" response because it

relaxes the body and slows high energy functions (Biaggioni, 2012). These two systems are crucial in enabling the body to react as needed in response to different stimuli, and then return to a more relaxed and less energy-intensive state and begin recovery when appropriate.

The vagus nerve is responsible for parasympathetic control not only of the heart but also of the lungs and the digestive tract (Porges, Doussard-Roosevelt, & Maiti, 1994). RSA and the accompanying variability in heart rate show that the vagus nerve is doing its job, which in turn indicates parasympathetic nervous system functioning (Porges, 1995, 2001).

The vagus nerve plays an important role in the functioning of the parasympathetic nervous system: it is believed that the vagus nerve can impede sympathetic activation and promote relaxation in safe contexts that don't require reactive responses that use a large amount of energy (Porges, 2007). RSA is a derivative of HRV and respiration which provides researchers with insight into the functioning of the complex parasympathetic nervous system which has significant impacts on an individual's physiological, emotional, and social functioning (Porges, 1995, 2001).

There are numerous studies that show positive associations between high resting RSA and beneficial behaviors (Beauchaine & Thayer, 2015). When RSA is measured while an individual is at rest, higher levels indicate the ability to adapt and react to environmental stimuli and stressors (Beauchaine, 2001; Porges, 2001). According to the neurovisceral integration model, higher resting high-frequency heart rate variability (HF-HRV), a marker of parasympathetic influence over cardiac function, reflects greater activation of the prefrontal cortex suggesting a greater capacity for cognitive

engagement (Thayer et al., 2009). Higher resting RSA is associated with a greater capacity for emotion regulation and is generally considered adaptive. HRV alone is not synonymous with RSA, but in many empirical studies, HF-HRV and RSA are terms used interchangeably. Resting HRV is shown to be higher among adults with greater emotion regulation ability (Thayer & Lane, 2009), and Shook and colleagues found that higher resting HRV is also associated with a greater willingness to approach new positive objects (cited in Thayer et al., 2012). In a sample of highly rejection-sensitive adults, high resting RSA appeared to be a protective factor against impulses to display negative affect and act in hostile ways towards their romantic partners (Gyurak & Ayduk, 2008). In sum, higher resting RSA is considered to be a biomarker of emotion regulation (Beauchane & Thayer, 2009) and is associated with more self-regulatory control and behaviors that are indicative of effective social engagement (Porges, 1995, 2001).

Conversely, in adults, low resting RSA is common among those who experience emotion dysregulation. Abnormally low resting RSA in adults correlates with symptoms of internalizing and externalizing psychopathology (Beauchaine, 2001, 2012; Porges, 2007), as well as a number of other psychopathological outcomes including phobias (Åhs et al., 2009), anxiety (Hastings et al., 2008), and depression (Rottenberg, Wilhelm, Gross, & Gotlib, 2002). Overall, empirical findings show an association between low resting RSA and poorer psychological outcomes.

Resting RSA is also associated with behaviors in childhood. Studies have shown that there is an association between high resting RSA in children and their resilience to early adversity (Beauchaine, 2015). In a sample of preschool-age children, higher

resting RSA was positively related to effortful control (Sulik et al., 2013). This evidence supports the understanding that from early childhood through adulthood, higher resting RSA is associated with numerous measures that indicate a greater ability to regulate emotion in a way that benefits an individual and their relationships with others.

Emotion Regulation

Intrinsic emotion regulation involves an individual's ability to moderate their own emotions, and may be either intentional and explicit or implicit, without conscious intent (Gross, 2013). Capacity for emotion regulation is related to the ability to make decisions, engage with others in socially appropriate ways, and delay gratification. One biomarker of emotion regulation is RSA. Both RSA and emotion regulation are closely connected to the parasympathetic nervous system which, in Porges' polyvagal theory, regulates facial muscles involved in emotion expression (Porges, 1994, 1995). It is through this system that individuals are able to engage in warm and effective social engagement (Clark et al., 2016).

The environment in which a child is living can significantly impact the development of their capacity for emotion regulation. Researchers have found an association between exposure to chronic stressors and parts of the brain that are crucial to emotion regulation (Kim et al., 2013). Specifically, Kim and colleagues found an association between childhood poverty (one stressor measured in the ACE survey) and reduced neural activity in regions of the brain that are key to emotion regulation (Kim et al., 2013). These findings illustrate a possible neural mechanism of adversity on emotion regulation, beginning with early experiences of adversity.

The Adverse Childhood Experiences (ACE) Survey

The CAPS lab uses the ACE survey to gather data on participants' early life experiences. The survey was created as a part of the ACE Study which began in 1994 as a collaboration between the Centers for Disease Control (CDC) and private company Kaiser Permanente, the nation's largest not-for-profit health plan (CDC, 2016; Felitti et al., 1998). When the study began, medical investigators had only recently begun to research the relationship between child maltreatment and negative physical health outcomes.

