The Link Between Low Childhood SES and Adult Stress: Evidence from EEG

By

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Abstract

Low childhood SES has been associated with diminished health and neurocognitive outcomes (Noble et al., 2005), though few studies have examined how the neurological stress response in adults is impacted by socioeconomic factors from childhood. This study uses EEG measures of frontal midline theta (FMT) and P300 to index cognitive control and arousal during economic threat and aversive stimuli presentation. Participants who grew up in lower SES environments showed an increased need for cognitive control indexed by FMT during threat. In those from low SES backgrounds, need for control was found to mediate the relationship between economic uncertainty and distress during aversive stimuli indexed by increased P300 amplitudes during auditory oddball. The results suggest that hypervigilance towards threat and adaptive goal-monitoring for survival in impoverished upbringings may create conflict-processing loops that increase one's neuro-physiological response towards stressful stimuli later in life. A neurocognitive mechanism of increased stress and reduced emotion regulation (ER) in low childhood SES individuals is presented. Implications for protective factors against reduced ER are discussed.

Preface

This thesis is an original work by Shafa Mazidi. The research projects, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board (Protocol 00084513).

Acknowledgments

Thank you to my supervisor, Kyle Nash, for your knowledge, spirit, and dedication to the lab and your students. You taught me why research is vital and why staying calm is always step one. Thank you to David Simpson and Paige Faulkner for your help and friendship. Thank you to Josh Leota and Alex Tran for modelling how to be fantastic researchers.

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Introduction

Low socioeconomic status (SES) in childhood is associated with physical and psychological health issues that persist into adulthood (Luo & Waite, 2005; Milaniak & Jaffee, 2019; Pool et al., 2021). To explain these disparities between adults with impoverished vs. enriched childhoods, researchers have focused on emotion regulation processes as a mechanism (Brito & Noble, 2014; Evans, 2004; Gallo & Matthews, 2003; McEwen & Gianaros, 2010; Miller et al., 2011; Shonkoff et al., 2009; Taylor et al., 2004). Emotion regulation (ER) is one's ability to moderate emotional change caused by endogenous or exogenous stimuli (Gross, 2015). The downregulation of negatively valenced emotion in response to stress is particularly important during threat as it helps the body to regulate goal-directed behaviour and respond intelligently to danger (McRae & Gross, 2020). ER is also implicated in reorienting to new task after distress to successfully approach new goals (Marigold et al., 2010). Low ER is linked to a host of health impacts such as chronic illness, poor physical function, and reduced resilience (DeSteno et al., 2013; Troy & Mauss, 2011). Although ER is found to underlie important emotional functions in adulthood, the differences in ER capacity may begin to develop as early as 3 months old (Zimmermann & Iwanski, 2014). ER increases over childhood development into adulthood with this trajectory being partially explained by parental factors. In a study of 4 – 7-year-olds, emotion regulation trajectories were shown to increase over time, but this improvement in regulatory skill was dampened for children whose caregivers showed greater depressive symptomatology (Oppenheim et al., 1997). Therefore, early environments play an important role in healthy emotion regulation capacity. SES is an environmental factor that touches all components of life (Adler et al., 1999), which may explain why SES is so impactful on ER development.

Children of lower SES backgrounds encounter more uncontrollable stressors, have fewer personal resources, and experience less warmth and interactive stimulation from their caregivers (Hackman, Farah, & Meaney, 2010; Miller et al., 2011; Taylor et al., 2004). For low SES households, increased levels of stress may influence the neurological development of threat response systems that lead to the healthy development of ER strategies into adulthood. During effortful regulation of negative emotion, children from lower family incomes show reduced dorsolateral prefrontal cortex activity, a region implicated in executive function, and increased amygdala activity, a region responsible for threat reactivity (Kim et al., 2013). Importantly, this pattern was not observed with variations in adult income. This suggests that elevated levels of chronic stress and diminished opportunities for stress reduction for low SES individuals negatively impact ER development and may impart lasting psychological and physical consequences into adulthood.

Despite the impact of childhood SES on ER and its long-term consequences on health, little research has experimentally examined vulnerability to stress and reduced ER among adults that experienced low SES in childhood. The neurological mechanisms by which low SES reduces ER are not yet well understood. In the current study, I examined if childhood SES would moderate neurocognitive functioning in response to a poignant, real-world stressor in young adults. The aim was to determine how low SES contributes to reduced ER, and in what conditions. Using EEG, I measured the impact of SES on economic threat sensitivity and arousal to aversive stimuli. This allowed for the previous work on models ER in SES to be studied in a controlled laboratory setting. Such experimental work can help explain why low SES in childhood is associated with increased physical and psychological health issues (Brito & Noble,

2014). This may give insight into possible neurological mechanisms of reduced ER, and further inform potential interventions that might recover resilience.

SES and HPA

When faced with stressful stimuli, the body initiates a physiological stress response through the hypothalamic-pituitary-adrenal (HPA) axis. Once a stressor triggers the hypothalamus, a cascade of neuroendocrine pathways are activated, releasing epinephrine, norepinephrine, and cortisol that divert the body's cellular response from long-term metabolic activity toward primary survival mechanisms (Guilliams & Edwards, 2010). Chronic activation of the HPA axis can be physiologically dangerous. Overactive HPA has been associated with lymphatic organ atrophy, adrenal gland hypertrophy, and stomach ulcers, as well as depression, diabetes, and sleep disorders (Gianotti et al., 2021; Guilliams & Edwards, 2010; Iob et al., 2020). Notably, cortisol levels and HPA dysregulation are disproportionately high in children from low SES backgrounds (Cohen et al., 2006; Vliegenthart et al., 2016). This disparity in HPA dysregulation may be underscored by differences in psychological response to threat. When early life stressors increase without the resources to effectively respond to these challenges, neurological and physiological dysregulation of the generalized stress response may result. For children from low SES households who have fewer resources to respond to stress, overactive HPA and emotional dysregulation are increased. Consequently, high childhood SES may be a buffer against low ER and afford more opportunities to combat a chronic stress response.

