A pilot study investigating heart rate variability as a measure of stress in healthy school children responding to experimental stressors

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List of Abbreviations

Abbreviation	Definition
ACE	Adverse Childhood Experiences
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
ANS	Autonomic Nervous System
APA	American Psychological Society
BART	Biofeedback-Assisted Resilience Training
BB	Battle Breathing
BMI	Body Mass Index
BSI	Brief Symptom Inventory
CAPS	Clinician Administered PTSD scale
CASP	Critical Appraisal Skills Programme
CG	Control Group
CI	Confidence Interval
CINAHL	Cumulative Index to Nursing and Allied Health Literature
CONSORT	Consolidated Standards of Reporting Trials
CP	Cold Pressor
CPT	Cold Pressor Test
CTQ	Childhood Trauma Questionnaire
CTS	Childhood Trauma Screening Questionnaire
CYRM-R	Child and Youth Resilience Measure (CYRM-R)
DSM	Diagnostic and Statistical Manual
ECG	Electrocardiogram
ELS	Emotional Life Stress
EMDR	Eye Movement Desensitisation and Reprocessing
ENS	Enteric Nervous System
ETI	Essen Trauma Inventory
FSS	Felt Security Scale
GP	General Practice
HF	High Frequency
HP	Heart Periods
HPA	Hypothalamus–pituitary– adrenal
HR	Heart Rate
HRV	Heart Rate Variability
IBM	International Business Machines Corporation
LF	Low Frequency
MESM	Mental and Emotional Self-Management
MIST	Montreal Imaging Stress Task
MSE	Multimedia Stressor Environment
NIRS	Near Infra-Red Spectroscopy
NREM	Non-Rapid Eye Movement
PANAS	Positive And Negative Affect Schedule
PB	Paced Breathing
PB1	Paced Breathing 1
PCL	PTSD Checklist
PDS	Pubertal Development Scale

PHQ	Patient Health Questionnaire
PICOS	Population, Intervention, Comparison, Outcomes, and Study
PNS	Parasympathetic Nervous System
PPG	Photoplethysmography
PRESIT	Predeployment Stress Inoculation Training
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analysis
PSS	Perceived Stress Scale
PTG	Post-Traumatic Growth
PTSD	Post-Traumatic Stress Disorder
RA	Reward Anticipation
RCT	Randomised Control Trial
REM	Rapid Eye-Movement
RMSSD	Root Mean Square of Successive Differences
RP	Resting Period
RP1	Resting Period 1
RSA	Respiratory Sinus Arrhythmia
RSQ	Relationship Structures Questionnaire
SBP	Systolic Blood Pressure
SCL	Skin Conductance Level
SDNN	Standard Deviation of all R-R intervals
SE	Standard Error
SECPT	Socially Evaluated Cold Pressor Test
SG	Sample Group
SG1	Sample Group 1
SG2	Sample Group 2
SNS	Sympathetic Nervous System
SPSS	Statistical Package for Social Sciences
SS	Social Stressor
STAI	The State-Trait Anxiety Inventory
TAU	Treatment As Usual
TFR	Trauma Film Ratings
TISUK	Trauma Informed Schools United Kingdom
TLE	Traumatic Life Event
TSST	Trier Social Stressor Test
TST	Total Sleep Time
UCLA	The UCLA Child/Adolescent PTSD Reaction Index for DSM-5
VIF	Variance inflation factors

Abstract

The body's response to stress, both in the short-term and long-term, is a key early indicator of potential psychological disturbances. Heart rate variability (HRV) is increasingly being utilised as a marker for physiological resilience. A pilot study involving a cross-sectional convenience sample of healthy 9- to 11-year-old schoolchildren (n=66) from East Anglia found that a physiological stressor triggered a stronger parasympathetic response ($M = 16.41$, $SD = 29.4$) compared to a social stressor ($M = 5.33$, $SD = 32.96$) $p < .001$. Furthermore, the children exhibited a greater parasympathetic response post stressor when following a breathing pacer (RSA) than when resting. The study also suggested a potential link between traumatic life events, as identified by a screening tool, and increased physiological resilience, indicated by higher HRV. However, this finding was not replicated when the event was validated using a more clinically established measure, possibly due to the limited sample size. In this study, self-reported resilience did not appear to correlate with physiological resilience.

The pilot study provided valuable insights into the methods used and revealed ways to refine them as the project advanced. This process enabled observations and assessments of the impact of these adjustments, leading to a better understanding of which approaches would be most effective for optimizing the design of a larger-scale school-based study in the future. The study also underscored the challenges of working within a multi-faceted project team and engaging with school children in a school setting.

The concepts of stress, resilience, HRV, and trauma are broad and complex, remaining essential areas for future research. This study explored some of this complexity, emphasizing the need for careful interpretation of conclusions. Nonetheless, the findings add to the growing body of literature that will help shape future policy, clinical interventions, school services, and healthcare systems.

Introduction

Overview

This introduction section will establish the theory and research that underpins this project. It will begin with describing the background of the topic of PTSD, trauma & resilience, and how this contributes to the construction of the research question this project answers. The main aims and objectives will then be specified. This section then presents a systematic review which uses critical methods to identify, define and assess the body of literature that informs our understanding of this area.

Trauma events and PTSD

The Diagnostic and Statistical Manual of Mental Disorders – 5 (DSM-5) defines Post- Traumatic Stress Disorder (PTSD) as the exposure to a traumatic event as well as four clusters of symptoms (Acheson, Geyer & Risbrough, 2014). A traumatic life event could include examples such as combat stress, physical and sexual assaults, muggings/robberies, motor vehicle accidents, forced captivity, life-threatening illness, and natural disasters among other events (Breslau, 2009). The four symptom clusters include; negative alterations in cognitions and mood, intrusion, alterations in arousal and reactivity, and avoidance (Acheson, Geyer & Risbrough, 2014).

It is estimated that 90% of the adult population will experience some form of event during their lifetime that could be considered traumatic (Kilpatrick, Resnick, Milanak, Miller, Keyes, & Friedman 2013). If a child or adolescent experiences trauma, around 16% will go on to develop PTSD (Kolaitis, 2017). Why this pathology develops in some individuals who have experienced a traumatic event but not others, is an important question that continues to draw focus from the research community. PTSD can be a potentially debilitating disorder that is characterised as an avoidance of associated trauma stimuli, hypervigilance, intrusion ymptoms, marked

physiological reactions to trauma cues (APA, 2013a). The National Audit Office (2010) calculated that the cost of providing treatment to trauma patients was between£300 and £400 million a year. Whilst traditional interventions for PTSD and trauma target the cognitive, emotional and behavioural domains, the underlying physiological mechanisms are often not a focus (Arpaia, & Andersen, 2019). In order to understand why trauma develops it is worth outlining how the body adapts to, and regulates, stressful stimuli in everyday life.

The physiology of stress responses & PTSD

A typical adaptive response to a traumatic event is one in which an individual endures an initial acute stress, subsequent anxious or depressive symptoms over the course of several days after the event, followed by a recovery (Schmidt, Kaltwasser, & Wotjak, 2013). A sustained stress response, which occurs in individuals experiencing chronic stress, has complex and wide-ranging effects on people socially, psychologically and physically (Epel, Crosswell, Mayer, Prather, Slavich, Puterman & Mendes, 2018). This includes links to physical conditions such as cardiovascular disease, diabetes, stroke, obesity, immune deficiencies (Iqbal, Elahi, Redon, Vazquez, Wijns & Shahzad, 2021) and mental conditions including anxiety, depression and many other psychopathologies (Snyder, Young, & Hankin, 2019).

Elevated physiological reactivity, or 'startle response', is a common feature of those presenting with PTSD. This elevation has been explored as a possible risk factor immediately after exposure to a traumatic event (Acheson, Geyer & Risbrough, 2014). Studies have shown that an elevated HR following exposure to a traumatic event predicts development of symptoms of PTSD (Zatzick, Russo, Pitman, Rivara, Jurkovich & Roy-Byrne, 2005; Kuhn, Blanchard, Fuse, Hickling & Broderick, 2006; Gould, McKibben, Hall, Corry, Amoyal, Mason, McCann & Fauerbach, 2011). Twin studies have suggested that this acute, elevated HR response is acquired following the traumatic exposure, rather than as a risk factor for PTSD (Pitman,Gilbertson, Gurvits,

May, Lasko, Metzger, Shenton, Yehuda, Orr, & Harvard/VA PTSD Twin Study Investigators, 2006). Further longitudinal research would be needed to clarify this claim further.

The major neural pathway activated by stress is known as the autonomic nervous system (ANS) (Won & Kim, 2016). The ANS has three distinct regions: the (SNS), the parasympathetic nervous system (PNS) and the enteric nervous system (ENS). The SNS and the PNS can be conceptualised as the accelerator and brake of your nervous system, respectively (Miller-Karas, Dust & Citron, 2013). Experiencing stress causes SNS activation and the subsequent release of adrenalin from the adrenal glands (McCorry, 2007). Further stress hormones are produced, such as cortisol, which triggers the release of glucose and energy so that the body can react to the stressful environment (Salai, Vassányi & Kósa, 2016). This SNS activity is linked to the 'fight or flight' response in the body in the advent of acute stress. Whilst the SNS is being stimulated, the PNS, linked to the 'rest and digest' functions in the body, is secondary. Once the stressful experience subsides and the individual is safe, the PNS becomes stimulated. The PNS restores the body to homeostasis (Dalmeida, & Masala, 2021). This balancing of the SNS and the PNS during acute stress reflects the individual's response to stressful or traumatic events. When an acute stressor starts to become converted to a chronic or recurrent stress, the SNS response is sustained and the PNS does not intervene. This continuous hyperactivity of the SNS is a feature of ANS dysregulation that links both the psychological and physiological pathologies inherent within PTSD (Kemp & Quintana, 2013).

Despite the heavy burden that PTSD places on individuals and society, it is often not diagnosed in a timely manner because of its overlapping symptom profile with other psychological disorders, as well as a predisposition for clinicians not to suitably appraise symptoms of trauma during clinical practice (Lewis, Raisanen, Bisson, Jones & Zammit, 2018). Measurement and monitoring of ANS dysregulation could elucidate how PTSD and other chronic stress-related psychophysiological problems develop in individuals. Heart rate variability (HRV) is a very

popular measure of ANS activity due to being both non-invasive as well as relatively inexpensive and easy to monitor (Zygmunt, & Stanczyk, 2010). HRV has been shown to be associated with a range of psychophysiological pathologies such as emotional dysregulation (Zhu, Ji & Liu, 2019), anxiety disorders, panic disorders (Prasko, Latalova, Diveky, Grambal, Kamaradova, Velartova, Salinger, Opavsky & Silhan, 2011), bipolar disorder or personality disorders (Carr, de Vos & Saunders, 2018), depression (Kemp, Quintana, Matthews & Jelinek, 2012) and PTSD (Ge, Yuan, Li & Zhang, 2020).

HRV as a marker of psychophysiological stress

Stress detection stimulates multiple physiological mechanisms which include increasing heart rate, causing the dilation of blood vessels in the heart and other muscles, and increasing the metabolic rate (Begum, Ahmed & Funk, 2013). The DSM-5 criteria for PTSD describes a consistently hyper-aroused state that has a strong physiological component to it. This component can be measured by several peripheral measures including blood pressure, sweating activity, breathing rate, and increased heart rate (Mellman, Knorr, Pigeon, Leiter, & Akay, 2004). Increased heart rate has been observed to be a correlate for PTSD in patients for several decades (Dobbs & Wilson, 1960).

A healthy heart is not metronomic, but their oscillations are complex and non-linear. ANS flexibility is an indicator that an individual is more physiologically resilient in responding to challenges (Acharya, Joseph, Kannathal, Lim, & Suri, 2006). HRV represents a non-invasive and objective measure of ANS functioning or parasympathetic nervous system (PNS) activity. HRV is calculated as the discrepancy in time between consecutive beats of the heart. HRV is primarily determined by the ongoing balance between the SNS and PNS. Activation of the SNS increases HR and decreases HRV, however PNS activity decreases HR and increases HRV

(Berntson, Bigger, Eckberg, Grossman, Kaufmann, Malik, Nagaraja, Porges, Saul, Stone, & van der Molen, 1997). As the vagus nerve is the main nerve that contributes to the PNS, parasympathetic activity can be referred to as 'vagal tone' (Brodal, 2010). Consistent time intervals between heartbeats means that the HRV will be low, whereas, if heartbeat intervals are irregular then the HRV will be high. If the human body is under stress (perceived ongoing threats in the environment, inflammation, lack of recovery etc) the sympathetic activity of the ANS is raised and this influences the HRV. Accordingly, HRV can be seen as an accurate objective measure and correlate of overall bodily stress. A low HRV at rest signals a polarity in ANS functioning and, as is often characterised in psychopathology, could represent an overstimulation of the sympathetic and a debilitated parasympathetic impact on the heart (Cattaneo, Franquillo, Grecucci, Beccia, Caretti, & Dadomo, 2021). When at rest, a high HRV demonstrates better health and performance because it signals ANS flexibility (Shaffer & Ginsberg, 2017).

There are different ways to measure HRV. Methods of data collection are generally affordable, non-invasive and pain free meaning that HRV is widely accessible to researchers. An electrocardiogram (ECG) is used most often. An ECG involves attaching electrodes to the skin using conductive pads (Galli, Montree, Que, Peri & Vullings, 2022).

There are 70 variables that can be calculated from an analysis of HRV data (Bravi, Longtin & Seely, 2011). The majority of HRV data within psychiatric research has been calculated using short-term recordings which are durations that are between one and five minutes (Quintana, Alvares & Heathers, 2016). A Task Force statement suggests that a minimum of sixty seconds continuous recordings to quantify the relevant indexes accurately (Task Force, 2016). HRV analysis can be performed using time-domain, frequency-domain and non-linear indices. The main variables for psychophysiological research can be seen in Table 1. All indexes are concerned with the 'RR interval', which refers to the time interval between successive ECG R-

wave occurrence times usually recorded in milliseconds (ms) (Task force, 2016). Frequency-domain HRV analysis methods describe the distribution of HRV into different frequency parameters. Very shorter-term HRV recording, that is most used in research contexts, is typically divided into low frequency (LF: 0.04-0.15 Hz), and high frequency (HF: 0.15-0.4 Hz) components (Rogers, Schaffarczyk, & Gronwald, 2022).

The standard deviation of all R-R intervals (SDNN) is a time-domain variable reflecting overall HRV, and because of this, represents both SNS and PNS activity. The root mean square of successive differences (RMSSD) represents the average change in interval between consecutive heart beats. RMSSD reflects the activity of the vagal nerve in a process known as 'vagal tone'. The percentage of successive normal sinus R-R intervals that is more than 50ms gives the index 'pNN50' which is also representative of vagal tone (Laborde, Mosley & Thayer, 2017). However, RMSSD is typically thought to provide a more accurate assessment of vagal tone and so is normally preferred to pNN50 (Otzenberger et al., 1998). RMSSD is considered the most accurate and appropriate method for quantifying HRV, and indexing PNS activity (Bravi, Longtin & Seely, 2011). RMSSD HRV has been shown to be negatively correlated with psychological distress (Koenig, Kemp, Beauchaine, Thayer, & Kaess, 2016). RMSSD also has been shown to be the most valid indicator of emotional state in non-competitive situations among time-domain parameters (Immanuel, Teferra, Baumert, & Bidargaddi, 2023). It has also been found to be negatively correlated with ruminative symptoms which characterise psychological dysfunction in non-clinical settings (Immanuel et al., 2023).

Table 1: *A Table to illustrate the Time-domain and Frequency Domain HRV Index Descriptions*

	Variable	**Description**	**Physiological Origin**
Time-domain	SDNN	Standard deviation of all R-R intervals	Cyclic components resposibilb for heart rate variablity
	RMSSD	Root mean square of successive differences	Vagal tone

	pNN50	Percentage of successive normal sinus RR intervals more than 50 ms	Vagal tone
Frequency-domain	LF	Low frequencies	Mix of sympathetic and vagal activity, baroreflex activity
	HF	High frequencies	Vagal tone
	LF/HF	Low frequencies/ high frequencies	Mix of sympathetic and vagal activity

Interoceptive Regulation

Adaptations to stress are somewhere on a continuum that has mind-oriented adaptations at one end and body-oriented adaptations, such as body cues and physiological sensations, at the other end. Interoception refers to a sense of the physiological condition of our body (Craig, 2003). Much of the processing of afferent signals from the body to the brain takes place outside of conscious awareness. Many sensations, such as the beating of your heart, the tension of your skeletal muscles, the clenching of your stomach, are made available to the conscious mind because they represent changes in bodily states that may require a behavioural response (Craig, 2003). How we interpret and respond to these signals has important consequences for our wellbeing. Interoceptive regulation can be described as the ability one may have to match bodily signals to a desired state by either altering the bodily signals or altering the state itself (Mehling, Price, Daubenmier, Acree, Bartmess & Stewart, 2012). Following cold-pressor pain induction, it was found that individuals who paid close attention to the details in the sensations of their hands showed the most rapid recovery from pain when compared to a group who either distracted themselves or mentally tried to suppress the pain (Cioffi & Holloway, 1993). Significantly, it was also found that those who suppressed pain from the cold pressor task also rated more unpleasant feelings when subjected to an innocuous vibration an hour later (Cioffi & Holloway, 1993). This indicates that the suppression of unpleasant somatic experiences can create a more marked response to, and thus contaminate, subsequent experiences. The moment in which an individual decides to distract from, or suppress, their bodily experiences probably

represents one of the early stages that lead to interoceptive dysregulation and, ultimately, psychiatric dysfunction. The skill of regulating the quality of one's attention to interceptive cues may be a key feature in developing a resilience to emotional and physical harm.

Understanding how the ability to interoceptively regulate alters during neurodevelopment, would broaden our comprehension of how and why it becomes pathological. Adolescence is characterised as a period of great psychological change. Self-awareness, self-reflection, strategic thinking capacity, cognitive flexibility and self-identity all change significantly during this stage (Blakemore and Choudhury, 2006; Rutter and Rutter, 1993). It is also a time in which individuals first develop the psychiatric disorders which may characterise their adult lives (Paus, Keshavan & Giedd, 2008). Additional studies are needed to understand how interoceptive abilities, such as interoceptive regulation, develop in a typical adolescent and pre-adolescent individual. This may then elucidate how and why atypical interoception is characterised in this stage and how related psychopathological developments take place.

Notable changes in HR can occur during respiration in a healthy individual. Inhaling (taking a breathe in), causes a faster beating of the heart, whereas exhaling (breathing out), causes slower beating of the heart. The name for this physiological phenomenon is respiratory sinus arrhythmia (RSA) (Eckberg & Eckberg, 1982; Russo, Santarelli, & O'Rourke, 2017). Inspiration decreases intrathoracic pressure which then cuts off stimulation of the vagus nerve, and this leads to an increase in HR. Conversely, expiration causes an increase in intrathoracic pressure, an activation of baroreceptors (sensors that regulate blood pressure) and a stimulation of the vagus nerve. This leads to a decrease in HR (Russo et al. 2017). RSA is under voluntary control and has been utilized for centuries by archers and riflemen; releasing the arrow or pulling the trigger during the expiratory phase, when the heart rate slows, enhances accuracy (Coote, 2010; Quintana & Heathers, 2014). RSA is an accepted marker of cardiac-linked parasympathetic regulation that, according to polyvagal theory, is an index of emotional

regulation (Tonhajzerova, Mestanik, Mestanikova & Jurko, 2016). As noted already, the parasympathetic nervous system initiates the self-soothing process in response to the activation of sympathetic stress. An elevated HRV isn't simply a marker of good psychological or physiological health though, it represents a heightened need to self-soothe in the face of stressors or adverse environments (Hill & Thayer, 2019).

Resilience

Resilience can be defined as the process by which an individual positively and dynamically adapts to adversity (Llistosella, Gutiérrez-Rosado, Rodríguez-Rey, Liebenberg, Bejarano, Gómez-Benito, & Limonero, 2019). Resilience should be understood in relation to the interactions between exposure to risk and available resources that bring about adaptation (Ungar, 2008). More specifically, it refers to the ability to employ cognitive, emotional and physiological resources as a response to a stressor. Fostering resilience protects individuals from developing psychopathological conditions such as depression, anxiety, and trauma (Collin-Vézina, Coleman, Milne, Sell, & Daigneault, 2011; Davydov, Stewart, Ritchie, & Chaudieu, 2010). Stress resilience has been shown to be dynamic and modifiable over the course of an individual's life largely as a result of external stimuli (McEwen, 2016). The ecological model of resilience says that an individual becomes resilient as a result of the interaction between individual, relational, communal and cultural variables (Ungar, 2008). The Child and Youth Resilience Measure (CYRM) explores the availability of these variables to a child and calculates their overall resilience from answers to self-report questions (Jefferies, McGarrigle, & Ungar, 2018).

It is worth noting that many psychological resilience studies include both adversity and positive adaption to that adversity, rather than simply a measure of variables that may indicate resilience (Fletcher and Sarkar, 2013). Many modern resilience studies comprise four elements: a)

predictors of resilient outcomes, b) baseline or pre-adversity; c) the adversity itself; d) post-adversity resilient outcomes; (Bonanno et al. 2015).

In the context of this project, resilience is understood as something that an individual can self-report consciously within a measure but it can also consist of unconscious somatic processes which can be measured physiologically. Terms such as 'physiological resilience' and 'interoceptive regulation' are often interchangeable.

Systematic Review

The literature examining the effects that trauma and stress have on the body, as well as how interventions can target the physical aspects of trauma, appears to be growing. Understanding further mechanisms that contribute to how the body becomes resilient to, and regulates, stress, and why some individuals experience potentially traumatic events but don't develop PTSD, would significantly contribute to the current literature.

Aims for the systematic review

1) The primary aim of this review is to investigate how experiments investigating stress and trauma used HRV to understand resilience. Studies are likely to do this either by experimentally subjecting individuals to stressors, or by observing developmental physiological differences in clients that have endured stressful life events. This review is interested in both.
2) A secondary aim of this review, is to understand the different ways in which HRV is measured and the ways in which the data was used to calculate corresponding resilience or response to trauma.

Methods

A systematic review of scientific literature was carried out to identify journal articles that described applications of HRV to markers of trauma or resilience. A review protocol was created from the preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines.

Search Strategy

The search was designed to identify studies that included measures of HRV either as a primary or secondary outcome. Initial searches were carried out to identify articles that examined HRV in healthy children or adolescents, but these searches were too narrow and limiting for a full review.

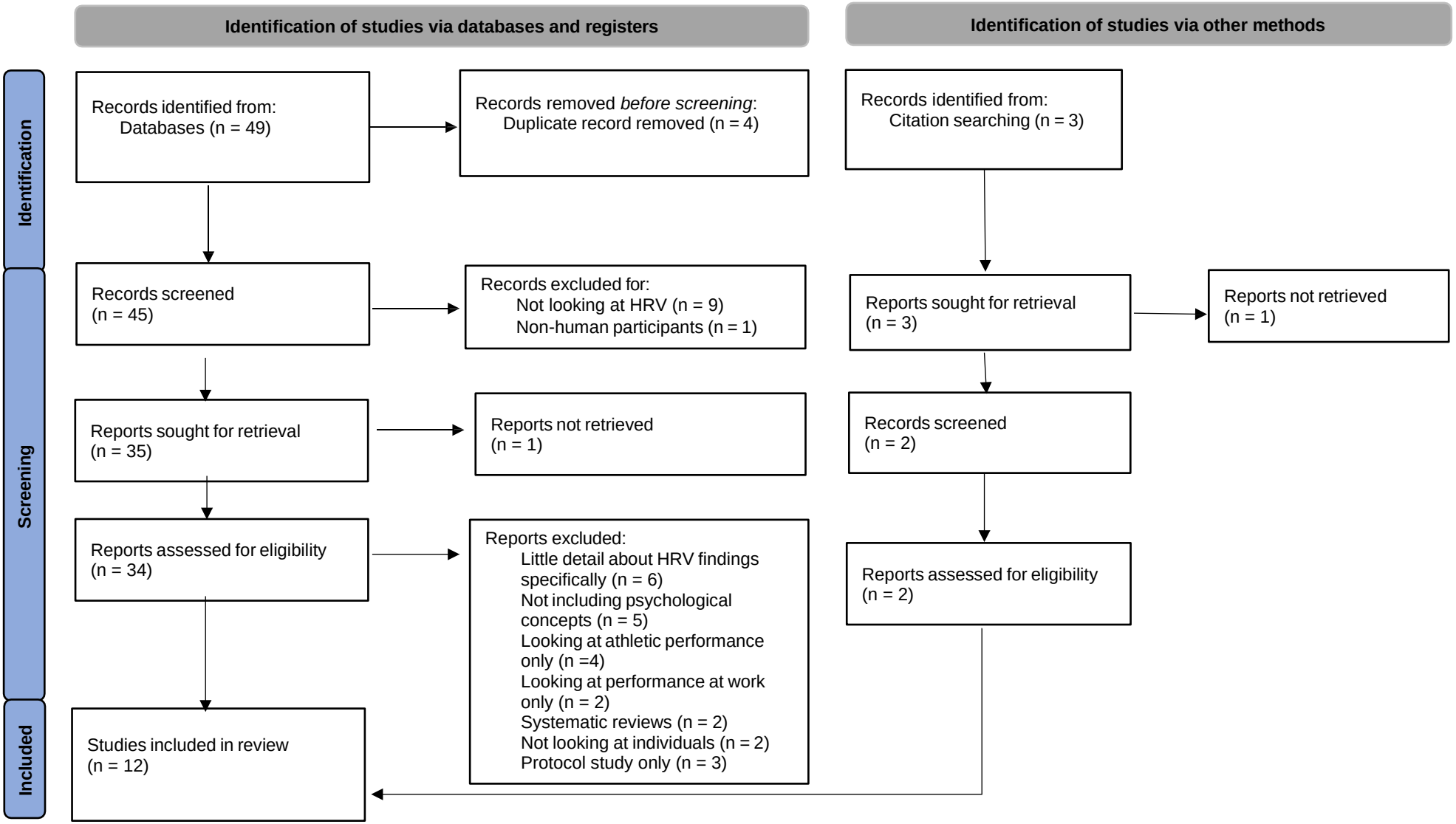
A systematic database search was performed using CINAHL Complete, APA PsycArticles, APA PsycInfo, E-Journals and MEDLINE which were accessed through EBSCOhost. A Boolean search was carried out on all databases and websites using the following words: 'trauma informed care' OR 'trauma informed practice' OR 'trauma' OR 'trauma informed approach'; AND 'resilience' OR 'resiliency' OR 'resilient' OR 'strengths' OR 'coping' OR 'hardiness' OR 'adaptation' OR 'regulation'; AND 'heart rate variability' OR 'HRV'. The search results were sourced from academic journals and published between '2012' and '2023'. That used human participants.

Study Selection and inclusion criteria

For a flow chart of the identification, screening and inclusion process, please see Figure 1. After identification of the articles using the search terms, duplicate records were removed. The screening process involved looking for keywords and terms within the title, abstract, and main text of the articles. Articles were removed during the screening process if they did not contain reference to measurement of heart rate (HR) or heart rate variability (HRV) in participants. Initially, only controlled studies were looked for, but as the data extraction progressed, more studies were needed for analysis to produce a large enough sample of studies to evaluate. Having

a control group was removed as an inclusion criterion but an evaluation of any control groups, comparator groups or study design remained. Articles containing non-human participants were removed, as were articles that weren't investigating neuroscientific or psychological impacts on HRV. The screening process removed some review articles and protocol studies that wouldn't have any results or data to analyse. There were four studies that were specifically looking at HRV in the context of athletic performance and these were removed as they were not relevant to the scope of this review. Three studies were found via a search within the references of other articles. Two of these studies could be accessed online and were included in the review.

Figure 1: *A Flow Diagram to Illustrate the Search, Screen and Exclusion/Inclusion Process*



Study Appraisal and synthesis

PICOS categories (Population, Intervention, Comparison, Outcomes & Study type) were modified and reported (O'Connor, Green & Higgins, 2008) (see Table 2). This review then extracted data from the included studies using the CASP tool for for cross-sectional studies. This was chosen for all but one of the studies. Minassian et al. (2015) were observing the relationship between HRV and risk of developing PTSD in marines over several time points. Therefore, the CASP tool for cohort studies was used to evaluate Minassian et al. (2015). This review will appraise each article using a CASP checklist to evaluate the quality and validity of the studies. By doing this, this review provided a deeper understanding of the study's framework, the influences of potential biases, and the strength of the conclusions drawn. The answers to both sets of checklist questions can be found in table 3 and table 4. Synthesis and comparison of the methodological strengths, weaknesses and omissions of the studies will then be discussed.