There is a demonstrated association between high ACE scores and several of the leading causes of death in the United States (Felitti et al., 1998). Studies have since indicated a significant association between having an ACE score of 4 or more and an increased risk of negative health outcomes and physically harmful behaviors including alcoholism, drug abuse, and severe obesity (Felitti et al., 1998). Felitti and colleagues (1998) found that compared to those with an ACE score of zero, those with a score of 4 or more were twice as likely to be smokers, seven times more likely to have alcoholism, ten times more likely to have injected street drugs, and twelve times more likely to have attempted suicide. Results from the same study showed a strong graded relationship between ACE scores and presence of risk factors for the leading causes of death in adults (Felitti et al., 1998). Thompson and colleagues found that whether ACE scores and health outcomes have a dose-related effect or threshold effect depends on the specific health outcome in question and at what age an individual experienced ACEs (Thompson et al., 2015). The original ACE study primarily centered around the relationship between adverse childhood experiences and disease conditions that resulted

from high risk behaviors including smoking and physical inactivity (Felitti et al., 1998). The correlation between high ACE scores and health issues resulting from elective risky behavior has been supported by numerous empirical studies and with various populations since the original 1994 study (Norman et al., 2012). It is essential to maintain that the ACE survey is used to assess risk within a large study, and ACE scores are not deterministic of health or behavioral outcomes.

While several longitudinal studies have explored the relationship between chronic exposure to stressors and resting RSA in children (Hinnant & El-Sheikh, 2011; El-Sheikh & Whitson, 2006), there are few studies that explore the relationship within an adult population, and none that use the ACE survey with Child Welfare-involved women. Investigating a possible relationship between ACE scores and resting RSA in adults is an important avenue of research because RSA in turn has been shown to be connected to an individual's health, behavior, and emotion regulation in adulthood. Evidence to show that emotional experiences can impact health at the physiological level and increased understanding of factors and mechanisms that may impact the behavior and emotion regulation of adults involved with Child Welfare are crucial in developing appropriate maltreatment prevention and intervention programs. Evidence-based findings can also be integral in influencing policy to secure funding and support for such programs.

The Present Study

In this study, we are investigating resting RSA and ACE survey scores in adult women who have been involved with the Lane County Department of Human Services, Child Welfare. An increased understanding of the impacts that childhood adversity may

have on an individual during their lifetime could better inform prevention and intervention efforts. Our primary question is whether there is a significant correlation between resting RSA and ACE survey scores in this sample. Research indicates a possibility that repeated exposure to adversity which causes frequent activation of the "fight or flight" response of the sympathetic nervous system may wear down the parasympathetic nervous system over time, and result in lower resting RSA (Porges, 2007). Given these empirical findings, I hypothesize that higher ACES scores will be associated with lower resting RSA scores.

Method and Materials

Participants.

This study uses a subsample from the CAPS Study who have enrolled and completed baseline assessments at the time of this project. The CAPS Study recruits participants who have either an open or a recently-closed case with Lane County Department of Human Services, Child Welfare. Families were eligible to participate if the caregiver was a Lane County, Oregon resident of at least 18 years of age, and if the caregiver was the biological or custodial parent of a child between the ages of 3 and 7 at the time of the baseline assessment. Additionally, caregivers needed to reside in the same home setting as child, have English fluency, and both parents and children needed the physical ability to complete assessment. Exclusion criteria prohibited participation for dyads where the child had a sexual abuse history and in cases where the perpetrator had ongoing access to child.

Participants in this sample were 65 caregiver-child dyads. Of the adults in the sample, 64 of the women were the mothers of the child with whom they were

participating in the study, and one was a grandmother and legal foster-mother. This study examines an exclusively female sample to control for sex-based differences in RSA. Mothers were between 18 and 64 years old with a mean age of 31 years (SD = 6.496). Maternal ethnicity distribution was 64.8% European American/White, 21.9% Biracial/Multi Ethnic, 3.8% Native/Alaskan Aleut, 1.9% African American/Black, 1.9% Pacific Islander, and 2.9% unknown. The majority of caregivers reported their marital status as single at 47.6%. Twenty-seven percent of participants reported that they were either married or living with a partner, and 20.9% were separated or divorced. The educational level of the caregivers varied widely. Of this sample, 1.9% completed 7th grade, 1.9% completed middle school, 18.1% attended some high school and did not graduate, 9.5% earned a technical or vocational training certificate or course, 12.4% completed an associates or junior college degree, and 2.9% completed a bachelor's degree. The mean monthly income of this sample was $1,469 (*SD* = $1,155.712).

Procedure.

All procedures were approved by the Internal Review Board. This analysis includes data from participants who completed the first baseline assessment at the lab within the first 20 months of the study. Participants arrived to laboratory assessments by bus, car, or were provided with a taxi ride. Families were compensated $200 to complete the two baseline assessment visits, were provided snacks, and children were given small toys.

Measures.

Respiratory Sinus Arrhythmia. After consent was obtained, participants were fitted with seven disposable electrocardiogram electrodes. The three leads that collected

heart-rate variability (HRV) data were positioned on the distal end of the right clavicle, and on the right and left sides of the lower end of the ribcage. These electrodes transmitted electrocardiogram (ECG) data from Mindware mobiles to Mindware software on a PC in a control room adjacent to the family room where participants spend the majority of the first visit.

RSA was collected while mother and child sat next to each other on a couch and watched a 5-minute video of swimming fish accompanied by soothing electronica. Participants were asked to sit apart from each other to avoid the influence that physical contact may have on heart and respiratory activity. Additional physiological and behavioral data was collected during the first baseline visit, but the conclusion of the 5-minute fish video concluded the collection of physiological data used in this study.