FMT and Cognitive Control

The Adaptive Control Hypothesis (TACH) proposes that need for cognitive control, i.e., increased uncertainty/conflict monitoring, and anxiety are functionally related in the midcingulate cortex (MCC). It proposes that increased theta frequency bands (~ 4 – 8 Hz

oscillations) in the MCC, known as frontal midline theta (FMT), index both anxiety and need for cognitive control (J. F. Cavanagh & Shackman, 2015). This neurological state represents underlying mechanisms used for threat monitoring and attending to potentially aversive outcomes (Grupe & Nitschke, 2013). FMT is associated with various anxiety-related constructs. For example, anxious individuals display increased FMT during gambling tasks, while non-anxious counterparts show no increase (Schmidt et al., 2018). Additionally, administering oxytocin during social rejection has been shown to flatten the increase seen in FMT during social pain when no oxytocin is administered (Zhang et al., 2021). Finally, theta increases when negative response feedback is given (Zheng et al., 2020).

P300 and Emotion Regulation

One method of neurologically measuring distress is indexing P300 (P3) event-related potentials (ERPs) to aversive stimuli. The P3 ERP is a positive voltage deflection that occurs ~300ms after presenting startling or unexpected stimuli (Sutton et al., 1965). Often measured over fronto-cortical brain regions, increases in P3 amplitude can index exposure to aversive events. For example, increased P3 has been shown after the onset of unpleasant auditory beeps (Smith et al., 1990), novel visual stimuli (Rozenkrants & Polich, 2008), or stimuli that require response inhibition (Bokura et al., 2001). Based on adaptive gain theory (see Nieuwenhuis et al., 2005) and the related locus coeruleus-norepinephrine (LC-NE) system (Aston-Jones & Cohen, 2005), P3 can be considered a neural analogue of physiological arousal.

Appropriate down-regulation of heightened arousal is essential for social and cognitive function (Bokura et al., 2001). Healthy emotion regulation comprises both up and down-regulation of emotion, however, here I will focus on down-regulation. For individuals from low SES backgrounds who are disproportionately exposed to high arousal states, downregulation of

arousal may be especially important given the connection between a chronically active HPA axis and diminished health (Jokinen & Nordström, 2009). Experimentally, emotional regulation can be inferred using P3 ERPs paired with aversive stimuli (Füstös et al., 2013). High social-anxiety individuals show greater P3 amplitudes after the presentation of gaze-averted faces compared to low-anxiety individuals (Schmitz et al., 2012), suggesting that response to unpleasant social stimuli may be heightened by high anxiety. Consequently, individuals with difficulty downregulating anxiety may exhibit stronger P3 ERPs in response to aversive stimuli after economic distress. This suggests that increased P3 activation during aversive stimuli can be used to index increased distress and impaired downregulation of negative emotion following threat, illustrating reduced capacity for ER.

Background on Economic Threat

In this study, I focused on economic threat as exogenous stressor. Economic threat has profound emotional and social consequences. It has been associated with higher stress levels, anxiety, depression, and suicide (Bechtel, 2012; Diener et al., 2010; Fitch et al., 2011; Stevenson & Wolfers, 2008). Economic threat has also been associated with increases in authoritarianism, prejudice, anti-immigrant sentiment, and nationalism (Baughn & Yaprak, 1996; Burhan & van Leeuwen, 2016; Butz & Yogeeswaran, 2011; Durvasula & Lysonski, 2006; Fabian et al., 2020; Gidron & Hall, 2017). Despite the connection between economic threat and reduced health outcomes, it is still being determined if low childhood SES leaves adult individuals more vulnerable to economic threat regardless of current SES. It is possible that with increased stress around basic needs and economic security in childhood, adults from low SES backgrounds are particularly susceptible to economic threat in adulthood. One study that explored how adults from different SES backgrounds respond to resource scarcity found that those from low

childhood SES are more impulsive, had higher responses to temptation, and are riskier when sacristy is salient (Griskevicius et al., 2013). This suggests that low childhood SES individuals may respond differently to scarcity, however, it is unclear what mechanisms underlie this relationship. With increased riskiness during stress, economic threat seems to increase approach motivation for those from low SES backgrounds more than high SES. However, while ER is suggested as a possibly mechanism, no study has shown this experimentally using neurological measures. Here, the relationship between childhood SES, and neural response to economic threat will be explored to gain insight into this gap in the literature.

Examining potential vulnerabilities during economic threats may be particularly important in the current economic climate. The 2008-09 global recession had a profound impact on emotional and social outcomes (Aslanidis, 2016; Bianchi, 2016; Buffel et al., 2015; Roszkowski & Davey, 2010; Ybarra et al., 2016). This same economic uncertainty persists in the wake of COVID-19 and may have consequences for those who grew up in underprivileged and marginalized communities. Understanding how children at the bottom of the socioeconomic ladder respond to distress during economic uncertainty in adulthood is critical to exploring how resilience and health are achieved post-pandemic. Determining the mechanisms through which low childhood SES contributes to the adult stress response may help reduce some of the adverse social and emotional outcomes of previous economic collapses. If, as the literature on ER suggests, adults who experienced low childhood SES are less equipped to regulate negative emotions, these individuals may be more vulnerable to economic threat and display greater distress towards adverse stimuli.

Rationale and Overview

I reasoned that if the link between childhood SES and adult psychological and physical well-being is partially explained by individual differences in emotion regulation capacity, then childhood SES should moderate the effects of psychological threat on neural markers of anxiety during neurocognitive emotion regulation processes. With reduced ER, low childhood SES should increase anxiety during distressing events and should impart difficulty in subsequently regulating this arousal in unrelated tasks. Past research has typically relied on self-report of emotion and distress (Füstös et al., 2013; Spinelli et al., 2021; Troy et al., 2017). Though this research has been crucial in understanding ER, there is a need for more objective measures. To explore ER processes, I measured FMT during a distressing event (economic threat) to index need for cognitive control. Consequently, people who can regulate this stress, and don't exhibit increased economic threat anxiety should not demonstrate increased FMT. On the other hand, people who feel an increased need for control due to economic threat should demonstrate increased FMT. Further, individuals with lower childhood SES should demonstrate increased FMT, indexing higher anxiety during threat, which will mediate the relationship between threat and difficulty regulating distress in a subsequent task. To index distress, I administered an auditory oddball task and measured P3 mean amplitude during unexpected, aversive, white noise blast. Here, increased P3 mean amplitude would suggest increased arousal and potential difficulty with emotion regulation.