Table 2: *Study Characteristics, Outcomes & Quality Ratings*

Author(s)	Sample	Gender	Diagnosis/ Condition	Intervention/ Observation	Measures	Quality (High/Med/Low)	HRV outcome
Beranbaum et al., 2023	SG: 83	Male: 27 Female: 56	Healthy Adults	Waves for Change: a psychosocial, surf-based, mental health intervention	**HRV (RMSSD)** **BART-Y** CEQ PSS	**Low Quality** Small sample Self-report measures unreported (low validity) Limited demographics Correlations only	There was a significant relationship between at-risk community location and HRV. Data revealed a higher HRV (RMSSD) among participants from a higher-risk area, compared to participants from a lower risk area, t(57) = 2.21, p = .032, 95% CI [2.57, 54.07]*. This doesn't imply causation. There was also a stated conclusion that higher HRV in the higher-risk taking area was significantly correlated with lower risk taking behaviour propensity, but the data was not quoted in the text[+].
Dale et al., 2018;	SG: 60 CG: 34	Female: 60	Healthy adolescents & maltreated adolescents	Stationary cycling (physiological S) and viewing a video of child maltreatment (SS)	**HRV (RSA)** CTQ BSI PTSD - CCV	**Low Quality** Female only opportunity sample Self-report measures unreliable so unreported Thorough exclusion criteria	HRV (RSA) significantly changed during the physical stressor $F(2, 57)$ _ 181.85, p = .001, _2 _ .60, (large effect). There was no significant group effect or Group vs Condition interaction*[+]. Correlational analyses indicated that RSA reactivity to both stressors was significantly correlated, r = 44, p = .001.
Dust et al, 2023;	SG1: 26 SG2: 34 CG: 23	Male: 40 Female: 43	Healthy Adults	The Community Resilience Model (CRM) and Mental and Emotional Self-Management (MESM)	**HRV pa** SES ACE	**Low quality** Small sample (pilot) Very little significance due to short interventions No stress induction	Participants in the MESM condition (n = 30) saw a statistically significant difference between post-test active baseline (M = 7.40, SD = 0.91) and baseline (M = 7.11, SD = 1.05), M = 0.285, 95% CI [0.010, 0.560], t(29) = 2.123, p = 0.04, d = 0.388 (medium effect). After adjustment for baseline HRV, a between subjects ANCOVA showed statistically significant difference in HRV during active baseline between the conditions, F(2,72) = 6.01, p = 0.004, ηp2 = 0.143. Active baseline HF HRV was statistically significantly greater in the MESM condition vs. the CRM (Mdiff = 0.44, 95% CI [0.02, 0.86], p = 0.034) and control conditions (Mdiff = 0.54, 95% CI [0.123, 0.96], p = 0.006) *

***Effect size data not available**
+P value data not available b Individual scale scores not available c Item in bold to show primary outcome for the study

KEY: All HRV outcomes are described where possible. Other primary outcomes are mentioned without statistical detail as intended as a summary only SG1/2: Sample group 1/2, CG: Control Group, TAU: Treatment As Usual, CTQ: Childhood Trauma Questionnaire, BART-Y: Balloon Analogue Risk Task for Youth, BSI: Brief Symptom Inventory, RSA: Respiratory Sinus Arrhytmia, FSS: Felt Security Scale, TFR: Trauma Film Ratings, PTSD-CCV: PTSD Checklist Civilian Version, BF: biofeedback, SES: Socioeconomic status, ACE: Adverse Childhood Experiences, PRESIT: Predeployment Stress Inoculation Training, BB: Battle Breathing, MSE: Multimedia Stressor Environment, CAPS: Clinician Administered PTSD scale, PCL-C: PTSD Checklist—Civilian Version, CES-D: Center for Epidemiologic Studies Depression, CBP: current best practice lecture, RSQ: Relationship Structures Questionnaire, STAI-T: The State-Trait Anxiety Inventory, PHQ-9: Patient Health Questionnaire, ETI: Essen Trauma Inventory, MIST: Montreal Imaging Stress Task, PANAS: positive and negative affect schedule, REM: Rapid Eye Movement, NREM: Non-Rapid Eye Movement; ELS: Emotional Life Stress; RA: Reward Anticipation

Table 2: (*Continued)*

Author(s)	Sample	Gender	Diagnosis/ Condition	Intervention/Observation	Measures	Quality (High/Med/Low)	HRV outcome
Hourani et al., 2016	SG: 352 CG: 97	Male: 352	Healthy Adults (marines)	PRESIT (SG) or CBP (CG)	**PRESIT BF PCL-C CES-D CBP HRV**	**Medium quality** Strong rationale for pre-deployment bolstering resilience before exposure to trauma; control group; randomised allocation; large sample but all male marines; lower levels of combat exposure reduce validity.	SG & CG groups showed similar autonomic levels before the breathing training. t tests indicated that the SG group showed a significantly greater increase in HRV (t (112) = 2.60, p = 0.01) *.
Hu et al., 2020;	SG: 66	Females: 42 Males: 24	Healthy Adults	Trier social stress test in RA vs non-RA	**HRV CTQ PANAS**	**Medium Quality** Sample size in line with power calculation Opportunity sample of advert recruited students. Healthy sample with ELS not representing trauma Data not balanced across genders	HRV (RMSSD) in the RA group was significantly higher than that in the non-RA group (β = .274, p = .022, 95% CI: 0.028, 0.343). Moreover, the interaction of ELS × reward anticipation (RA) on HRV (RMSSD) was significant (β = −.295, p = .015, ΔR2 = 0.083, 95% CI: −0.027, −0.003) *. HRV (RMSSD) in the RA group was significantly higher than that in the non-RA group among participants with low ELS (p = .036), but not among participants with high ELS (p = .288) +*.
Karl et al., 2021;	SG: 101	Didn't say	University students	Trauma film exposure following attachment priming and oxytocin	**HRV RSQ FSS TFR**	**High Quality** Double blind Large sample (101) Thorough inclusion criteria A priori power analysis	Secure priming was significantly associated with higher HRV increase at the start of priming (b = 0.44, SE = 0.11, p < .001) *. This association was additionally observed in several time intervals throughout the priming stage

***Effect size data not available**
+P value data not available
b Individual scale scores not available
c Item in bold to show primary outcome for the study

KEY: All HRV outcomes are described where possible. Other primary outcomes are mentioned without statistical detail as intended as a summary only SG1/2: Sample group 1/2, CG: Control Group, TAU: Treatment As Usual, CTQ: Childhood Trauma Questionnaire, BART-Y: Balloon Analogue Risk Task for Youth, BSI: Brief Symptom Inventory, RSA: Respiratory Sinus Arrhytmia, FSS: Felt Security Scale, TFR: Trauma Film Ratings, PTSD-CCV: PTSD Checklist Civilian Version, BF: biofeedback, SES: Socioeconomic status, ACE: Adverse Childhood Experiences, PRESIT: Predeployment Stress Inoculation Training, BB: Battle Breathing, MSE: Multimedia Stressor Environment, CAPS: Clinician Administered PTSD scale, PCL-C: PTSD Checklist—Civilian Version, CES-D: Center for Epidemiologic Studies Depression, CBP: current best practice lecture, RSQ: Relationship Structures Questionnaire, STAI-T: The State-Trait Anxiety Inventory, PHQ-9: Patient Health Questionnaire, ETI: Essen Trauma Inventory, MIST: Montreal Imaging Stress Task, PANAS: positive and negative affect schedule, REM: Rapid Eye Movement, NREM: Non-Rapid Eye Movement; ELS: Emotional Life Stress; RA: Reward Anticipation

Table 2: (*Continued)*

Author(s)	Sample	Gender	Diagnosis/ Condition	Intervention/ Observation	Measures	Quality (High/Med/Low)	HRV outcome
Kizakevich et al., 2019	207 (49 in HRV arm)	Female: 23 Male: 26	Military personnel, veterans, and civilian first responders	Biofeedback-assisted Resilience Training via various cognitive stressors	**HRV**	**Low quality** Interim study looking primarily at testing feasibility. Little data analysed	HRV decreased from mean 7.37 (SE 1.77) at rest to mean 6.92 (SE 1.41) during the stressor phase, reflecting a reduction in parasympathetic activation during the stressor task. During the poststress recovery segment, the HRV rebounded to mean 7.148 (SE 1.42), approaching the prestress baseline (P=.02) *. During training, HRV increased significantly to mean 8.205 (SE 1.39), reflecting strong parasympathetic activation during slow paced breathing (P<.001)*.
Kobayashi et al., 2014;	SG1: 20 SG2: 18	Females : 26 Males: 12	Resilience (traumatic exp no trauma) and PTSD	Nocturnal ANS activity and its relationship to sleep in PTSD and resilience groups.	**HRV CAPS**	**Medium Quality** Small sample Comparator group Thorough screening Non-clinical sample reduces generalisability Robust findings despite small sample.	Time-in-bed demonstrated significantly lower HRV in the PTSD group. Hierarchical regression analyses revealed that adding the PTSD × total sleep time (TST) interaction significantly increased R^2 (R^2 = .16, p = .011 in accounting for LF/HF; and R^2 = .20, p= .002 in accounting for time-in-bed nHF). Average TST was significantly correlated with both time-in-bed nHF (r = .75, p = .001) and LF/HF (r = −.64, p = .008) in the resilient group, but not in the PTSD group.
Kobayashi et al., 2016;	SG: 71	Females : 43 Males: 28	Resilience (traumatic exp no trauma) and PTSD	The impact of PTSD vs. resilience on ANS activity as a function of sleep stage and time of sleep.	**HRV CAPS**	**Medium Quality** Small sample Comparator group Thorough screening Non-clinical sample reduces generalisability Robust findings despite small sample**.**	Results showed that REM–NREM nHF was significantly correlated with REM% in the resilient group (r = 0.345, p = 0.049), but not in the PTSD group (r=0.063, p=0.708).

***Effect size data not available**
+P value data not available b Individual scale scores not available c Item in bold to show primary outcome for the study

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Table 2: (*Continued)*

Author(s)	Sample	Gender	Diagnosis/ Condition	Intervention/ Observation	Measures	Quality (High/Med/Low)	HRV outcome
Lewis et al., 2015;	SG: 891 CG: 422	Females : 40 Males: 851	Air Platoons of the U.S. Army	Predeployment stress inoculation training (PRESTINT)	**HRV**	**High Quality** Double blind Randomly assigned to PRESTINT or control Convenience sample of 70% women	Analysis of group differences found a significant impact of the PRESTINT intervention on autonomic regulation of the heart during the initial, eyes closed section of the battle breathing training when compared to CG (Intervention minutes 1–3, SE 0.157 (0.063) 2.47 p = .014; Intervention minutes 4–6, SE 0.240 (0.062) 3.85, p < .001).
Majewski et al., 2023;	SG: 27 CG: 15	Male: 5 Female: 37	PTSD vs healthy controls	Trier social stress test (TSST)	**HRV ETI**	**Medium Quality** Small-medium sample Largely female Medication and comorbidities present Clear, significant findings related to PTSD, inflammation and HRV	For RMSSD, repeated measures ANOVA revealed a significant time effect (F (2.85, 91.30) = 12.60; p < 0.001) indicating stress reactivity in SG compared to CG. Furthermore, a significant group-by-time interaction revealed group differences in HRV stress responses over time (F (2.85, 91.30) = 5.59, p < 0.001). Healthy participants showed a significant decrease in RMSSD in three intervals during the TSST compared to baseline, and a fast recovery thereafter. This pattern was absent in PTSD patients, who showed a generally lower RMSSD without stress reactivity (F (1, 32) = 0.28, p = 0.60).
Minassian et al., 2015;	SG1: 1415 SG2: 745	Male: 2160	Active duty Marines	Marine Resiliency Study	**HRV CAPS**	**High Quality** Longitudinal study Large Sample Young male sample only LF:HF not always considered a robust and specific measure of SNS vs PNS balance 5 minute HRV recording only Small PTSD group	No linear relationship between predeployment HRV and postdeployment PTSD symptoms observed. Because of the large sample size, correlations between predeployment log-transformed LF and HF and postdeployment CAPS scores approached or reached statistical significance. The variance in symptom severity predicred by HRV was found to be low (Total CAPS score: Pearson r = −0.06, P = .03; CAPS Avoidance-Numbing: Pearson r = −0.07, P = .02; and CAPS Arousal: Pearson r = −0.07, P = .02; HF correlations with CAPS Avoidance-Numbing: Pearson r = −0.08, P = .01 and CAPS Arousal: Pearson r = −0.06, P = .04).

***Effect size data not available**
+P value data not available b Individual scale scores not available c Item in bold to show primary outcome for the study

KEY: All HRV outcomes are described where possible. Other primary outcomes are mentioned without statistical detail as intended as a summary only SG1/2: Sample group 1/2, CG: Control Group, TAU: Treatment As Usual, CTQ: Childhood Trauma Questionnaire, BART-Y: Balloon Analogue Risk Task for Youth, BSI: Brief Symptom Inventory, RSA: Respiratory Sinus Arrhytmia, FSS: Felt Security Scale, TFR: Trauma Film Ratings, PTSD-CCV: PTSD Checklist Civilian Version, BF: biofeedback, SES: Socioeconomic status, ACE: Adverse Childhood Experiences, PRESIT: Predeployment Stress Inoculation Training, BB: Battle Breathing, MSE: Multimedia Stressor Environment, CAPS: Clinician Administered PTSD scale, PCL-C: PTSD Checklist—Civilian Version, CES-D: Center for Epidemiologic Studies Depression, CBP: current best practice lecture, RSQ: Relationship Structures Questionnaire, STAI-T: The State-Trait Anxiety Inventory, PHQ-9: Patient Health Questionnaire, ETI: Essen Trauma Inventory, MIST: Montreal Imaging Stress Task, PANAS: positive and negative affect schedule, REM: Rapid Eye Movement, NREM: Non-Rapid Eye Movement; ELS: Emotional Life Stress; RA: Reward Anticipation

Table 3: *Quality Assessment using the CASP Checklist for Cross-Sectional Studies*

	Checklist items										
	Did the study address a clearly focused issue?	Did the authors use an appropriate method to answer their question?	Were the subjects recruited in an acceptable way?	Were the measures accurately measured to reduce bias?	Were the data collected in a way that addressed the research issue?	Did the study have enough participants to minimise the play of chance?	How are the results presented and what is the main result?	Was the data analysis sufficiently rigorous?	Is there a clear statement of findings?	Can the results be applied to the local population?	Is the research valuable?
Beranbaum et al., 2023;	Yes	Yes	Can’t Tell	Yes	Yes	No	Yes	Yes	Yes	No	Can't Tell
Dale et al., 2018;	Yes	Yes	Can’t Tell	Yes	Yes	Can't tell	Yes	Yes	Yes	No	Can't Tell
Dust, 2023;	Yes	Yes	Yes	Can't tell	Yes	No	No	Yes	No	Can't Tell	No
Hourani et al., 2016;	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Can't Tell	Yes
Hu et al., 2020;	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Karl et al., 2021;	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Kizakevich et al., 2019;	Yes	Yes	Yes	Yes	No	Can't Tell	Yes	Yes	No	Yes	Can't Tell
Kobayashi et al., 2014;	Yes	Yes	No	Yes	Can't Tell	No	No	Yes	Yes	No	No
Kobayashi et al., 2016;	Yes	Yes	No	Can't Tell	Can't Tell	No	No	Yes	Yes	No	No
Lewis et al., 2015;	Yes	Yes	Yes	Can't Tell	Yes	Yes	Yes	Yes	Yes	Can't Tell	Yes
Majewski et al., 2023;	Yes	Yes	Yes	Can't Tell	Yes	No	Yes	Yes	Yes	Can't Tell	Can't Tell

Table 4: Quality Assessment using the CASP Checklist for Cohort Studies

	Checklist items											
	Did the study address a clearly focused issue?	Did the authors use an appropriate method to answer their question?	Were the cases recruited in an acceptable way?	Were the controls selected in an acceptable way	Was the exposure accurately measured to minimise bias?	Aside from the experimental intervention, were the groups treated equally?	Have the authors taken account of the potential confounding factors in the design and/or in their analysis?	How large was the treatment effect?	How precise was the estimate of the treatment effect?	Do you believe the results?	Do you believe the results?	Do the results of this study fit with other available evidence?
Minassian et al., 2015;	Yes	Yes	Yes	No	Yes	No	Can't tell	No	Can't tell	Yes	Yes	Yes

Risk of bias

There were some risks of bias within the search that was carried out. The search only considered articles in English and so a language bias was present. Only articles that were published in peer-reviewed academic journals were considered. This may mean that studies that discovered nonsignificant findings may not be accounted for in this review.

Results

The search identified 49 studies. 4 duplicate articles were removed from the search results by EBSCOhost and this was checked manually for accuracy afterwards. 45 studies were screened for preliminary inclusion criteria, specifically whether HRV data had been collected or was being tested, and whether human participants were used. The full text of the remaining 37 studies were then analysed for inclusion criteria (see Figure 1).

Two studies were found using a citation search. The full-text version of one of these citations couldn't be retrieved and so the authors were contacted. The authors of the study didn't respond and so this was excluded. The remaining study was then analysed for inclusion criteria.

In total, 12 studies met criteria for inclusions and further analysis (see table 2). Each of the studies reported collection and analysis of HRV data. The 12 studies were: Beranbaum et al., 2023; Dale et al., 2018; Dust, 2023; Hourani et al., 2016; Hu et al., 2020; Karl et al., 2021; Kizakevich et al., 2019; Kobayashi et al., 2014; Kobayashi et al., 2016; Lewis et al., 2015; Majewski et al., 2023; Minassian et al., 2015.

Study Characteristics

A total of 3,405 individuals were evaluated in these 12 studies. Table 2 shows a breakdown of the primary characteristics of the studies based on the adapted PICOS data extraction parameters. Thirteen studies were cross-sectional in design and examined the changes in HRV in participants exposed to stressors or stress-inducing programmes at a single time point. The type of participant varied from patients with PTSD (e.g. Majewski et al., 2023), military or marine personnel (e.g. Kizakevich et al., 2019), or healthy volunteers (e.g. Dust, 2023). One study examined HRV in participants who had experienced some form of stressful life event (e.g. Kobayashi et al, 2014). One study was longitudinal in design and investigated changes in HRV and development of PTSD within marines from pre-deployment to post-deployment (Minassian et al., 2015).

Measurement and use of HRV

This section addresses the secondary aim of this review. Nine of the twelve studies measured HRV via an ECG (e.g. Kobayashi et al., 2016). An ECG examination consists of electrodes which are fitted to a participant's chests to analyse heart behaviour directly from the source. Three studies (Beranbaum et al., 2023; Hourani et al., 2016; Lewis et al., 2015) measured HRV via photoplethysmography (PPG) which is another non- invasive detection method. PPG uses a light source with a photodetector on the surface of skin to measure variations in blood circulation (Castaneda, Esparza, Ghamari, Soltanpur & Nazeran, 2018). Both methods of HRV measurement have been shown to provide almost perfect correlation for recording the RMSSD index of HRV (Plews, Scott, Altini, Wood, Kilding & Laursen, 2017). It is worth noting that the vast majority of the studies didn't point to a standardized operating procedure for measuring and manipulating HRV in participants. This reduces the validity of some of the findings. Koboyashi et al. (2014) and Koboyashi et al (2016) acknowledged that their procedure was relatively novel.

Significant HRV changes

In several of the experimental studies investigating responses to artificial stressors, HRV was shown to increase significantly in response to physical stressors (Lewis et al., 2015; Dale et al., 2018) such as riding a bicycle, social/emotional stressors (Lewis et al., 2015; Majewski et al., 2023) such as a mock job interview, or combat simulations (Hourani et al, 2016) (See Table 2)

Many of the studies were unable to find significant changes in HRV between their comparator groups. For example, Dust et al. (2023) found no significant change in HRV when comparing community skills-based resilience programmes to control groups of no training.

This also included Minassian et al. (2015) who primarily were looking to understand if lower HRV might predict PTSD development in a sample of US marines after combat deployment. They found HRV didn't significantly predict PTSD development after deployment, but that pre-existing or chronic PTSD was strongly correlated with HRV. Hourani et al. (2016) were interested in whether a programme of predeployment stress inoculation training (PRESIT) could be applied as a preventative intervention to protect against exposure to combat related stressors. They found that PRESIT protected against PTSD in marines without baseline mental health problems compared to the control group and this was indicated by increased HRV after training and before deployment as well as after deployment (Hourani et al., 2016). This wasn't corroborated within self-reported stress measures such as the Perceived Stress Scale (PSS) in which no significant differences were reported post deployment.

Investigating naturally occurring PTSD, Kobayashi et al. (2014) compared sleep and nocturnal autonomic functioning (HRV) in both a group of individuals who had experienced a traumatic event *and* developed PTSD ('PTSD'), with a group of individuals who had experienced a traumatic event *but not* developed PTSD ('resilient'). They found that PTSD individuals spend significantly less time in bed, lower HRV, and their sleep contained significantly less in the normalised high frequency (nHF) domain which indexes parasympathetic functioning. The same

research team expanded their investigation into nocturnal autonomic functioning and sleep to include periods of rapid eye movement (REM) and non-REM sleep (Kobayashi et al. 2016). Greater autonomic arousal (increased HRV) during REM was observed in resilient individuals but not in PTSD individuals. These findings are consistent with their prior findings and suggested that PTSD development is related to impairment in nocturnal regulatory autonomic activity (Kobayashi et al. 2016).

One study used biofeedback as part of a programme of resilience training for 207 military personnel, veterans, and civilian first responders (Kizakevich et al., 2019). The programme consisted of weekly resilience training, which included cognitive stressors followed by paced breathing, for a total of six weeks via a smartphone app called BART. The researchers compared a group that received feedback in the form of calm and parasympathetically stimulated (green) or stressful and parasympathetically lowered (red) psychophysiological states, with a group that received no biofeedback (Kizakevich et al., 2019). Researchers found that the participant's HRV bounced back during the post-stressor and increasingly during the training periods which reflected strong parasympathetic activation as a result of slow-paced breathing.

Identification of covariates

Beranbaum et al (2023) found that male participants (M = 140.03, SD = 58.76) had a higher RMSSD value than female participants in the study (M = 101.61, SD = 43.37), t(57) = -2.80, p = .017, 95% CI [-65.87, -10.98]). This was a trend noted in other studies that investigated baseline RMSSD in participants (Semizel, Öztürk, Bostan, Cil & Ediz, 2008). Lewis et al (2015) discovered that the higher the level of education an individual has achieved, the greater the baseline HRV, even after adjusting for age. They also found that individuals who continued their education beyond high school, showed a greater HRV reactivity when exposed to the earliest combat stressor (Lewis et al, 2015). This corroborates the finding of studies looking at

neuroprotective myelination of brain regions, who found a link between education, fitness, cardiac health and education (Gordon, Rykhlevskaia, Brumback, Lee, Elavsky, Konopack, McAuley, Kramer, Colcombe, Gratton & Fabiani, 2008; Teipel, Meindl, Wagner, Kohl, Bürger, Reiser, Herpertz, Möller & Hampel, 2009). Neuroanatomical correlates of aging, cardiopulmonary fitness level, and education. Notably, none of the studies featured in this review examined cardiovascular fitness or exercise levels as covariates, despite the evidence for their influence on HRV (Swart & Constantinou, 2023).

Analysis of bias

One way in which a study can limit bias and increase the validity of their findings is to use control groups in their designs (Malay & Chung, 2012). Six of the twelve studies used control groups in their design. The control group was either a non-intervention group or non-exposure group, such as in Kizakevich et al. (2019) who tested two groups to see if HRV biofeedback would improve resilience training in military personnel, or it functioned as a control group of healthy individuals who hadn't developed a condition, such as in Majewski et al. (2023) who looked at how PTSD individuals and healthy controls responded differently to a social stress test. Of these six studies, four randomly assigned their participants to either the intervention or the control group. One study used a double-blind, experimental mixed factorial design randomised control trial design to investigate whether attachment priming (recalling a mental representation of a secure attachment figure) and/or a dose of exogenous oxytocin were able to aid recovery and prevent development of PTSD symptoms after exposure to a trauma film (Karl et al., 2021).

Three studies instead used comparator groups to compare variables. This was likely due to the design of these studies being observational in nature rather than experimental. For example, Kobayashi et al (2014) observed the nocturnal ANS functioning of African Americans in a 'PTSD' group alongside a 'resilience' group of individuals who had experienced a high-impact

trauma event but had never developed PTSD.

Many of these studies have samples that are underpowered. For example, the sample of 90 participants within Dust et al. (2023), had only a 50% chance of detecting an effect. The study compared results across three conditions and this would have contributed to a more underpowered sample. The sample of marines within Hourani et al. (2016) were numerous (n = 351) however power was significantly reduced because of large number of variables that required statistical control in the analysis. This included many personnel with self-reported pre-deployment mental health problems.

Only three of the twelve studies in this analysis used effect sizes from previous literature which examined the same intervention in similar populations to conduct an a priori power analysis (Hu et al., 2020; Karl et al., 2021; Minassian et al., 2015). Most of the remaining studies didn't state why they hadn't been able to perform the power analysis, apart from Dust et al. (2023) who stated that there was a lack of research investigating resilience in non-traumatized (or healthy) populations.

There was a high level of ethnic or geographical homogeneity within the overall sample across the studies. All 12 studies were carried out in Western countries. This is most likely because this review only looked at studies that had been written, or had been translated, into English. The vast proportion of the pooled sample of studies came from the US (66.6% of the pooled sample). Two German and one British study comprised the European proportion of the participants (25% of the pooled sample). The vast majority of studies recruited a convenience sample of participants. Most of these were University students who were recruited via flyers and campus events.

Using exclusion criteria to select a sample is an important way to ensure greater reliability and reproducibility of the findings (Patino & Ferreira, 2018). Five studies did not use exclusion criteria other than to exclude those participants that did not contribute complete datasets. Many

of the studies excluded participants who had a mental health or physical conditions, or had taken drugs or medication that would affect blood pressure or respiration, or pregnancy. A higher Body Mass Index (BMI) has been found to significantly reduce HRV (Speer, Koenig, Telford, Olive, Mara, Semple, Naumovski, Telford & McKune, 2021), and, accordingly, several of the studies excluded participants that were ≥ 40 BMI which would be considered 'obese'.

Measurement of PTSD or Stress

The studies varied in how they approached analysing stress or PTSD. Some studies looked at ostensibly healthy participants and incited stress using stress inducing tasks to observe HRV changes. For example, Hu et al. (2020) employed the standardized psychosocial stress test known as the Trier social stress test (TSST) which asked participants to prepare and perform a presentation for a mock interview, as well as complete fast, continuous mathematical problems out loud. These could be categorised experimentally as both cognitive and social stressors. Other studies observed HRV differences in participants who had either a history of a traumatic event or a diagnosis of PTSD.

For example, Dust et al. (2023) investigated whether novel resilience training programmes such as the Community Resilience Model (CRM) and Mental and Emotional Self-Management (MESM) would increase HRV in healthy 18–30-year-olds.

Outcomes of resilience independent of HRV

It is worth noting that some of these studies examined psychological or physiological resilience to stress/PTSD outside of the measurement and investigation of HRV. Karl et al. (2021) also measured physiological arousal in the form of skin conductance level (SCL) and baseline heart rate (HR). The study investigated whether drug priming using oxytocin or secure attachment priming would induce changes in these measures immediately after, and during the subsequent

week, following exposure to a trauma film. It was found that both SCL and HR were reduced by the secure attachment priming but not through priming with oxytocin.

Hu et al. (2020) found that anticipation of a reward would provide a stress relieving state that buffered the decreased HRV normally induced by psychosocial stressors. This buffering effect was shown to be less prevalent in individuals who had experienced higher levels of early life stress (ELS).

Hourani et al. (2016) investigated the effect of pre-deployment stress inoculation training (PRESIT) on the length of heart periods (HP) as a marker for physiological arousal. Their sample of marines showed longer HP's (or slower heart rates) after the PRESIT training along with lower scores on the PTSD Checklist—Civilian Version (PCL-C) compared to a control group.

Beranbaum et al. (2023) observed that their findings counter some more traditional narratives that individuals who are exposed to violence in their youth lack emotional regulation skills and experience elevated risk taking. Their data highlights that individuals exposed to violence in their youth were more cautious in the face of danger-free risk and had increased emotional regulation in the form of higher HRV. The authors concluded that elevated HRV reflected continual activation of the parasympathetic nervous system and an increased need to adapt to stressful and adverse environments (Beranbaum et al. 2023). It is worth noting that the sample size was modest, and this prevented further analysis of relevant demographics and identities. Furthermore, self-report measures were not included due to reported low reliability of the measures across different language groups.

It is interesting to note that Beranbaum et al. (2023) and Hu et al. (2020) found early life stress had opposing effects on HRV in their samples.

Discussion

Understanding better how the experience of stress or PTSD can lead people down a pathway of longer- term health consequences, is an important research and public health question. This review primarily aimed to determine how experiments investigating responses to stress or lifetime PTSD used HRV as a marker for resilience. The results obtained from the studies included in this review provide a complex and varied picture that requires consideration and evaluation of multiple dimensions.

Some studies concluded that an altered state of ANS functionality, exemplified as changes measured in HRV, contributes to either vulnerability or resilience to the development of PTSD symptoms (Minassian et al. 2015; Dale et al. 2018; Kobayashi et al. 2014; Lewis et al. 2015). Markedly low HRV can also be linked to a heightened stress response (Hu et al. 2020; Majewski et al 2023) or stress system dysregulation (Karl et al., 2021). In a community youth setting, Beranbaum et al (2023) found results that suggested elevated HRV and low risk-taking behaviours were more likely in individuals who had witnessed a violent event at least once.

Limitations

One question that this review raises, is whether experimental stress induction can validly represent the experiences of individuals suffering with PTSD as a result of traumatic life events. Karl et al. (2021) noted that the trauma film exposure produced different outcomes than they expected based upon previous literature findings. They discussed the validity of the trauma film to reliably induce stress in their participants. The authors did attempt to account for this by asking the participants to report their distress levels and how relevant the films felt to them. These were found to be rated as moderate and low respectively on average for the sample group. This profile of experience may in fact be representative of something akin to the orientating reflex (Sokolov, 1963), in which the participants found the films interesting and non-threatening. The authors acknowledge that they could have measured interest or engagement in the films to

indicate whether these physiological responses were because of the reflex orientation. This same limitation should be acknowledged in many of the other studies inducing stress that are investigated in this review as it is likely an extraneous variable common to these experimental designs.

A limitation of Kizakevich et al., (2019) is that cognitive stress may not represent a valid surrogate for combat and operational stressors in a military population. Similarly, Karl et al. (2021) acknowledges that the moderate stress induced in their experiments might not validly represent the real-life experiences of traumatic PTSD. They do suggest that inducing more than a moderate level of stress within their sample starts to raise ethical complications.. However, as explained earlier in this thesis, we know that the physiological mechanisms that become disrupted in response to trauma, or prolonged or chronic stress are different from the individual's short-term physiological response to acute stressors. Several of the studies acknowledge that their findings are speculative without longer term health outcomes. Whilst the 'healthy' (or 'subclinical') sample that had experienced adverse childhood events (ACEs) did display a blunted stress response (in the form of RSA activity), they can't say whether this is beneficial adaptation or evidence of an altered stress response that buffers reactivity in the short term but may lead to adverse longer term outcomes, such as major depression or anxiety disorders (Zorn, Schür, Boks, Kahn, Joëls & Vinkers, 2017).

Hourani, et al. (2016) stated that the troops that made up their sample often changed mission and saw much less tactical engagement than they expected. This corresponded to a relatively reduced amount of combat exposure during their deployment. The resulting low incidence of probable PTSD cases, along with large confidence intervals (CIs), suggests that the study's findings should be interpreted with caution.

With the exception of one study (Majewski et al, 2023), studies primarily examined their participants cross-sectionally. This means that many results can only make inferences about

correlation rather than causality. Dust et al. (2023) noted that economic limitations meant that their resiliency training programmes had to be compressed from three days into one three-hour workshop. This limited the amount of practice time and skill learning for the participants. Furthermore, it removes the advantages of multiple time periods that can illustrate how variables, such as HRV, can develop over time in relation to other variables. Despite this, studies highlighted the short-term stability of HRV and that their often-short-term recordings of HRV would likely be sufficient to capture HRV parameters (Koboyashi et al. 2016).

Because of the ethnocentrism evident within the samples, we can't generalise the experiences of PTSD or stress to a more universal view of experience. For example, the medicalising of an individual's suffering may risk limiting our understanding of that suffering. The term PTSD may in fact be a cultural construct in many ways. For example, a medical anthropologist who wrote about the individuals living through the cultural revolution in China, wrote that: "to interpret such problems, because of the bodily idioms that frequently accompany them, solely as illness is to medicalize (and thereby trivialize and distort) their significance" (Kleinman & Kleinman, 1991). The usefulness of any diagnosis and/or social construct to describe or predict a phenomenon in the current culture should therefore be the primary focus.

Whilst the participants used in the samples are quite homogenous, and this creates an issue of generalisability, experimental studies do benefit from this uniformity, because it can limit variance in other extraneous variables. Several of the studies used an opportunity sample of healthy higher education students who volunteered their participation. This group would imply self-selection bias in favour of more stress-resilient individuals.

Concluding remarks

Overall, this literature review has somewhat achieved its primary aim of understanding how HRV is used to illustrate the relationship between PTSD, or stress, and resilience. Whilst there are some inferences that can be made more confidently about the relationship between these variables,

there are also multiple exceptions where the results elucidate a need for a broader theory that underpins how resiliency to stress is developed. There are some notable limitations in the literature search and the subsequent analysis, which suggests we should be careful in drawing unequivocal conclusions.

HRV is a popular measure used within healthcare research and military training settings. With a focus on the secondary aim of this review, these studies suggest that ECG recording is the most common way to record HRV. However, there doesn't appear to be many references to standard operating proccedures or gold standard procedures in the literature.

The Current Study

This pilot study is part of a broader research project examining interoceptive awareness in schoolchildren. While the rationale, research aims, protocol, and results of the larger project will not be detailed in this paper, reference will be made to these aspects when discussing certain practical and feasibility considerations. The research team worked collaboratively on the conceptualisation, design and data collection for the wider project, and this included the pilot study. The data analysis, interpretation and write up was completed by the author of this paper only. Unless otherwise clearly stated, this write up will focus on aspects of this pilot study only.

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This pilot study's research aims will cover two parts: 1) experimental aims exploring putative

relationships between variables using hypothesis testing (see below); and 2) feasibility aims that evaluate the feasibility and acceptability of this small-scale research project. We will now briefly outline the rationale for the experimental design and then the aims of this study.

Over the past two decades, studies have been increasingly using HRV as an affordable and straightforward measure to collect clinically relevant markers for psychophysiological disorders (Pham, Lau, Chen & Makowski, 2021). A meta-analysis of 43 studies found that adults with PTSD had lower HRV scores compared to healthy controls, both at rest and under stress (Schneider & Schwerdtfeger, 2020). However, there have been few studies that have looked at HRV in healthy children or who have experienced a traumatic life event (i.e. are 'resilient') but not gone on to develop PTSD. The index RMSSD in particular has been shown to be negatively correlated with psychological distress (Koenig, Kemp, Beauchaine, Thayer, & Kaess, 2016), it is the most valid of the time-domain parameters in indicating non-competitive situations (Immanuel, Teferra, Baumert, & Bidargaddi, 2023), and is negatively correlated with characteristics of psychological dysfunction in non-clinical settings (Immanuel et al., 2023). A number of studies have highlighted the importance of identifying covariates that might affect HRV in an experimental setting. These should be considered when designing furture procedures that capture HRV. The literature review has indicated that different stressors (socio/emotional or physiological) may elicit different HRV responses within the children. Therefore, this pilot study aimed to explore whether there were any differences between a modified TSST or the cold pressor test – two of the most commonly used and researched stressors found in the literature (McRae, Saladin, Brady, Upadhyaya, Back & Timmerman, 2006). The pilot study was also interested in whether a children's HRV would respond differently post stressor if they were either at rest or they were stimulating RSA via paced breathing.

The research aims (see below) covered were constructed with reference to the journal *Pilot and Feasibility Studies* () and the CONSORT extension to pilot and feasibility trials (Eldridge, Chan,

Campbell, Bond, Hopewell, Thabane, Lancaster, & PAFS consensus group, 2016). These offer relevant guidelines for early-stage feasibility and pilot studies that test preliminary hypotheses of associations between variables, the feasibility of implementing a novel procedure, and the implementing of research findings (Lancaster & Thabane, 2019), often in smaller samples and with limited resources. The rationale therefore, was that piloting all three of these areas will also be beneficial for future research into novel interventions. Through hypothesis testing, this would then help make inferences about that child's psychological and physiological resilience that will inform future larger-scale cohort studies. Whilst Eldridge et

al. (2016) report pilot trials do not need to report effectiveness or efficacy within hypothesis testing, Lancaster & Thabane (2019) state that early feasibility testing in larger samples is important to clarifying the theoretical underpinning of an intervention. Eldridge et al. (2016) state that a '*pilot study is a study in which a future study or part of a future study, is conducted on a smaller scale to ask the question whether something can be done, should we proceed with it, and if so, how'.*

This pilot study was also interested in evaluating several aspects of feasibility. This included how such a project could be run by recruiting school children and schools, how the experimental battery of tests were feasibly and effectively carried out in a school environment, how validly and feasibly a cross sectional sample of school children's resiliency to stress could be measured.