ECG signals were monitored by a research assistant to ensure HRV signals were suitable for analysis. Trained research assistants use MindWare Technologies HRV Analysis 3.1.3 to process the data, using a sampling frequency of 500. The RSA frequency band was set between 0.12 and 0.40, and maternal RSA was calculated in 30-second epochs across the three minutes of resting baseline. Erroneously identified or missing heart beats were manually deleted or inserted as appropriate. The resulting inter-beat interval time series was subjected to a fast-Fourier transformation, and power in the respiratory frequency band was derived from the spectral density function (e.g., Berntson et al., 1997; Berntson, Cacioppo, & Quigley, 1993). RSA is averaged across the six epochs to create the mean resting RSA scores. A portion of randomly selected files are coded a second time for reliability.

The Adverse Childhood Experiences Survey. The Adverse Childhood Experiences Survey (ACES) was administered to adult participants by a research assistant during the second baseline laboratory visit (CDC, 2016). Along with other surveys that covered sensitive topics, the ACES survey was administered with only the parent and the research assistant in the room to ensure privacy. The survey was administered via the Qualtrics web program, and questions were read out loud by the research assistant to remove the factor of literacy and reader-error from the measure. The ten questions cover whether an individual, before they reached the age of eighteen, had experienced certain types of adversity, by responding with "yes" or "no." Participants were asked questions about the following: whether they had often witnessed domestic violence; whether they had experienced physical, verbal, or sexual abuse; whether they had been emotionally and/or physically neglected; and whether they lived with someone who had alcohol or drug problems, who had been incarcerated, or if they had resided with someone who experienced mental illness (CDC, 2016). Participants' "yes" scores were summed and ACE scores ranged from zero to ten, with higher scores indicating higher levels of childhood adversity and lower scores reflecting fewer experiences of childhood adverse experiences.

Analysis Plan.

Data analyses were performed in SPSS (version 22). First, descriptive statistics including means, standard deviations, and ranges of all study variables were assessed by producing and visually inspecting frequency distribution tables to begin to understand the sample, to screen the data for normality, and to identify potential outliers. Next, a Pearson product-moment correlation coefficient was computed to assess the relationship

between resting RSA and ACE scores, the main research question. A follow-up Independent Samples t-test was run to assess mean differences of resting RSA between two groups: 1) participants who had experienced three or fewer ACEs and, 2) participants who had experienced four or more ACEs.

Results

Preliminary Analyses

The most commonly reported item on the ACE survey was a "yes" response to whether parents had been separated or divorced, at 71%. Seventy percent of participants reported having lived with someone who had substance abuse problems, making that item the second most frequently reported (see Figure 1 in appendix for full chart of ACEs frequencies).

Main Study Analysis

A Pearson correlation was computed to assess the relationship between parent ACE scores (0-10) and mean resting RSA. There was no significant correlation between resting RSA and ACE scores, $r = -0.0095$, $n = 65$, $p = 0.45$. While not statistically significant, the association between resting RSA and ACE scores was in the predicted direction, with higher resting RSA scores non-significantly trending with lower ACE scores.

Follow-up Exploratory Analyses

An independent samples *t*-test was conducted to compare mean differences in resting RSA between two groups: 1) participants who had experienced three or fewer ACEs ($n = 22$) and, 2) participants who had experienced four or more ACEs ($n = 43$).

There was no significant difference in RSA scores for the lower ACEs group (M = 6.31, SD = 1.60) and the higher ACEs group (M=6.18, SD=1.58); $t(63)=0.307$, p=0.760. A study including a larger sample size with balanced groups may have more illuminating results.

Discussion

The main finding of this study was support for the null hypothesis: within this sample, there is no significant correlation between adult ACE scores and resting RSA. While not statistically significant, the association between the two measures was in the expected direction, with mean resting RSA lowering as ACE scores increased. If a negative association between RSA and ACE scores were to exist, these findings suggest that it would be a smaller effect size which would require a much larger sample of participants to fully test. In other words, a relationship between adult ACE scores and mean resting RSA may exist, as there were significant limitations to this study (namely, small sample size). There is a wealth of empirical substantiation that adverse childhood experiences are related to negative lifetime health outcomes (Felitti et al., 1998; Thompson et al., 2015) and to lower resting RSA in children (Hinnant & El-Sheikh, 2011; El-Sheikh & Whitson, 2006). Given this finding and the knowledge that high resting RSA is associated with emotional regulation and low resting RSA with numerous psychopathologies, further inquiries that have more statistical power are needed to provide a strong test of this hypothesis. Such potential evidence is worthy of further inquiry.

Limitations and Sources of Error

Sample size.

The small sample size of this study is a limitation. A sample size of only 65 hardly allows for a deeper examination of the relationships of other variables without losing a significant amount of power in the process. However, the sample has an average ACE score above 5 which constitutes a high risk for harmful health behaviors including drug abuse and smoking (Felitti et al., 1998) and a broad array of health complaints including poor health, illnesses that necessitate medical attention, and other health complaints of any nature (Flaherty et al., 2009). High risk populations are very important to study, and this sample is comprised not only of participants with relatively high ACES (a 2015 survey found that 22% of Oregonians had experienced four or more ACEs [Wilcox & Theodorou, 2015]) but also of caregivers who are involved with Child Welfare. It is essential to understand this population in order to know how best to structure maltreatment prevention and intervention efforts.