In sum, I expected that individuals with low childhood SES would experience an increased need for cognitive control during economic uncertainty, as indexed by increased FMT. This increase in FMT would then mediate an increase in arousal to aversive stimuli, as indexed by P3 mean amplitude to unexpected white noise blasts, thereby demonstrating increased

difficulty downregulating negative emotion. Importantly, I expected that adult SES would not show this same moderating role in the relationship between threat and need for cognitive control.

Materials and Method

Participants

110 undergraduates enrolled in a first-year psychology course at the University of Alberta participated in this study in exchange for class credit (N = 110; modal age = 19; age range = 17–26; females = 61). Based on pilot data indicating that the current manipulation had a medium to large effect size on anxious uncertainty (Cohen's d = 0.65), a sample of 50 individuals per condition were targeted. Power analyses in G*Power (Faul et al., 2009) using this expected effect size suggested a sample size of 78 (difference between two independent groups, effect size d = 0.65, alpha = 0.05, power = 0.80, groups = 2, N = 78). Data collection stopped at the end of the 2019 fall term.17 participants were excluded due to poor EEG impedance (> 10 kOhms) or missing EEG data leaving a final sample of 93. Participants were not obligated to complete any materials and could withdraw at any point. Criteria to participate included having normal or corrected vision, being fluent in English, and not having hair that would interfere with successful EEG capping. Ethics approval was provided by the University of Alberta Human Research Ethics Board (Protocol 00084513).

Procedure

Participants first completed an electronic informed consent form and then were fitted with a 64-channel EEG headset (Brain Products) and seated at a computer station in an electrically-and sound-shielded room where the study took place. Participants first answered demographic questions and several personality questionnaires as part of a larger research project

on individual differences in neurological function and conflict detection (all data available upon request). Participants were then randomly assigned in a between-subjects design to either the *Economic Threat* or *No-Threat Control* conditions. Participants then completed a passive auditory oddball task. As part of a separate line of research, participants then completed a colour-naming Stroop task, and a Balloon Analogue Risk-Taking task (Leota et al., 2023). Participants completed a manipulation check where they rated the degree to which the economic threat manipulation made them feel a range of different positive and negative emotions, including anxiety and uncertainty (1 = Strongly Disagree, 5 = Strongly Agree). Next, they completed a measure of conscientiousness. Participants were then debriefed, had their EEG cap removed, their hair washed, and thanked for their time.

Economic Threat Manipulation

In the *Economic Threat* condition of the study, participants were presented with an ostensibly real article, supposedly from CBC.ca, that outlined a concerning economic forecast for Canada, with a specific focus on the potential impact on young adults. The article claimed to be based on research conducted by top Canadian economists, who predicted an impending recession that would disproportionately affect students due to their vulnerability, citing the 2008 economic crisis. To bolster the cover story, participants were told the article was being used to study how people process information, and that at the end of the study, they would need to submit a catchy headline. This article was designed to cater to the sample population of young students. In contrast, the *No-Threat Control* condition, participants were presented with a similar article that provided a more neutral economic forecast, emphasizing relative stability and a continuation of the current status quo. Notably, both articles were based on publicly available

economic predictions from reputable financial news outlets and were designed in form and content to replicate real articles from CBC.ca.

Auditory Oddball

Following the manipulation, participants completed the auditory oddball task. Participants were first instructed to fixate on a small circle presented on the computer screen and were informed that they would hear noises during the task. A sequence of standardized tones and white noise bursts were played, with standard tones of 1000 Hz lasting 50 ms, and aversive white noise blasts with a distinct 'hissing' sound ranging from 0 to 20,000 Hz, also lasting 50 ms. Tones were presented at 75 (standard) and 80 (white noise) db, respectively, with a 1:9 ratio of white noise to standard tones once per second for three and a half minutes, yielding a total of 210 tones. The passive nature of this auditory oddball task allowed for the investigation of more basic conflict detection processes without interference from task-based processing in the dorsal ACC (Nash et al., 2020).

Socioeconomic Status

I used an established measure of subjective SES (Adler et al., 2000) for both childhood and current SES. In this measure, socioeconomic rank is presented pictorially as a ‘social ladder,’ in which lower rungs on the ladder represent lower status relative to other individuals in society. Participants were instructed to select the step or rung (1 = lowest; 9 = highest) that corresponded to the perceived status of their parents during childhood, as well as their own current or attained status.

EEG Recording and Pre-Processing

An ActiCHamp, Ag-AgCl, EEG system (Brain Products) was used to record continuous EEG with a 64-array channel. The electrodes were positioned according to the 10/10 system and

digitized at a sampling rate of 512 Hz with 24-bit precision and a bandwidth of 0.1–100 Hz. During recording, signals were referenced to the TP9 electrode located over the left mastoid. Offline, EEG was re-referenced to the average mastoids (TP9-TP10), down-sampled to 256 Hz, band-pass filtered between 0.1 and 30 Hz, and notch filtered at 60 Hz. To remove blinks, an automatic ocular correction was used (Gratton et al., 1983). Artifacts were automatically detected based on the following criteria: min/max threshold of −100 to +100 μV, maximum voltage step of 50 μV, and the lowest allowed voltage of 0.5 μV in 100-ms intervals.

FMT

Recorded EEG was segmented into the reading duration (60s) of the economic threat manipulation for each participant. Contiguous artifact-free epochs of 2s were extracted through a hamming window and overlapped by 75% to avoid data loss. Power spectra were calculated via fast Fourier transform, and power values (in μV^2) were averaged over all artifact-free and blink-free epochs. Absolute power was averaged for the theta frequency band (3.5–7.5 Hz) at frontal midline nodes. The FMT dependent variable was calculated as theta power at the mid-frontal site, node Fz (J. F. Cavanagh & Shackman, 2015). Natural log was then applied to help normalize the distribution of the variable.

P3

EEG recording during the oddball task was segmented into 1000-ms epochs locked on either standard tone or white noise presentation, with a window from 200 ms before to 800 ms after the stimulus. For each participant, artifact-free epochs were averaged and baseline-corrected by subtracting the average voltage during the −200–0 ms time period prior to the stimulus. The P3 dependent variable is a difference score, calculated as the mean amplitude (in μV) between 200 - 400 ms after stimulus onset for white noise blasts, minus mean amplitude

between 200 - 400 ms after stimulus onset for standard tones where the startle component was maximal at the central electrode, Cz.