Research aims

The research aims of the study comprised two experimental aims and one feasibility aim (see below). The study aimed to:

1. Determine if school children's HRV responded to stressors designed to stimulate their parasympathetic nervous systems (see experimental hypotheses below).

2. Determine whether either self-reported resilience, or a history of traumatic events interacted with HRV responses to stressors (see hypotheses below).
3. Evaluate the feasibility and acceptability of implementing a relatively novel battery test procedure which combines two of the HRV stressors researched in the introduction and literature review; 1) the cold pressor stressor and the 2) social stressor

Experimental hypotheses

1. School children will demonstrate an increased HRV during paced breathing timepoints after both the cold pressor and the social stressor.
2. The cold pressor stressor would elicit a greater change in RMSSD HRV than the social stressor.
3. Self-reported resilience (CYRM-R) would predict RMSSD HRV change after both the cold pressor stressor, and the social stressor.
4. School children who have experienced traumatic life events but not PTSD (as verified by the UCLA) will demonstrate increased HRV in timepoints after both stressors.

This pilot study intended to make a novel contribution to the research literature through, firstly, the development of a new test procedure designed to elicit HRV changes in response to different stressors. This procedure will be implemented in schools, focusing on schoolchildren. Secondly, this study intended to establish further links between HRV defined parasympathetic bounceback, resilience and traumatic life events.

Methods

Epistemological positioning

Ontology refers to the branch of philosophy which is focused on describing the structure and nature of the world (Wand & Weber, 1993). The two distinct positions are objectivism and constructionism. Objectivism states that there is an independent reality that can be observed and constructionism assumes that reality is determined by social pressures and processes (Bernard, 2013).

Positivism employs an objectivist, hypothetico-deductivist model of science that firstly involves formulating a priori hypotheses to be tested. Secondly, an experiment is designed through the operationalising of variables and then, finally, this empirical experiment is conducted (Park, Konge & Artino, 2020). The aim of positivist research is to uncover the casual relationships between explanatory factors, known as independent variables and outcomes, known as dependent variables.

In order to investigate the relationships between the variables of psychological resilience, physiological resilience and trauma in developmentally younger individuals, we have chosen to adopt a positivist position. We are therefore assuming that these phenomena exist in an independent observable reality that can be explained using scientific methods. We will go on to discuss the limits of this epistemological position and how different lenses might be used to broaden our understanding of this topic, in the discussion section.

This study

As explained in previous sections, this pilot was one part of a broader research project entitled: 'Social Influences on the Development of the Brain'. This broader project looked at collecting data from school children on school premises. It featured a more extensive battery of tests

which examined other aspects of interoceptive awareness such as a heartbeat accuracy test. It also employed further self-report measures that captured information on a range of other psychological and physical markers such as and inventory for somatic disorders. This section, however, will outline only the methodological steps (sampling, procedure, data analysis) involved in the pilot study only.

Participants

A total of ninety-one school children were initially recruited for this cross-sectional study. The convenience sample of school children ranged from nine to eleven with the mean age for the total sample being eleven years old. Most of the individuals were recruited from schools (n = 3) in the local East Anglian area and a few were recruited from an existing research database called 'babylab' (n = 8). The latter consisted of children who were of a suitable age and who had expressed willingness to engage in research with the University of Essex.

Recruitment

Prospective schools in the East Anglian region of England were contacted either because of their involvement in the Trauma Informed Schools UK (TISUK) network or via existing relationships within the Department of Psychology at the University of Essex. According to their website, the TISUK initiative 'aims to provide appropriate training for schools, communities and organisations so that they become trauma informed and mentally healthy places for all' (TISUK, 2023). After the study was explained, information sheets (see Appendix 1) were sent out to the schools explaining the expectations, proposal for work, and benefits of involvement in the research. Schools who consented generally did so via the head teacher or deputy head of the school. Once consent was given, the schools were then able to distribute our electronic flyers to parents along with a link to our online survey platform, Qualtrics, where they could read information about the study, leave their consent for their child to participate, (see Appendix 1)

as well as answer some of the self-report measures (detailed in the 'Methods' section below), and demographic information ahead of their child's participation in the battery of tests. Parents were then called by a member of the research team for a phone screen which involved screening for developmental disabilities, medical or neurological conditions and other things (see Figure 2 below).

For those individuals recruited via the 'babylab' database, emails were sent out and a trained research assistant administered phone screens (Figure 2 below) and introductions to interested participants who had responded. Parents were then sent a link to the Qualtrics platform as detailed in previous paragraph.

Figure 2: *A figure showing the table of exclusion criteria captured during the telephone screening*

Exclusion Criteria	
Developmental Disabilities?	
Any syndromes (e.g., William's, Prader-Willi, Down, Fetal Alchol, PKU)?	
Premature birth (< 4.4lbs / < 30 weeks)?	
Other medical or neurological conditions affecting growth and development (e.g., seizure disorder, diabetes, congenital heart disease)?	
Vision or hearing problems?	
Developmental Disabilities?	
Current medications?	
Primary home language?	

Self-report Measures

Copies of the self-report measures used in this study can be found in the appendices (see Appendices 2, 3, 4, 5). These measures were completed during a school visit day during the first phase of the procedure in the waiting area before the battery of tests was completed (See Figure 1).

Child and Youth Resilience Measure CYRM-R

The Child and Youth Resilience Measure (CYRM-R) is a 17-item self-report questionnaire designed to assess social-ecological resilience across different age groups, including children (5-9 years old), youth (10-23 years old), and adults (18+). It uses either 3-point or 5-point Likert scales, with the youth version being particularly suited for those aged 10 to 23 years (Jefferies, McGarrigle, & Ungar, 2019; 2018). A simplified language revision ensures clarity for younger respondents, especially those at the lower end of the age range, such as eleven-year-olds, who are only two years older than the 5-9 year group (Jefferies, McGarrigle & Ungar, 2019).

The CYRM-R is easy to use, requiring an average of just two minutes to complete, with all questions positively worded and scoring based on summing the responses (Resilience Research Centre, 2022). It includes two subscales: personal resilience, which assesses interpersonal and intrapersonal characteristics, and caregiver resilience, which relates to resilience in key relationships such as those with a primary caregiver, family, or partner (Jefferies, McGarrigle, & Ungar, 2018). The measure has been validated using the Rasch model, meeting criteria for unidimensionality, good fit statistics, and the absence of item biases. It demonstrates high internal reliability, with Cronbach's alpha values of .82 for both the personal and caregiver subscales, and .87 for overall resilience (Jefferies, McGarrigle, & Ungar, 2019). Additionally, concurrent validity has been established through strong positive correlations with self-esteem and acceptance, as well as strong negative correlations with trauma and PTSD (Daigneault, Dion, Hébert, McDuff & Collin-Vézina, 2013; Collin-Vézina, Coleman, Milne, Sell & Daigneault, 2011; Zahradnik, Stewart & O'Connor, 2009).

Child Trauma Screening Questionnaire

The Child Trauma Screening Questionnaire *(*CTS) is a 10-item measure for screening trauma exposure and PTSD symptoms in children and young people aged 6-17 (Lang & Connell, 2018). The measure has shown strong properties including high internal consistency; ($\alpha = .78$) (Lang & Connell, 2018). Example questions include: 'have you ever seen people pushing, hitting,

throwing things at each other, or stabbing, shooting, or trying to hurt each other?'; or 'has someone ever really hurt you?'; or 'has anyone ever hit, punched, or kicked you really hard with hands, belts, or other objects, or tried to shoot or stab you?'.

With only ten questions, the CTS has the advantage of being very brief, and it has been found to be highly correlated with the PTSD-RI-5 (see 'semi-structured interviews' section, below), a comprehensive self-report instrument intended to screen for PTSD symptom severity (Doric, Stevanovic, Stupar, Vostanis, Atilola, Moreira, Dodig-Curkovic, Franic, Davidovic, Avicenna, Noor, Nussbaum, Thabet, Ubalde, Petrov, Deljkovic, Antonio, Ribas, Oliveira & Knez, 2019). The CTS has been found to correctly classify 85% of young people according to a likely PTSD diagnosis, and has demonstrated internal consistency (Cronbachs $\alpha = 0.76$) (Lang, Connell & Macary, 2021).

In our study, the CTS was carried out via an iPad in the 'wating area' before the battery of tests commenced (see Figure 3). The CTS was included to flag those individuals who had disclosed sufficient details of traumatic experiences to be considered for the UCLA (see 'semi-structured interview' section below). Any participant who scored within the 'Events' section would be considered as suitable for a further UCLA after the battery of tests (see Figure 3).

Pubertal Development Scale

The Pubertal Development Scale (PDS) is a measure designed to assess pubertal status amongst eleven – fifteen year olds. It has been correlated with measures of pubertal development derived from physical examination (Pompéia, Zanini, Freitas, Inacio, Silva, Souza, Vitalle, Niskier & Cogo-Moreira, 2019). The PDS can be split into male and female versions, which ask the respondents to report levels of development according to five indices. The male version of the PDS involves asking boys whether their growth in the dimensions of: body or face hair, voice or skin change, and growth spurts, has 'not begun', 'barely begun', 'is definitely underway', or has finished. The female PDS asks the same questions about body hair, skin change and growth

spurt, but also features breast development. Responses to these questions are coded on four-point scale (no development = 1, completed development = 4). Also worth noting for the girls, is that there is a yes-no question about the beginning of the menarche (first menstrual cycle), which is weighted more heavily (no = 1, and yes = 4). A total score is created by averaging the scores for physical maturation for both genders (Petersen et al., 1988). The measure clearly bypasses the cost of hiring professionals, adequate equipment or suitable settings for physical examinations. Unlike other measures, it also does not involve images, or descriptions of genitalia which has been shown to cause much less embarrassment which may affect their willingness to be involved and the answers they choose to give (Dorn, Dahl, Woodward & Biro, 2006). It has also shown good inter-rater reliability (Pompéia et al., 2019), validity and high test-retest reliability and validity (Koopman-Verhoeff, Gredvig-Ardito, Barker, Saletin & Carskadon, 2020). The Cronbach's α is .91-.96 Koopman-Verhoeff et al., 2020).

Semi-structured Interview

The UCLA Child/Adolescent PTSD Reaction Index for DSM-5 (RI-5)

The *UCLA Child/Adolescent PTSD Reaction Index for DSM-5 RI-5* is a semi-structured interview that is designed to assess a school-age child or adolescent's trauma history and whether or not they meet any of the *DSM-5*'s PTSD symptoms or diagnostic criteria. The measure consists of three main portions: assessment of trauma types; a *DSM-5* symptoms scale; and an assessment of distress and impairment. The measure was evidenced to have criterion-referenced validity by demonstrating positive correlational of total scores with depressive symptoms (Kaplow, Rolon-Arroyo, Layne, Rooney, Oosterhoff, Hill, Steinberg, Lotterman, Gallagher & Pynoos, 2020). It was also shown to have favourable predictive validity when benchmarked against more extensive diagnostic interviews conducted by clinicians (Kaplow et al., 2020). The *RI-5* total scale demonstrated good to excellent internal consistency reliability across age ranges, sex, and racial/ethnic groups (α = .88-.91) (Steinberg, Brymer, Kim, Briggs,

Ippen, Ostrowski, Guly & Pynoos, 2013)

Procedure

This research was approved by the University of Essex's Ethics Committee (ETH1920-0699). The data gathering and research protocol took place within three schools in the East Anglian region of England. The school data was collected over the course of four independent days.

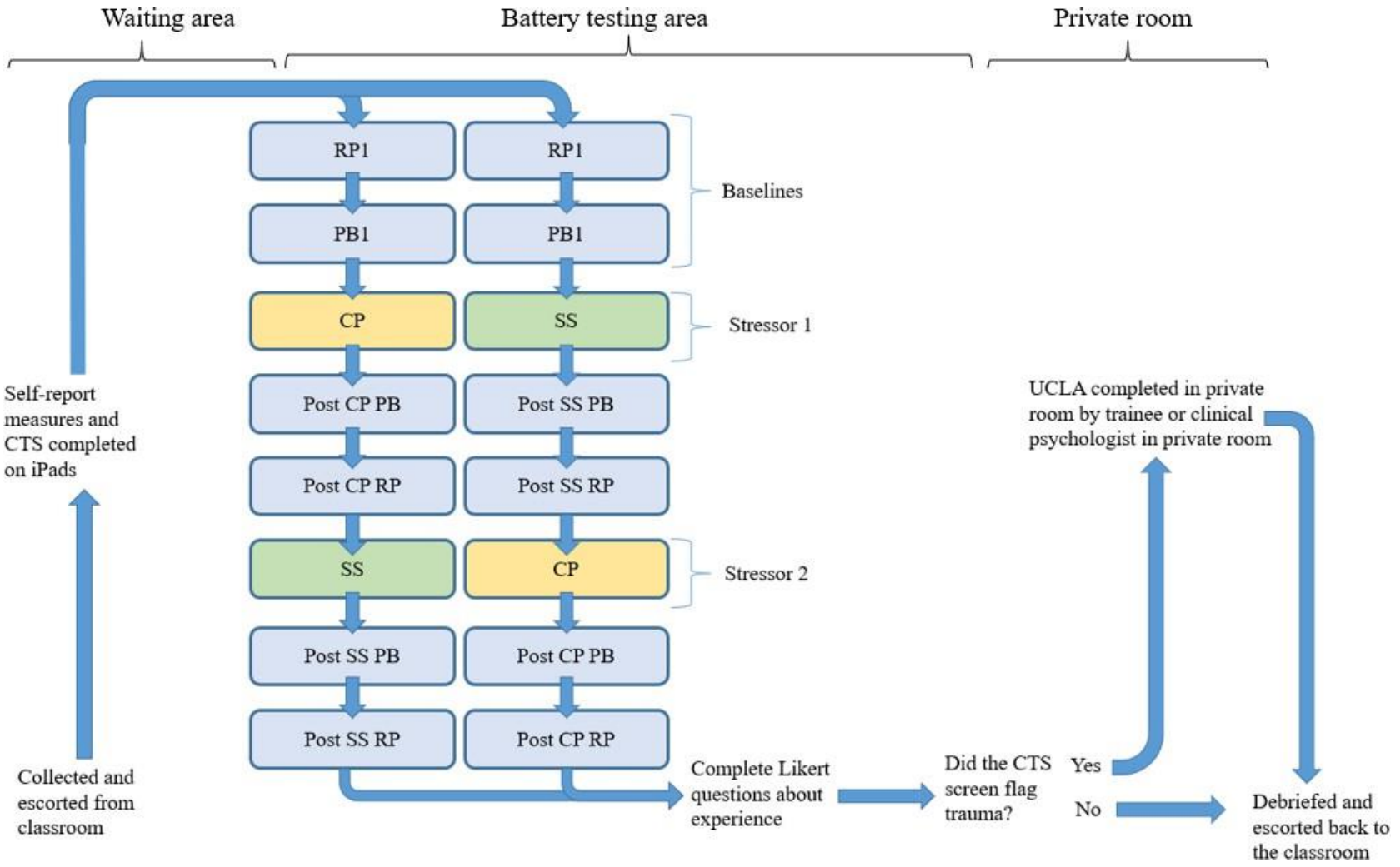
Once the research team were set up on the school grounds, individuals were located with the help of an administrative member of the faculty and retrieved from their respective classrooms using a time ordered register of those children involved. An average of 12 children a day were seen each day onsite. Parental consent had already been obtained (see Appendix 9) however the children were asked for their consent to continue with the study as planned. If the children were happy to continue, they were escorted to the sports hall or experiment area. Participants were supervised by at least two experimenters in this area at all times.

It was agreed with the school during the recruitment phase that the procedure would need to take place on school grounds during lesson time, with some equipment supplied by the schools such as desks, chairs and an open space like a sports hall. Information sheets (see appendix 2) were designed to give teachers an explanation of the study as well as what to expect on the experiment days taking place at the schools, including the expected break in class that would occur for the student sample. Children who successfully completed the Qualtrics onboarding process, were organised into a schedule over the school day. This schedule was shared with the teachers and school staff. Children were supervised by the research team and escorted back to their lessons after completion of the tests and a debrief (See Figure 1). If they had been flagged by the CTS earlier, the participant was evaluated by a the project lead and clinical psychologist to determine level of risk and facilitate the appropriate referral services (e.g., referral to the school's wellbeing service that the research team had been informed about prior).

Children from the babylab database were invited to attend the University campus to complete the same battery of tests on the University grounds. The same research team collected this data as collected the data within the schools although less were needed onsite as fewer children would attend at once.

As this thesis is one part of a larger project, there were other physiological measures taken before and after the testing detailed for this study. On average, each participant spent 20-30 minutes within the experiment area before being escorted back to their classroom. The participants had their HRV monitored (see *'ECG monitoring'* below). To account for order effects, the stressor order was randomised for each of the children.

Figure 3: *a chart to illustrate the procedural process*



KEY: PB1 = paced breathing 1; RP1 = resting period 1; CP = cold pressor; Post CP PB = post cold pressor paced breathing; Post CP RP = post cold pressor resting period; SS = social stressor; Post SS PB = post social stressor paced breathing; Post SS RP = post social stressor resting period; CTS = child trauma

One part of a wider project

This research was part of a broader study encompassing a wide array of measures to evaluate predictors and outcomes related to both mental and physical health throughout childhood and adolescence. The researchers developed a comprehensive battery of assessments that addressed the study's objectives while minimizing participant burden. The broader study utilized a variety of pre-existing, validated measures administered via iPad questionnaires, along with neurological and physiological testing. These measures were non-invasive, and participants had the option to withdraw at any point. The feasibility of running this specific study within the broader project is explored further in the discussion section.

Physiological Recording

ECG Monitoring

The general procedure and HRV analysis methods laid out in this section are mostly based upon the guidelines given in the *Standards of measurement, physiological interpretation, and clinical use: Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology* (1996). These guidelines are widely used in HRV studies and, according to a PubMed search in June 2024, have been cited over 4,000 times in research projects or reviews examining HRV.

The ECG equipment consisted of fitting three electrodes to the children. The research team gave a quick demonstration of how and where these would be placed, encouraging the children to fit the electrodes themselves. The researchers would step in and assist with fitting after this.

A ground electrode was placed above the right side of the collarbone and the two active electrodes were placed on the left side at heart level or on the right lower abdomen.

A respirator belt was also fitted to each of the participant’s waist making sure not to be too tight

but sturdy enough not to slip up or down from the diaphragm region. This was used to measure breathing rate. Participants were encouraged to fit these themselves too but assistance was provided if needed.

Each device was connected to ports within a NeXus dock that was further connected to a laptop which was pre-installed with the NeXus software. The software allows the physiological information to be displayed in real-time to the experimenters, as well as the participants (specifically useful for periods in which paced breathing was implemented). During the remaining procedure, one experimenter would assist and time the participant during completion of the tasks, whilst the other experimenter recorded timestamps on the software at significant moments in the procedure to aid post-hoc data analysis.

Time periods

The children were randomly assigned to one of two protocols that differed by order of stressor (see Figure 2). Once participants were fitted with the physiological devices, they were asked to complete two breathing periods for two minutes each. One of these involved the participant following and breathing along to a breathing pacer on the laptop screen ('PB1') and one involved the participant sitting and resting with no pacer looking away from the laptop screen ('RP1'). There were a total of 7 time periods that were captured and differentiated. They were as follows:

a) 'PB1', b) 'RP1', c) 'CP' (stressor condition 1), d) 'Post CP PB', e) 'Post CP RP'

f) 'SS' (stressor condition 2), g) 'Post SS PB', h) 'Post SS RP` (see Figure 2).

For each of the time periods, time-domain HRV analyses were carried out (Task Force of the European Society of Cardiology and the North American Society of Pacing and Eectrophysiology, 1996). This uses the interbeat intervals between successive heartbeats known as the 'RR intervals'. The root mean square of successive RR interval differences (RMSSD) was calculated for each of the time periods.

Cold Pressor Task Procedure

The following cold-pressor task procedure was a modified version of the cold pressor task (CPT) found in von Baeyer, Piira, Chambers, Trapanotto, & Zeltzer (2005). The CPT has been used in many child studies of pain, hormonal stress and autonomic reactivity (von Baeyer, Piira, Chambers, Trapanotto, & Zeltzer, 2005) and has been shown to be safe and feasible for use in children (Zeltzer, Fanurik & LeBaron, 1989). Modifications were made after researching the total costs for the equipment listed in study by von Baeyer, Piira, Chambers, Trapanotto, & Zeltzer (2005) and after some preliminary piloting of the procedure revealed some work arounds. This included the designing of the cold-pressor apparatus to be made of two containers; one smaller metal one placed in the other plastic one to create an outer chamber and an inner chamber. The outer chamber was filled with ice packs before water was poured in to fill up both chambers. The inner chamber would then have ice-free water. The water temperature of inner chamber was intended to reach 9° C and was monitored and maintained by checking it every 15 minutes with an electronic thermometer and adding further ice packs as needed. After baseline readings at 'paced' and 'resting' states were taken, subjects were given a brief overview of the cold-pressor task verbally which included reminding them they would only be asked to keep their hand submerged for a maximum time of 4 minutes. Children were asked to keep their non-dominant hands in the water up to the wrist for as long as possible, and then asked to remove their hands when the sensation became intolerable to them. If the participant hadn't removed their hand after 4 minutes they were informed of this limit and instructed to remove their hand immediately.

After completion of this task. The children were given a clean towel to rest their hand on whilst the rest of the battery of tests were completed.

Social Stressor Task Procedure

The procedure used is based on an adapted version of the Trier social stressor test for Children

(TSST-C) first described by Buske-Kirschbaum, Jobst, Wustmans, Kirschbaum, Rauh & Hellhammer (1997). The TSST-C was specifically designed to be used in children and adolescents aged 7-16 years. The TSST-C involves a public speaking task and a mental arithmetic task. We removed the arithmetic task as is sometimes done if researchers need to keep their experimental procedure brief (Allen, Kennedy, Dockray, Cryan, Dinan & Clarke, 2016). The social stressor used in this study involved asking each participant to give a speech on 'where the world will be in 5 years'. Each participant was given one minute to prepare what they had to say with a pen and paper if necessary. They were then given one minute in which to give their speech to the experimenters present.

Likert questionnaires & Debriefing

After the final set of breathing periods, the participants were given a short questionnaire which involved asking the participant about their experiences of both of the stressors (see Appendix 8). These questions involved using 10-point Likert ratings to rate their performance on each of the tasks against their perception of their same-age peer's performance. To control for people taking their hands out at variable degrees of subjective pain, we asked them to rate the pain they felt at the point of removing their hands and how long they perceived their hand to have been kept in the water for. To control for individual variability in reactions to the social stressor, we asked for the children to rate the stress they experienced during the social stressor as well as the degree of experience they have in performing in front of an audience of people.

The participants were given a short debrief by the experimenters and a debrief handout to take with them. This debrief included a short explanation of the project (see Appendices), a reminder of the data protection policy, the ethical considerations for the participant, including right to withdraw their data at any time, along with some contact information. They were asked to rate how they are feeling following the tests (see Appendix 8). They were also asked if they feel any distress as a result of completing the tasks. If any participants felt any remaining distress they were referred to the project lead onsite who is a mental health professional who can assess the participant for further support needs.

Method of Analysis

To ensure correct interpretations and reliability of analysis, careful pre-processing steps were completed with the raw data. This included noise detection; identifying and excluding periods of the ECG signal that are so noisy they can't be reliably recognised, beat correction; to correct abnormal beat intervals that are often duplicated or misaligned (Lipponen & Tarvainen 2019), trend removal; removing very low frequency trend components from the between beat interval data, thereby making the HRV analysis more sensitive to the low and high frequency variability (Tarvainen, Ranta-Aho & Karjalainen, 2002).

Statistical Analysis

Statistical analysis was carried out using IBM SPSS Statistics 20 software. We carried out correlation tests to determine the relationship of the variables collected. This was a way to identify covariates for other analysis steps. We also carried out a series of t-tests. Some were tested within subjects to compare the effects of the stressors, and others compared groups according to whether they had experienced a traumatic life event or not. We then carried out repeated measures We carried out multiple and linear regressions to determine which variables were most likely to predict HRV changes following a stressor.

Table 5: *A table to outline the corresponding measures and tests that will be used to test the experimental hypothesese*

Experimental Hypothesis	**Measures**	**Test**
1. School children will demonstrate an increased HRV during paced breathing timepoints after both the cold pressor and the social stressor	Heart Rate Variability (RMSSD)	T-test (within subjects) One-way repeated measures ANOVA Two-way repeated measures ANOVA
2. The cold pressor stressor will elicit a greater change in RMSSD HRV than the social stressor	Heart Rate Variability (RMSSD)	T-test (within subjects)
3. Self-reported resilience (CYRM-R) would predict RMSSD HRV change after both the cold pressor stressor, and the social stressor	Heart Rate Variability (RMSSD) CYRM-R	Regression
4. School children who have experienced traumatic life events but not PTSD (as verified by the UCLA) will demonstrate increased HRV in timepoints after both stressors	Heart Rate Variability (RMSSD) UCLA	T-test (between subjects)

Ethical Considerations

Risk

There was a potential risk that the schoolchildren may experience anxiety or distress when completing the measures, the battery of tests, or the semi-structured interviews. If this situation occurred, the first step would have been to communicate to the children that they are able to stop participating in the study at any time they want or are able to take a break at any time. The research assistants were trained to monitor the participant's distress and implement strategies to decrease stress or stop the study as needed. Weekly or fortnightly supervision sessions were conducted with the research team who were trained in the administration of psychological interviews and the necessary ethical and confidentiality considerations when working with children.. As part of the training, and as detailed in the standard operating procedures, the research assistants would report to the principal investigator (PI) if any child was not responding to these strategies or if they were increasingly presenting as clinically risky. The PI of the study is a licensed clinical psychologist who could provide the child with resources or an appropriate

referral as needed. If there was an identified risk of such evidence emerging, the PI and the research assistant would assist the child in contacting their GP Surgery with an appropriate letter should they consent to this. It was particularly important to follow a standardized procedure considering the sensitivity and risks involved in working with schoolchildren in this way and that there were multiple members of the research project onsite collecting data at any one time which could lead to inconsistencies in approach. The PI was onsite at every instance of collecting data to provide oversight and make sure that procedures were followed.

Confidentiality & data

All personal identifying information was removed from the participants' study records and participants were identified by a study identification number. Information linking participant's personal information to their study record was password protected and only trained research staff had access to this information. All data obtained was stored on confidential servers.

It is also worth noting that data was collected by a team of people that made up part of the broader project. This means that individuals were privy to data that they didn't further analyse personally after data collection. All data collected within the project was done so to address an aim or hypothesis and so no data was collected that wasn't intended to be used.

Results

Overview

The results section will begin with stating whether each of the experimental hypotheses were either accepted or rejected. Then this section will describe the the analysis and interpretations that address these experimental hypotheses. This results section will then outline the specific outcomes that address the first of the feasibility and acceptability aims described in the introduction section. This was aim (a) 'evaluating the feasibility and acceptability of recruiting

for and administering an experimental procedure with school children from multiple local schools'. The other two feasibility and acceptability aims require more conceptual and experimental interpretations that will be better suited for the discussion section later.

Please refer back to Figure 2 in the methods section for the breakdown of the timepoints which will be referenced throughout this section.

Experimental Hypothesis either 'accepted' or 'rejected'

1. School children will demonstrate an increased HRV during paced breathing timepoints after both the cold pressor and the social stressor – ***Accepted***
2. The cold pressor stressor will elicit a greater change in RMSSD HRV than the social stressor - ***Accepted***
3. Self-reported resilience (CYRM-R) would predict RMSSD HRV change after both the cold pressor stressor, and the social stressor - ***Rejected***
4. School children who have experienced traumatic life events but not PTSD (as verified by the UCLA) will demonstrate increased HRV in timepoints after both stressors - ***Rejected***

The data was analysed using several steps. The first step included looking at the variables of interest and investigating their normality and distribution. Following this, correlational relations were investigated. Then t- tests of the dataset (n = 52) were calculated to understand differences in timepoint RMSSD scores as well as scores in the CYRM-R. These t-tests were firstly pairwise to understand if there were significant differences between the two stressors (cold pressor or social stressor). Repeated measures ANOVA were also carried out to compare paced breathing and resting periods across the three timepoints (baseline, post stressor 1, post stressor 2). Then independent t-tests were carried out to establish differences between groups of schoolchildren who were either split up by their self-reported trauma (n = 34), or not (n = 18), or their trauma that had been verified by the UCLA PTSD Reaction Index (n = 12) or not (n = 40) (see Table 5).

Finally, a series of linear regressions were carried out to determine what variables predict the paced breathing timepoints after each stressor.

Demographic Data

Unfortunately, the demographic information that was included in the screening questionnaires were not filled in correctly. This is suspected to have occurred because the design of these initial questionnaires did not make it mandatory for this information to be completed first. The limitations of this omission will be discussed in the discussion section.

Table 6: *Table of Age, Pubertal Development Scores (PDS) and CYRM-R scores split by sex*

	Statistic	Age (years)	CYRM-R-P	CYRM-R-C	CYRM-R-T	PDS-Boys	PDS-Girls	PDS-Total	CP Likert 1	CP Likert 2	CP Likert 3	CP Likert 4	SS Likert 1	SS Likert 2	SS Likert 3
	N	52	52	52	52	–	–	52	52	52	52	52	52	52	52
Total	Mean	11.3	41	31	73	–	–	9	42	5	4	34	6	5	5
	Median	11.6	42	33	75	–	–	10	30	6	4	20	6	5	4
	N	23	23	23	23	23	–	23	22	23	23	22	23	23	23
Boys	Mean	11.5	41	31	72	4.91	–	8	41	5	3	26	5	5	4
	Median	11.9	44	33	75	5.00	–	7	33	6	4	12	6	5	4
	N	29	29	29	29	–	29	29	29	29	29	29	29	29	29
Girls	Mean	11.1	41	32	73	–	5.97	11	43	6	5	40	6	5	5
	Median	11.5	41	33	76	–	5.00	11	29	5	4	20	7	5	4

Key: CYRM-R-P = The Child and Youth Resilience Measure – Parent; CYRM-R-C = The Child and Youth Resilience Measure – Caregiver; CYRM-R-T = The Child and Youth Resilience Measure – TOTAL; PDS - Boys = Puberty Development Scale – Boys; PDS - Girls = Puberty Development Scale – Girls; PDS - Total = Puberty Development Scale – Total; CP Likert 1 = Cold pressor Time Rating; CP Likert 2 = Cold pressor social comparison; CP Likert 3 = Cold pressor pain rating; CP Likert 4 = Cold pressor time estimation; SS Likert 1 = social stressor stress rating; SS Likert 2 = social stressor social comparison; SS Likert 3 = social stressor prior speech experience; [a] = more than one value is available

Table 7: *Table of RMSSD (ms) scores at different timepoints and change scores following different stressors*

		RP1_RMSSD_	PB1_RMSSD	Post_CP_PB	Post_CP_RP	Post_SS_PB	Post_SS_RP	Change_PB1_RP1	Change_CP_PB	Change_CP_RP	Change_SS_PB	Change_SS_RP
N	Valid	56	56	56	56	56	55	56	56	58	58	58
	Missing	35	35	35	35	35	36	35	35	33	33	33
Mean		76.56	79.94	96.35	85.27	85.28	80.90	3.38	16.41	5.15	5.15	2.80
Median		73.35	74.65	93.95	84.10	85.60	74.60	5.70	10.45	0.95	0.45	3.35
Std. Deviation		35.98	32.52	33.10	36.21	36.13	41.75	29.07	29.63	32.40	28.48	34.46
Skewness		0.83	0.80	0.64	0.33	0.53	1.78	-0.13	0.58	0.61	0.54	-0.67
Std. Error of Skewness		0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.31	0.31	0.31
Kurtosis		1.87	0.92	1.02	-0.72	0.24	6.88	2.42	1.88	0.47	5.50	1.35
Std. Error of Kurtosis		0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.62	0.62	0.62
Minimum		14.50	22.30	29.90	14.80	18.10	24.50	-77.90	-50.50	-60.20	-93.90	-110.00
Maximum		206.90	179.80	208.80	162.10	179.30	273.30	101.40	122.30	93.50	115.90	66.40
Sum		4287.40	4476.70	5395.50	4775.20	4775.50	4449.60	189.30	918.80	298.50	298.80	162.20

Key*: see Figure 3 (methods section) for outline of these timepoints in the procedure that correspond to these*

Distribution and Normality

Kolmogorov-Smirnov (K-S) tests were conducted to test for normality with the self-reported resilience scores (CYRM-R personal, CYRM-R caregiver & CYRM-R total), pubertal development scores (PDS), and RMSSD timepoint scores. It was found that the CYRM-R-personal scores, $D(52) = 0.13$, $p < .05$, the CYRM-R-caregiver scores, $D(52) = 0.28$, $p < .05$, and the CYRM-R-total scores, $D(52) = 0.18$, $p < .05$, were all significantly non-normal. This was corroborated by plotting histograms of the frequency distributions (see Appendix 11*).* K- S tests found that normality held for RMSSD in all 6 of the relevant timepoints (see Appendix 12*).* These populations were found to be mostly moderately skewed (see Table 2).