Study design.

Because this is a cross-sectional and correlational study, conclusions about whether the relationship between childhood adversity and RSA is causational cannot be inferred. Future studies should use a larger sample size and employ longitudinal designs so that they have the potential to identify causation between early adverse experiences and RSA. Between the age of 18 and the present date, there are factors and conditions that could confound the impact of ACEs on resting RSA that are not considered or controlled for in this study.

ACE survey.

While the ACE survey is widely used and accepted as a measure of early experiences, like any tool designed to convert unique human experiences into numerical values, the survey has its shortcomings. First, it is both self-report and retrospective, which leaves room for error and social desirability bias (Callegaro, 2008). However, the self-report format is valuable in that it draws from the participant's perception of their own experience, which is the only source for that information. If an individual feels as though they did not have the emotional support they needed as a child, their response to the survey will match their perception of their experience, which mitigates the drawbacks of the retrospective format. Another limitation of the ACE survey is that it converts each experience into a binary. Research has shown that few yet chronic ACEs have a stronger impact than more numerous yet infrequent ACEs (Thompson et al., 2015), which means that while ACEs are related to health outcomes, the 0-10-point scale format is perhaps too reductive to capture the whole picture. For example, a participant in this study may have experienced physical abuse nearly daily for the majority of their childhood, and yet their ACE score could be as low as 1. Conversely, a participant could have experienced several types of adversity two or three times in total and have a much higher score. While an experience does not have to be chronic to have a significant impact on a person, more research on the impact of chronicity may improve our understanding of negative health outcomes related to ACEs.

Future Directions

The more that we know about the impacts of early adverse experiences on lifelong health and behavior, the more informed and effective intervention and

prevention endeavors will be. For example, if higher ACE scores are associated with lower resting RSA in adults, interventionists may use knowledge of a client's ACEs to more thoroughly screen for challenges related to emotion regulation and psychopathology, and develop informed treatment plans.

The venture to identify possible mechanisms through which adverse experiences result in negative life outcomes is an important one. Numerous studies have identified a relationship between early childhood adversity and negative lifetime mental and physical health outcomes (El-Sheikh & Whitson, 2006; Felitti et al., 1998; Hinnant & El-Sheikh, 2011). Future studies, with larger sample sizes, will have more freedom to analyze resulting data by different categories including age, income, and specific ACEs. Detailed and specific findings will lead to more informed interventions and the potential to allocate prevention resources more efficiently.

Future studies should include a deeper examination of participants' social contexts. This project examines events that an individual experienced before the age of eighteen and their resting RSA as an adult, but there are a number of factors that could impact RSA during the period of time between an individual's eighteenth birthday and the day they come into the CAPS lab. Such factors include income, education, lack of access to healthcare, and disability [Nurius, Logan-Green & Green, 2012], and information on each is collected via CAPS baseline surveys. These factors could be influencing RSA or exacerbating the influence that ACEs may have on RSA, and may even be related to or caused by specific items identified in the ACE survey. For example, if an association is observed between low resting RSA and the ACE item regarding not having enough to eat as a child, physiological impacts could be caused

not by childhood stress resulting from physical neglect but rather by growing up poor and continuing to live with insufficient resources.

The ACE survey model is an advancement from the earlier format of researching each category of childhood stress in isolation (Nurius et al., 2012). Future studies may mitigate this effect by controlling for the presence (and prevalence) of social disadvantage. However, treating social context as a confounding factor blocks the potential to examine variables that may influence health and behavior outcomes just as much if not more than ACEs experienced only in childhood. A larger sample size would enable an examination of the sample within a social disadvantage framework (Nurius et al., 2012). Such a framework as used by Nurius, Logan-Green and Green (2012) is considered a facet of the "next horizon" of youth adversity and lifetime outcome research. Results may have the added effect of testing how robust the ACE survey is beyond correlated factors of social disadvantage (Nurius et al., 2012).

Another way to improve the examination of this research question is a longitudinal study. Gathering data on ACEs and chronicity from a younger population (possibly ranging 18-21 years-old, as the survey asks about experiences before age 18 and this would limit the impact of retrospection), may result in new findings about how RSA changes through life, with social context considered. Additionally, while the high-risk sample used in this project is important to study, examining resting RSA and ACE scores of individuals with a wider range of experiences will yield results applicable to a larger population. While the relationship between ACE scores and mean resting RSA identified by this study was not strong enough to be statistically significant, in a more general population (within which this sample would be near the higher risk end of the

spectrum) a trend of resting RSA increasing from high risk to low risk participants, if present, may be more observable.