Statistical Analyses

To examine if childhood SES moderates neurocognitive and affective responses to economic threat, I first conducted moderated multiple regression analysis using the PROCESS macro MODEL 1 in the statistical software SPSS (see Hayes, 2013), with the economic threat manipulation entered as the X variable, childhood SES entered as the moderator, and FMT entered as the Y variable. It was expected that threat would increase FMT for those with low childhood SES (-1 SD), while threat would have no impact on FMT for those with high childhood SES (+1 SD).

Next, I repeated this analysis with current-attained SES as the moderator to determine whether adult SES moderates FMT. Economic threat manipulation was entered as the X variable, current SES as the moderator, and FMT entered as the Y variable. I expected that current SES would not moderate, this relationship.

Next, I examined if an increased need for control might mediate an increase in emotional arousal to economic threat, particularly amongst those low in childhood SES. I conducted moderated mediation analyses using the PROCESS macro Model 7 in SPSS (see Hayes, 2013), with the economic threat manipulation entered as the X variable, P3 entered as the Y variable, FMT entered as the mediating variable between X and Y, and childhood SES entered as the moderating variable between X and the mediator. Here, I expected that FMT would moderate increased P3 during auditory oddball, only at low childhood SES (-1 SD).

Again, this analysis was repeated, this time with current SES as the moderator between threat and FMT to determine its role in the overall mediation model. No moderated mediation of condition on P3 through FMT by current SES was expected.

Results

Manipulation Check

At the end of the study, participants were asked to rate the degree to which the reading manipulation made them feel 17 different emotions on a scale of 1-5 (1 = not at all; 5 = very much). This list included adjectives such as happy, successful, frustrated, confused, and anxious. Negatively valence adjectives were summed and averaged to give a composite index of manipulation anxiety (Chronbach's $\alpha = .92$). This was done to confirm whether the economic threat had the expected affect of increasing anxious uncertainty. An independent t-test revealed that those in the *Economic Threat* condition (M = 2.88, SD = .73) had significantly increased reported negativity over the *No-Threat Control* condition (M = 2.00, SD = .77), t (94) = -5.68, $p < .001$.

Moderation Analysis

Assumptions for moderation were checked and passed. No outliers were identified, while independent variables were mean-centered (Aiken et al., 1991). Gender demonstrated a strong relationship with FMT ($r = .437$, $p < .001$), therefore I entered this variable, along with age and current SES to control for the possibility of confounds in the results. Importantly, entering gender, age, and adult SES, as covariates does not impact the analysis, as all the primary findings are nearly identical without controlling for these variables (analyses and results available upon request).

To examine if childhood SES moderated neurocognitive and affective responses to economic threat, I first conducted moderated multiple regression analysis (Model 1 in PROCESS, Hayes 2013) in the statistical software SPSS. Condition was entered as the X variable, childhood SES entered as the moderator, and FMT entered as the Y variable. Analysis revealed a significant interaction effect of childhood SES and economic threat on FMT, B = -.11, SE = .06, t (86) = -2.00, p = .04, 95% CI [-.22 - -.00]. Notably, simple slopes analysis demonstrated that economic threat increased FMT only for those with low childhood SES (-1 SD), B = .35, SE .13, t (86) = 2.31, p = .01, 95% CI [.09 - .62]. For those at high childhood SES (+1 SD), there was no significant increase in FMT due to economic threat, B = -.05, SE = .15, t (86) = -.33, p = .74, 95% CI [-.34 - .25] (see Figure 1).

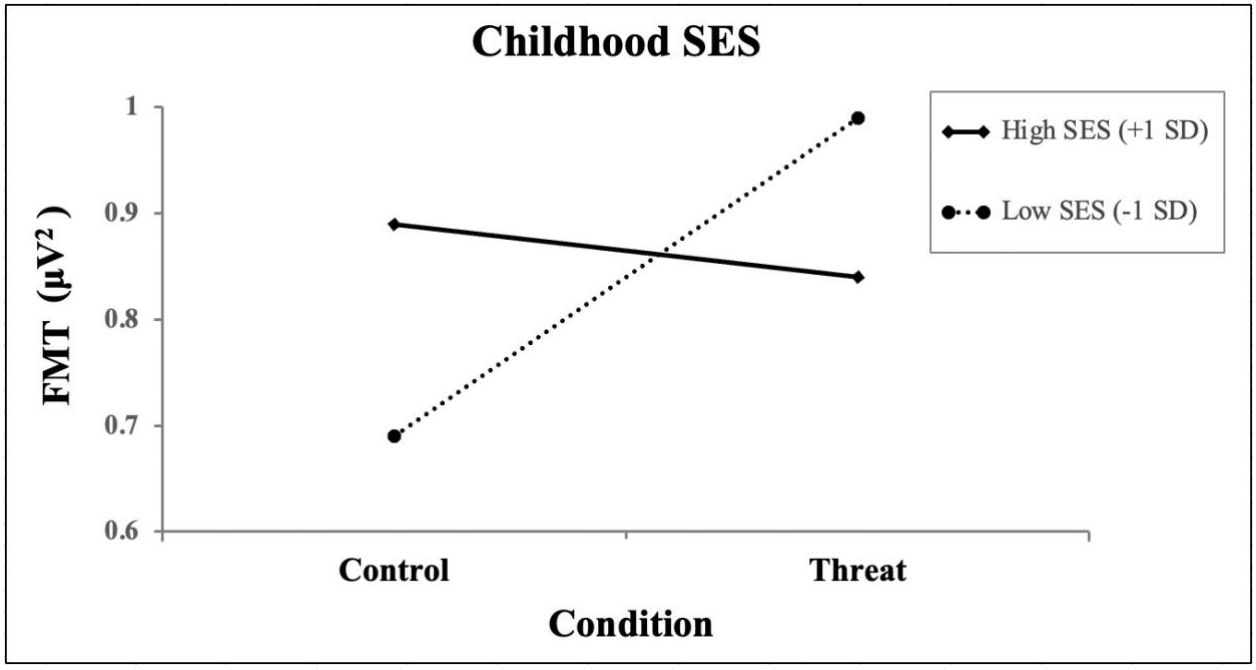

Figure 1. A significant interaction effect (p = .04) of condition and childhood socioeconomic status (SES) on Frontal Midline Theta power (FMT) during the economic threat manipulation task. The simple slope of condition on FMT for low SES (-1 SD) showed a positive significant effect (p = .01), while the slope for high SES (+1 SD) was non-significant (p = *.74*). Point estimates have been reverse-transformed to their original units (μV^2).