Correlations

Correlations of variables found that there were some significant correlations of interest between the self-report measures, demographics, and other independent variables. This influenced the variables chosen to further analyse. For example, PDS-Girls score was shown to have a significant moderate negative correlation with Social Stressor - Change (r (50) = -.303, $p < .03$) PDS-Total score was approaching significance with a weak negative correlation (r (50) = -.259, $p = .06$).

As some of the variables, namely the CYRM-R scores, were non-normally distributed, Spearman Rank correlational tests were run when Pearson correlational tests weren't appropriate. Variables included: sex, pubertal development scores (PDS), CYRM-R-personal, CYRM-R-caregiver, CYRM-R-total, RMSSD timepoints, RMSSD timepoint changes Likert questions on child experience of the experiments post battery of tests. The baseline timepoints showed significant correlations with subsequent timepoints as expected. For example, PB1 was moderately positively correlated with Post_CP_PB (r (50) = .66, $p < 0.001$) and Post_SS_PB (r (50) = .703, $p < 0.001$).The comparative predictive power of the two baseline points (PB1) and (RP1) were investigated further in the regression analysis carried out later (see 'Simple Linear Regressions investigating predictive power of baselines' below).

Correlations between PDS, age and sex were present as was expected. PDS-Total demonstrated a significant, weak positive correlation with sex (r (50) = .377, $p < 0.01$) which means that increases in PDS-Total was correlated with the participants being female. Age was weakly positively correlated with PDS-Total (r (50) = .288, $p < 0.05$).

Interestingly, the Likert questions evaluating reported experiences of the cold pressor task (social comparison, pain rating, accuracy of time estimation) all significantly correlated with the CYRM-R (including the three subscales of 'CYRM-R personal', 'CYRM-R caregiver', and 'CYRM-R total'). The correlational coefficients were moderate to low. This suggests that these are potential covariates that may need to be controlled in further analysis.

Other than the correlations described above, there weren't any significant correlations between demographics, self-report measures or variables of interest.

T-tests comparing stressors (within subjects)

A series of t-tests were carried out to compare the HRV to see if there was a significant difference in RMSSD scores after cold pressor and after social stressor. Paced breathing periods and resting periods were both looked at as independent baselines.

Post CP PB vs Post SS PB

Both of the post stressor paced breathing timepoints were compared. The mean 'Post CP PB' RMSSD ms was 96.35 (M=-96.35; SD=33.1), and the mean 'Post SS PB' RMSSD was 85.27 (M= 85.27; SD=36.13). A paired samples t-test revealed that the difference in mean scores was highly significant difference $p < .001$.

Post CP RP vs Post SS RP

Both of the post stressor resting period timepoints were compared. The mean 'Post CP RP' RMSSD ms was 84.02 (M= 84.02; SD=35.29), and the mean 'Post SS RP' RMSSD ms was 80.90 (M= 80.90; SD=41.75). A paired samples t-test revealed that the difference in mean scores was non-significant $p > .25$.

T-tests comparing change periods (within subjects)

We tested the hypothesis that children would be differentially affected by the stressors by subtracting the values of RMSSD (ms) in the paced breathing period after each stressor from the initial value of RMSSD (ms) demonstrated at baseline. There were two baselines that were of interest: rest period 1 (RP1) in which the children were asked to sit and relax and one in which they were first encouraged to follow a pacer before exposure to any stressor (PB1). The former

would be more of an indication of the body during rest and the latter would be an indication of the individual's ability to activate their PNS through respiratory sinus arrhythmia (as discussed in the Introduction section).

The values obtained after this calculation will be referred to as:

- 'cold pressor paced breathing change' (change = 'Post-CP-PB' – 'PB1');
- 'social stressor paced breathing change' (change = 'Post-SS-PB' – 'PB1');
- 'cold pressor resting change' (change = 'Post-CP-RP' – 'RP1')
- 'social stressor resting change' (change = 'Post-SS-RP' – 'RP1').

A series of within-subjects t-tests were carried out to establish whether effects existed amongst the conditions. These included conditions involving each of the different stressors, as well as resting vs paced (or activated) breathing conditions. These values were either positive or negative i.e. they showed a relative drop or relative increase in HRV across these timepoints (See Appendix 6 for histograms that illustrate the distribution of RMSSD HRV change values).

*Cold pressor vs social stressor **paced breathing** – change in RMSSD*

The mean 'cold pressor paced change' was 16.41 (SD=29.40), and the mean 'social stressor paced change' was 5.33 (SD=32.96). A paired samples t-test revealed that there was a significant difference in the mean scores $p < .001$. This confirms the hypothesis that the cold pressor stressor would elicit a greater change in RMSSD.

*Cold pressor vs social stressor **resting period** – change in RMSSD*

The mean 'cold pressor resting change' was 5.14 (M=5.14; SD=32.40), and the mean 'social stressor resting change' was 2.80 (M= 2.80; SD=34.50). A paired samples t-test revealed that there was a non-significant difference in the mean scores $p = .34$.

In every analysis of the RMSSD HRV timepoints, it is worth noting that the standard deviation (SD) scores were relatively high. You can see the distribution of the total scores as histograms in the appendices (see appendix 11). Furthermore you can see how the RMSSD HRV change scores cluster quite broadly around the y axis which represents a change of zero (see appendix 11). This relatively high SD indicates that there was a large variation in the responses of the schoolchildren to the stressors. Please see Discussion section for interpretations and

implications of this high variance.

Investigating order effects

To test for stressor order effects, each of the participants were listed as either taking the cold pressor stressor first ('1') or the social stressor first ('2'). We conducted t-tests to determine whether there were any significant differences in the mean RMSSD (ms) scores in the various timepoints as well as the different change values (as described above).

The results revealed that the only significant difference when comparing RMSSD timepoint and change values by stressor order, was that of the CP_PB change value. School children who carried out the social stressor first showed a significantly higher CP_PB change value (M=22.26; SD=32.25) than those who carried out the cold pressor first (M=-8.6; SD=24.21). None of the other RMSSD timepoints or change values were significantly different when looking at stressor order.

Comparing multiple timepoints

A one-way repeated-measures ANOVA was performed to evaluate the effect of paced breathing timepoints on RMSSD HRV values. This included three timepoints: baseline paced breathing ('PB1'), post cold pressor ('Post CP PB'), and post social stressor ('Post SS PB'). Please refer back to Figure 2 in the methods sections for a breakdown of these procedure.

Mauchly's test indicated that the assumption of sphericity had been met. χ^2 (2) = 1.286, p = .526. The effect of the paced breathing timepoints on RMSSD HRV values was significant at the $p < .05$ level. F (2, 102) = 7.802, $p < .001$, partial η^2 = .164. Post hoc analysis with a Bonferroni adjustment revealed that RMSSD HRV was statistically significantly increased from baseline to post-cold pressor (-15.198 (95% CI, -24 to -6.44) ms, p < .001), but not from baseline to post-social stressor (-6.62 (95% CI, -16.58 to 3.35) ms, p = .32), or from post-cold pressor to post-social stressor (-6.62 (95% CI, -1.3 to 18.46) ms, p = .1).

A second one-way repeated-measures ANOVA was performed to evaluate the effect of resting period timepoints on RMSSD HRV values. This included three timepoints: baseline resting period ('RP1'), post cold pressor ('Post CP RP'), and post social stressor ('Post SS RP'). Please

refer back to Figure 2 in the methods sections for a breakdown of these procedure.

Mauchly's test indicated that the assumption of sphericity had been met. χ^2 (2) = .293, p = .864. The effect of the resting period timepoints on RMSSD HRV values were not significantly different at the $p < .05$ level. F (2, 102) = 1.245, p = .292, partial η^2 = .024. Post hoc analysis with a Bonferroni adjustment revealed no significant difference between baseline, post-cold pressor or post-social stressor (p = .41).

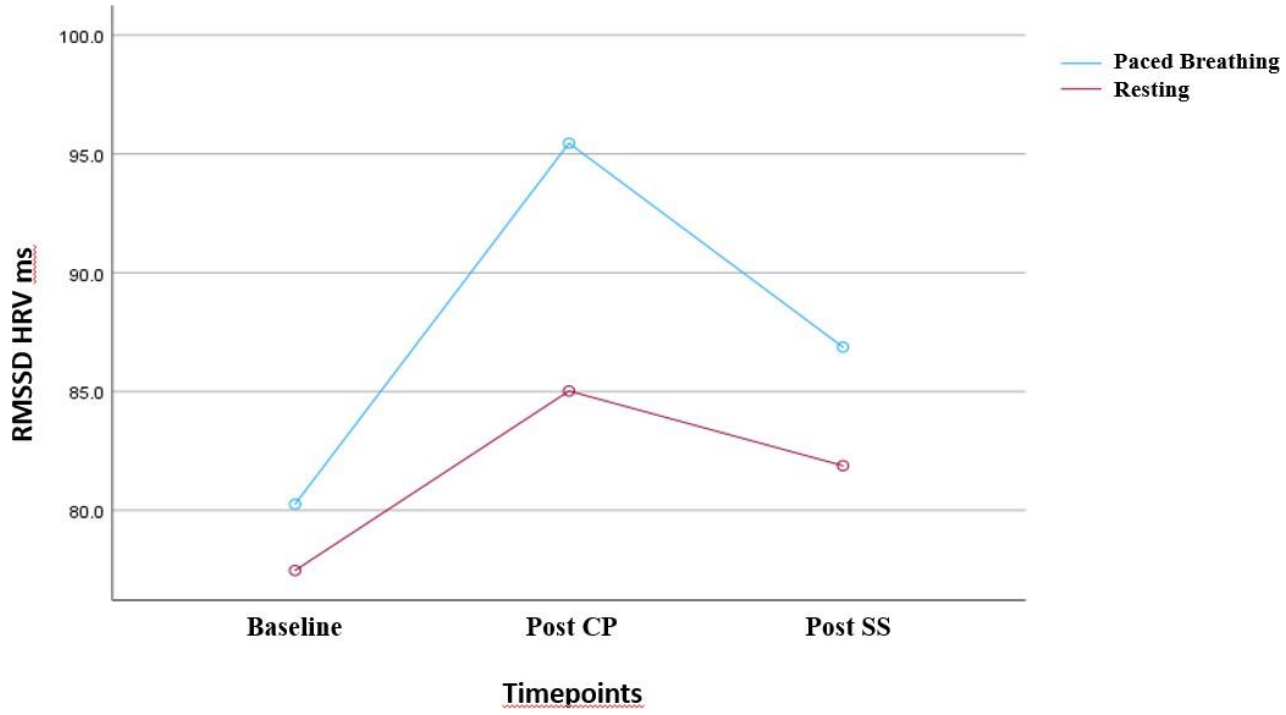
Two-way repeated measures ANOVA

A two-way repeated-measures ANOVA was performed to evaluate the condition effect ('paced breathing' or 'resting period') on timepoints ('baseline', 'post cold pressor', 'post social stressor') and on RMSSD HRV values. The means and standard deviations for paced breathing timepoints are presented in Table 5.

Mauchly's test indicated that the assumption of sphericity had been met for timepoint effect: $\chi 2$ (2) = .854, p = .653; and the interaction effect (timepoint x condition effect): $\chi 2$ (2) = 1.451, p = .484.

There was a statistically significant main effect of the condition ('paced breathing' or 'resting period') on RMSSD HRV values F (1, 51) = 4.794, $p < .05$, partial η^2 = .086. There was a statistically significant main effect of timepoint ('baseline', 'post cold pressor', 'post social stressor') on RMSSD HRV values F (2, 102) = 5.665, $p < .005$, partial η^2 = .1. The interaction between these two (condition x timepoint) was not significant F (2, 102) = 1.019, p = .4, partial η^2 = .02. Post hoc analysis was performed with a Bonferroni adjustment.

Figure 4: *Line graph illustrating the changes in RMSSD HRV in response to the cold pressor and social stressor*



Comparing Trauma Exposure Groups (between subjects)

Table 8*: Table illustrating the split of differently defined trauma exposure groups*

UCLA PTSD Index Trauma Event Defined

	Male	Female	Total
No Trauma Exposure	14	26	40
Trauma Exposure, not clinically ratified PTSD	9	3	12
Trauma Exposure, ratified PTSD	3	1	4
Total	23	29	56

CTS Defined Trauma Event Defined

	Male	Female	Total
No Trauma Exposure	6	12	18
Trauma Exposure	20	18	38
Total	26	30	56

Comparing UCLA defined trauma exposed (resilient) group to non-trauma exposed group

T-tests were run to compare the RMSSD HRV scores across timepoints to see if children who had been exposed to a traumatic event differed in their autonomic responses to stressors. 'Traumatic event' was defined in two separate ways for two independent analyses.

The first way involved splitting those children who were defined as having experienced a traumatic life event as per the child trauma screening (CTS) questionnaire. This group's RMSSD HRV scores, including 'change scores', and resilience (CYRM-R) scores, were compared to those who didn't experience a traumatic life event according to the CTS. The 52 children were split into 'trauma exposure' (n = 34) and 'no trauma exposure' (n= 18) via the CTS.

The second way involved an extra consideration whereby the traumatic life event uncovered by the CTS was further verified by the UCLA child/Adolescent PTSD Reaction Index for DSM-5 (RI-5) semi-structured interview as well as the judgement of a clinician; either a clinical psychologist, or a trainee clinical psychologist. This meant that the 52 children were split into 'trauma exposure ratified PTSD' (n = 4), 'not clinically ratified PTSD' (n = 12), 'no trauma exposure' (n = 40). This self-reported trauma is explored more in the section below (Comparing self-reported trauma exposed (resilient) group to self-reported non-trauma exposed group).

There were no significant differences in self-reported resilience scores (CYRM-R-personal, CYRM-R-caregiver, or CYRM-R-total) between the groups described above. There were no significant differences between the RMSDD scores for the RMSSD HRV timepoints. The mean Post-CP-PB RMSSD for children who had been exposed to traumatic event verified by the UCLA but didn't develop PTSD was higher (M = 106.383; SD = 30.75) than those who didn't meet these requirements (M = 92.172; SD = 29.17) but this did not meet significance p = .075.

Comparing self-reported trauma exposed (resilient) group to self-reported non-trauma exposed group

Some further independent measures t-tests were run to determine differences in timepoint RMSSD scores between those children who identified trauma in their lives (n = 38) in the screening questionnaire against those who didn't (n = 18). The self-reported trauma exposure group showed significantly ($p < .05$) increased mean Post_CP_PB RMSSD scores (M= 84.96, SD = 32.75) than the self-reported non-trauma exposure group (M = 101.742, SD = 32.28).

Other timepoints showed the differences in mean RMSSD scores (such as Post_CP_RP and Post_SS_RP) didn't reach the cut off of p< .05 to be deemed significant (see Appendix 7). Scores of the 'CYRM-R-caregiver' subscale demonstrated that self-reported trauma exposure group scored significantly (p < .05) lower (M = 30.82, SD = 3.819) than those who self-reported non-trauma exposure group (M = 32.39, SD = 2.03).

Predicting stressor responses

***Table 9**: a table of simple linear regressions to illustrate the predictive power of the two baselines*

Baseline Predictor (independent) variable	**Timepoint Predicted (dependent) variable**	**B**	**Standard Error B**	**β**	**t**	**p**	**Regression Results**
Resting Period Baseline	Post CP Resting	.505	.119	.501	4.259	<.001	R = .501 R^2 = .251 F = 18.135 p = < .05
	Post SS Resting	.734	.122	.638	6.036	<.001	R = .638 R^2 = .407 F = 36.433 p = < .05
Paced Breathing Baseline	Post CP Paced Breathing	.603	.112	.592	5.402	<.001	R = .592 R^2 = .351 F = 29.177 p = < .05
	Post SS Paced Breathing	.720	.115	.648	6.258	<.001	R = .648 R^2 = .420 F = 39.166 p = < .05

Simple Linear Regressions investigating predictive power of baselines

In order to further investigate how well the baseline HRV RMSSD measures labelled as the timepoints 'paced breathing 1' or 'resting period 1' predicted other timepoints, a series of linear regressions were carried out. The Paced Breathing Baseline predicted slightly more of the value of the subsequent post stressor timepoints when compared to the Resting Period Baseline (see Table 6 above for R^2 values).

*Regression test 1: What predicts RMSSD (ms) during paced breathing post **cold pressor** exposure?*

***Table 10:** Regression Model 1 with PB Baseline, Sex, CTS Defined Traumatic Life Event, PDS as predictors*

Coefficient	Estimate	SE	p-value
Intercept	59.31	30.78	.06
PB Baseline	.619	.095	<.001
Sex	-10	6.591	.136
CTS-TLE	-5.4	7.781	.490
PDS	-.06	.355	.858

Note: $F(4, 47) = 11.765$, $p < .001$, $R^2 = .500$

A multiple regression was run to predict 'RMSSD during paced breathing post cold pressor exposure' from four variables: baseline RMSSD, sex, CYRM-R total scores, and whether the children had flagged trauma on the trauma screening questionnaire but weren't found to have PTSD symptoms (n = 34). This last variable we are going to refer to as 'traumatic event exposure - PTSD?' for simplicity. We used self-reported trauma on the screening questionnaire in this set of regressions, rather than one that is verified by the UCLA PTSD Index, because significant differences in mean scores were described (see t-tests comparisons above). This may be due to the small sample of UCLA PTSD Index verified trauma cases (n = 12).

Prior to this analysis, tests to see if the data met the assumption of collinearity demonstrated that there wasn't a concern of multicollinearity (baseline RMSSD, Tolerance = .960, VIF = 1.042; sex, Tolerance = .867, VIF = 1.153; traumatic event exposure - no PTSD, Tolerance = .865, VIF = 1.157; CYRM-R total, Tolerance = .986, VIF = 1.014). The Durbin-Watson value was calculated to ascertain whether residual terms are uncorrelated. The data met the assumption of independent errors (Durbin-Watson value = 2.025).

These variables statistically significantly predicted 'RMSSD during paced breathing post cold pressor exposure'. $F(4, 47) = 11.765$, $p < .001$, $R^2 = .500$. Only baseline RMSSD added significantly to the prediction, p < 00.1. sex, CYRM-R total scores, and self-reported resilience did not (see Table 7).

Regression test 2: What predicts RMSSD (HRV, ms) during paced breathing post social stressor exposure?

Table 11: *Regression Model 2 with PB Baseline, Sex, CTS Defined Traumatic Life Event, PDS as predictors*

Coefficient	Estimate	SE	p-value
Intercept	22.14	39.585	.579
SS Baseline	.711	.122	<.001
Sex	-9.84	8.475	.251
CTS-TLE	10	10.006	.884
PDS	-.13	.457	.776

Note: F(4, 47) = 9.55, p < .001, R2 = .448.

A multiple regression was run to predict 'RMSSD during paced breathing post social stressor exposure' from the same four variables as with the cold pressor: baseline RMSSD, sex, CYRM-R total scores, and self-reported resilience.

Prior to this analysis, tests to see if the data met the assumption of collinearity demonstrated that there wasn't a concern of multicollinearity (baseline RMSSD, Tolerance = .954, VIF = 1.048; sex, Tolerance = .837, VIF = 1.195; traumatic event exposure - no PTSD, Tolerance =

.850, VIF = 1.176; CYRM-R total, Tolerance = .976, VIF = 1.024). The Durbin-Watson value was calculated to ascertain whether residual terms are uncorrelated. The data met the assumption of independent errors (Durbin-Watson value = 1.36).

These variables statistically significantly predicted 'RMSSD during paced breathing post social stressor exposure'. $F(4, 47) = 9.55$, $p < .001$, $R^2 = .448$. Only baseline RMSSD added significantly to the prediction, $p < 00.1$. sex, CYRM-R total scores, and self-reported resilience did not (see Table 8).

Regression test 3: What predicts RMSSD (ms) cold pressor change?

***Table 12**: Regression Model 3 with PB Baseline, Sex, CTS Defined Traumatic Life Event, PDS as predictors*

Coefficient	Estimate	SE	p-value
Intercept	55.274	48.940	.265
Sex	-15.451	7.417	.043
Age	-.746	2.553	.771
PDS	-.323	.398	.422
CTS-TLE	1.51	8.656	.862
Prior Speech Exp.	3.08	1.433	.037

Note: F(5, 46) = 1.854, p = .12, R2 = .168

A multiple regression was run to understand what variables predicted change in RMSSD after cold pressor. Because of the restrictive size of the sample, this allowed for a further variable to be included. A variable included this time was the score following the Likert question of 'how would you rate your prior experience of public speaking?' which was found to be correlated with resilience questionnaire scores as well as some of the RMSSD timepoint scores. We shall call this 'prior speech experience' for simplicity.

Prior to this analysis, tests to see if the data met the assumption of collinearity demonstrated that there wasn't a concern of multicollinearity (sex, Tolerance = .851, VIF = 1.75; age, Tolerance = .957, VIF = 1.045; traumatic event exposure – PTSD?, Tolerance = .869, VIF =

1.151; CYRM-R total, Tolerance = .977, VIF = 1.024, prior speech experience, Tolerance = .972, VIF = 1.029). The Durbin-Watson value was calculated to ascertain whether residual terms are uncorrelated. The data met the assumption of independent errors (Durbin-Watson value = 1.806).

These variables did not significantly predict 'RMSSD cold pressor – baseline change'. $F(5, 46) = 1.854$, $p = .12$, $R^2 = .168$. Sex ($p > .05$) and prior speech experience ($p < .05$) added significantly to the prediction. However, CYRM-R total, traumatic event exposure – PTSD, and age did not (see Table 9).

Regression test 4: What predicts RMSSD (ms) social stressor change?

Table 13*: Regression Model 4 with PB Baseline, Sex, CTS Defined Traumatic Life Event, PDS as predictors*

Coefficient	Estimate	SE	p-value
Intercept	55.274	48.940	.265
Sex	-15.451	7.417	.043
Age	-.746	2.553	.771
PDS	-.323	.398	.422
CTS-TLE	1.51	8.656	.862
Prior Speech Exp.	3.08	1.433	.037

Note: F(5, 46) = 1.854, p = .12, R2 = .168

A multiple regression was run to understand what variables predicted change in RMSSD after social stressor in a similar way to 'Regression test 3…'. This regression included use of the PDS-Total because the PDS-Girls score was shown to have a moderate negative correlation with this timepoint in the correlational analysis (r (50) = -.303, $p < .03$) and the total PDS score was approaching significance in being a weak negative correlation (r (50) = -.259, $p = .06$).

Prior to this analysis, tests to see if the data met the assumption of collinearity demonstrated that there wasn't a concern of multicollinearity (sex, Tolerance = .773, VIF = 1.293; PDS

Total, Tolerance = .944, VIF = 1.060; CTS - traumatic event exposure Tolerance = .876, VIF = 1.141; CYRM-R total, Tolerance = .944, VIF = 1.060, prior speech experience, Tolerance = .970, VIF = 1.031). The Durbin-Watson value was calculated to ascertain whether residual terms are uncorrelated. The data met the assumption of independent errors (Durbin-Watson value = 1.391).

These variables statistically significantly predict RMSSD social stressor change. $F(5, 46) = 1.854$, $p = .12$, $R^2 = .168$. Prior speech experience ($p < .05$) added significantly to the prediction. However, CYRM-R total, traumatic event exposure – PTSD, sex and age did not (see Table 10).

Omitted Regressional Analysis

Regression analysis of the three subscales within the CYRM-R was carried out independently to see if there were any significant findings with these acting as predictors of post stressor RMSSD. Neither were significant or contributed an increase in the R^2 value.

Discussion

Overview

The following chapter will discuss the findings from this experimental non-randomised pilot study. The main results will be discussed with reference to the original experimental hypotheses stated in the introduction section. Then we will discuss whether the research aim that examined the feasibility of this novel battery was achieved. The strengths and limitations of the design will be discussed, along with challenges faced by the research team, followed by recommendations for similar experimental studies in the future. Finally, the implications of this study for current and future clinical practice will be outlined.

Summary of experimental findings

The present study sought to determine whether schoolchildren's HRV responded to stressors designed to stimulate their parasympathetic nervous systems. The relationship between HRV, stress, and resilience in schoolchildren can be extrapolated from the results of this study. However, they should be interpreted cautiously for a number of reasons that will be explained later.

The experimental hypotheses already outlined are:

1. School children will demonstrate an increased HRV during paced breathing timepoints after both the cold pressor and the social stressor - ***this was accepted.***
2. The cold pressor stressor would elicit a greater change in RMSSD HRV than the social stressor - ***this was accepted.***
3. Self-reported resilience (CYRM-R) would predict RMSSD HRV change after both the cold pressor stressor, and the social stressor - ***this was rejected.***
4. School children who have experienced traumatic life events but not PTSD (as verified by the UCLA) will demonstrate increased HRV in timepoints after both stressors - ***this was rejected.***

RMSSD HRV Baselines

The mean resting period baseline RMSSD HRV for our schoolchildren was 76.6 ms and the paced breathing baseline was 79.6 ms. Comparing these to average values of RMSSD HRV collected with 346 6-13 year olds, both these scores lay between the fourth (uppermost) quartile and third quartile (Gąsior, Sacha, Pawłowski, Zieliński, Jeleń, Tomik, Książczyk, Wernern & Dąbrowski, 2018). Generally, higher baseline RMSSD HRV scores are associated with overall better autonomic flexibility and perfomance (Kim, Cheon, Bai, Lee, & Koo, 2018; Shaffer & Ginsberg, 2017). This may indicate that on average, the sample of schoolchildren we recruited

demonstrated better cardiovascular health or general physical health. Unfortunately, other than some simple screening questions, a more thorough assessment of physical health variables that might effect HRV, such as body mass index, diabetes, or lifestyle factors, such as diet, were not possible (Liao, Cai, Brancati, Folsom, Barnes, Tyroler & Heiss, 1995; Tiwari, Kumar, Malik, Raj & Kumar, 2021).

Interestingly, the baseline score for paced breathing, once RSA was stimulated, was very similar to that during resting. On the surface, this may appear to contradict the finding that RSA stimulation increases parasympathetic activation and vagal tone (Quintana & Heathers, 2014). However, several studies have shown that pre-emptive stress or anxiety in anticipation of a test or performance will inhibit vagal tone and stimulates sympathetic activation (Morgan, Cho, Hazlett, Coric & Morgan, 2002; Morgan, Aikins, Steffian, Coric & Southwick, 2007). The same research group found that active-duty military personnel enrolled in high intensity military training who had low vagal tone pre-stressful event actually performed significantly better in the subsequent stressful tasks (Morgan et al., 2007). This sympathetic activation is something that may be adaptive as it increases focus and mental preparation before an anticipated task (Morgan et al., 2002; Morgan et al., 2007). Therefore, the lack of change after RSA stimulation may demonstrate the schoolchildren's ability to apply their 'vagal brake'. This vagal brake would prevent parasympathetic activation when confronting an imminent stressful situation that requires concentration and physiological strain (Spangler & McGinley, 2020). This speaks to the complexity of the PNS – SNS autonomic balance and the conscious and unconscious factors at play.

Regression analysis found that both paced breathing and resting period baselines predicted a large proportion of the subsequent timepoints. This may firstly illustrate that the school children's unique HRV profiles remained stable across timepoints. It also may suggest that it is the individual differences that contribute to the changes in HRV across timepoints that is more

important than absolute or standardised values of HRV at certain timepoints.

Stressors and RSA affects

When investigating whether the order the children were exposed to the stressor would have an effect on the RMSSD HRV, we found that there was no significant order effects. Comparing both the post-stressor time points revealed that the cold pressor stressor elicited a significantly larger RMSSD HRV than the social stressor. This indicates that the parasympathetic 'bounce back' was larger following the cold pressor. In other terms, the cold pressor induced a greater parasympathetic regulatory reaction in the school children. This was only when the schoolchildren were instructed to follow a paced breather. During the post-stressor resting periods there wasn't a significant difference in RMSSD HRV scores. This confirmed experimental hypothesis one.

Analysis of the change scores showed that the cold pressor elicited a significantly greater change in RMSSD HRV than the social stressor. This finding further confirmed experimental hypothesis one. This suggests that the cold pressor stressor is a more effective experimental stressor in the context of this procedure and therefore should be considered in larger experimental studies looking at HRV and stressors in children. It is worth noting, that in other studies, the TSST-C has reliably induced changes in HRV (Seipäjärvi, Tuomola, Juurakko, Rottensteiner, Rissanen, Kurkela, Kujala, Laukkanen, & Wikgren, 2022).

Repeated measures ANOVA analysis was able to show that following these stressors, paced breathing did have a significant timepoint x treatment effect compared to resting periods. Susceptibility to stress-related diseases, such as PTSD, has been linked to the degree to which people respond physiologically to stressful situations (Sriram, Rodriguez-Fernandez, & Doyle, 2012). This therefore indicates that paced breathing was able to stimulate a parasympathetic 'bounceback' in the children, as their autonomic system resets and they self-sooth after a

stressful task.

However, caution should be employed in interpreting these results. Consulting the literature to understand the mechanisms behind these findings, there is a lack of consensus and in some places studies appear contradictory. For example, Sin, Sloan, McKinley & Almeida (2016) found that stressor frequency was unrelated to HRV. These inconsistencies have been discussed in detail in Saul & Valenza (2021). The authors state that because human stress response systems, including HRV, are often considered a linear system; wherein inputs and outputs are directly proportional. This means that the dynamics can be combined in a straightforward manner. However, in a nonlinear system, the dynamics cannot be described by merely adding the components together, leading to reduced predictability when using linear algorithms and analysis (Saul & Valenza, 2021).

Tonhajzerova et al. (2016) found that RSA reactivity varies with different stressor types: it typically decreases in response to cognitive tasks, reflecting sympathetic activation, whereas it tends to increase during emotional challenges, indicating effective processing of emotional stimuli. This 'vagal withdrawal' may reflect the vagal brake described earlier, when individuals are consciously pre-empting a challenging task they are more likely to perform in a lower HRV state (Morgan et al., 2007). Authors found that this process is reversed in emotionally challenging tasks whereby RSA increases and a greater parasympathetic reactivity is elicited (Tonhajzerova, Mestanik, Mestanikova & Jurko, 2016). RSA reactivity to stress may have significant implications for mental disorders, such as depression and anxiety (Tonhajzerova et al, 2016). Studying RSA as a non-invasive measure of 'brain-heart' communication could offer valuable insights into the connections between mental and physical health.

Trauma Groups

T-tests were run to compare the RMSSD HRV scores across timepoints to see if children who

had been exposed to a traumatic event differed in their autonomic responses to stressors, or differed in their resilience scores via the CYRM-R. 'Traumatic event' was defined in two separate ways for two independent analyses (as explained in the results section).

Independent t-tests showed that those 12 children, whose traumatic experience(s) were defined by the UCLA, did not differ significantly in either the RMSSD HRV scores, or the self-report resilience scores. This may suggest that there isn't a relationship between the variables being tested. It may be that traumatic experience exposure does not alter HRV in individuals. However, findings in key literature suggest that it does (Koboyashi et al. 2014; Koboyashi et al. 2016; Winzeler et al. 2017). One likely explanation is, therefore, that the sizes of the groups were too small to generate a significant result on this occasion. There was a large difference in the mean scores of RMSSD HRV during the post- cold pressor paced breathing timepoint. The 12 trauma exposed children who didn't develop PTSD elicited a greater parasympathetic regulatory response than those that weren't exposed to a trauma. This finding was approaching significance, though it did not reach it. This means that the fourth experimental hypothesis was rejected.

Though non-significant, this finding encourages further exploration of the relationship between RSA elicited parasympathetic regulation with a larger sample of individuals who have experienced a traumatic life experience but not gone on to develop PTSD. This may elucidate more about the unconscious or pre-conscious physiological mechanisms that contribute to fostering resilience to stress.

The schoolchildren were analysed as different groups for another set of t-tests. This time a simpler trauma screening tool was used to identity who had experienced a traumatic event or not. This screening tool yielded a much larger sample with which to analyse from. Using these group definitions, analysis was able to show that those children who had reported a life event, but hadn't gone on to develop PTSD, elicited a greater parasympathetic regulatory response than those who had experienced no traumatic event in their life. The reasons why significance was found in this definition of trauma groups compared to the UCLA-ratified group is likely

due to a multitude of factors that need to be further interrogated.