While the ACE survey used in this study does ask whether certain experiences happened "often," data might be more illuminating if it included chronicity in the ACEs measure. As Thompson and colleagues (2015) found, few yet more chronic ACEs may have a larger impact on health outcomes than many infrequent ACEs. Future studies could assess the difference between discrete versus chronic experiences of adversity by employing measures of chronicity which ask how frequent experiences were on a ten-point scale. Another avenue for introducing chronicity into the ACE survey may involve dividing childhood into five-year increments, asking how often an ACE occurred during each time period. Such specific retrospective report is challenging, but an individual who, for example, recalls experiencing emotional neglect during their entire childhood, will be able to relay that information. The resulting score may be more representative of the extent of an individual's experiences and may also provide insight into the impact that adverse experiences may have during different developmental periods.

Future studies should also examine the buffering effect that protective factors may have between early adverse experiences and negative mental and physical health outcomes. Research shows that children who have resilience factors in their lives are less harmed by stress: a meta-analysis of the impacts of protective factors on children's physical resilience outcomes found that protective factors had a moderate effect on sleep behavior, psychological health, and overall heath (Lavoie, Pereira, & Talwar, 2016). Empirically-founded protective factors include finding meaning in challenging

and stressful situations, supportive family environments, social support, and family and community connectivity (Lavoie, Pereira, & Talwar, 2016). Future studies should consider which factors support resilience and add to the ACEs survey a counterpart designed to measure protective factors. One feasible counterpart is the Adolescent Resilience Questionnaire, which measures resilience factors in the realms of self, family, peer, school, and community via 93 items and 12 scales (Gartland et al., 2011).

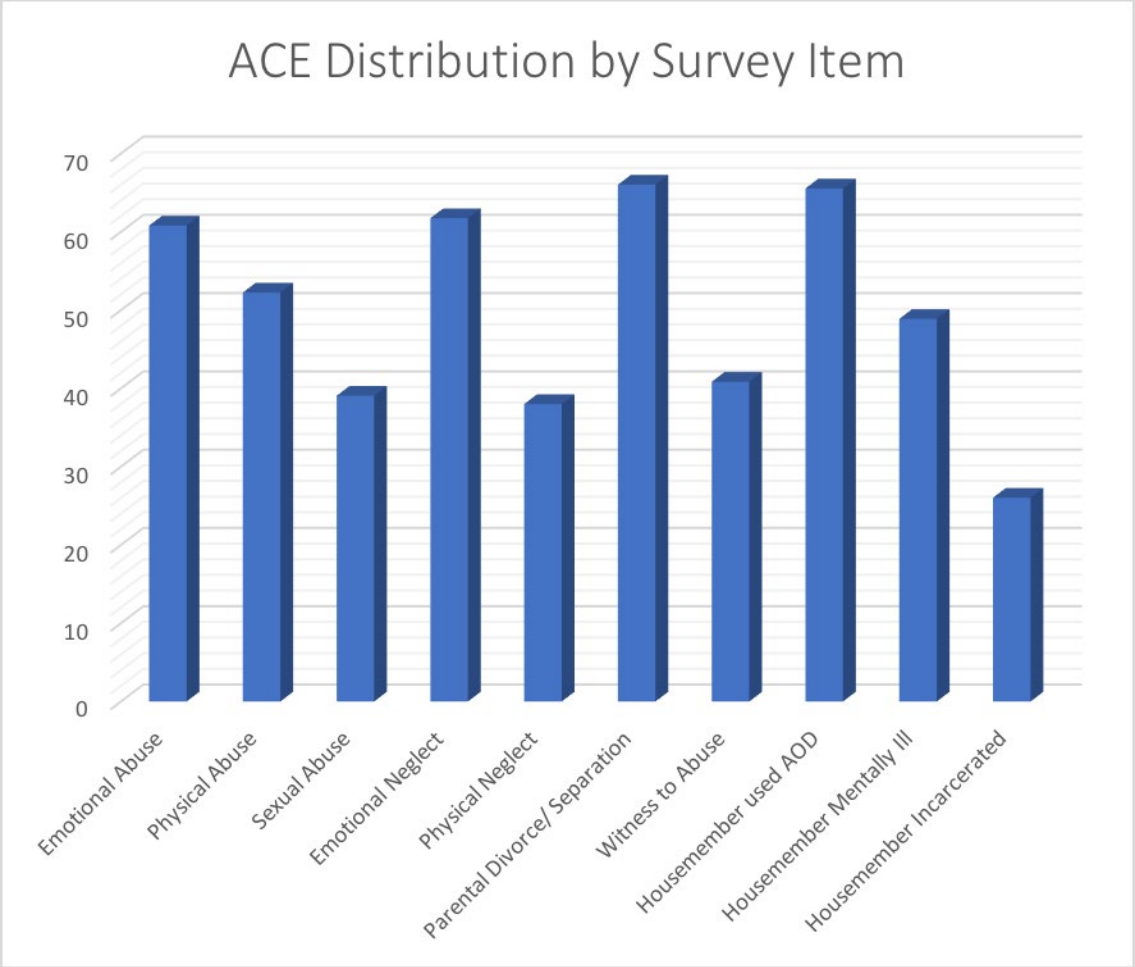
One relationship to analyze is that between the presence of protective factors and resting RSA within a sample of individuals with high ACE scores (4 or greater). If those with high childhood protective factor scores have higher resting RSA than those without, results may indicate that protective factors improve resilience enough to effectively buffer the impact of stress on resting RSA could inform prevention and intervention programs, and enable them to efficiently promote protective factors in the lives of children at risk for high ACE scores.