Next, I repeated this analysis with current-attained SES as the moderator to determine whether adult SES moderates the effect of condition on FMT in the same way as childhood SES. The same analysis method was used (Model 1 in PROCESS, Hayes 2013), this time with condition entered as the X variable, current SES entered as the moderator, and FMT entered as the Y variable. There was no significant interaction between condition and current SES on FMT, B = -.03, SE = .06, t (86) = -.49, p = .62, 95% CI [-.15 - .09], suggesting that current attained SES has no affect on the relationship between economic threat and FMT (see Figure 2).

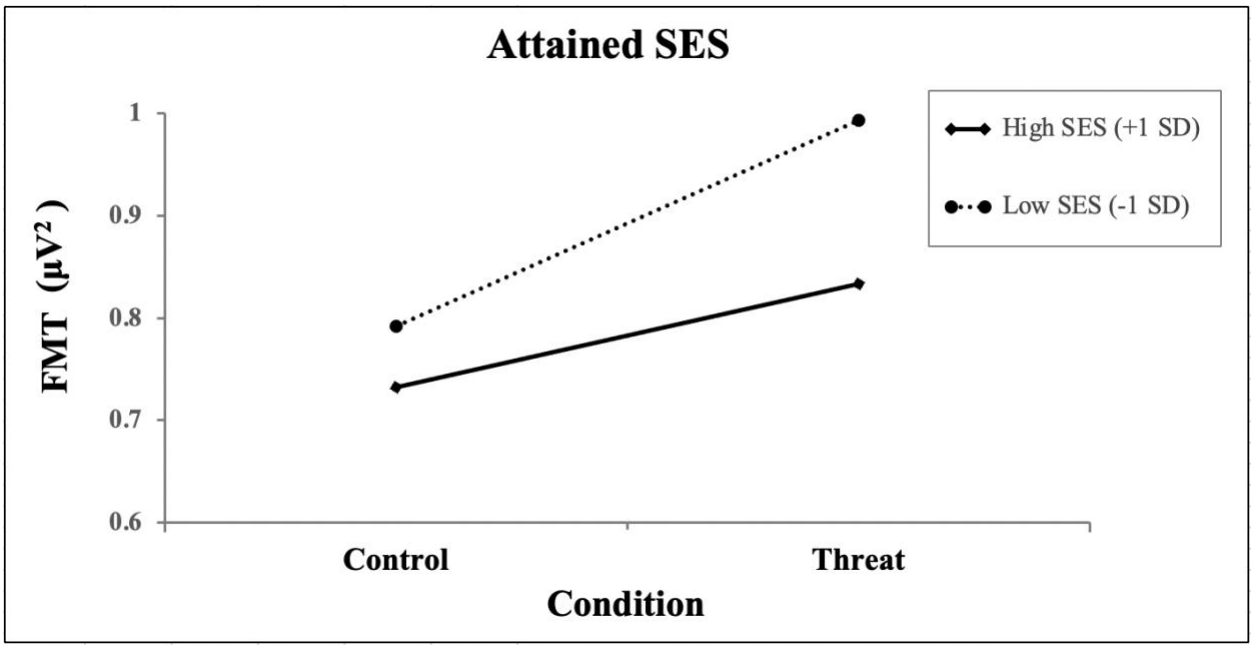

Figure 2. A non-significant interaction effect of condition and current-attained socioeconomic status (SES) on Frontal Midline Theta power (FMT) during the economic threat manipulation task. Main effect of condition on FMT is non-significant (p = .62). Point estimates have been reverse-transformed to their original units (μV^2).

Mediation Analysis

Moderated mediation analyses (Model 7 in PROCESS, Hayes 2013) was conducted to test if economic threat caused differences in P3 response, through increased FMT at different levels of childhood SES.

Mediation path analysis revealed that at low SES (-1 SD) there was significant moderated mediation effect of economic threat on P3 arousal through FMT, *B* = 1.95, bootstrapped *SE* = 1.15, bootstrapped 95% CI [.25 - 4.65] (see Figure 3). For those from high childhood SES (+1 SD), the mediation was non-significant, *B* = -.26, bootstrapped *SE* = .79, bootstrapped 95% CI [-2.09 – 1.05]. This suggests that only at lower levels of childhood SES, economic threat caused increased arousal to aversive stimuli (↑P3), and that this was driven by increased anxiety during the economic threat manipulation (↑FMT). The overall moderated mediation was marginally significant, Index = -.60, bootstrapped *SE* = .43, and bootstrapped 95%CI = [-1.63 - .00] which was likely do to a non-significant mediation at high childhood SES bringing down the overall mediation effect.