One question that is raised by this project is whether or not a stress response that is induced in an experimental setting has a strong relationship with a stress response evidenced in real-life situations. As this project only examines a cross-sectional sample on one occasion, we can't extrapolate the findings out further. Kim, Cheon, Bai, Lee, & Koo (2018) examined the ecological validity of the Trier social stress test (TSST). They found significant correlations between both subjective stress responses, and salivary cortisol levels, and acute stress responses in real life; in this case a university exam. Even still, the authors did find a clear increase in the pre-test response of the exam rather than the 'artificial' scenario of the TSST (Kim et al, 2018).

A criticism of this project is the way in which it classifies trauma for its participants. Mental disorders, including trauma, can be conceived as being on a spectrum. A spectrum of stress-related pathophysiology would more accurately encapsulate the iterative shifts in sensitivities and adaptations that our bodies undergo in response to our changing environment. Current day research continues to unearth new biomarkers, risk factors, or mechanisms of etiology that exist without a need to reference the border between 'disorder' and 'non-disorder' (Clark, Cuthbert, Lewis-Fernández, Narrow, & Reed, 2017). The Diagnostic and Statistical Manual (DSM)-5 attempts to account for the growing overlap between discrete disorders through use of terms such as 'high co-morbidity'.

The finding from this study that children who have been exposed to a traumatic event in their life but haven't gone on to develop PTSD have an increased capacity for physiological regulation assumes a 'disorder'- 'non-disorder' binary. A closer look at the scores from the UCLA Child/Adolescent PTSD Reaction Index for DSM-5 RI-5 reveals that some of those children in the 'Trauma Exposure, not clinically ratified PTSD' group were only a few scores away from the cut off that would have classified them as 'Trauma Exposure, ratified PTSD'.

However, we can't deduce the significance of these scores on the experiences of the children. For example, whilst trauma severity could be more accurately conceived on a spectrum, a cumulative trajectory along the UCLA scores may be felt by the child as exponentially severe rather than linearly.

The UCLA does offer a thorough grading framework for symptom severity in the form of 31 questions such as 'I try to stay away from people, places, or things that remind me about what happened' or 'I have trouble concentrating or paying attention'. These questions offer Likert style answers for the children along with a visual aid called a 'frequency rating sheet' to help the children better conceptualise 'none', 'little', 'some', 'much', 'most', days within the past month. A future study that uses this information as a dimension of PTSD symptom severity would be able to better mitigate the limitations of a categorical approach to trauma and PTSD. Considering that this project recruited its participants from mainstream schools, rather than a clinical setting, a spectrum or dimensional measure of trauma and/or trauma symptoms better suits such a sample than a measure with binary outcomes and cut-offs.

An open question is whether lower HRV is a risk factor for developing PTSD (vulnerability marker) or a consequence of PTSD (scar marker). Rombold-Bruehl, Otte, Renneberg, Schmied, Zimmermann-Viehoff, Wingenfeld, & Roepke (2019) found that low HRV could increase the risk of frequent and persistent intrusive memories, indicating potential vulnerability. To clarify HRV's role as a scar marker, longitudinal studies are necessary to track HRV changes before and during PTSD development. Current research mainly comprises cross-sectional studies, so causal relationships cannot be established from existing effect sizes. Further research is needed to better understand HRV's role in PTSD development.

For ethical reasons, the stressor exposure we subjected our participants to, will differ significantly from real-life traumatic events, which are often life-threatening. Given that the average Likert performance ratings indicated average pain, average stress, and the school children rated themselves as average to their peers in ability on both the stressors, it is likely

that the stressors elicited moderate distress levels within the school children. As Karl et al., 2018, also postulated in their discussion, our school children may have been exhibiting an 'orienting response' (Sokolov, 1960) rather than simply a stress response. The orienting response, along with what we understand about the heightened sympathetic nervous system activity in anticipation to performance optimisation, could be better accounted for in future studies. Measuring the interest elicited by the activities would have been helpful to determine if the physiological responses indeed indicated orientation.

As we have explored already in this report, a higher resting-state HRV is believed to be a central marker of robust emotional regulation capacity, indicating a system adept at responding to environmental challenges. A well-functioning vagal system is thought to signify psychological flexibility, emotional self-regulation, and positive adaptation (Cherland, 2012; Mather & Thayer, 2018). Conversely, low resting-state HRV indicates psychophysiological rigidity and a reduced ability to manage emotional responses to distressing events, that is linked with PTSD (Lakusic, Fuckar, Mahovic, Cerovec, Majsec & Stancin, 2007), and increased trauma exposure (Mather & Thayer, 2018). Furthermore, the RSA response to psychosocial stress has been shown to be blunted in non-clinical samples that have been exposed to post-traumatic stress (ArditiBabchuk, Feldman, & Gilboa-Schechtman, 2009; Dale, Carroll, Galen, Hayes, Webb & Porges, 2009). However, other sutides have found no differences in RSA baseline or reactivity in association with adverse childhood events (ACEs; Shenk, Putnam, Rausch, Peugh, & Noll, 2014; van Ockenburg et al., 2015).

It may be that the lower-level traumatic exposure found in these distinct groups indicate that the children have developed a more resilient and more flexible stress regulatory system. This is in line with findings from Beranbaum et al., (2023), who discovered that youth that had been exposed to violence, showed long term adaption to ongoing stressors through enhanced parasympathetic regulatory capacity. They concluded that high emotional regulation and low

risk-taking may act as protective factors, reducing further exposure to violence and maltreatment among the young people (Beranbaum et al., 2023). Unfortunately, the degree to which this has been brought about by one more potentially traumatic events, as ascertained by the CTS, or by a responsive parasympathetic response that has been tested in ongoing difficult or violent situations, is outside the scope of this pilot study. However, future studies looking at the role of potentially traumatic events and resultant HRV changes and mental health disorders, remains largely unexplored in the literature.

Resilience

This section will explore the experimental findings that related to experimental hypothesis 3: self-reported resilience (CYRM-R) predicts RMSSD HRV change after both the cold pressor stressor, and the social stressor. We found that self-reported resilience were not correlated with any of the other measures including the RMSSD HRV timepoints across the battery of tests. Four regression models were run to examine which predictors contributed to post stressor HRV RMSSD values or HRV RMSSD change. CYRM-R total scores did not predict HRV RMSSD values or HRV RMSSD change. Therefore, the third hypothesis; 'self-reported resilience (CYRM-R) would predict RMSSD HRV change after both the cold pressor stressor, and the social stressor' is rejected.

Similar to our findings, Hourani et al. (2016) found increases resting and stress induced HRV did not also corresponding to self-reported resilience. They looked at the perceived stress scale (PSS) rather than the CYRM-R.

A longitudinal study that developed and tested the validity of an Arabic version of the CYRM found that Jordanians reported few lifetime traumas, with fewer trauma events correlating with higher resilience scores (Panter-Brick, Hadfield, Dajani, Eggerman, Ager, & Ungar, 2018). Interestingly, higher trauma exposure did not consistently result in lower resilience scores

among refugees: some youth gained strength from overcoming trauma, while others faced ongoing distress. As Panter-Brick (2015) suggests, simple associations between risk, resilience, and adversity should not be expected.

Interestingly, significant correlations were found between self-reported resilience and some of post-test Likert questions. This included a positive correlation with one that asked children to rate the length of time they were able to hold their hand under the cold water in the cold pressor stressor compared to their perception of their peers. There was also a significant negative correlation with their rating of pain and their experience of prior public speaking - which might signify a factor that protects the children from the stress of the social stressor. The last question score was also used in a regression model to predict change in RMSSD HRV following the social stressor. It was found to contribute significantly to the predictive model. There is likely relationships between anxiety, public speaking and physiological biofeedback (Schmitz, Blechert, Krämer, Asbrand, & Tuschen-Caffier, 2012) that could be an interesting area for further research. It isn't simple to unpick the causality of these variables and whether or not resilient children are more likely to seek out opportunities that may expose them to social stress or whether they are more resilient because of their exposure.

Another interesting finding was that those who reported exposure to a traumatic event via the CTS scored significantly higher in the CYRM-R-caregiver subscale. This may indicate that the caregiver reports more resilience in those who have been exposed to a traumatic event, even if those individuals themselves didn't indicate a significant difference.

Feasibility and acceptability findings

To recap, the third aim of this study focussed on the feasibility and acceptability of implementing a relatively novel battery test procedure. This procedure combines two of the HRV stressors; 1)

the cold pressor stressor and the 2) social stressor. Firstly, we will discuss the recruitment and administrative factors that affected achievement of this aim. Secondly, we will discuss how well the battery test represented a valid measure of stress/ and or traumatic life events in our schoolchildren. Thirdly and finally, we will discuss whether the battery test produced novel insights about the variables we aimed to investigate.

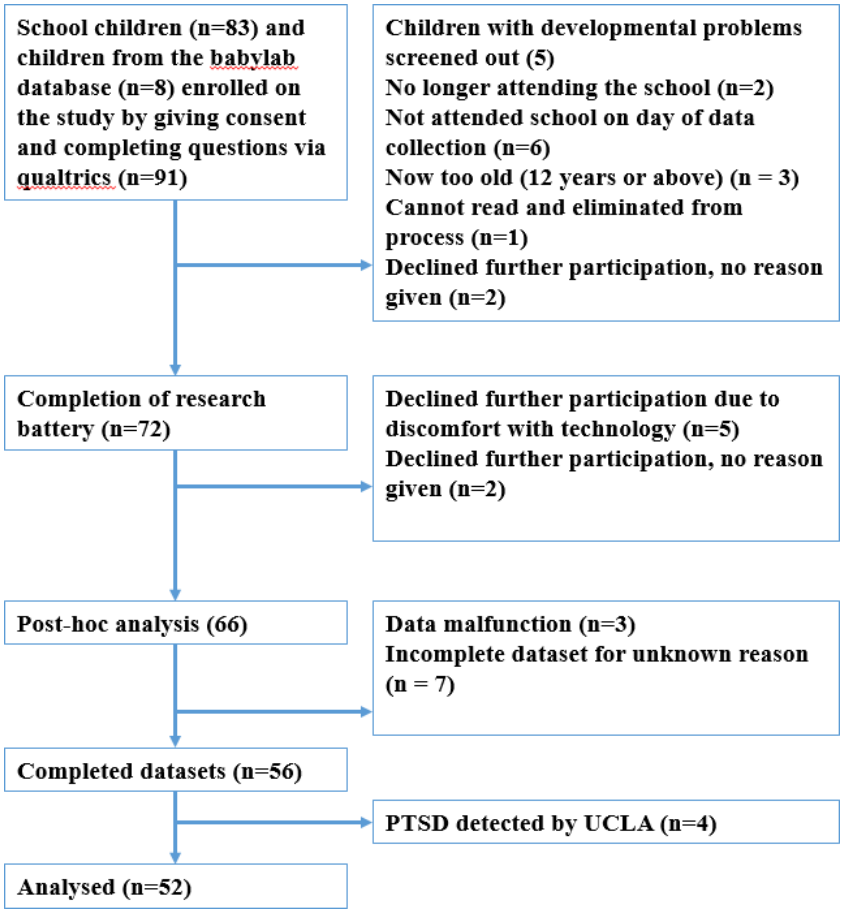
Recruitment & administration

We will now reference findings that address the feasibility and acceptability aim which focussed on recruitment for and administering of an experimental procedure with school children from multiple local schools. These will be discussed further in the discussion section.

The project team collectively aimed for, created and agreed a timeline that stated data collection would need to be completed before the 24th July 2023. This was to ensure we could involve the children and use the school premises before schools in the UK breakup for summer. The summer holiday ended on the 31st August 2023 and we decided this was too late to leave sufficient time for adjustments, data analysis and write up.

A delay on piloting the procedure occurred as a result of illnesses within the team, which meant we had less time to recruit schools, children and their parents to the study. We also began the project with some professional contacts within a community training provider that runs programmes for schools and communities in order that they can become more trauma informed cultures. These contacts were interested specifically in the research implications and what our findings and project might elucidate about mental health and emotional regulation in schoolchildren. Unfortunately, due to unforeseen circumstances, these contacts were no longer able to work with us after Spring 2023. This meant that more time needed to be spent on generating interest in our project with prospective schools in the nearby East Anglian area. The

Figure 5: *Flow diagram of participants progressing through the study*



project team of six individuals had to improvise an outreach programme.

Figure 5 (above) illustrates a flow diagram of the participants as they progressed through the study. As illustrated, 14 (16%) were screened as ineligible due to no longer attending the school (2%), not being able to read (1%), having developmental difficulties (5.5%), and now being outside the age range specified for this study (3%) (9-13 years old). As demonstrated in the

flow chart, 5.5% of children declined to continue during the battery testing due to discomfort with wearing some of the technology. Furthermore, 2% declined to continue but a reason either wasn't recorded or the child didn't give a reason for their desire to withdraw. The flow chart also shows that 2% of participant's data malfunctioned and was unreadable when looking back at the recordings on the HRV software. A further 8% of records were incomplete and therefore not eligible for analysis. After analysis had begun, four children (4%) who were found to have a diagnostic profile of PTSD, and weren't used in further analysis for this part of the project.

Outreach programme

We began this process of recruitment by contacting researching psychologists or other mental health practitioners who were listed as 'locality clinical leads' in a downloadable spreadsheet found using a search on the internet. We deduced that these clinicians would appreciate the importance of the implications of the research we were doing. As detailed in the methodology, we sent out a flyer and information sheet via the email supplied on this spreadsheet and then the six members of the project team would make some phone calls to these individuals via the switchboard numbers supplied on the website page for the community hub each locality clinical lead was based at. It was via replies to these and follow up telephone calls from the clinical leads that often put us into contact with a headteacher or assistant headteacher at a prospective school that we then sent the 'school study fliers' to (see Appendix 1), discussed timings, dates and available facilities over the next two months. After this point the headteacher or deputy headteacher would then arrange with their administration team for the consent and information letters (see Appendix 7 & 9) to be sent out via post and or email (if possible) to the parents. This distribution step was carried out by the schools and so the data management responsibilities lay with them. The letters contained a link or website to the qualtrics platform. This began the second phase of the recruitment process: data collection.

Without a centralized system or a structured method for recording our communications, it was difficult to maintain a consistent approach. As a result, some schools weren't contacted or followed up with as promptly, which may have affected the amount of data we were able to collect. Additionally, variations in how different clinicians or researchers conducted the testing could have influenced the quality of the data produced.

Overall, the recruitment efforts successfully yielded a sample large enough to make inferences

about the relationships between the experimental variables, aligning with recommendations for a pilot study (Eldridge et al., 2016; Lancaster & Thabane, 2019).

A larger, more extensive project based on some of the findings of this pilot study should consider a longer recruitment time, and an increased availability of the project team. This would allow for a greater recruitment drive to maximise the sample as well more support to conduct the research, devise and pilot the battery test, facilitate training of junior staff members in running the tests and using the equipment, as well as the clinical skills necessary to carry out semi-structure interviews.

Measuring and conceiving stress and/or traumatic life events

One question that is raised by this project is whether or not a stress response that is induced in an experimental setting has a strong relationship with a stress response evidenced in real-life situations. As this project only examines a cross-sectional sample on one occasion, we can't extrapolate the findings out further. Kim, Cheon, Bai, Lee, & Koo (2018) examined the ecological validity of the Trier social stress test (TSST). They found significant correlations between both subjective stress responses, and salivary cortisol levels, and acute stress responses in real life; in this case a university exam. Even still, the authors did find a clear increase in the pre-test response of the exam rather than the 'artificial' scenario of the TSST (Kim et al, 2018).

A criticism of this project is the way in which it classifies trauma for its participants. Mental disorders, including trauma, can be conceived as being on a spectrum. A spectrum of stress-related pathophysiology would more accurately encapsulate the iterative shifts in sensitivities and adaptations that our bodies undergo in response to our changing environment. Current day research continues to unearth new biomarkers, risk factors, or mechanisms of etiology that exist without a need to reference the border between 'disorder' and 'non-disorder' (Clark, Cuthbert, Lewis-Fernández, Narrow, & Reed, 2017). The Diagnostic and Statistical Manual (DSM)-5

attempts to account for the growing overlap between discrete disorders through use of terms such as ‘high co-morbidity’.

The finding from this study that children who have been exposed to a traumatic event in their life but haven’t gone on to develop PTSD have an increased capacity for physiological regulation assumes a ‘disorder’- ‘non-disorder’ binary. A closer look at the scores from the UCLA Child/Adolescent PTSD Reaction Index for DSM-5 RI-5 reveals that some of those children in the ‘Trauma Exposure, not clinically ratified PTSD’ group were only a few scores away from the cut off that would have classified them as ‘Trauma Exposure, ratified PTSD’. However, we can’t deduce the significance of these scores on the experiences of the children. For example, whilst trauma severity could be more accurately conceived on a spectrum, a cumulative trajectory along the UCLA scores may be felt by the child as exponentially severe rather than linearly.

The UCLA does offer a thorough grading framework for symptom severity in the form of 31 questions such as ‘I try to stay away from people, places, or things that remind me about what happened’ or ‘I have trouble concentrating or paying attention’. These questions offer Likert style answers for the children along with a visual aid called a ‘frequency rating sheet’ to help the children better conceptualise ‘none’, ‘little’, ‘some’, ‘much’, ‘most’, days within the past month. A future study that uses this information as a dimension of PTSD symptom severity would be able to better mitigate the limitations of a categorical approach to trauma and PTSD. Considering that this project recruited its participants from mainstream schools, rather than a clinical setting, a spectrum or dimensional measure of trauma and/or trauma symptoms better suits such a sample than a measure with binary outcomes and cut-offs.

An open question is whether lower HRV is a risk factor for developing PTSD (vulnerability marker) or a consequence of PTSD (scar marker). Rombold-Bruehl, Otte, Renneberg, Schmied, Zimmermann-Viehoff, Wingenfeld, & Roepke (2019) found that low HRV could increase the risk of frequent and persistent intrusive memories, indicating potential vulnerability. To clarify

HRV's role as a scar marker, longitudinal studies are necessary to track HRV changes before and during PTSD development. Current research mainly comprises cross-sectional studies, so causal relationships cannot be established from existing effect sizes. Further research is needed to better understand HRV's role in PTSD development.

Did the novel test battery produce significant insights?

This is a pilot study that included testing the feasibility of a relatively novel test battery with school children in a school setting. As discussed, the experimental battery was successfully able to generate results which, via quantitative analysis, has provided some tentative insights as to the relationship between social and physiological stress and traumatic life experiences.

A strength of the battery was that it was thoroughly designed and tested prior to data collection. In order to maximise staff resources, the two trainee psychologists worked on developing and documenting the standard operating procedures. Many helpful refinements were successfully implemented during the piloting phase, such as creating the inner chamber to better stabilise the temperature at 9 degrees, which optimised the battery for consistent data collection. This meant that most of the pupils completed the testing, and most of the data collected was useable. As already described above, several children dropped out of experiment due to discomfort around wearing the technology. As this project was part of a wider project, some of the equipment used is not described in this paper. A Functional near-infrared spectroscopy (fNIRS) cap in particular was uncomfortable for the children. Those who dropped out because of it were 5.5% of the total sample and 7% of those who attempted the battery of tests. The full test procedure was on average completed in 30 minutes including the questionnaire on the ipads completed beforehand. Although attrition is inevitable, particularly in child populations, future studies should bear this in mind and not overburden the children so much that they feel uncomfortable.

This battery examined whether certain stressors (physiological or social) elicited stress responses more reliably under experimental conditions. The literature shows that both the CPT,

and the TSST (albeit a shortened version was used in our battery) reliably elicit stress-induced sympathetic nervous system changes in participants (McRae et al. 2006). The battery designed for this experiment took a shorter and child adapted version of the Trier social stressor test for Children (TSST-C) (Allen, Kennedy, Dockray, Cryan, Dinan, & Clarke, 2016). As has been described before, different tests elicit different HRV responses depending on whether they are emotional or cognitive tasks. The battery was able to uncover that during our testing the social stressor didn't elicit significant changes in RMSSD HRV the way that the cold pressor did. This means that it may not function as usefully as a stressor in this setting with this sample in future studies. However, the TSST-C, and modified versions, has reliably been able to elicit increased RMSSD HRV levels, as well as other psychophysiological markers of stress, across different age groups (Seipäjärvi, Tuomola, Juurakko, Rottensteiner, Rissanen, Kurkela, Kujala, Laukkanen, & Wikgren, 2022) and this disrepency is explored more in the 'limitations' section of this discussion (below).

It is likely that the schoolchildren may have already been experiencing some stress during completion of the childhood trauma screen (CTS) prior to the baseline recordings. Therefore, the baselines HRV RMSSD scores may not reflect a completely stress-free or neutral state in the body, and a more reliable baseline for reference could be taken prior to completion of the CTS.

To control for order effects, the children were randomised as to which of the stressors they completed first. Analysis showed no significant order effects on RMSSD HRV at any of the timepoints. Reflecting on this design, it seems it may have also been an oversight not to randomise the order of the resting or paced breathing timepoints. As it stands, the resting period always followed the paced breathing. This raises the question as to whether the resting period could really be deemed as entirely neutral given that a few minutes of parasympathetic regulation has already taken place.

The battery test induces stress in discrete time blocks, with subjects experiencing stress during the experiment only. In real life, individuals encounter various stressors over time, but these represent isolated events with recovery periods in between. The findings of this study aren't as relevant to situations involving prolonged mental effort, such as exams or job interviews, which involve extended stress. However, further research is needed to understand how HRV metrics respond to brief stressors or to traumatic events. This is discussed further in the 'future research' section below.

Strengths & limitations

This relatively novel pilot study was able to investigate the intersection between traumatic life events and stress regulation in a cross-sectional sample of schoolchildren responding to two different experimental stressors. Interestingly, the analysis suggests that there may be differences in how such life experiences influence autonomic regulation and children's reactivity to physiological stressors versus social stressors.

One strength of this study is that it highlights the high degree of variance of baseline and post-stressor HRV that can occur in a cross-section of participants and therefore makes a strong case for longitudinal research to chart adaptations to stressor responses over several separate testing points.

Another strength is that 'stress' and 'resilience' were treated as multi-faceted concepts and therefore multiple measures were used to account for this. For example, resilience was considered at the conscious appraisal level in the form of a self-reported questionnaire, as well as at the unconscious autonomic level in the form of HRV responses.

Another is that studying school children is seldom done (Plummer, Galla, Finn, Patrick, Meketon, Leonard, Goetz, Fernandez-Vina, Bartolino, White & Duckworth, 2014), and so not only were the findings interesting to observe in this population, but that the study provided an opportunity to test the feasibility of a an experimental test in such conditions. The study met many operational challenges along the way, but, as explained in the results and discussion sections, the team were able to adapt to these challenges.

We have already discussed some limitations in the experimental design, the feasibility of the

recruitment plan, and the reductive conceptions of trauma and stress. There are further limitations to consider that mean we should accept this projects results with caution. The main limitation, as discussed already, is that the sample (n=52) was underpowered. The caution needed to interpret the results may have been mitigated had the sample size had been as originally intended (n=80). Some of the significance levels of the findings have undoubtedly reduced as a result and those that are significant should encourage future retesting of the experimental hypotheses.

One further pattern seen across much of the RMSSD HRV timepoint analysis during the battery testing, was that the standard deviation values were consistently high. This suggests that there is a high degree of variance across our sample. Whilst some participants were excluded, the convenience sample of school children would inevitably generate a higher degree of variance than if we were looking at a specific clinical sample. We attempted to control for some of this variance by using covariates in some of our analysis including the Puberty Development Scale (PDS), age, and sex. All three of these produced correlations with the HRV data. In line with other studies (Frasier, Oliveira Sergio, Starski, Grippo & Hopf, 2023), females were more likely to have lower RMSSD HRV scores, age correlated positively with RMSSD HRV scores, as did PDS. The scope of this pilot study didn't allow for capturing further covariates and variables that are known to impact HRV, including: body mass index (BMI), general physical health, ethnicity, physical activity, diet, sleep problems, or other pain issues (Hourani, Davila, Morgan, Meleth, Ramirez, Lewis, Kizakevich, Eckhoff, Morgan, Strange, Lane, Weimer & Lewis, 2020; Gleichmann, Solis, Janowich, Wang, Calhoun, Wilson & Stephen, 2020). Such control or use of these covariates in analysis may have reduced the variance observed within the results to further elucidate the patterns between the main variables of baseline RMSSD HRV, post-stressor RMSSD HRV, CYRM-R, and traumatic life experience.

Beyond covariates for controlling extraneous influences on HRV, our pilot study had limited

access to participants' demographic information, such as race, religion, family structure, and socioeconomic status. This significantly restricts the ability to conduct analyses related to key identities.

This study primarily examined only one index of HRV; RMSSD. This was decided due to its popularity in the HRV literature as a reliable measure of parasympathetic regulation (Bravi, Longtin & Seely, 2011), as well as it's association with psychological distress (Koenig et al., 2016). Further exploration of the literature following interpretation of the results has provided a possible reason why RMSSD may not have altered as significantly following exposure to the social stressor as it did the cold pressor stressor. The hypothalamus–pituitary– adrenal (HPA) axis is a communication system that, like the vagal-mediated autonomic system, is involved in hormonal responses to stressors and stress adaptations in the body. The main function of the HPA axis is to release cortisol and in turn promote homeostatic regulatory responses to stress (Herman, McKlveen, Ghosal, Kopp, Wulsin, Makinson, Scheimann & Myers, 2016). While a connection between vagal activity and the HPA axis is presupposed (Thayer & Sternberg, 2006), numerous studies have indicated that the relationships between changes in HRV and cortisol levels in response to stress are either weak or insignificant. An individual's reaction to stress encompasses not only the immediate aftermath of facing a stressor but also the anticipation of the stress itself. Research by Zandara, Garcia-Lluch, Villada, Hidalgo, and Salvador (2018) has demonstrated that the HPA axis and cortisol response to stress ar significantly linked to this anticipation. A decrease in HRV during anticipation of stress was correlated with cortisol release, but interestingly, not recovery (Zandara et al., 2018). In this way it is appears to be involved with a different phase of the stress response to the parasympathetic or vagal tone. As social stressors such as the TSST, are thought to be more linked to HPA axis stimulation than vagal mediated HRV (Schommer, Hellhammer, & Kirschbaum, 2003), it suggests that RMSSD which directly links to parasympathetic activity (Bravi, Longtin & Seely, 2011) and vagal tone (Laborde, Mosley & Thayer, 2017) may not be as suitable to measuring HRV changes in

response to social stressors. This may explain why we didn't see significant changes in RMSSD HRV in response to the social stressor. This is a useful finding and one that a larger study would benefit from considering.

Implications of findings

The findings of this pilot study have important implications for services, policy, clinical practice, and future research.

Service and policy updates

Schools in the UK are increasingly being encouraged to incorporate a 'trauma-informed approach' to ensure that the impact of traumatic life events on children and caregivers is recognised (TISUK, 2023). Whilst our experimental findings are modest, they do suggest that further understanding of the interaction of traumatic life experience and resilience in schoolchildren is important to enable schools to respond appropriately and safely. One point that Beranbaum et al. (2023) made in their conclusion was that through increases in parasympathetic mediated regulatory capacities, violent exposed youths were able to adapt to life stressors more effectively. The authors were also able to link these enhanced emotional regulatory skills to observable protective changes such as less risk taking behaviours (Beranbaum et al, 2023). Our findings corroborate this: we found that schoolchildren, who stated at least one traumatic life event, had a more pronounced parasympathetic response to the cold pressor stressor. Unfortunately, we can't say with confidence whether these life experiences promoted resilience or not. We also can't account for whether lower-level but sustained stressors, such as a long-lasting exposure to bullying, which has also been shown to elicit changes in HRV (Michels, Sioen, Clays, De Buyzere, Ahrens, Huybrechts, Vanaelst & De Henauw, 2013), are contributing to a school child's overall resilience profile.

HRV biofeedback involves individuals following a paced breather designed to stimulate their RSA whilst receiving real-time information on how their HRV is being affected (Lehrer & Gevirtz, 2014). University students deemed as having low resilience according to a brief self-report questionnaire, were given 5 sessions of HRV biofeedback and significantly improved their resilience scores (Shahirah Sha'ari, & Amin, 2021). This shows the importance of moving beyond cross-sectional studies when looking at stress and HRV. HRV biofeedback training could certainly be applied to schools to see not only if school children can improve scores of subjective resilience via self-reports, but whether their parasympathetic response to stressors adapts.

Clinical practice

An essential component of clinical psychology practice is formulation, which involves developing a hypothesis or understanding of the origins of a person's distress (Dallos & Stedmon, 2014). Given the multitude of causes and symptoms associated with psychological disorders, it is challenging to obtain consistent biological measurements and markers in children that correspond to psychological dysfunctions observed in more clinical populations. Therefore, a young person's individual physical, psychological and medical history should be carefully considered when interpreting HRV results. HRV should be viewed as a reflection of overall autonomic health rather than a marker of specific mental illnesses or disease states. Since stress encompasses both biological and psychological elements, integrating objective physiological assessments with self-reported information, or clinical interviews is essential when using HRV to evaluate stress in clinical practice. Numerous studies have identified a link between mental health and HRV (Schneider & Schwerdtfeger, 2020; Koenig et al., 2016). However, due to HRV's connection with various stress factors, including stress duration, individual coping mechanisms, and lifestyle habits, interpreting this study's findings as well as other studies, can be complex.

Future Research

As touched on previously, future research that allows examination of changes over time would offset some of the limitations in this cross-sectional design. For example, repeated exposure to stressors can illustrate how quickly an individual's stress responses can adapt over time. This longitudinal approach could illustrate a more valid picture of an individual's resilience to stress. A well-documented example of this habituation process has been show using the TSST (Schommer, Hellhammer, & Kirschbaum, 2003). After repeated TSST exposure, cortisol and heart rate response diminishes (Schommer, Hellhammer, & Kirschbaum, 2003). However, studies on cold-induced stress habituation have been inconsistent (Minkley, Schröder, Wolf, & Kirchner, 2014; Truijen, Davis, Stok, Kim, van Westerloo, Levi, van der Poll, Westerhof, Karemaker, & van Lieshout, 2011).

Other stressors that combine social, psychological and physiological elements might be more effective at eliciting a stress response in future research. For example, a simpler way of combining the TSST and cold pressor may exist in a form of test known as the socially evaluated cold pressor test (SECPT; Schwabe, Haddad & Schachinger, 2008). The SECPT involves submerging the participants hand in ice-cold water whilst being videotaped and continuously observed by an investigator. Furthermore, these two extra components are considered socio-evaluative components which are thought to be more linked with the HPA axis rather than the vagal mediated ANS (Shaffer & Ginsberg, 2017). As already discussed, this might mean that another stress response measure instead of an index of HRV might be more able to capture adaptations to stress. For example, salivary cortisol (Becker, Schade & Rohleder, 2019) or systolic blood pressure (SBP; Winzeler, Voellmin, Hug, Kirmse, Helmig, Princip, Cajochen, Bader & Wilhelm, 2017).

Lifetime stress can be conceptualised in different ways. Broadening the scope beyond traumatic life events, future research could further explore the effect of adverse childhood experiences

(ACEs) on baseline and stress induced HRV changes. ACEs which include domestic violence, parental abandonment, parental mental health conditions, neglect, abuse and others, are increasingly acknowledged as a major health risk that warrants addressing and managing with the same level of urgency and effort as other established health risks like smoking (Bouillier & Blair, 2018). The existence of ACEs blunts heart rate reactivity to stress tasks in children but this was shown to be mediated by systolic blood pressure (SBP) as opposed to respiratory sinus arrhythmia (RSA; Winzeler et al., 2017). A diminished stress response could be beneficial in situations of repeated significant, but not overwhelming, stress exposure, as it may help reduce chronic activation, fearfulness, and psychophysiological responses to future stressors (Gunnar, Talge & Herrera, 2009; Leitzke et al., 2015). Whether a blunted SNS stress response is a beneficial adaptation or a predictor of altered stress reactivity with potential long-term health risks would require long-term health data. The relationship between post-traumatic growth (PTG) and its link with HRV has not been explored very extensively to date (Tedeschi, 2023). Although individuals with a high adverse childhood experiences (ACEs) score typically have a low baseline HRV (Ge, Yuan, Li & Zhang, 2020), improvements in HRV baseline may also indicate that interventions are aiding in the recovery of their nervous system (Wei, Han, Zhang, Hannak, Dai & Liu, 2017). This enhancement can lead to increased resilience, better emotional regulation, improved social engagement, and other key aspects of post-traumatic growth.