In analyzing studies on resilience, Lavoie and colleagues (2016) also found that while protective factors were indicative of resilience when adversity was low, the impact was less noticeable in situations with high levels of adversity. This finding suggests that interventions supporting at risk individuals via protective factors alone is insufficient. There are numerous issues that contribute to the high rates of child maltreatment and neglect in the US: wealth inequality and minimum wages that are below the poverty line put stress on parents and force them to work long hours, leaving children at home; drug and alcohol use can stimulate aggressive behavior and/or lead to neglect; and social norms resulting in communities that are more individualistic than communal, as families in which maltreatment occurs are often less socially connected

(*The Causes of Child Abuse,* 2013). On a grand scale, intervention and prevention efforts must include policy advocacy to combat racial, gender, and wealth inequality, and improve social provisions and access to healthcare. Large systemic changes will create a terrain in which psychophysiologically-informed interventions have maximal and lasting impacts on people who have endured adverse childhood experiences and may still be living with the impacts.

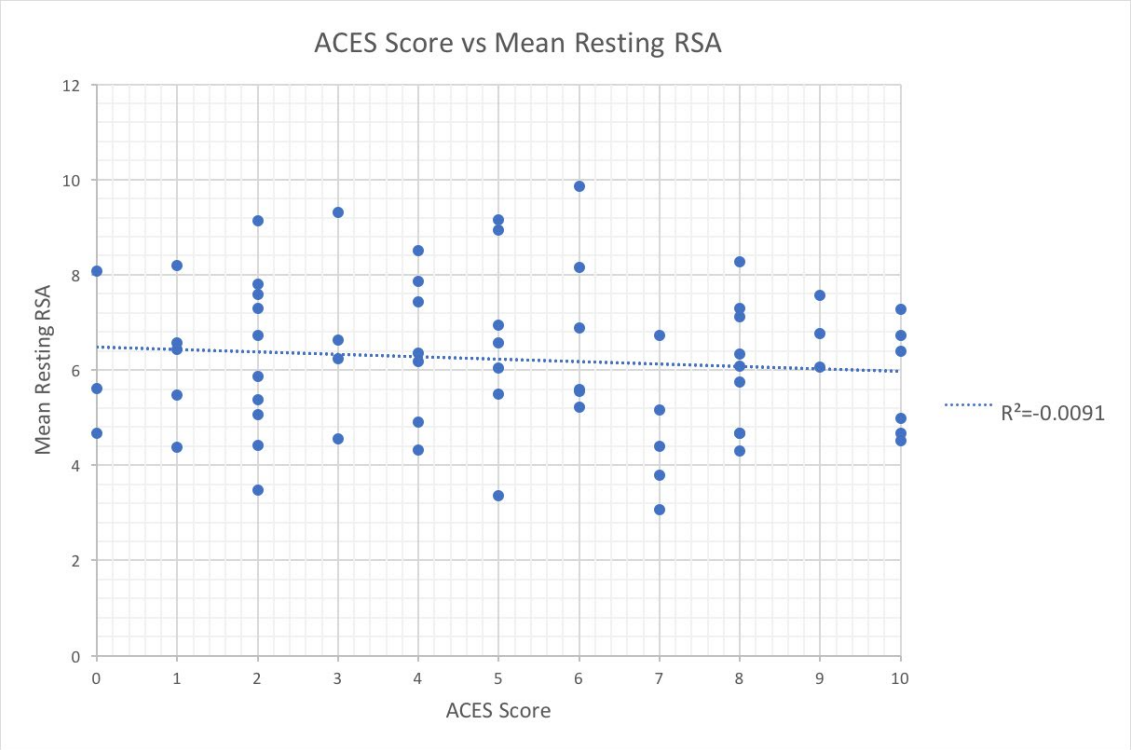
Appendix A

Number of participants who experienced each ACE.



Appendix B

Correlation between ACES Scores and Mean Resting RSA



References

Åhs, F., Sollers, J. J., Furmark, T., Fredrikson, M., & Thayer, J. F. (2009). High-frequency heart rate variability and cortico-striatal activity in men and women with social phobia. *NeuroImage*, *47*(3), 815–820. http://doi.org/10.1016/j.neuroimage.2009.05.091

Beauchaine, T. P. (2001). Vagal tone, development, and Gray's motivational theory: Toward an integrated model of autonomic nervous system functioning in psychopathology. Development and Psychopathology, *13*(2), 183-214.

Beauchaine, T. (2012). Physiological Markers of Emotional and Behavioral Dysregulation in Externalizing Psychopathology. Monographs of the Society for Research in Child Development, *77*(2), 79-86.

Beauchaine, T. P. (2015). Future Directions in Emotion Dysregulation and Youth Psychopathology. Journal of Clinical Child & Adolescent Psychology, *44*(5), 875–896. http://doi.org/10.1080/15374416.2015.1038827

Beauchaine, T. P., & Thayer, J. F. (2015). Heart rate variability as a transdiagnostic biomarker of psychopathology. *International Journal of Psychophysiology*, *98*(2), 338–350. http://doi.org/10.1016/j.ijpsycho.2015.08.004

Benarroch, E. E. (1997). The central autonomic network. *Clinical autonomic disorders* (pp. 17-23). Philadelphia: Lippincott-Raven.