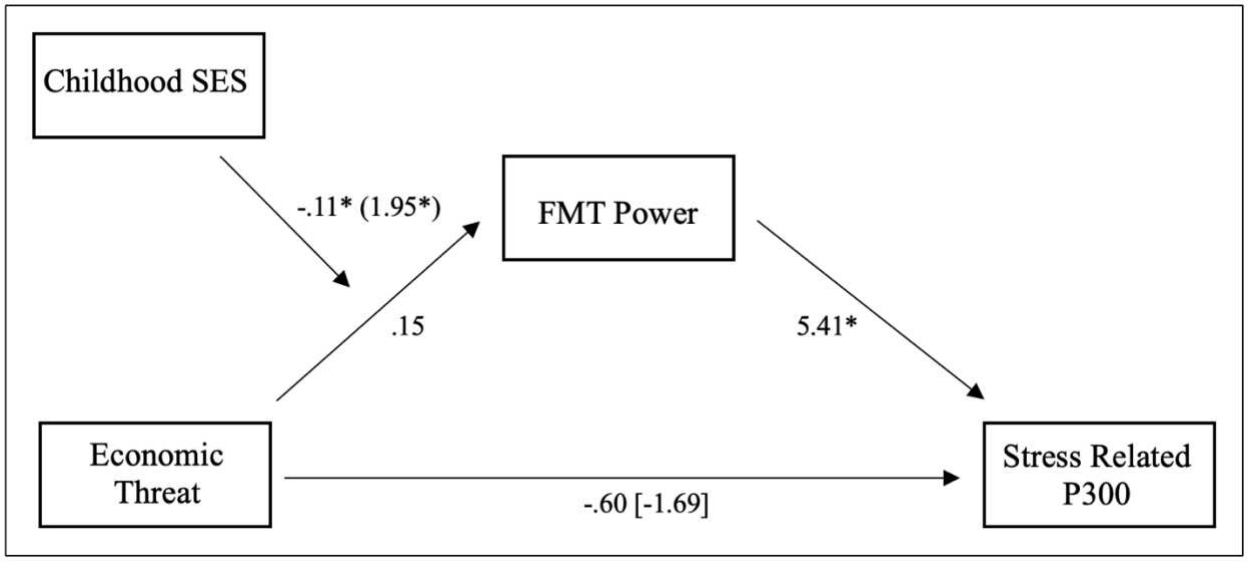

Figure 3: shows a significant moderated mediation of economic threat on P300 during auditory oddball, through FMT, only at low childhood SES (-1 SD). Statistic in parentheses show the coefficient of mediation at low childhood SES. Statistic in brackets shows the direct effect coefficient.
* = $p < .05$

Current SES entered as the moderator showed no significant moderated mediation effect, Index = -.30, bootstrapped *SE* = .32, and bootstrapped 95%CI = [1.02 - .24]., Suggesting that mediation occurs only at low childhood SES.

Discussion

The link between low childhood SES and poor adult psychological and physical health is often attributed to differences in emotion regulation capacity (Brito & Noble, 2014; Evans, 2004; Gallo & Matthews 2003; McEwen & Gianaros, 2010; Miller et al., 2011; Shonkoff et al., 2009; Taylor et al., 2004). Children of lower SES tend to experience higher levels of chronic stress and have fewer opportunities to regulate that stress, presumably limiting emotion regulation development (Hackman et al., 2010; Miller et al., 2011; Taylor et al., 2004). Although the link between low SES and ER is well documented, few studies have demonstrated this mechanistic relationship in a lab setting. Additionally, there is a lack of research that had explored ER during economic threat manipulation using neural measures of brain activity. The present study demonstrates a model of reduced emotion regulation capacity for adults from lower SES backgrounds, and gives evidence for downstream neurocognitive outcomes of childhood socioeconomic environment.

Here, I used an economic threat manipulation and white noise blasts to examine how adults from different childhood SES backgrounds regulate arousal responses to aversive stimuli after economic threat. Using EEG measures of FMT to index need for cognitive control and P3 to index arousal, I found that participants who grew up in lower SES environments showed increased need for cognitive control (↑*FMT*) when presented with economic uncertainty. High childhood SES participants did not show this increase in need for cognitive control. Need for control was also found to mediate the relationship between economic uncertainty and distress

during aversive stimuli indexed by increased P3 amplitudes during auditory oddball. Importantly, this mediation was only present for those with low childhood SES. However, current-attained SES showed no moderation of threat on FMT.

The increase in FMT during economic threat only for those from low SES upbringings suggests that individuals who grow up with less socioeconomic resources demonstrate increased vigilance after facing an aversive or psychologically-threatening event. When presented with uncertainty, individuals who grow up in underprivileged environments may respond to distress with increased arousal because of challenges in developing emotion regulation mechanisms. We know that children with low SES have reduced opportunities for warmth and support from caregivers (Miller et al., 2011). With fewer moments to develop these critical trusting relationships in childhood, individuals from low SES backgrounds may not be able to respond to unpredictability in the same way as those from high SES backgrounds.

The relationship between economic threat and P3 activity mediated by FMT suggests that increases in P3 activity in response to aversive stimuli moved through an increased need for cognitive control. Because childhood SES moderated this mediational effect only at low SES, it suggests that only those from low SES backgrounds who exhibit increases in FMT show greater arousal to aversive oddball stimuli. When current SES was entered into the model, there was no mediation effect of threat on P3 through FMT, suggesting that the mediated mechanism between increased FMT and threat arousal does not depend on current-attained SES.

The above moderation and mediation models experimentally demonstrate a reduced capacity of emotion regulation for individuals from low SES backgrounds. Here, the economic threat manipulation caused an increase in anxiety towards economic uncertainty only in those from low childhood SES, shown by increases in FMT. Through this increased FMT, individuals

from low SES backgrounds showed increased arousal towards aversive white noise blasts (↑ P3), indicating a reduced capacity to downregulate negative emotion following economic threat. Individuals from high SES backgrounds did not show an increase in FMT or P3, demonstrating that this challenge in downregulating negative emotion was not present for those from enriched childhood upbringings. Together, the moderation and mediation models illustrate that ER capacity may be different for individuals from low versus high childhood SES. Although low childhood SES impacted FMT and P3 responses during aversive tasks for these adult participants, their current SES played no role in their propensity to emotionally regulate after economic threat. Measuring this relationship in adulthood shows the importance of childhood SES in the development of healthy ER capacity into adulthood.

Heightened daily stress, interpersonal conflict, and increased uncertainty around safety and support in childhood for those from low SES backgrounds (Hackman, Farah, & Meaney, 2010; Miller et al., 2011; Taylor et al., 2004), can adversely affect one's ability to cope with economic uncertainty. Consequent challenges in downregulating negative emotion elicited by aversive experiences suggest that hypervigilance towards threat and adaptive goal-monitoring for survival in impoverished upbringings may create physical and emotional loops that increase one's neuro-physiological response towards stressful stimuli later in life. Early childhood experiences may impact our stress response system in adulthood regardless of how enriched our adult environments become. This adds to the research on mechanisms of reduced health through poverty by suggesting that low SES impact cognitive and emotional function into adulthood. It also suggests that attempting to buffer low childhood SES experiences with enriched adult experiences may not help recover the reductions in emotional regulation from childhood.

I demonstrate a mechanism of reduced ER and increased arousal to distress through heightened cognitive vigilance during threat for individuals from low SES backgrounds (see Figure 4). Through this mechanism, reduced childhood SES increases anxiety to threat which impacts arousal during an unrelated aversive task, illustrating reduced ability to downregulate negative emotion. The findings address the gap in literature by providing evidence for the mechanism of reduced ER and hyper-arousal to distress in adults from low SES backgrounds.