Self-reflexivity

This section provides a reflective account of my learning and positioning in relation to this thesis through self-reflexivity. Self-reflexivity involves a researcher critically examining their own assumptions, biases, positioning, and life experiences and considering how these factors might impact their research (Potter & Hepburn, 2012). In adopting a reflexive stance towards my research, I am guided by Burnham's (1992) concept of 'Approach,' which pertains to how a

therapist or researcher situates themselves within their work.

I found myself drawn to this project as it fulfilled an interest in mind-body linkages that has been growing in me for the past few years. Working as an assistant psychologist before embarking on my doctorate, my supervisor at a community psychosis service recommended the book: *The Body Keeps the Score* (Van der Kolk, 2015). This book had a chapter that introduced a term I'd never heard of before: 'interoception'. I had already begun to notice just how much both physical and mental health are invariable intertwined. A conversation with my supervisor, who had an interest in philosophy posed the question: 'if Descartes hadn't split the mind from the body, would we see them as so separate now?' This question really interested me. It got me thinking about how much we split ourselves up into rational and non-rational parts, and how much of a priority we give to the rational mind. At around the same time I began practicing mindfulness meditation every day and this helped me to better identify and tune in to the felt sense of my body. It also helped me to calm myself and not get too stuck in repeating, ruminative thoughts that my more 'rational' part assumed was like a programme that needed to be run until it was solved. Learning to sit with the unfinished nature of many thoughts or outcomes in life was, in fact, a much healthier way for me to exist in the world.

These ideas and experiences convened as I begun my training. I was also starting to read articles on general psychopathology (p factor) that helped me to consider the commonalities to psychological dysfunction (Caspi, Houts, Belsky, Goldman-Mellor, Harrington, Israel, Meier, Ramrakha, Shalev, Poulton & Moffitt, 2014). By the time I chose my thesis topic, 'Interoception' stood out as an area I wanted to further understand and study. It became apparent to me that atypical interoception may be an early sign of psychopathology across a vast range of conditions and traditional diagnostic categories (Brewer, Murphy & Bird, 2021).

As a trainee clinical psychologist currently in my final year of specialist placement with a psychotherapy team, my role includes conducting long-term Psychodynamic Psychotherapy and

Eye-Movement Desensitisation and Reprocessing (EMDR) therapy with adult clients who have experienced various traumas. Both modalities emphasise the significance of early life experiences, and in particular traumatic life events, in shaping our responses to our external and internal environments (Shedler, 2010; Shapiro, 2014). Adverse or traumatic life events, particularly during childhood, induce many physical and psychological symptoms that I see in my clinical work.

I have developed a certain perspective as a therapist that has informed my experience during the course of this study. The therapeutic process hinges on deeply understanding the client and being attuned to both how they affect me and the emotions I may provoke in them. This involves a collaborative effort with the client over months or even years to comprehend and make sense of their distress. Psychodynamic psychotherapy, therefore, focuses on individual experiences at a phenomenological level, including their life history, self-perceptions, and the meanings they attach to their experiences (Locher, Meier & Gaab, 2019). In contrast, analysing data quantitatively presents a significant departure from this approach and from my role as a therapist. With such a dataset, there is a risk of reducing the unique experiences of individual participants to mere numbers and figures. This has led me to consider that a phenomenological perspective on personal experiences, such as distress or financial hardship, is what is often lacking in quantitative research designs. Additionally, I observed that my role as a 'therapist' had to be minimized in favor of my role as a 'researcher' during this study. My clinical instincts and intuition led me to monitor the children's well-being throughout the battery testing. I also found it challenging to resist the urge, heightened by my training, to offer additional support and space to children after conducting semi-structured interviews about their traumatic experiences. Despite this, I believe my clinical background was beneficial in guiding the interviews and helping the children stay as relaxed as possible.

I've observed from conversations on my training course that the word 'resilience' seems to have negative connotations. After describing the concepts behind my project at peer-to-peer

presentations and workshops, a few of my colleagues have expressed that the word ‘resilience’ does not sit comfortably with them as clinicians. They have explained that they feel there is an implication that the causal factors, clinical formulations or resultant interventions considered will be restricted to the individual level only. Such a restriction would be an understandable concern. As has been explained in this study, resilience need not just refer to individual resources but also communal and cultural ones. I believe this reaction highlights a growing shift on my course and in the clinical psychology field more broadly, away from an individualistic perspective that neglects relational factors influencing identity, toward a 'systemic' approach that focuses primarily on the relational aspects and power dynamics at play in society. My colleagues are very sensitive to the possibility of ‘victim-blaming’ which seems to be a construct designed to protect victims from circumstances out of their control, from being further blamed and shamed, as is unfortunately common in many types of abuse and PTSD (Raz, Rubinstein, Shadach, Chaikin, Ben Yehuda, Tatsa-Laur, Kedem & Shelef, 2023). Whilst I personally feel a kinship and sympathy for this viewpoint, and it is surely a necessary correction to the more individualist psychological approaches of the distant past, I do wonder if the individualist-collectivist dichotomy is one that reduces the complexities of human relations to a false binary. Throughout my work on placement this year in a psychodynamic psychotherapy placement, I’ve been encouraged to use psychoanalytic concepts about interpersonal relationships in my clinical work such as ‘container/contained’ (Bion, 1962). I believe that this concept can be extrapolated across a dimension of complexity. This starts with bodily signals, emotions, thoughts and identities (contained) being integrated within the body (container). The body is a system which needs to notice, understand, and metabolise noxious bodily signals. The parent (container) functions to metabolise the emotions for the infant (contained). The wider layers of containment systems extrapolated out from here become family, community, society and even universe. I remember reading that deep trauma can come from either a single event or a slow disruption of the working models we have about our place

in the universe. For some individuals, trauma becomes a deep fissure that breaks apart the previously benevolent container of the world around them. They can be left feeling disconnected, alone, confused, and unsafe. Individual's who blame themselves for something catastrophic happening to them, may be internalising blame in a way that is maladaptive and unjust considering what was inflicted on them by forces more powerful than them. But to remain in a state of complete powerlessness is also to remain traumatised. A traumatised individual who blames himself or herself may be attempting to locate the unpredictability of the universe within themselves in an understandable attempt to take back some control. The concept of post-traumatic growth (PTG) is one that recognises this. This being said, sociological factors play a huge role in determining the risk that someone may develop PTSD, trauma, or suffer adverse life events. This study wasn't able to explore the broader socio-economic, educational, familial, religious or racial factors that undoubtedly would have an effect on a child's resilience and reaction to stress.

This project has been a challenge. I have learnt a great deal about the level of effort that is required to collaborate with other individuals who have their own interests, as well as how to conceptualise, design, implement, analyse and discuss a study of this nature. I have a greater level of respect for researchers who grapple with the complexities of their participants, their environment, as well as biological and psychological concepts. This study has addressed some of these complexities. I didn't consider when I first chose this topic how vast the associated concepts were. This has meant that it has been a challenge on many occasions to keep the project well defined. However, I have also enjoyed its breadth and depth for this very reason. I will continue to add to my growing interest in trauma, resilience and interoception.

Conclusion

This pilot study which involved a cross-sectional convenience sample of 9- to 11-year-old schoolchildren from East Anglia found that a physiological stressor triggered a stronger

parasympathetic response than a social stressor. Additionally, the children exhibited a greater parasympathetic response following a breathing pacer (RSA) period than a rest period. The study also suggested a potential link between traumatic life events, as identified by a screening tool, and increased physiological resilience, indicated by higher HRV. However, this finding was not replicated when the event was validated using a more clinically established measure. However, this was possibly due to the limited sample size. Further, self-reported resilience did not appear to correlate with physiological resilience.

The pilot study effectively yielded insights into the methods and produced knowledge of ways to refine the methods as the project progressed. This allowed for observations and evaluations of the impact of these changes. This process led to a clearer understanding of which methods would be most effective in optimizing the design of a larger-scale study in the future. The study importantly highlighted the challenges of working in a multi-faceted project team and of working with school children in a school environment.

The concepts of stress, resilience, HRV, and trauma are extensive and intricate, remaining crucial areas for future research. This study has delved into some of this complexity,

highlighting the need for cautious interpretation of conclusions. Nevertheless, the findings contribute to the expanding body of literature that will help inform future policy, clinical interventions, school services, and healthcare systems.

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Appendix 1

CASP Checklist:
For Descriptive/Cross-Sectional Studies

Reviewer Name:	
Paper Title:	
Author:	
Web Link:	
Appraisal Date:	

During critical appraisal, never make assumptions about what the researchers have done. If it is not possible to tell, use the "Can't tell" response box. If you can't tell, at best it means the researchers have not been explicit or transparent, but at worst it could mean the researchers have not undertaken a particular task or process. Once you've finished the critical appraisal, if there are a large number of "Can't tell" responses, consider whether the findings of the study are trustworthy and interpret the results with caution.

Section A: Are the results valid?	
1. Did the study address a clearly focused issue?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: *A question can be 'focused' in terms of* • *the population studied* • *the risk factors studied* • *is it clear whether the study tried to detect a beneficial or harmful effect* • *the outcomes considered*	
2. Did the authors use an appropriate method to answer their question?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *Is a descriptive/cross-sectional study an appropriate way of answering the question* • *did it address the study question*	
3. Were the subjects recruited in an acceptable way?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: *We are looking for selection bias which might compromise the generalisability of the findings:* • *Was the sample representative of a defined population* • *Was everybody included who should have been included*	
4. Were the measures accurately measured to reduce bias?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: *Look for measurement or classification bias:* • *did they use subjective or objective measurements* • *do the measurements truly reflect what you want them to (have they been validated)*	
5. Were the data collected in a way that addressed the research issue?	☐ Yes ☐ No ☐ Can't Tell

CONSIDER: • *if the setting for data collection was justified* • *if it is clear how data were collected (e.g., interview, questionnaire, chart review)* • *if the researcher has justified the methods chosen* • *if the researcher has made the methods explicit (e.g. for interview method, is there an indication of how interviews were conducted?)*	
6. Did the study have enough participants to minimise the play of chance?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *if the result is precise enough to make a decision* • *if there is a power calculation. This will estimate how many subjects are needed to produce a reliable estimate of the measure(s) of interest.*	
7. How are the results presented and what is the main result?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *if, for example, the results are presented as a proportion of people experiencing an outcome, such as risks, or as a measurement, such as mean or median differences, or as survival curves and hazards* • *how large this size of result is and how meaningful it is* • *how you would sum up the bottom-line result of the trial in one sentence*	
8. Was the data analysis sufficiently rigorous?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *if there is an in-depth description of the analysis process* • *if sufficient data are presented to support the findings*	
9. Is there a clear statement of findings?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *if the findings are explicit* • *if there is adequate discussion of the evidence both for and against the researchers' arguments* • *if the researchers have discussed the credibility of their findings* • *if the findings are discussed in relation to the original research questions*	
10. Can the results be applied to the local population?	☐ Yes ☐ No ☐ Can't Tell

CONSIDER: • *the subjects covered in the study could be sufficiently different from your population to cause concern.* • *your local setting is likely to differ much from that of the study*	
11. How valuable is the research?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *one descriptive/cross-sectional study rarely provides sufficiently robust evidence to recommend changes to clinical practice or within health policy decision making* • *if the researcher discusses the contribution the study makes to existing knowledge (e.g., do they consider the findings in relation to current practice or policy, or relevant research-based literature?)* • *if the researchers have discussed whether or how the findings can be transferred to other populations*	

APPRAISAL SUMMARY: *List key points from your critical appraisal that need to be considered when assessing the validity of the results and their usefulness in decision-making.*		
Positive/Methodologically sound	**Negative/Relatively poor methodology**	**Unknowns**

Appendix 2

CASP Checklist:
For case control studies

Reviewer Name:	
Paper Title:	
Author:	
Web Link:	
Appraisal Date:	

During critical appraisal, never make assumptions about what the researchers have done. If it is not possible to tell, use the "Can't tell" response box. If you can't tell, at best it means the researchers have not been explicit or transparent, but at worst it could mean the researchers have not undertaken a particular task or process. Once you've finished the critical appraisal, if there are a large number of "Can't tell" responses, consider whether the findings of the study are trustworthy and interpret the results with caution.

Section A: Are the results of the study valid?	
1. Did the study address a clearly focused issue?	☐ Yes ☐ No ☐ Can't Tell

CONSIDER: *An issue can be 'focused' In terms of* • *the population studied* • *whether the study tried to detect a beneficial or harmful effect* • *the risk factors studied*	
2. Did the authors use an appropriate method to answer their question?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *is a case control study an appropriate way of answering the question under the circumstances* • *did it address the study question*	
3. Were the cases recruited in an acceptable way?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: *We are looking for selection bias which might compromise validity of the findings* • *are the cases defined precisely* • *were the cases representative of a defined population (geographically and/or temporally)* • *was there an established reliable system for selecting all the cases* • *are they incident or prevalent* • *is there something special about the cases* • *is the time frame of the study relevant to disease/exposure* • *was there a sufficient number of cases selected* • *was there a power calculation*	
4. Were the controls selected in an acceptable way?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: *We are looking for selection bias which might compromise the generalisability of the findings* • *were the controls representative of the defined population (geographically and/or temporally)* • *was there something special about the controls* • *was the non-response high, could non-respondents be different in any way* • *are they matched, population based or randomly selected* • *was there a sufficient number of controls selected*	
5. Was the exposure accurately measured to minimise bias?	☐ Yes ☐ No ☐ Can't Tell

CONSIDER: *We are looking for measurement, recall or classification bias* • *was the exposure clearly defined and accurately measured* • *did the authors use subjective or objective measurements* • *do the measures truly reflect what they are supposed to measure (have they been validated)* • *were the measurement methods similar in the cases and controls* • *did the study incorporate blinding where feasible* • *is the temporal relation correct (does the exposure of interest precede the outcome)*	
6. a) Aside from the experimental intervention, were the groups treated equally?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: *List the ones you think might be important, that the author may have missed* • *genetic* • *environmental* • *socio-economic*	
6 b) Have the authors taken account of the potential confounding factors in the design and/or in their analysis?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *restriction in design, and techniques e.g. modelling, stratified-, regression-, or sensitivity analysis to correct, control or adjust for confounding factors*	
Section B: What are the results?	
7. How large was the treatment effect?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *what are the bottom-line results* • *is the analysis appropriate to the design* • *how strong is the association between exposure and outcome (look at the odds ratio)* • *are the results adjusted for confounding, and might confounding still explain the association* • *has adjustment made a big difference to the OR*	
8. How precise was the estimate of the treatment effect?	☐ Yes ☐ No ☐ Can't Tell

CONSIDER: • *size of the p-value* • *size of the confidence intervals* • *have the authors considered all the important variables* • *how was the effect of subjects refusing to participate evaluated*	
9. Do you believe the results?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *big effect is hard to ignore!* • *can it be due to chance, bias, or confounding* • *are the design and methods of this study sufficiently flawed to make the results unreliable* • *consider Bradford Hills criteria (e.g. time sequence, does-response gradient, strength, biological plausibility)*	
Section C: Will the results help locally?	
10. Can the results be applied to your patients/the population of interest?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *the subjects covered in the study could be sufficiently different from your population to cause concern* • *if your local setting is likely to differ much from that of the study* • *can you quantify the local benefits and harms*	
11. Do the results of this study fit with other available evidence?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *all the available evidence from RCT's Systematic Reviews, Cohort Studies, and Case Control Studies as well, for consistency*	

Remember One observational study rarely provides sufficiently robust evidence to recommend changes to clinical practice or within health policy decision making. However, for certain questions observational studies provide the only evidence. Recommendations from observational studies are always stronger when supported by other evidence.

APPRAISAL SUMMARY: *List key points from your critical appraisal that need to be considered when assessing the validity of the results and their usefulness in decision-making.*		
Positive/Methodologically sound	**Negative/Relatively poor methodology**	**Unknowns**

Appendix 3

Seeking Children, Adolescents and Their Parents For Neuroscience Research

The Developmental Interoception and Social Cognition (DISC) lab within the Psychology Department at the University of Essex is conducting brain imaging, physiological, and behavioural research in children, adolescents and their parents! We are looking for participants to volunteer for this exciting study.

This study uses cap- based and non-invasive and safe imaging of the brain with functional NIRS. In addition to imaging the brain, we also monitor the participant's body with physiological equipment, and administer interviews, behavioural tasks, and questionnaires.

Children and Adolescents Who Qualify:

- Are between ages 3 and 18
- Do not have a known genetic condition, significant medical problems that will interfere with your participation in this study, developmental delays and/or low IQ.
- Have a parent who is also willing to participate in the study

You will receive:

- £10 for every two hours of study participation
- A brain t-shirt

For more information, or to enroll in the study
e-mail: developingbrain@essex.ac.uk

DISC LAB
Developmental Interoception and Social Cognition Lab

For general information about participant rights, contact University of Essex Research Governance and Planning Manager at +44(0)1206 873561

Appendix 4

University of Essex

Department of Psychology

Social influences on the development of the brain, body and psychopathology

Date of approval:

Invitation to our study

We would like to invite you to participate in this research project. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. Before you decide whether you want to take part, it is important for you to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or you would like more information.

Background to the project

This study examines the social influences of the developing brain, body and psychopathology. We hope to learn more about how the brain and body functions in children and adults and contributes to mental health problems.

The study

This is a 10-year study. The procedures listed below may be repeated after a certain period of time up to 15 times. Overall, the interview and tests may take up to four to six hours for each time-point. This time will be divided into several sessions. This study will include the following activities:

1) Interviewing and Testing: We will interview the participant about their life, behaviour and your child (when applicable). The participate will also be asked to engage in tests and activities that assess social and emotional functioning, developmental level, history and behaviour at both the initial evaluation and again if the participant returns for additional study visits. Participants under the age of twenty will be asked to identify their developmental stage by a written questionnaire. Finally, participants will also complete assessments about themselves or their child (when applicable). Participants can refuse to answer any question, if desired. This interviewing and testing may take up to two to four hours depending on how many breaks are needed.

(2) NIRS (Near-Infrared Spectroscopy) scan of the head: This is a specialized examination of the head that use infrared light to examine the function of the brain. The NIRS scan involves sitting in a chair or lying on a table, in a regular office room. Small probes (plastic disks of about ¼ of an inch with wires coming out from them) will be placed on the top of your head. There is no sensation of any kind from the infrared light, and it is not harmful. The actual NIRS scan takes less than one hour. Participants will engage in computer activities and/or interact with another person (see multi-person NIRS below). The NIRS scan may require one or more sessions to complete. You might be asked to return for additional scans at a future time.

(3) Body Monitoring: Participant's heart rate, breathing rate, skin conductance, stomach activity or eye-movement will be monitored during our experiments. For this, the participant will wear a belt around the chest or abdomen to measure breathing rate, have stickers with wires placed on the stomach and one or more clips or wires on the fingers or upper chest to measure heart rate and skin conductance during the experiment. Participants can refuse to have their body monitored at any time.

University of Essex

Department of Psychology

(4) Participants will be invited to return for experimental sessions on an annual basis for up to 10 years.

(5) Audio and video recording: Some experiments will require audio and video recording so that behavioural data (which cards were played, etc) and performance can later be assessed. The recordings will be transferred to secure servers and archived in digital form along with other experimental data.

(6) Simultaneous multi-person neuroimaging using NIRS: This experimental paradigm involves performing functional NIRS scans on multiple individuals at once. Participants will be engaged in games (or tasks) and/or during conversations with other participants, while getting their brains scanned and brain activity measured using separate NIRS channels.

EXCLUSION

You should immediately inform the project director or study staff if you or your child have been diagnosed with a serious medical, or neurological condition (e.g., seizure disorder, heart disease, dementia), or sensory impairment (vision or hearing loss) as this may disqualify you from participation.

PARTICIPANT RESPONSIBILITIES

As a participant, your responsibilities include:

- Following the instructions of the Protocol Director and study staff.
- Keeping your study appointments. If it is necessary to miss an appointment, please contact the Protocol Director or research study staff to reschedule as soon as you know you will miss the appointment.
- Telling the Protocol Director or research study staff about any side effects that you may have.
- Completing your questionnaires as instructed.
- Asking questions as you think of them.
- Telling the Protocol Director or research staff if you change your mind about staying in the study.

While participating in this research study, you should not take part in any other research project without informing the Protocol Director.

WITHDRAWAL FROM STUDY

Your participation in this study is entirely voluntary. If you decide to participate, you are free to withdraw your consent and to discontinue participation at any time without prejudice to your relationship with the protocol director or with the University of Essex.
At the discretion of the protocol director, subjects may be taken out of this study due to unanticipated circumstances without your consent. Some possible reasons for withdrawing a subject from the study include:

- Failure to follow the instructions of the Protocol Director and/or study staff.
- The Protocol Director decides that continuing your participation could be harmful to you.
- Pregnancy (if applicable).
- You need treatment not allowed in the study.
- The study is cancelled.
- Other administrative reasons.
- Unanticipated circumstances.

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Department of Psychology

POSSIBLE RISKS, DISCOMFORTS, AND INCONVENIENCES
In some cases, there is a risk of you experiencing anxiety or feeling sad or angry during the interviewing, testing, or psychophysiological measures. In such case, you may discontinue or take a break at any time.

Economic risks include potential financial impact of missing work and transportation costs to and from facilities for study visits.

The study procedures may involve risks to the subject that are currently unforeseeable.

NIRS: There are no known associated risks with NIRS. The only discomfort may be that you have to sit in a chair or lie on a bed for approximately an hour and put plastic disks and a cap on the participant's head.

POTENTIAL BENEFITS
There is no direct benefit for you or your child. The possible general benefit for science resulting from participating in this study consists of adding to the knowledge regarding human behaviour and brain function. Once started, you can also change your mind at any time about whether you want to continue in the project. If you decide not to participate, we invite you to ask questions about any part of the project.

WE CANNOT AND DO NOT GUARANTEE OR PROMISE THAT YOU WILL RECEIVE ANY BENEFITS FROM THIS STUDY.

GIVING ADVICE
There is the potential risk that the investigator may discover psychological or physical problems of which a participant is unaware as a part of participation in this study. In such situations, the investigator will use sound judgement to determine if not discussing this with the participant will contribute to an endangered future well-being for the participant. If there is an identified risk of such evidence emerging, the Protocol Director and the research study staff will assist you in contacting your Surgery and/or the appropriate referral.

In the normal course of psychological research if participants ask for advice about educational, personality, behavioural or health issues from the protocol director or research staff, advice and/or feedback about the participant and/or child's performance will not be given to during or after their participation in this research study.

SUBJECT'S RIGHTS
You should not feel obligated to participate. Your questions should be answered clearly and to your satisfaction.

You will be informed if any important information is learned from your research participation that may significantly influence your willingness to continue participation in this study. While participating in this study, you should inform the investigators if you are to participate in any other research projects.

CONFIDENTIALITY
Your identity will be kept as confidential as possible. You will not be identified by name, address, telephone number, or any other direct personal identifier. The results of this research study may be presented at scientific or medical meetings or published in scientific journals. However, your identity will not be disclosed. Confidentiality maybe broken if an

issue that puts your or your child's safety at risk arises during this study. In this instance, the law indicates that this information may be shared with the appropriate authorities. Your research records may be disclosed outside of The University of Essex, if you consent to sharing your research data as a part of a larger database. But in this case, you will be identified only by a unique code number. Information about the code will be kept in a secure location and access limited to research study personnel.

PRIVACY NOTICE/DATA PROCESSING
This section explains how we will process your data:

- Signed consent forms will be kept separately from individual experimental data and locked in a drawer or saved on a secure, encrypted and password protected hard drive and/or server. This is the only personal data about you that we will keep. Only approved research staff will have access to this information.
- Participants will be assigned an identification number that will be used to anonymise the data; all personally identifying information will be removed from your experimental data. The only link between your personal identifying data and this identification number will be a password protected spreadsheet, which will be shared only with select research staff.
- The data will be gathered by the methods detailed above.
- We will collect data from each participant as described above.
- We are using your data to examine how social interactions influence the developing brain, body and their associated behaviours so that we can better understand the development of psychopathology.
- The anonymised experimental data may be shared in permanent, publicly accessible archives.
- The data controller is the University of Essex.
- Essex University's Data Protection Officer can be contacted on dpo@ess[redacted]

DECEPTION AND DEBRIEFING
Deception will not be used during this experiment and no post-experiment debriefing will occur.

FINDINGS
After the end of the project, we may publish the findings of our experiments (all data published will be anonymised).

FINANCIAL CONSIDERATIONS

Payment:
On behalf of you and/or your child's participation in the study, you will be offered monetary compensation based on the time commitment required at the rate of £10 per two hours of participation.

Costs:
There is no cost to you for participating in this study.

ETHICAL APPROVAL
This project has been reviewed on behalf of the University of Essex Science and Health Sub-Committee and had been given approval with the following number: ETH1819-0045.

CONCERNS AND COMPLAINTS
If you have any concerns about any aspect of the study or you have a complaint, in the first instance please contact the Principal Investigator of the project (see contact details below). If you are still concerned or you think your complaint has not been addressed to your satisfaction, please contact the Director of Research in the Principal Investigator's department (see below). If you are still not satisfied, please contact the University's Research Governance and Planning Manager [redacted].

Emergency Contact: If you feel you have been hurt by being a part of this study or need immediate assistance, please contact [redacted]

Principal investigator
[redacted]

Director of Research, Dept of Psych[redacted]

University of Essex Research Governance and Planning Manager
[redacted]

Appendix 5

CTS
Child Report (Age 6–17)

1

Child Name/ID: _____ Age: _____ Gender: ☐ Male ☐ Female ☐ Other

Administered By: _____ Date Completed: _____

2

EVENTS: Sometimes, scary or very upsetting things happen to people. These things can sometimes affect what we think, how we feel, and what we do.

	Yes	No
1. Have you ever seen people pushing, hitting, throwing things at each other, or stabbing, shooting, or trying to hurt each other?	☐	☐
2. Has someone ever really hurt you? Hit, punched, or kicked you really hard with hands, belts, or other objects, or tried to shoot or stab you?	☐	☐
3. Has someone ever touched you on the parts of your body that a bathing suit covers, in a way that made you uncomfortable? Or had you touch them in that way?	☐	☐
4. Has anything else very upsetting or scary happened to you (loved one died, separated from loved one, been left alone for a long time, not had enough food to eat, serious accident or illness, fire, dog bite, bullying)? *What was it?* _____	☐	☐

3

REACTIONS: Sometimes scary or upsetting events affect how people think, feel, and act. The next questions ask how you have been feeling and thinking recently.

How often did each of these happen in the last 30 days?	Never/ Rarely	1-2 times per month	1-2 times per week	3+ times per week
5. Strong feelings in your body when you remember something that happened (sweating, heart beats fast, feel sick).	0 ☐	1 ☐	2 ☐	3 ☐
6. Try to stay away from people, places, or things that remind you about something that happened.	0 ☐	1 ☐	2 ☐	3 ☐
7. Trouble feeling happy.	0 ☐	1 ☐	2 ☐	3 ☐
8. Trouble sleeping.	0 ☐	1 ☐	2 ☐	3 ☐
9. Hard to concentrate or pay attention.	0 ☐	1 ☐	2 ☐	3 ☐
10. Feel alone and not close to people around you.	0 ☐	1 ☐	2 ☐	3 ☐

NOTES:

Appendix 6

Child & Youth Resilience Measure-Revised (CYRM-R)

CYRM-R						
To what extent do the following statements apply to you? There are no right or wrong answers.		Not at all [1]	A little [2]	Somewhat [3]	Quite a bit [4]	A lot [5]
1	I cooperate with people around me	1	2	3	4	5
2	Getting an education is important to me	1	2	3	4	5
3	I know how to behave in different social situations	1	2	3	4	5
4	My parent(s)/caregiver(s) really look out for me	1	2	3	4	5
5	My parent(s)/caregiver(s) know a lot about me	1	2	3	4	5
6	If I am hungry, there is enough to eat	1	2	3	4	5
7	People like to spend time with me	1	2	3	4	5
8	I talk to my family/caregiver(s) about how I feel	1	2	3	4	5
9	I feel supported by my friends	1	2	3	4	5
10	I feel that I belong/belonged at my school	1	2	3	4	5
11	My family/caregiver(s) stand by me during difficult times	1	2	3	4	5
12	My friends stand by me during difficult times	1	2	3	4	5
13	I am treated fairly in my community	1	2	3	4	5
14	I have opportunities to show others that I am becoming an adult and can act responsibly	1	2	3	4	5
15	I feel safe when I am with my family/caregiver(s)	1	2	3	4	5
16	I have opportunities to develop skills that will be useful later in life (like job skills and skills to care for others)	1	2	3	4	5
17	I enjoy my family's/caregiver's cultural and family traditions	1	2	3	4	5

For administration instructions and scoring, please refer to the accompanying manual.

When using the measure, please cite the following:

Jefferies, P., McGarrigle, L., & Ungar, M. (2018). The CYRM-R: a Rasch-validated revision of the Child and Youth Resilience Measure. *Journal of Evidence-Informed Social Work*, 1-24. https://doi.org/10.1080/23761407.2018.1548403

Appendix 7

A Self-Administered Rating Scale for Pubertal Development

Introduction: The next questions are about changes that may be happening to your body. These changes normally happen to different young people at different ages. Since they may have something to do with your sleep patterns, do your best to answer carefully. If you do not understand a question or do not know the answer, just mark "I don't know."

Question	Response Options	Point Value
1. Would you say that your growth in height:	has not yet begun to spurt[2]	1
	has barely started	2
	is definitely underway	3
	seems completed	4
	I don't know	
2. And how about the growth of your body hair? ("Body hair" means hair any place other than your head, such as under your arms.)		
Would you say that your body hair growth:	has not yet begun to grow	1
	has barely started to grow	2
	is definitely underway	3
	seems completed	4
	I don't know	
3. Have you noticed any skin changes, especially pimples?		
	skin has not yet started changing	1
	skin has barely started changing	2
	skin changes are definitely underway	3
	skin changes seem complete	4
	I don't know	
FORM FOR BOYS:		
4. Have you noticed a deepening of your voice?		
	voice has not yet started changing	1
	voice has barely started changing	2
	voice changes are definitely underway	3
	voice changes seem complete	4
	I don't know	
5. Have you begun to grow hair on your face?		
	facial hair has not yet started growing	1
	facial hair has barely started growing	2

facial hair growth has definitely started	3
facial hair growth seems complete	4
I don't know	

FORM FOR GIRLS:

4. Have you noticed that your breasts have begun to grow?

have not yet started growing	1
have barely started growing	2
breast growth is definitely underway	3
breast growth seems complete	4
I don't know	

5a. Have you begun to menstruate (started to have your period)?

yes	4
no	1

5b. If yes, how old were you when you started to menstruate?

age in years

Appendix 8

UCLA PTSD REACTION INDEX FOR CHLDREN/ADOLESCENTS - DSM-5©

Child/Adolescent Name: _____ ID #_____ Age: _____ Sex: □ Girl □ Boy
Grade in School _____ School: _____ Teacher: _____ City/State _____
Interviewer Name/I.D. _____ Date (*month, day, year*) ____/____/____ (Session #_____)

TRAUMA/LOSS HISTORY SCREENING QUESTIONS: Use the questions in the screening form provided below to ask about history of different types of trauma and loss. Place a check mark in the box on the left for each type of trauma /loss experience that has occurred. In interviewing the child/adolescent, you may ask: ***Sometimes people have scary or violent things that happen to them where someone could have been or was badly hurt or killed. I'm going to ask you some questions about whether any of these kinds of things have happened to you so that you can tell me if they did.*** [For those children/adolescents able to complete the form on their own, you may instruct them to place a check mark in the box on the left of the screening form to indicate that the trauma/loss has happened to them.] In either case, follow up on those items endorsed using the **TRAUMA/LOSS DETAILS** form provided in the next section.

	TRAUMA/LOSS HISTORY SCREENING QUESTIONS
□	**Serious Accidental Injury**: Have you ever been in a bad accident (like a serious car, bus, train or bicycle accident or a bad fall) where you or someone else was or could have been badly hurt or killed? Have you ever seen a bad accident where someone was badly hurt or killed?
□	**Illness/Medical Trauma**: Have you ever been so sick that you and your parents (or people taking care of you) were scared that you might die? Did you have a medical treatment that was very scary or painful? Did you ever see someone you really care about get so sick that you were scared they might die?
□	**Community Violence**: Did you ever see a bad fight or shooting in your neighborhood, like between gangs? Were you afraid of getting badly hurt or killed? Have you seen someone mugged, robbed, stabbed or killed in your neighborhood?
□	**Domestic Violence**: Have you ever seen adults you live with get in a bad fight with each other, where someone got punched, kicked or hit with something? Have adults you live with threatened to hurt each other? Have you ever seen an adult you live with forced to do something sexual by another adult you live with?
□	**School Violence/Emergency**: Were you ever at school when something really scary happened, like a shooting, a stabbing, a fire, where you or someone else got badly beaten up or someone attempted or committed suicide?
□	**Physical Assault**: Have you ever been badly physically hurt (punched, kicked, stabbed) by someone outside of your family or who was not taking care of you? Have you ever been badly hurt by someone outside your family, like someone in your neighborhood, a boy or girl friend or a stranger?
□	**Disaster**: Have you ever been in a natural disaster, like a hurricane, tornado, earthquake, flood or wildfire where you were hurt or could have been hurt or killed? Have you been in a natural disaster where you saw someone badly hurt or killed? Have you been in a place where there was a chemical spill or explosion?
□	**Sexual Abuse**: Did someone who was taking care of you ever force you to do something sexual? Did someone taking care of you ever make you watch something sexual?
□	**Physical Abuse**: Have you ever been badly hurt (punched, kicked, stabbed, shaken) by someone who is in your family (like a parent, brother or sister) or someone who was taking care of you? Have you seen another child in your family being badly physically hurt by a parent, caregiver or legal guardian?
□	**Neglect**: Has there ever been a time when someone who should have been taking care of you didn't, like they didn't take you to a doctor when you were really sick, they left you alone for too long, didn't make sure you were going to school or didn't do their best to keep you healthy or safe?
□	**Psychological Maltreatment/Emotional Abuse**: Did anyone in your family ever keep telling you that you are no good, keep yelling at you or keep threatening to or send you away?