Benarroch, E. E. (1993). The central autonomic network: Functional organization, dysfunction, and perspective. *Mayo Clinic Proceedings*, 68, 988-1001.

Berntson, G. G., Bigger, J. T., Eckberg, D. L., Grossman, P., Kaufmann, P. G., Malik, M., et al. (1997). Committee report: Heart rate variability: Origins, methods, and interpretive caveats. *Psychophysiology, 34,* 623-648.

Berntson. G. G.. Cacioppo. J. T., & Quigley, K. S. (1993). Respiratory sinus arrhythmia: Autonomic origins. physiological mechanisms, and psychophysiological implications. *Psychophysiology, 30, 183-196.*

Biaggioni, I. (2012). *Primer on the autonomic nervous system* (3rd ed.) (Low, P. A., Polinsky, R. J., & Patton, J. F., Eds.). London: Elsevier.

Billman, G. E. (2011). Heart rate variability – A historical perspective. *Frontiers in Physiology*, *2*, 86. http://doi.org/10.3389/fphys.2011.00086

Callegaro, M. (2008). Social desirability. In P. J. Lavrakas (Ed.), *Encyclopedia of survey research methods* (pp. 826-826). Thousand Oaks, CA: SAGE Publications. doi: 10.4135/9781412963947.n537

The Causes of Child Abuse. (2013). Family Resource Center. From https://www.frcmo.org/resources/resources-for-professionals/causesofabuse/

Centers for Disease Control and Prevention. (2016). About the CDC-Kaiser ACE Study. Retrieved from https://www.cdc.gov/violenceprevention/acestudy/about.html

Clark, C. A. C., Skowron, E. A., Giuliano, R. J., & Fisher, P. A. (2016). Intersections between cardiac physiology, emotion regulation and interpersonal warmth in preschoolers: Implications for drug abuse prevention from translational neuroscience. *Drug and Alcohol Dependence*, *163*, S60–S69.

The Adverse Childhood Experiences Study: A springboard to hope. (n.d.) *The ACE score*. Retrieved from http://www.acestudy.org/the-ace-score.html

El-Sheikh, M., & Whitson, S. A. (2006). Longitudinal relations between marital conflict and child adjustment: Vagal regulation as a protective factor. *Journal of Family Psychology*, *20*(1), 30–39. http://doi.org/10.1037/0893-3200.20.1.30

Felitti, V. J., Anda, R. F., Nordenberg, D., Williamson, D. F., Spitz, A. M., Edwards, V., Koss, Mary P., & Marks, J. S. (1998). Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults. *American Journal of Preventive Medicine*, *14*(4), 245–258.

Flaherty, E. G., Thompson, R., Litrownik, A. J., Zolotor, A. J., Dubowitz, H., Runyan, D. K., English, D. J., & Everson, M. D. (2009). Adverse childhood exposures and reported child health at age 12. *Academic Pediatrics*, *9*(3), 150–156. http://doi.org/10.1016/j.acap.2008.11.003

Gartland, D., Bond, L., Olsson, C. A., Buzwell, S., & Sawyer, S. M. (2011). Development of a multi-dimensional measure of resilience in adolescents: the Adolescent Resilience Questionnaire. *BMC Medical Research Methodology*, *11*(1), 134. http://doi.org/10.1186/1471-2288-11-134

Gross, J. J. (Ed.). (2013). Handbook of emotion regulation, second edition. Retrieved from https://ebookcentral-proquest-com.libproxy.uoregon.edu

Gyurak, A., & Ayduk, Ö. (2008). Resting respiratory sinus arrhythmia buffers against rejection sensitivity via emotion control. *Emotion, 8*(4), 458-467. http://doi.org/10.1037/1528-3542.8.4.458

Hastings, P. D., Sullivan, C., McShane, K. E., Coplan, R. J., Utendale, W. T., & Vyncke, J.D. (2008). Parental socialization, vagal regulation and preschoolers' anxious difficulties: Direct and moderated fathers. *Child Development*, *79*, 45–64. doi:10.1111=j.1467-8624.2007.01110.x

Hinnant, J. B., & El-Sheikh, M. (2011). Marital conflict, respiratory sinus arrhythmia, and allostatic load: Interrelations and associations with the development of children's externalizing behavior. *Development and Psychopathology*, *23*(2), 815-829. http://doi:10.1017/S0954579411000320

Hughes, K., Bellis, M. A., Hardcastle, K. A., Sethi, D., Butchart, A., Mikton, C., Jones, L., & Dunne, M. P. (2017). The effect of multiple adverse childhood experiences on health: a systematic review and meta-analysis. *The Lancet Public Health*, *2*(8), e356–e366. http://doi.org/10.1016/S2468-2667(17)30118-4

Kim, P., Evans, G. W., Angstadt, M., Ho, S. S., Sripada, C. S., & Swain, J. E. (2013). Effects of childhood poverty and chronic stress on emotion regulatory brain function in adulthood. *Proceedings of the National Academy of Sciences of the United States of America, 110*(46), 18442–18447, http://dx.doi.org/10.1073/pnas.1308240110.