Previous research has proposed ER as one of the potential mechanisms for reduced health in low childhood SES. However, to my knowledge, no study has experimentally demonstrated this mechanism in lab using economic threat until now. This study gives evidence for the reduced capacity in ER that previous research has suggested underlies disparities in health across different childhood environments.

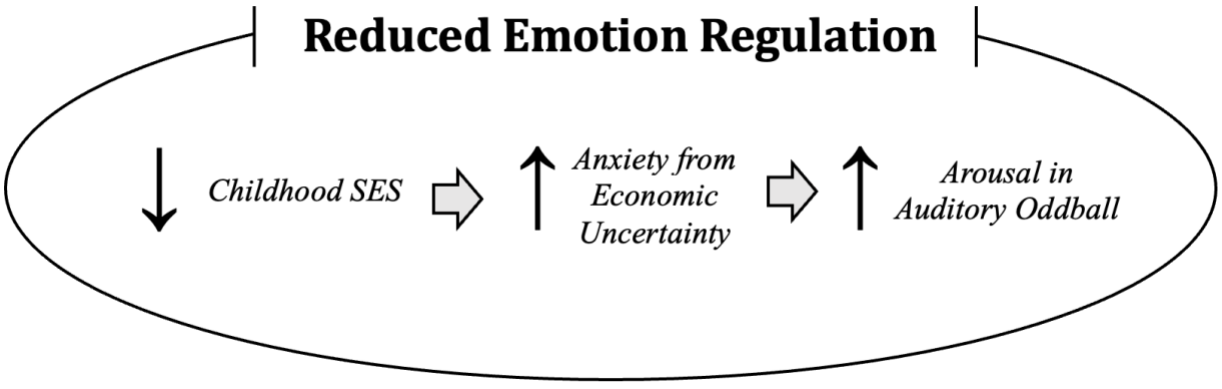

Figure 4. Illustrates mechanism of reduced emotion regulation capacity for individuals from low childhood SES backgrounds. Moves through anxiety during threat (indexed by FMT) and increased arousal during a subsequent aversive oddball task (indexed by P3).

Implication For Childhood ER

The impact of low childhood SES on arousal and emotion regulation underscores the importance of supporting families caught in lower socioeconomic brackets to combat the ballooning economic disparity seen in recent years (Diffenbaugh & Burke, 2019; Zucman, 2019). As inequality increases and more of the population finds itself in relative low socioeconomic positions, more families will be exposed to situations that negatively impact their children's long-term health (Cohen et al., 2006). Although, legislation and social policy are necessary to combat the growing rates of social disparity and income inequality. Some research has suggested that economic advancement may be a way to reduce the burden of low income on health by bringing more families out of poverty (Roemer & Gugerty, 1997), however, more pointed interventions may be needed to foster health for those who find themselves in impoverished childhood environments. Research on factors that promote perceived control in childhood and downstream emotion regulation in adulthood are essential for reducing the socioeconomic health gap.

Subjective vs. Objective SES

SES was measured subjectively in this study. This was done intentionally to allow for a more representative measure of socioeconomic deprivation rather than creating arbitrary categories of income and social position. Measuring subjective SES was practical given the overarching topics of ER and emotional response to threat. Emotion and threat response generation are both highly complex and personal experiences related to feeling (Damasio, 1995). Had SES been measured using objective numerical groupings, the importance of individual understanding and experience of childhood upbringing may not have been factored. In other

words, measuring objective SES instead may have been an inaccurate measure of the construct. However, future research should examine how these findings relate to objective measures of income and how measures of absolute deprivation compare to these results. A subjective rating for SES in comparison to one's community may expose the importance of income inequality in the construct of SES and its impact on ER. Future research should aim to compare the differences between socioeconomic deprivation and income inequality in the conversation on SES and health.

Limitations and Future Direction

By measuring arousal to aversive stimuli using P3 ERPs, this study focused on the downregulation of negative emotion. However, emotion regulation encompasses up and down-regulation (McRae & Gross, 2020). While these findings imply that individuals from low SES backgrounds have difficulty downregulating negative emotion, it remains unclear if this pattern holds for the upregulation of positive emotion. Studies examining ERPs and mood have found that depressed individuals may show a muted P3 response to emotional stimuli (J. Cavanagh & Geisler, 2006; Hajcak et al., 2012; Kayser et al., 2000). In these cases, challenges to regulate emotion may be shown by reduced capacity to upregulate rather that downregulate. This underscores the importance of considering both increased and decreased arousal in adaptive ER. The present study did not explore up-regulation of arousal to positive stimuli and therefore cannot speak to this component of ER and its connection to SES. Future studies should measure arousal to positive and negative stimuli after manipulations to explore how stimuli valence may interact with SES.

Manipulating economic threat allowed me to examine how SES impacts cognitive and emotional responses to a domain-relevant threat construct. Here, individuals from lower SES

backgrounds had increased cognitive responses to economic threat, suggesting that this type of threat impacts individuals from diverse socioeconomic circumstances differently. This adds to the gap in the literature on economic threat, childhood SES, and emotional reactivity. However, one should be cautious before extending these findings to other threat domains. While various types of threat have all been shown to impact common underlying neurocognitive systems (McGregor, 2006), future research should examine how threats such as mortality salience (Greenberg et al., 1990), social inequality (Bigman et al., 2021), and achievement threat (Nash et al., 2011), impact cognitive control and arousal for different socioeconomic realities.

The results suggest that people from high SES backgrounds were not affected by economic uncertainty in the same way as individuals from low SES backgrounds. There could be multiple explanations for this effect, but one possibility is that individuals from high SES backgrounds do not have strong sensitivities to economic threat domains. For those who have resources to deal with economic downturn and uncertainty, swings in the economy may not be anxiety provoking to the same degree as they are for those without this privilege. Because economic threat was used as the anxiety manipulation, those from high SES upbringing may not have shown increases in FMT during threat because for them it was not domain relevant. It is possible that had the manipulation been more relevant for high childhood SES individuals, such as social exclusion or disorder, they may have shown markers of increased need for cognitive control. It is important to note that current SES had no impact on threat anxiety indexed by FMT. Even for those from current low socioeconomic situations, FMT did not increases during threat, suggesting that the pattern of increased cognitive control and arousal in this study is more related to childhood environment than adult economic position. Even with this noted, it is possible that high childhood SES individuals are protected from anxious reactions to economic uncertainty in

adulthood because sensitivity to this stressor may not be strongly developed in childhood. Less need to worry about economic uncertainty in childhood may allow high SES children to feel protected from economic downturn, even into adulthood. More research is needed on how high SES upbringings develop reduced sensitivity to economic threat, and how current SES interacts with diverse threat domains.