☐	**Impaired Caregiver**: Was there ever a time when someone who was supposed to take care of you couldn't, like they were too sick, they were so sad they stayed in bed or they had a drinking or drug problem?
☐	**Sexual Assault/Rape**: Did someone outside your family ever force you to do something sexual? Did you ever see someone else being forced to do something sexual?
☐	**Kidnapping/Abduction**: Have you ever been stolen or kidnapped (taken somewhere against your will) by someone without the permission of your parent or legal guardian?
☐	**Terrorism**: Were you ever there when a terrorist attack happened, like a bombing, chemical attack or where people were taken hostage?
☐	**Bereavement**: Has someone you really cared about ever died?
☐	**Separation**: Were you ever separated for a long time from someone you depend on, like a parent went to jail or was hospitalized, or you were placed in foster care?
☐	**War/Political Violence**: Have you lived in a country where a war or armed conflict was happening (like soldiers or groups were fighting with weapons)? Did you see people who had been badly hurt or killed in a war or where soldiers were fighting?
☐	**Forced Displacement**: Have you ever been forced to move out of your house due to war, armed conflict or disaster, like having to move to a trailer or refugee camp?
☐	**Trafficking/Sexual Exploitation**: Have you ever done sexual things for money, food, clothes, shelter, or protection? Were you ever sold to someone to work for them? Have you been forced into having sex (prostitution) or doing sexual things, like being in sexual pictures (pornography)?
☐	**Bullying**: Has someone your age or a student at your school ever bullied you, like kept calling you dirty names, making sexual comments, threatening to beat you up or spreading mean rumors around school or online?
☐	**Attempted Suicide:** Have you ever tried to kill yourself?
☐	**Witnessed Suicide**: Have you ever seen someone after he/she committed suicide?

TRAUMA/LOSS DETAILS: For each experience endorsed on the Trauma/Loss History Screening Questions form, place a check mark to indicate whether the specified trauma details were present, whether the child/adolescent was a *victim*, *witness* or *learned about** the trauma, and the age(s) over which the trauma occurred. (Both of these forms may be updated over the course of treatment as additional information about trauma history is revealed or as additional traumas occur.) **Learned about* **only** refers to indirect exposure in learning aversive details of violent personal assault, homicide, suicide, serious accident, or serious injury to a close relative or friend. It does **not** include learning about death due to natural causes.

Trauma Type	Trauma Details	Role in Event	Age(s) Experienced 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Serious Accidental Injury	☐ Motor Vehicle ☐ Fall ☐ Dog Bite ☐ Hospitalized ☐ Other _____	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Illness/Medical Trauma	☐ Self ☐ Family ☐ Friend ☐ Type _____ _____ _____	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Trauma Type	Trauma Details	Role in Event	Age(s) Experienced 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Community Violence	☐ Robbery ☐ Mugging ☐ Killed ☐ Gang-Related ☐ High Crime Community ☐ Drug Traffic ☐ Other _____ _____	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Domestic Violence	☐ Witnessed bad fight ☐ Threatened harm ☐ Witnessed sexual assault ☐ Weapon Used ☐ Serious Injury ☐ Report Filed	☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
School Violence/Emergency	☐ Shooting ☐ Stabbing ☐ Fire ☐ Suicide ☐ Bomb threat ☐ Assault ☐ Other _____ _____	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Physical Assault	☐ Punched ☐ Kicked ☐ Stabbed ☐ Shaken ☐ Weapon Used ☐ Reported to CPS (if a minor) ☐ Reported to police ☐ Other _____ _____	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Disaster	☐ Earthquake ☐ Fire ☐ Flood ☐ Hurricane ☐ Tornado ☐ Chemical spill ☐ Explosion Other _____ ☐ Lost Home ☐ Injured	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Trauma Type	Trauma Details	Role in Event	Age(s) Experienced 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Sexual Abuse	☐ Forced sexual behavior ☐ Watch something sexual ☐ Penetration occurred ☐ CPS report filed ☐ Investigation conducted ☐ Charges filed ☐ Conviction ☐ Perpetrator removed from home	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Physical Abuse	☐ Badly physically hurt ☐ Punched ☐ Kicked ☐ Stabbed ☐ Shaken ☐ Weapon Used ☐ Reported to CPS ☐ Reported to police	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Neglect	☐ Medical (did not take to Dr.) ☐ Left alone/unsupervised ☐ School ☐ Failure to promote health ☐ Failure to promote safety ☐ Other _____ ☐ Reported to CPS ☐ Child removed from home ☐ Caregiver removed from home	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Psychological Maltreatment/ Emotional Abuse	☐ Berating/humiliating ☐ Threatened abandonment ☐ Excessive punishment ☐ Other _____	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Trauma Type	Trauma Details	Role in Event	Age(s) Experienced 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Impaired Caregiver	**Impairment Due to:** ☐ Medical illness ☐ Mental health problem ☐ Alcohol use/abuse/addiction ☐ Drug use/abuse/addiction **Affected Caregiver:** ☐ Mother ☐ Father ☐ Other relative ☐ Other (non-related) adult ☐ Other _____	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Sexual Assault/Rape	**Perpetrator**: ☐ Relative ☐ Boy or girl friend ☐ Position of trust (teacher, coach, minister) ☐ Acquaintance (neighbor etc) ☐ Stranger **Trauma Details:** ☐ Weapon used ☐ Drug used/suspected ☐ Penetration occurred ☐ Date/Acquaintance rape ☐ Reported to police ☐ Investigation conducted ☐ Charges filed ☐ Conviction ☐ Other _____	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Kidnapping/ Abduction	**Perpetrator**: ☐ Relative ☐ Position of trust (teacher, coach, clergy, etc.) ☐ Acquaintance (neighbor etc) ☐ Stranger ☐ Other _____	☐ Victim ☐ Witnessed ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Trauma Type	Trauma Details	Role in Event	Age(s) Experienced 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Terrorism	☐ Shooting ☐ Suicide bombing ☐ Bombing (package, vehicle) ☐ Chemical agent ☐ Biological agent ☐ Radiological agent ☐ Hostages taken ☐ Other _____	☐ Victim ☐ Witnessed ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Bereavement	**Deceased:** ☐ Parent ☐ Sibling ☐ Other Relative ☐ Friend ☐ Other _____ **Cause of Death:** ☐ Drug overdose ☐ Natural Causes (illness, age) ☐ Accident (car, drowning) ☐ Natural disaster ☐ Homicide ☐ Suicide ☐ Other _____	☐ Witnessed ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Separation	**Cause of Separation:** ☐ Parents separated ☐ Parents divorced ☐ Parent hospitalized ☐ Parent deported ☐ Parent/sibling incarcerated ☐ Child placed in foster care ☐ As refugee, separated from relatives/close friends in country of origin ☐ Other _____ _____		☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Trauma Type	Trauma Details	Role in Event	Age(s) Experienced 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
War/Political Violence	☐ Lived in war-torn region ☐ Saw wounded people ☐ Saw dead bodies ☐ Home damaged/destroyed ☐ Internally displaced ☐ War refugee ☐ Other _____	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Forced Displacement	**Cause of Displacement:** ☐ War/political violence ☐ Disaster ☐ Other _____ **Site of Displacement:** ☐ Trailer ☐ Refugee camp ☐ Relocation center ☐ Other _____		☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Trafficking/Sexual Exploitation	☐ Sex for money, food, clothes ☐ Pornography ☐ Sold into prostitution ☐ Sold into slave labor (unpaid servant or worker) ☐ Other _____	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Bullying	☐ Verbal insults ☐ Threats of physical harm ☐ Sexual comments ☐ Rumors at school/internet ☐ Other _____	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Attempted Suicide	**Method:** ☐ Drug ☐ Hanging ☐ Drowning ☐ Firearm ☐ Other _____	☐ Victim ☐ Witness ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Trauma Type	Trauma Details	Role in Event	Age(s) Experienced 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Witnessed Suicide	☐ Mother ☐ Father ☐ Brother ☐ Sister ☐ Other relative ☐ Close friend ☐ Acquaintance/schoolmate ☐ Stranger ☐ Other _____	☐ Witnessed suicide ☐ Witnessed body/scene ☐ Learned about	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

If only one trauma/loss type is endorsed above, write in the trauma/loss type in this blank: _____.
If more than one trauma/loss type is endorsed, have the child/adolescent choose the trauma/loss experience that BOTHERS THEM THE MOST NOW and identify that trauma/loss type in this blank: _____.

Clinician: Provide a brief description of the trauma/loss type that is most bothersome now:

_____
_____
_____
_____
_____
_____
_____

POSTTRAUMATIC STRESS SYMPTOMS

Here is a list of problems people can have after bad things happen. Please think about the bad thing that happened to you that bothers you the most now. For each problem **CIRCLE ONE** of the numbers (0, 1, 2, 3 or 4) that tells how many days the problem happened to you **in the past month,** even if the bad thing happened a long time ago. Use the **Frequency Rating Sheet** to help you decide how many days the problem happened **in the past month**.

HOW MUCH OF THE TIME DURING THE PAST MONTH…		None	Little	Some	Much	Most
1_{E3}	I am on the lookout for danger or things that I am afraid of (like looking over my shoulder even when nothing is there).	0	1	2	3	4
2_{D2}	I have thoughts like "I am bad."		1	2	3	4
3_{C2}	I try to stay away from people, places, or things that remind me about what happened.	0	1	2	3	4
4_{E1}	I get upset easily or get into arguments or physical fights.	0	1	2	3	4
5_{B3}	I feel like I am back at the time when the bad thing happened, like it's happening all over again.	0	1	2	3	4
6_{D4}	I feel like what happened was sickening or gross.	0	1	2	3	4
7_{D5}	I don't feel like doing things with my family or friends or other things that I liked to do.	0	1	2	3	4
8_{E5}	I have trouble concentrating or paying attention.	0	1	2	3	4
9_{D2}	I have thoughts like, "The world is really dangerous."	0	1	2	3	4
10_{B2}	I have bad dreams about what happened, or other bad dreams.	0	1	2	3	4
11_{B4}	When something reminds me of what happened I get very upset, afraid, or sad.	0	1	2	3	4
12_{D7}	I have trouble feeling happiness or love.	0	1	2	3	4
13_{C1}	I try not to think about or have feelings about what happened.	0	1	2	3	4
14_{B5}	When something reminds me of what happened, I have strong feelings in my body like my heart beats fast, my head aches or my stomach aches.	0	1	2	3	4
15_{D3}	I am mad with someone for making the bad thing happen, not doing more to stop it, or to help after.	0	1	2	3	4
16_{D2}	I have thoughts like "I will never be able to trust other people."	0	1	2	3	4
17_{D6}	I feel alone even when I am around other people.	0	1	2	3	4
18_{B1}	I have upsetting thoughts, pictures or sounds of what happened come into my mind when I don't want them to.	0	1	2	3	4
19_{D3}	I think that part of what happened was my fault.	0	1	2	3	4
20_{E2}	I hurt myself on purpose.	0	1	2	3	4
21_{E6}	I have trouble going to sleep, wake up often, or have trouble getting back to sleep.	0	1	2	3	4
22_{D4}	I feel ashamed or guilty about some part of what happened.	0	1	2	3	4
23_{D1}	I have trouble remembering important parts of what happened.	0	1	2	3	4
24_{E4}	I feel jumpy or startle easily, like when I hear a loud noise or when something surprises me.	0	1	2	3	4
25_{D4}	I feel afraid or scared.	0	1	2	3	4
26_{E2}	I do risky or unsafe things that could really hurt me or someone else.	0	1	2	3	4

27_{D4}	I want to get back at someone for what happened.	0	1	2	3	4
With Dissociative Symptoms (Dissociative Subtype)						
28_{A1}	I feel like I am seeing myself or what I am doing from outside my body (like watching myself in a movie).	0	1	2	3	4
29_{A1}	I feel not connected to my body, like I'm not really there inside.	0	1	2	3	4
30_{A2}	I feel like things around me look strange, different, or like I am in a fog.	0	1	2	3	4
31_{A2}	I feel like things around me are not real, like I am in a dream.	0	1	2	3	4

Clinician: Check whether the reactions (thoughts and feelings) above appear to cause clinically significant ***distress*** *or* ***functional impairment***.

☐ **Clinically Significant Distress:** (check if youth endorses #1 below)
☐ Yes ☐ No 1. Do these reactions (thoughts and feelings) bother or upset you a lot?

☐ **Clinically Significant Functional Impairment**: (check if functional impairment at home, at school, in peer relationships, in developmental progression)

☐ **Home**: (check if youth endorses #1, #2 or #3 below)
☐ Yes ☐ No 1. Do these reactions (thoughts and feelings) make it harder for you to get along with people at home?
☐ Yes ☐ No 2. Do these reactions (thoughts and feelings) get you into trouble at home?
☐ Yes ☐ No 3. Do these reactions (thoughts and feelings) cause some other problem at home?
Describe: _____

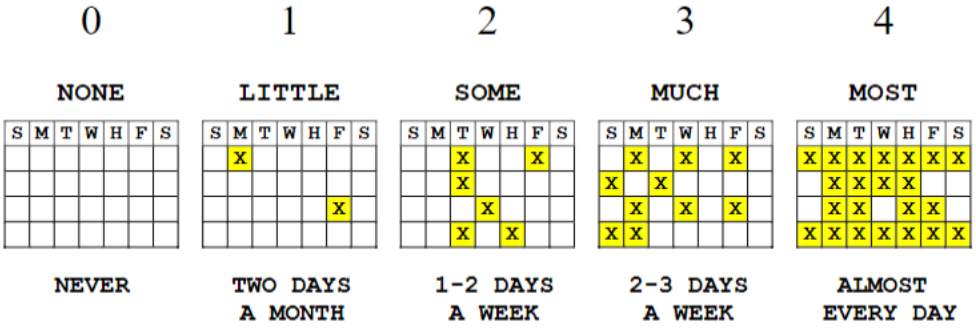
☐ **School**: (check if youth endorses #1 *or* #2 below)
☐ Yes ☐ No 1. Do these reactions (thoughts and feelings) make it harder for you to do well in school?
☐ Yes ☐ No 2. Do these reactions (thoughts and feelings) cause other problems at school?
Describe: _____

☐ **Peer Relationships**: (check if youth endorses #1 below)
☐ Yes ☐ No 1. Do these reactions (thoughts and feelings) make it harder for you to get along with your friends or make new friends?
Describe: _____

☐ **Developmental Progression**: (check if youth endorses #1 below)
☐ Yes ☐ No 1. Do these reactions (thoughts and feelings) make it harder for you to do important things that other kids your age are doing?
☐ Yes ☐ N0 2. Other (describe) _____
_____

FREQUENCY RATING SHEET

HOW MANY DAYS DURING THE PAST MONTH DID THE PROBLEM HAPPEN?



UCLA PTSD REACTION INDEX FOR CHILDREN/ADOLESCENTS - DSM-5©
SCORE SHEET

Subject ID#_____ Age____ Sex (circle): M F Date: _____ Subject Name: _____

For Items 2, 9, and 16: indicate highest score only for DSM-5 Symptom D2; for Items 15 and19: indicate highest score only for DSM-5 Symptom D3; for Items 6, 22, 25, and 27: indicate highest score only for DSM-5 Symptom D4; for Items 20 and 26: indicate highest score only for DSM-5 Symptom E2. Category B Total: Sum scores for symptoms B1-B5; Category C Total: Sum scores for symptoms C1 **and** *C2; Category D Total: Sum scores for symptoms D1-D7; Category E Total: Sum scores for symptoms E1-E6; PTSD-RI Total Scale Score: Sum Category B, C, D, and E.*

Item #	DSM-5 Symptom	Score *(0-4)*
18	B1	
10	B2	
5	B3	
11	B4	
14	B5	
SYMPTOM CATEGORY B SUMMATIVE SCORE:		____
13	C1	
3	C2	
SYMPTOM CATEGORY C SUMMATIVE SCORE:		____

Item #	DSM-5 Symptom	Score *(0-4)*
23	D1	
2*	D2	
9*	D2	____
16*	D2	
15*	D3	
19*	D3	____
6*	D4	
22*	D4	
25*	D4	____
27*	D4	
7	D5	
17	D6	
12	D7	
SYMPTOM CATEGORY D SUMMATIVE SCORE:		____

Item #	DSM-5 Symptom	Score *(0-4)*
4	E1	
20*	E2	
26*	E2	____
1	E3	
24	E4	
8	E5	
21	E6	
SYMPTOM CATEGORY E SUMMATIVE SCORE		____

Dissociative Symptoms

28. A1 ____
29. A1 ____
(*Indicate highest score for A1*) ___

30. A2 ____
31. A2 ____
(*Indicate highest score for A2*) ___

PTSD-RI TOTAL SCALE SCORE

_____

DSM-5 PTSD DIAGNOSIS

B: One or more Category B symptoms present: ☐
C: One or more Category C symptoms present: ☐
D: Two or more Category D symptoms present: ☐
E: Two or more Category E symptoms present: ☐
F: Symptom duration greater than one month: ☐
G: Symptoms cause clinically significant *distress* or *impairment*: ☐
Specify Dissociative Subtype:
One or more dissociative symptoms present: ☐

Estimating Whether DSM-5 PTSD Category B, C, D, and E Symptom Criteria are Met

If symptom score is 3 or 4, then score symptom as "present." For question #4, #10, and #26; use a rating of 2 or more for symptom presence. Then determine whether one or more B symptoms are present; whether one or more C symptoms are present; whether two or more D symptoms are present; and whether two or more E symptoms are present. If one or more Dissociative Symptoms are present, then assign Dissociative Subtype.

Appendix 9

University of Essex

DISC LAB

WINNER UNIVERSITY OF THE YEAR THE AWARDS 2018

10th of February, 2020

Dear Parent / Guardian,

[redacted] research lab, the Developmental Interoception and Social Cognition lab (DISC lab) within the Department of Psychology at the University of Essex is investigating how children process emotions, empathy and internal cues from their bodies (hunger, satiety, heartbeat ect). We would like children aged 7-11 years old (year groups 3-6) to participate in this research and kindly ask for permission for your child(ren) to take part.

Children will have the opportunity to participate in the following projects, depending on your preferences and your child's interest in the study. During class, the children will complete a battery of child-friendly questionnaires that measure emotion, empathy, relationships and aspects of their personality. If you do not want your child to participate in the questionnaires, please opt-out using our study preferences link: [redacted]

Additionally, you and your child can choose to participate in additional tasks, depending on your preferences. All of these studies will be carried out by DBS cleared researchers. If you want your child to participate in these arms of the study, you will be required to specially opt-in via our study preferences link (above). These tasks include the following:

- Body cue tasks: Your child will engage in tasks the monitor the state of their body (such as heart rate ect).
- An emotion task: We will video record children while they tell emotional stories and they will be asked to rate how they felt while telling the story.
- An empathy task: Your child will watch videos and we will assess your child's empathy while watching the video.
- Brain Imaging: We will use a non-invasive, safe and portable cap-based brain imaging technology to measure your child's brain functioning during some of the tasks, if we receive your permission to specifically do so. This technology uses infrared light to look at the brain's signal and is called functional Near-Infrared Spectroscopy (fNIRS). It is painless and is a fast, popular and effective way to study the developing brain. The exact procedure to be followed will be explained to your child fully by a trained researcher.

We have also prepared for you the following YouTube video so that you can learn more about our research. Check it out! [redacted] After watching the video, if you have additional questions, please email us at [redacted] and we will be happy to arrange a phone call or video conferencing meeting in [redacted] cerns.

Participation in this study is entirely voluntary and your child may withdraw at any time, including during the procedure, without any prejudice. All data will be collected in strict accordance with our ethical guidelines and will be securely stored and immediately anonymised. We would like to stress that we will not evaluate any individual child's performance.

Thank you in anticipation for your help.

[redacted]

Colchester Campus
[redacted]
T [redacted]

Appendix 10

University of Essex

DISC LAB
Developmental Interoception and Social Cognition Lab

WINNER UNIVERSITY OF THE YEAR
THE AWARDS 2018

10th of February, 2020

Dear Parent / Guardian,

[redacted] the Developmental Interoception and Social Cognition lab (DISC lab) within the Depar[redacted]ychology at the U[redacted]is investigating how children process emotions, empathy and internal cues from their bodies (hunger, satiety, heartbeat ect). We would like children aged 7-11 years old (year groups 3-6) to participate in this research and kindly ask for permission for your child(ren) to take part.

Children will have the opportunity to participate in the following projects, depending on your preferences and your child's interest in the study. During class, the children will complete a battery of child-friendly questionnaires that measure emotion, empathy, relationships and aspects of their personality. If you do not want your child to participate in the questionnaires, please opt-out using our study preferences link:
[redacted]

Additionally, you and your child can choose to participate in additional tasks, depending on your preferences. All of these studies will be carried out by DBS cleared researchers. If you want your child to participate in these arms of the study, you will be required to specially opt-in via our study preferences link (above). These tasks include the following:

- Body cue tasks: Your child will engage in tasks the monitor the state of their body (such as heart rate ect).
- An emotion task: We will video record children while they tell emotional stories and they will be asked to rate how they felt while telling the story.
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- Brain Imaging: We will use a non-invasive, safe and portable cap-based brain imaging technology to measure your child's brain functioning during some of the tasks, if we receive your permission to specifically do so. This technology uses infrared light to look at the brain's signal and is called functional Near-Infrared Spectroscopy (fNIRS). It is painless and is a fast, popular and effective way to study the developing brain. The exact procedure to be followed will be explained to your child fully by a trained researcher.

We have also pr[redacted]ing YouTube video so that you can learn more about our research. Check it out! [redacted] After watching the video, if you have additional questions, please email us at [redacted] and we will be happy to arrange a phone call or video conferencing meeting in order to further address your concerns.

Participation in this study is entirely voluntary and your child may withdraw at any time, including during the procedure, without any prejudice. All data will be collected in strict accordance with our ethical guidelines and will be securely stored and immediately anonymised. We would like to stress that we will not evaluate any individual child's performance.

Thank you in anticipation for your help.

[redacted]

Colchester Campus
Wivenhoe Park
Colchester CO4 3SQ
United Kingdom

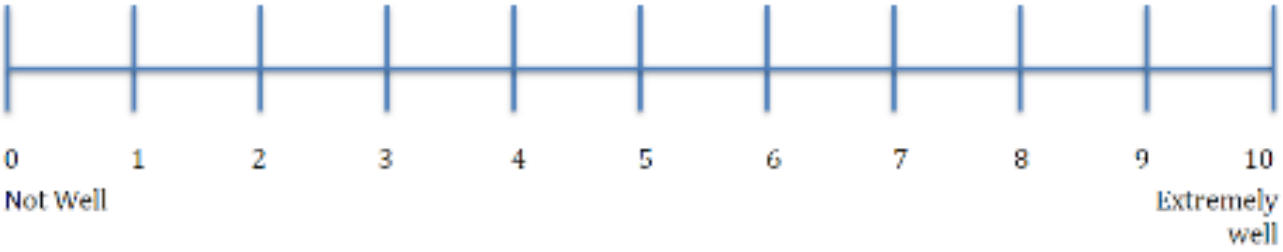
[redacted]

Appendix 11

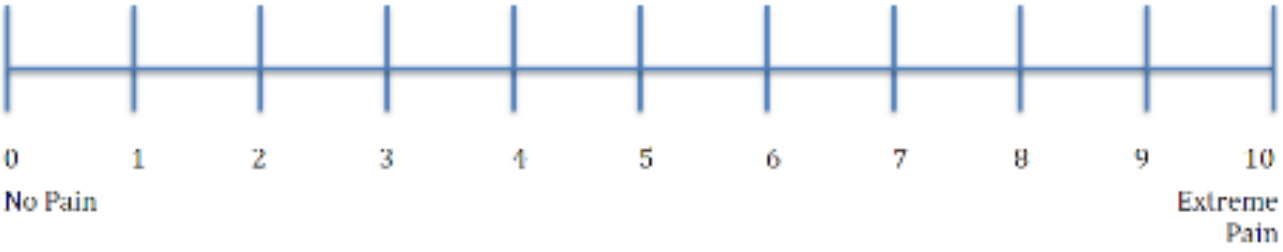
Subject _____

Performance Rating on Stressor Tasks

Compared to your peers, how well do you think you did in the cold-water task?

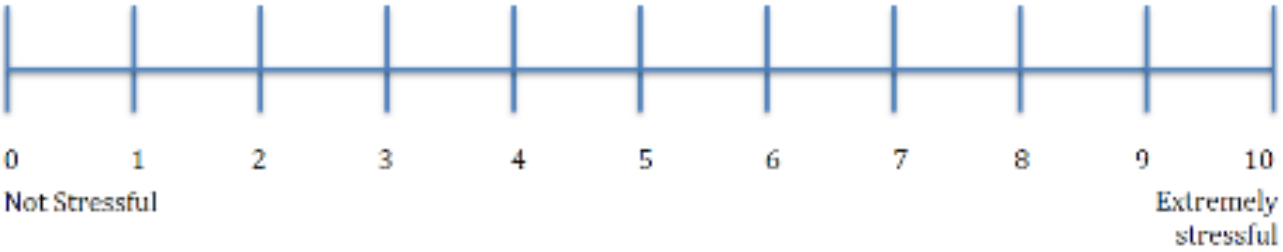


How much pain did you feel in your hand when you decided to take it out?



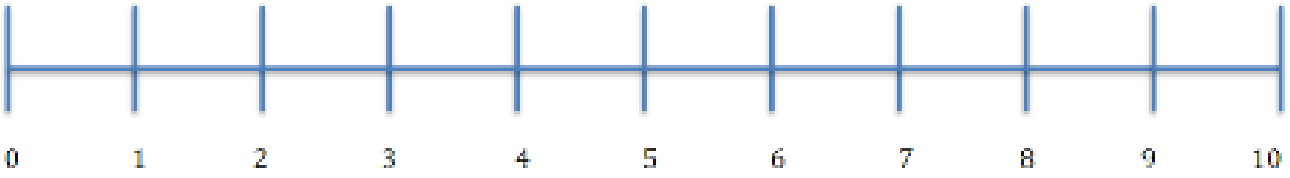
How long do you think you kept your hand in the water for?

In the '5 years' time' speaking task, how stressful was it to give a speech?



Subject _____

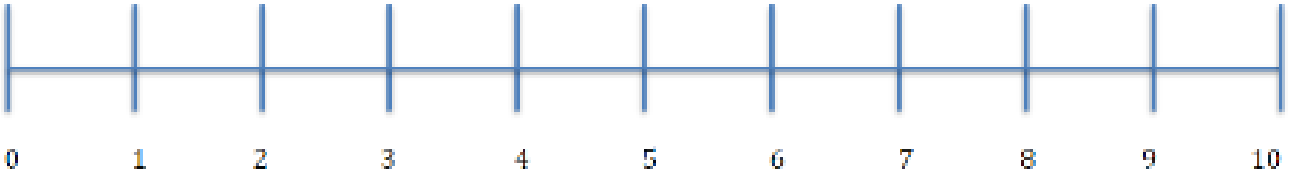
Compared to other people your age, how well do you think you did in the '5 years' time' speaking task?



0 1 2 3 4 5 6 7 8 9 10

Not Well Extremely well

How much experience do you have of speaking like that or performing in front of an audience of people?



0 1 2 3 4 5 6 7 8 9 10

No experience Extremely experienced

Appendix 12

Social influences on the development of the brain, body and psychopathology

Consent Form

Protocol Director: [redacted]

Please print your full name: _____
Age: _____

Please check one of the following:

_____ You are an adult subject in this study.

_____ You are the parent or guardian granting consent for a minor in this study.

_____ You are the parent or guardian granting consent for participating in this study with my child.

Print minor's name here:

_____

The following information applies to the individual or to his/her minor child. If the subject is a minor, use of "you" refers to "your child".

Please initial box

☐ **I confirm that I** have read and understand the Information Sheet dated xx for the above study. I have had the opportunity to consider the information, ask questions and have had these questions answered satisfactorily.

☐ I understand that my participation is voluntary and that I am free to withdraw from the project at any time without giving any reason and without penalty.

☐ I understand that the identifiable data provided will be securely stored and accessible only to the members of the research team directly involved in the project or other researchers under the direction of the Principal Investigator and I understand that my confidentiality.

☐ I understand that fully anonymized data collected as a part of this study will be used for publications, reports, news articles.

☐ I give permission for the de-identified data to be deposited in a secure, confidential data repository so that it can be used for future research and learning.

Appendix 13

Study: Social influences on the development of the brain, body and psychopathology

University of Essex

☐ I agree to be contacted in the future by the researchers.

☐ I consent to video recording the data. I understand that the recordings will be transferred to secure services and archived in digital form along with other experimental data.

☐ I consent to showing video data to other study participants for its use as stimuli for a future empathy task

POSSIBLE RISKS, DISCOMFORTS, INCONVENIENCES

In some cases, there is a risk of you experiencing anxiety or feeling sad or angry during the interviewing, testing, or psychophysiological measures. In such case, you may discontinue or take a break at any time.

Economic risks include potential financial impact of missing work and transportation costs to and from facilities for study visits.

The study procedures may involve risks to the subject that are currently unforeseeable.

There are no known associated risks with NIRS. The only discomfort may be that you have to sit in a chair or lie on a bed for approximately an hour and put plastic disks and a cap on the participant's head.

There is no direct benefit for you other than the possible benefits from participating in the evaluation. The possible general benefit for science resulting from participating in this study consists of adding to the knowledge regarding human behavior and brain function. Once started, you can also change your mind at any time about whether you want to continue in the project.

WE CANNOT AND DO NOT GUARANTEE OR PROMISE THAT YOU WILL RECEIVE ANY BENEFITS FROM THIS STUDY.

Please initial box below:

☐ I acknowledge the previously described risks and benefits for participating in this study.