Lampert, R., Tuit, K., Hong, K., Donovan, T., Lee, F., & Sinha, R. (2016). Cumulative stress and autonomic dysregulation in a community sample. *Stress* (Amsterdam, Netherlands), *19*(3), 269-79.

Lavoie, J., Pereira, L. C., & Talwar, V. (2016). Children's physical resilience outcomes: Meta-analysis of vulnerability and protective factors. *Journal of Pediatric Nursing*, *31*(6), 701–711. http://doi.org/10.1016/j.pedn.2016.07.011

Norman, R. E., Byambaa, M., De, R., Butchart, A., Scott, J., & Vos, T. (2012). The long-term health consequences of child physical abuse, emotional abuse, and neglect: A systematic review and meta-analysis. *PLOS Medicine*, 9(11), 1-31. http://doi.org/10.1371/journal.pmed.1001349

Nurius, P. S., Logan-Greene, P., & Green, S. (2012). Adverse Childhood Experiences (ACE) Within a Social Disadvantage Framework: Distinguishing Unique, Cumulative, and Moderated Contributions to Adult Mental Health. *Journal of Prevention & Intervention in the Community*, *40*(4), 278–290. http://doi.org/10.1080/10852352.2012.707443

Odgers, C., & Jaffee, S. (2013). Routine versus catastrophic influences on the developing child. *Annual Review of Public Health*, *34*, 29-48.

Porges, S. W. (2001). The polyvagal theory: Phylogenetic substrates of a social nervous system. *International Journal of Psychophysiology. 42*. 123-46. 10.1016/S0167-8760(01)00162-3.

Porges, S. W. (1998). Love: An emergent property of the mammalian autonomic nervous system. *Psychoneuroendochronology*, *23*(8), 837–861. http://doi.org/10.3949/ccjm.76.s2.17

Porges, S. W. (1995). Cardiac vagal tone: A physiological index of stress. *Neuroscience and Biobehavioral Reviews*, *19*(2), 225–233.

Porges, S.W. (2007). The polyvagal perspective. *Biological Psychology*, 74, 116–143, http://dx. doi.org/10.1016/j.biopsycho.2006.06.009.

Porges, S., Doussard-Roosevelt, J. A., & Maiti, A. K. (1994). Vagal tone and the physiological regulation of emotion. *Monographs of the Society for Research in Child Development*, *59*(2/3), 167-186.

Rottenberg, J., Wilhelm, F. H., Gross, J. J., & Gotlib, I. H. (2002). Respiratory sinus arrhythmia as a predictor of outcome in major depressive disorder. *Journal of Affective Disorders*, *71*, 265–272. doi:10.1016=S0165-0327(01)00406-2

Saul, J.P. (1990). Beat-to-beat variations of heart rate reflect modulation of cardiac autonomic outflow. *News in Physiological Science*, *5*, 32-37.

Shonkoff, J. P., Boyce, W. T., & McEwen, B. S. (2009). Neuroscience, molecular biology, and the childhood roots of health disparities: Building a new framework for health promotion and disease prevention. *Journal of the American Medical Association*, *301*, 2252–2259.

Sulik, M. J., Eisenberg, N., Silva, K. M., Spinrad, T. L., & Kupfer, A. (2013). Respiratory sinus arrhythmia, shyness, and effortful control in preschool-age children. *Biological Psychology*, *92*(2), 241–248. http://doi.org/10.1016/J.BIOPSYCHO.2012.10.009

Thayer, J. F. (2007). What the heart says to the brain (and vice versa) and why we should listen. *Psychological Topics*, *16*, 241–250. http://doi.org/10.1016/j.ijcard.2012.02.004

Thayer, J. F., Hansen, A. L., Saus-Rose, E., & Johnsen, B. H. (2009). Heart rate variability, prefrontal neural function, and cognitive performance: The neurovisceral integration perspective on self-regulation, adaptation, and health. *Annals of Behavioral Medicine*, *37*(2), 141–153. http://doi.org/10.1007/s12160-009-9101-z

Thayer, J. F., & Lane, R. D. (2009). Claude Bernard and the heart-brain connection: Further elaboration of a model of neurovisceral integration. *Neuroscience and Biobehavioral Reviews*, *33*(2), 81–88. http://doi.org/10.1016/j.neubiorev.2008.08.004

Thayer, J. F., Åhs, F., Fredrikson, M., Sollers, J. J., & Wager, T. D. (2012). A meta-analysis of heart rate variability and neuroimaging studies: Implications for heart rate variability as a marker of stress and health. *Neuroscience and Biobehavioral Reviews*, *36*(2), 747–756. http://doi.org/10.1016/j.neubiorev.2011.11.009

Thompson, R., Flaherty, E. G., English, D. J., Litrownik, A. J., Dubowitz, H., Kotch, J. B., & Runyan, D. K. (2015). Trajectories of adverse childhood experiences and self-reported health at age 18. *Academic Pediatrics*, *15*(5), 503–509. http://doi.org/10.1016/j.acap.2014.09.010

Wilcox, C., & Theodorou, L. (2015). *Trauma, Toxic Stress, and Adverse Childhood Experiences (ACEs): The OHA Perspective*.