The current findings may also help inform interventions to foster resilience in the socioeconomically disadvantaged. For example, researchers could focus on treatments known to improve emotion regulation capacity in children. Treatments such as mindfulness and attentional training, have been shown to be useful in this domain (Eldar et al., 2012; Schuppert et al., 2009; Semple et al., 2010), and should be explored to see how they interact with different socioeconomic backgrounds. Increased capacity to regulate distress could help buffer disadvantaged children from the chronic stress associated with low SES and improve adulthood outcomes. Alternatively, researchers could attempt to directly improve functionality in the underlying neurobiological system. For example, neurofeedback or regulatory skill training manipulations could be used to improve perceived control (Raymond et al., 2005; Zweerings et al., 2020) to foster robust neurocognitive mechanisms that may improve health and emotional regulation in adulthood. Some research suggests that a "shift and persist" strategy of stress acceptance and reappraisal may be useful for increasing emotional and physical health, especially at low socioeconomic incomes (Chen & Miller, 2012). More research is needed on how these strategies may be used to buffer against economic uncertainty and increase emotion regulation.

Conclusion

EEG was used to examine how adults from both low and high-SES backgrounds respond to economic uncertainty and aversive auditory oddball task. It was found that economic threat elicits an increased need for cognitive control, indexed by FMT, in individuals from low (-1 SD), but not high (+1 SD) childhood SES. FMT was also found to mediate the relationship between threat and increased arousal during unpleasant auditory oddball, as indexed by increased P3 amplitude, only for low childhood SES individuals. Importantly, this pattern of results was not present for current attained SES, suggesting that childhood SES impacts these neurocognitive mechanisms independently of adult socioeconomic position.

The dependent variable of SES in this study asked participants to rate how they felt in relation to others in their communities. This construct may underscore a spread or hierarchy of resources just as much as a lack or presence of them. Here, inequality in the social spectrum has potential to play a role in increased sensitivity to economic uncertainty and reduced ER. As GDP continues to increase across the globe (Kubiszewski et al., 2013), wealth may not be enough to counteract the adverse effects of low childhood SES on ER (Biggs et al., 2010). Exploring how social disparity impacts ER development could be a fruitful and illuminating line of research.

Overall, these findings add to the growing literature on the cognitive and affective systems that undergird the psychological effects of SES (Farah, 2017). They support several models that explain health disparities associated with childhood SES as partially due to differences in emotion regulation capacity (Brito & Noble, 2014; Evans, 2004; Gallo & Matthews 2003; McEwen & Gianaros, 2010; Miller et al., 2011; Shonkoff et al., 2009; Taylor, et al., 2004). More broadly, these findings add to this research by demonstrating a neuro-cognitive

model of ER though childhood SES and cognitive reactivity to threat and aversive stimuli. These long-term and consequential outcomes of childhood SES further validate the idea that interventions are critical to better ensure equity in social opportunity and pave the way for future explorations on the neurobiological mechanisms that underlie psychological differences associated with childhood SES.

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Appendix A

No-Threat Control Manipulation

TORONTO—A high profile report released by leading economists at University of Toronto paints a reassuring economic picture for Canadians. The report argues that the Canadian economy is recovering from the recent economic downturn and that there are indicators that this recovery will be stable.

In 2016, Federal Reserve officials worried that banks would go bankrupt, but new regulations similar to those already in place in countries like Canada have now attenuated that risk. Businesses benefited from the recent downturn by becoming more competitive, and this will continue to pay economic dividends over the next 10 years. Global business leaders are once again earning profits. The G20 countries' recent agreement to slash their deficits will improve global economic conditions by stimulating the economy and creating jobs for Canadians. Statistics Canada, Canada's national statistical agency, reported on Wednesday that income inequality has reached its lowest point in the last 30 years. Both unemployment rates and student debt are at a record low, suggesting an easier transition into the labour force for university graduates as well as those looking to re-enter the employment market.

In sum, the report projects economic stability in Canada, and that Canada is well positioned because its economy is based on export industries that are in demand during such periods of stability. University graduates entering the job market for the first time will have employment opportunities. The report concludes that, "In addition to the adequate levels of employment that will occur as a result of the predicted stability, prices of basic necessities like food, shelter, gas and medical supplies will remain affordable."

Appendix B

Economic Threat Manipulation

TORONTO—Leading economists at University of Toronto paint an unsettling economic picture for Canadians. Although the Canadian economy may appear stable, there are ominous indicators that this false recovery will soon give way to an economic collapse.

The University of Toronto economists say that wage stagnation, declining job quality, and fewer long-term employment opportunities all signal trouble, particularly for the university graduates. Even now, those who are employed are working longer hours for less pay, while still struggling to secure basic necessities like food, shelter, gas, and medical supplies. Economic red flags suggest that these problems will spread and that the financial conditions of young Canadians over the next 10 years are likely to worsen. Unemployment rates have risen significantly, with university graduates bearing the brunt, juggling historic levels of student debt. A 2018 Ipsos poll found that more than 75 per cent of Canadian graduates under the age of 40 regret taking on student debt.

Robert Mundell, Nobel prize winner and professor of economics, cites new technology and income inequality as factors suppressing wages for Canadians. According to Mundell, computerization threatens to put a substantial percentage of the current labour force out of work over the next 10 years. Additionally, Mundell points out that Canada has one of the highest levels of income inequality among big, rich countries. Mundell worries that the Canadian economy is "enriching the few at the expense of the many", which in turn "is making a mockery of democracy". Such levels of income inequality are a strong indication that an impending economic recession is likely.

The Toronto economists link the rising rates of depression, anxiety, and drug and alcohol abuse among Canadian workers, with growing economic insecurity, income stagnation, and wealth inequality. It is likely working Canadians are faced with an uncertain path moving forward.