☐ I agree to take part in this study

_____ _____

Signature of Adult Participant Date

_____ _____

Signature of Parent, Guardian or Conservator Date

Appendix 14

[redacted]
Study: Social influences on the development of the brain, body and psychopathology

University of Essex

_____
Authority to act for participant

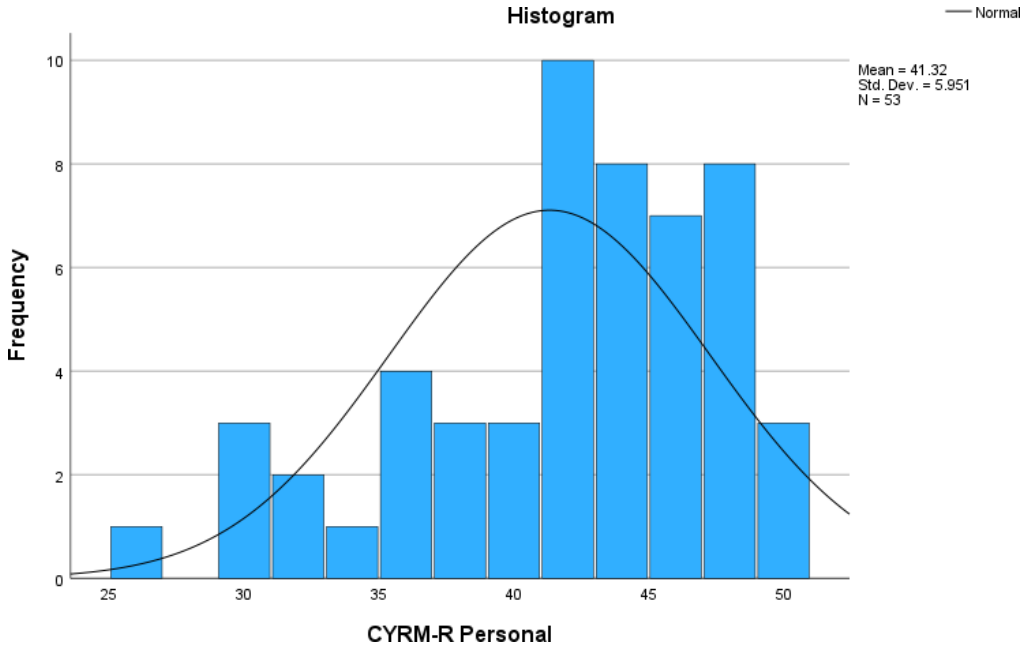
Person Obtaining Consent

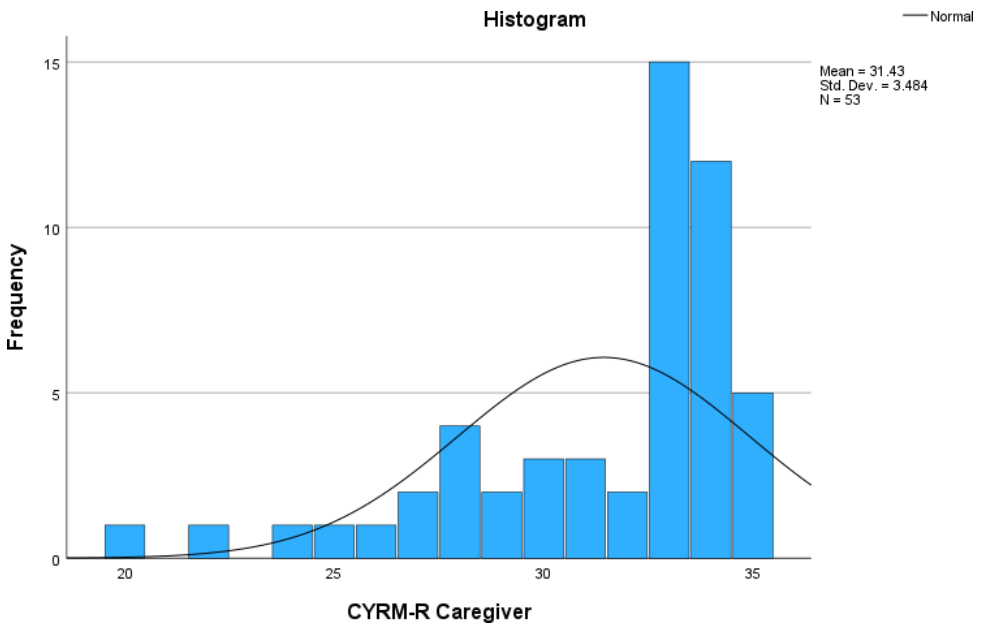
I attest that the requirements for informed consent for the research project described in this form have been satisfied – that the subject has been provided with the Information Sheet that I have discussed the research project with the participant and explained to him or her in non-technical terms all of the information contained in this informed consent form, including any risks and adverse reactions that may reasonably be expected to occur. I further certify that I encouraged the participant to ask questions and that all questions asked were answered.

_____
Printed Name of Person Obtaining Consent

_____ _____
Signature of Person Obtaining Consent Date

Appendix 15


Histogram
Normal
Mean = 41.32
Std. Dev. = 5.951
N = 53
Frequency
0
2
4
6
8
10
25
30
35
40
45
50
CYRM-R Personal


Histogram
Normal
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Std. Dev. = 3.484
N = 53
Frequency
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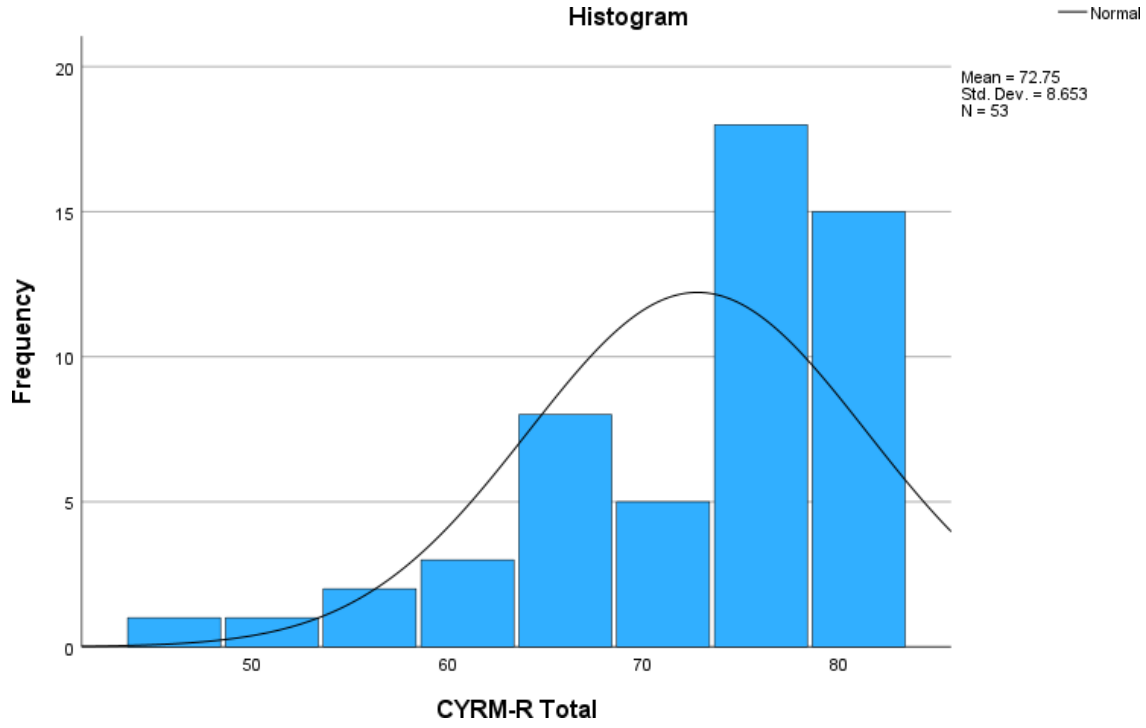
10
5
0
20
25
30
35
CYRM-R Caregiver


Histogram
Normal
Mean = 72.75
Std. Dev. = 8.653
N = 53
Frequency
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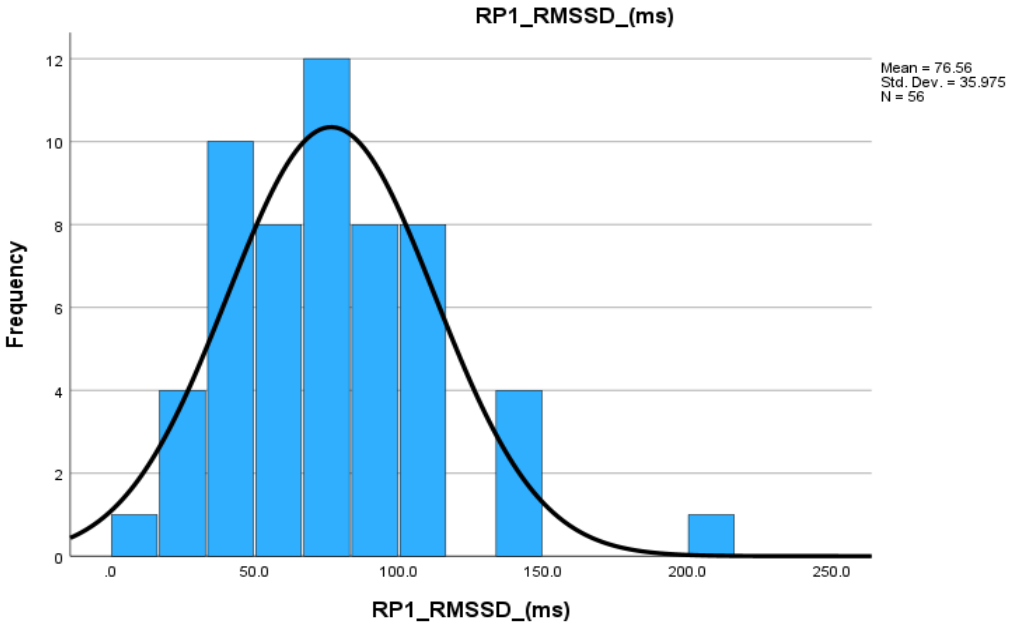
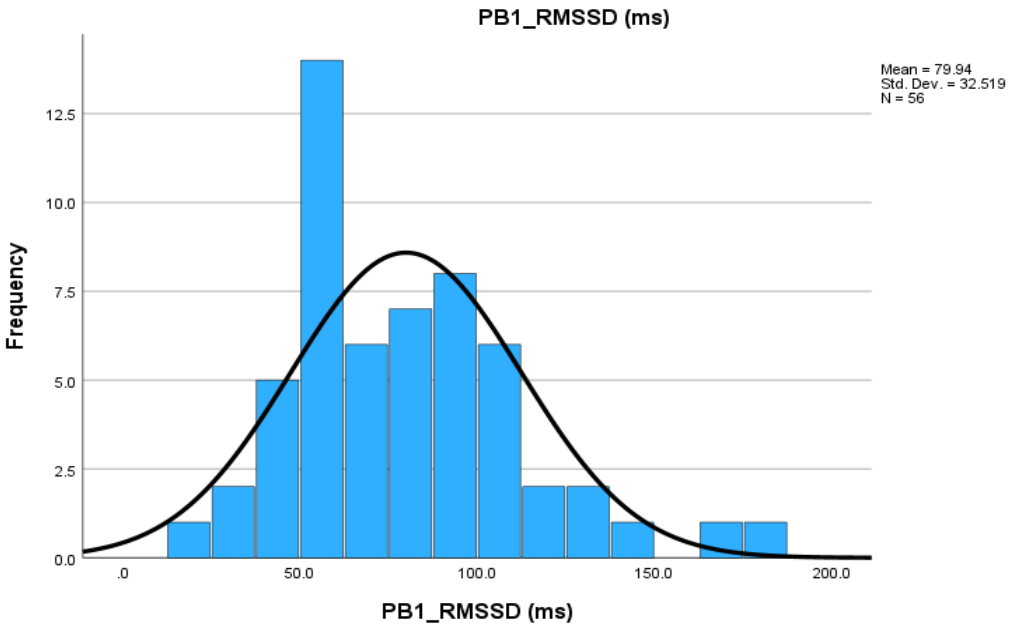
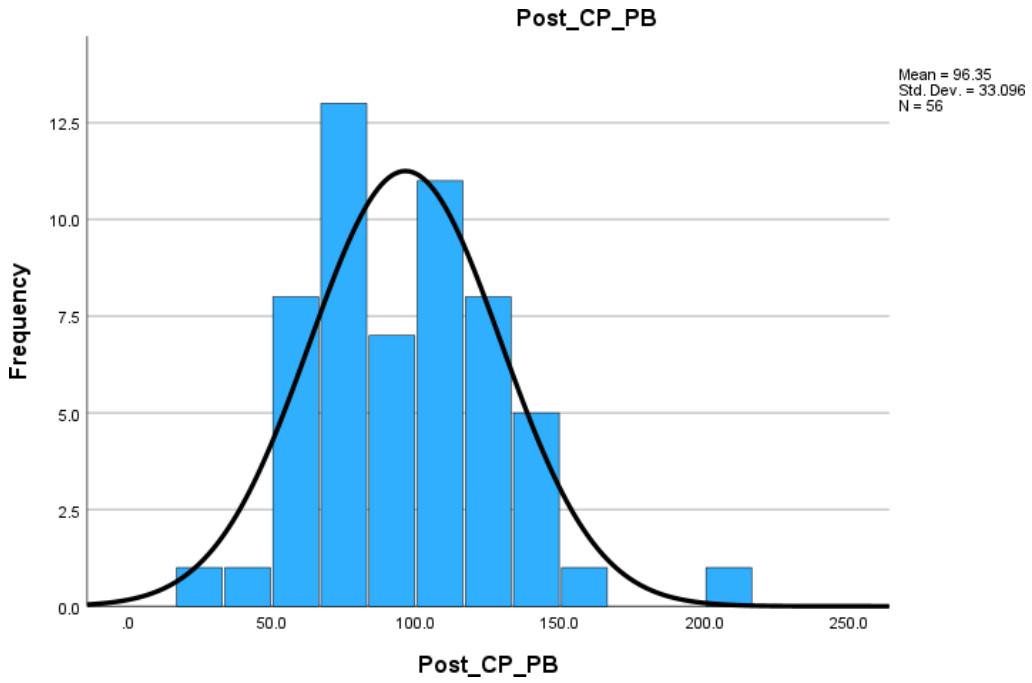
15
10
5
0
50
60
70
80
CYRM-R Total

Appendix 16


RP1_RMSSD_(ms)
Mean = 76.56
Std. Dev. = 35.975
N = 56
Frequency
RP1_RMSSD_(ms)


PB1_RMSSD (ms)
Mean = 79.94
Std. Dev. = 32.519
N = 56
Frequency
PB1_RMSSD (ms)


Post_CP_PB
Mean = 96.35
Std. Dev. = 33.096
N = 56
Frequency
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7.5
5.0
2.5
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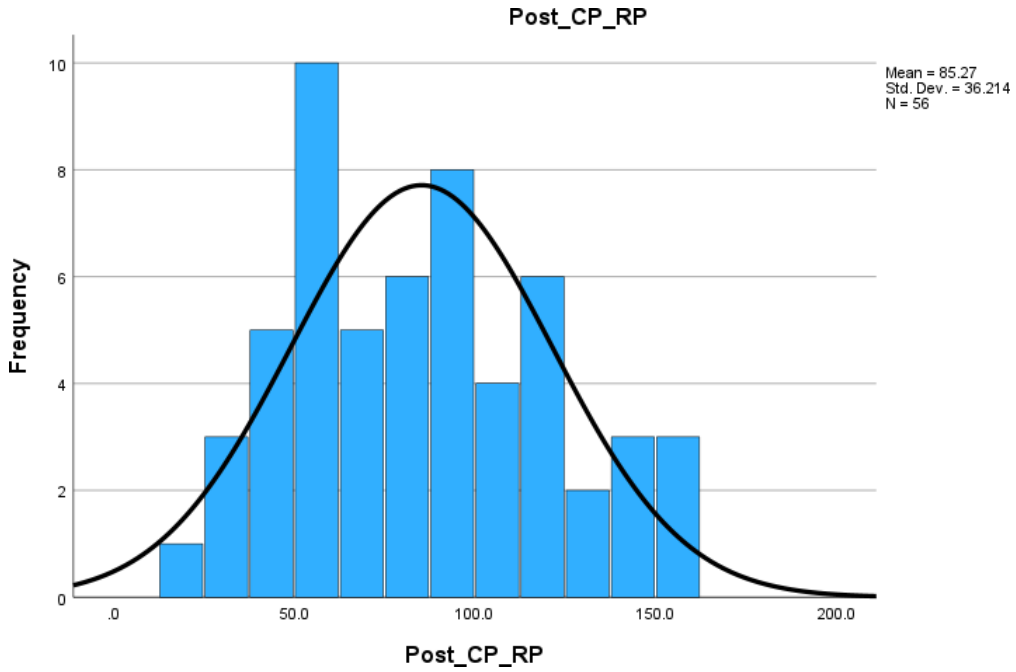
.0
50.0
100.0
150.0
200.0
250.0
Post_CP_PB


Post_CP_RP
Mean = 85.27
Std. Dev. = 36.214
N = 56
Frequency
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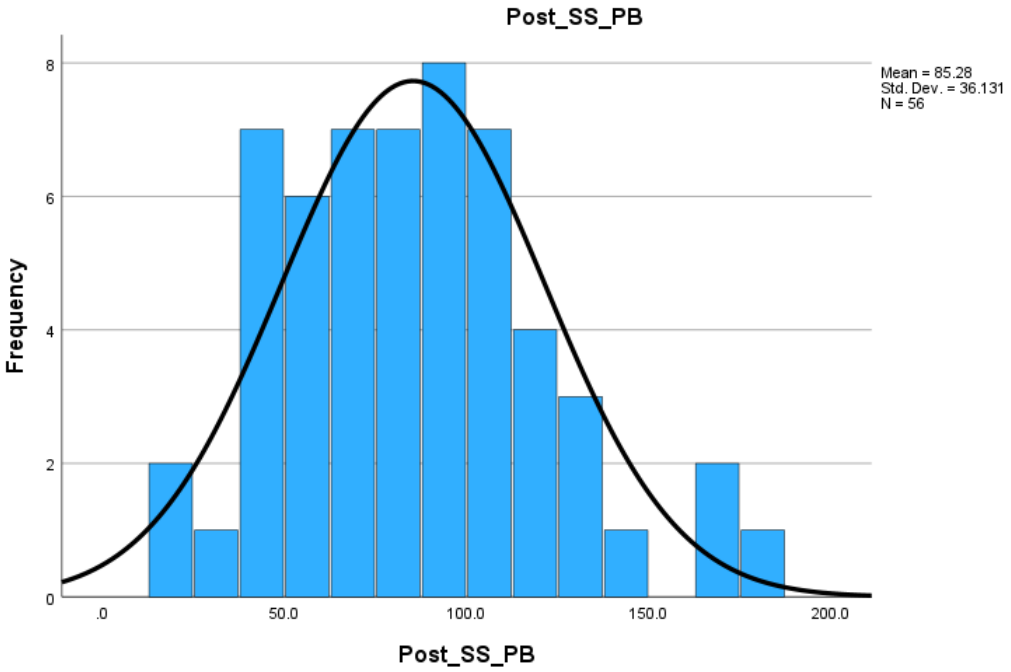
8
6
4
2
0
.0
50.0
100.0
150.0
200.0
Post_CP_RP


Post_SS_PB
Mean = 85.28
Std. Dev. = 36.131
N = 56
Frequency
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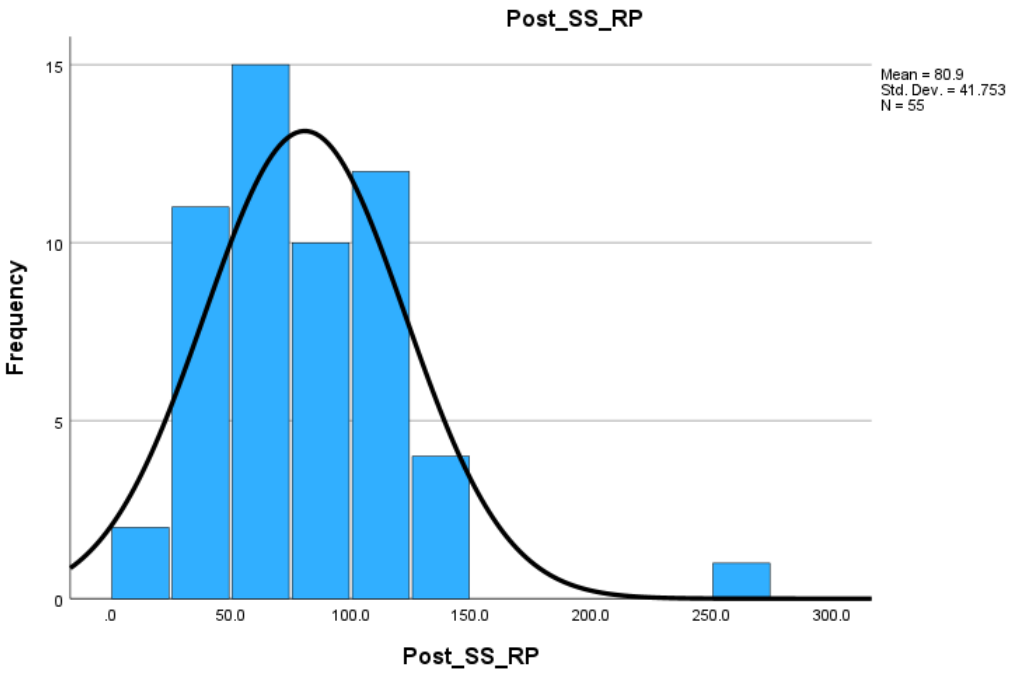
4
6
8
.0
50.0
100.0
150.0
200.0
Post_SS_PB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Mean = 80.9
Std. Dev. = 41.753
N = 55
Frequency
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10
15
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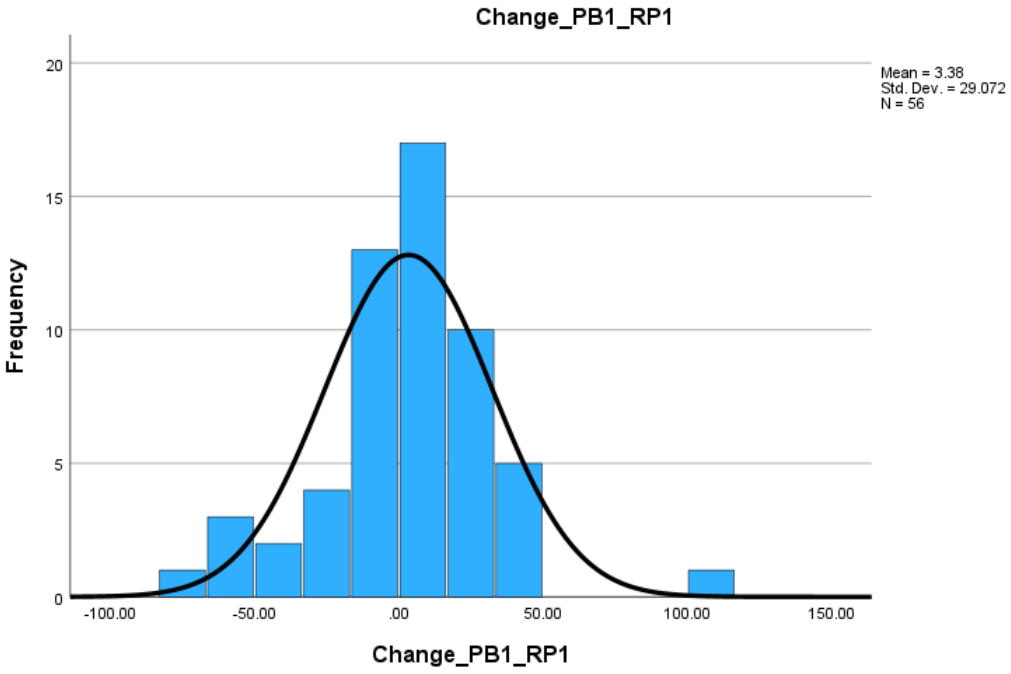
50.0
100.0
150.0
200.0
250.0
300.0
Post_SS_RP


Change_PB1_RP1
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Std. Dev. = 29.072
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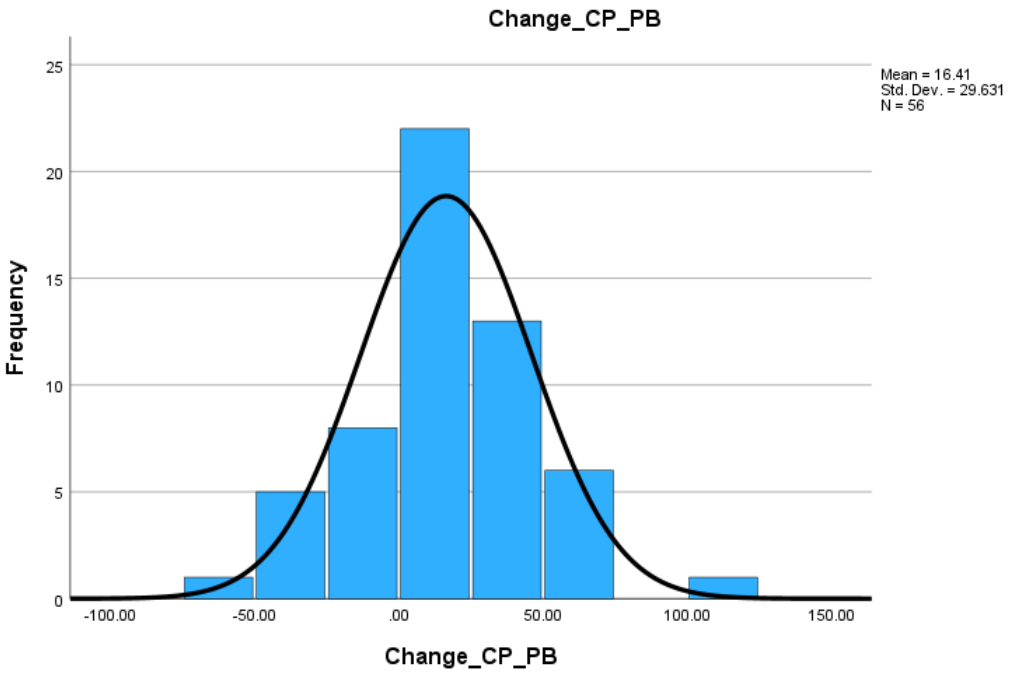
-50.00
.00
50.00
100.00
150.00
Change_PB1_RP1


Change_CP_PB
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Std. Dev. = 29.631
N = 56
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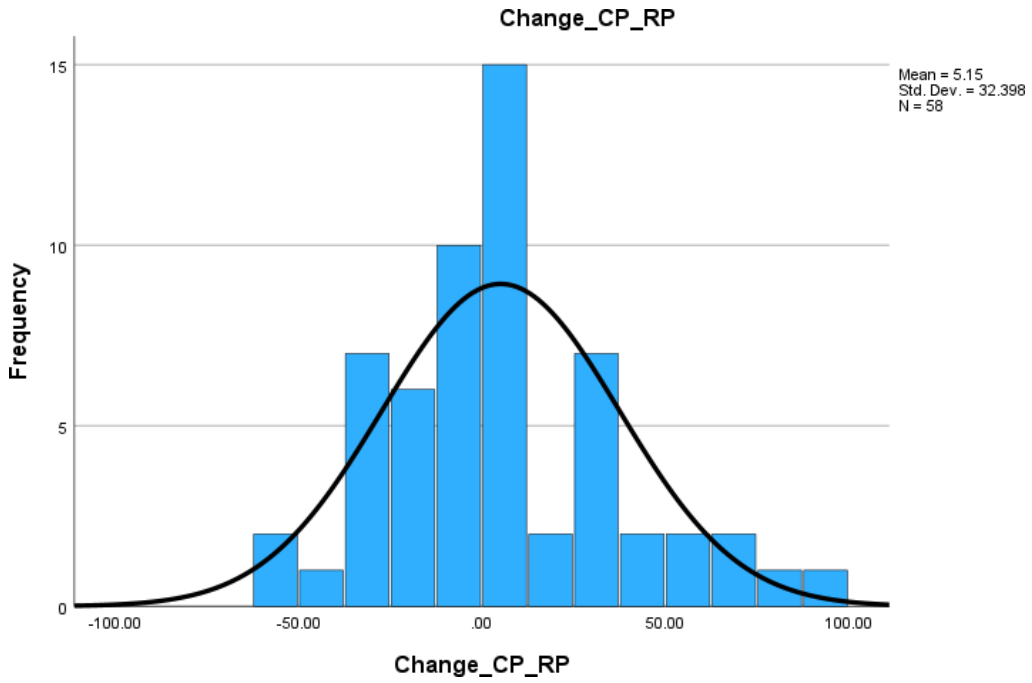
.00
50.00
100.00
150.00
Change_CP_PB


Change_CP_RP
Mean = 5.15
Std. Dev. = 32.398
N = 58
Frequency
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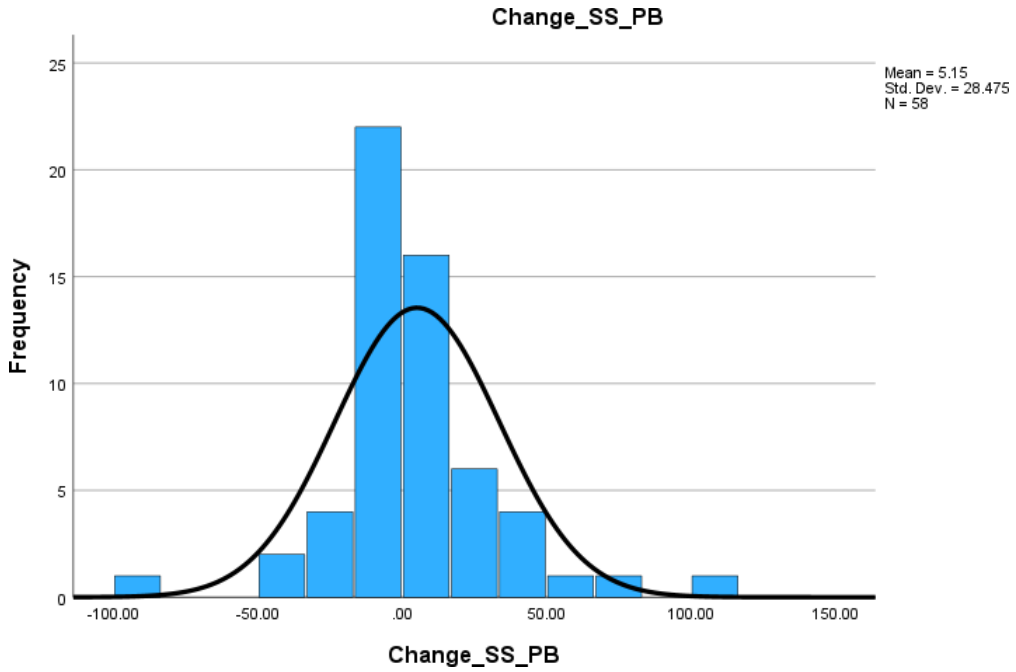
-50.00
.00
50.00
100.00
Change_CP_RP


Change_SS_PB
Mean = 5.15
Std. Dev. = 28.475
N = 58
Frequency
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10
5
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-50.00
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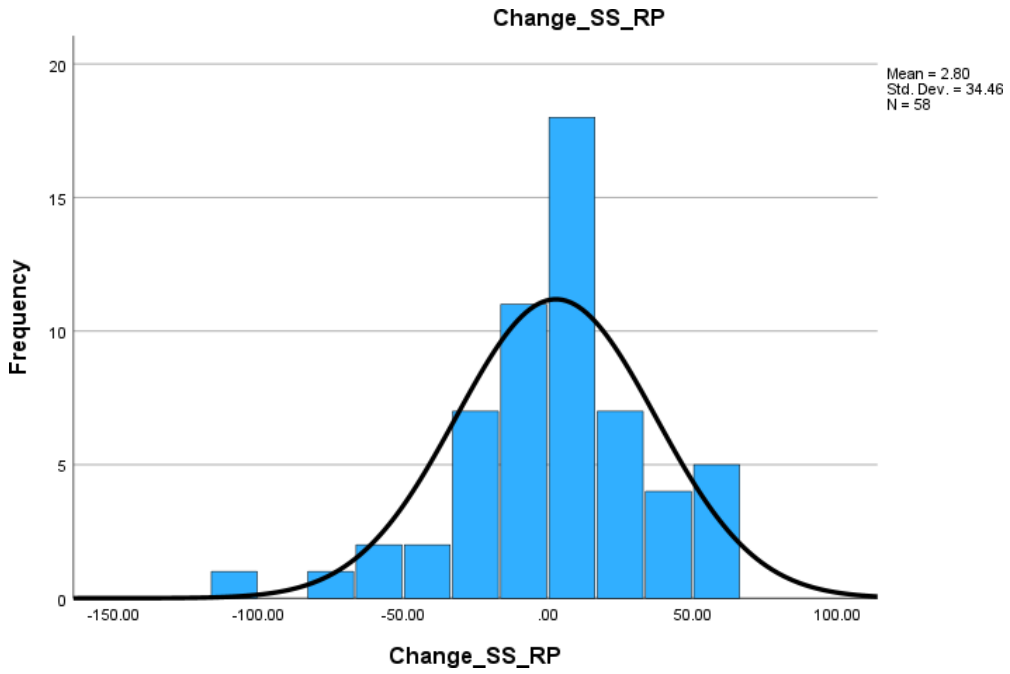
50.00
100.00
150.00
Change_SS_PB


Change_SS_RP
Mean = 2.80
Std. Dev. = 34.46
N = 58
Frequency
20
15
10
5
0
-150.00
-100.00
-50.00
.00
50.00
100.00
Change_SS_RP

Appendix 17

	Kolmogorov-Smirnov[a]				
	Statistic	df	Sig.	According to the K-S test	Skewness
PDS Boys	0.197	53	0.000	Not normal	
PDS Girls	0.189	53	0.000	Not normal	
PDS Total	0.129	53	0.029	Not normal	
CYRM-R personal	0.158	53	0.002	Not normal	
CYRM-R caregiver	0.277	53	0.000	Not normal	
CYRM-R total	0.180	53	0.000	Not normal	
RP1_RMSSD_(ms)	0.075	56	.200*	Normal	0.816
PB1_RMSSD (ms)	0.110	56	0.090	Non-normal	0.767
Post_CP_PB	0.109	56	0.092	Normal	0.723
Post_CP_RP	0.113	56	0.072	Normal	0.373
Post_SS_PB	0.065	56	.200*	Normal	0.495
Post_SS_RP	0.106	56	0.182	Normal	0.495`