Physiology in Anxious Children and Adolescents:

A Systematic Review and Empirical Thesis

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Declaration of Originality

I hereby confirm that all material contained in this project is of my original authorship and ideas, except where work has been acknowledged or referenced. I also confirm that the work has not been submitted for a higher degree to any other university or institution. The research project was approved by the Macquarie University Human Research Ethics Committee (Approval No. 5201600388).

Jessica Shen

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Abstract

Cognitive models of anxiety disorders, anxiety studies and diagnostic criteria highlight the role of physiology and somatic sensations in characterising and maintaining anxiety disorders. However, the bulk of research has focused on cognitive and behavioural components of anxiety disorders as targets for prevention and treatment programs, utilising adult samples. Studies indicate anxious adults demonstrate biased perception of somatic changes, and those individuals with anxiety exhibit abnormal physiological systems. It is unclear if these findings translate to children and adolescents with anxiety symptoms and disorders. We conducted a systematic review into the PsycINFO database, including the ancestry approach, and found 104 child and adolescent studies investigating physiology (hypothalamic-pituitary-adrenal axis and autonomic nervous system) at rest and/or reactivity to stress. The studies were largely heterogeneous, investigating healthy youths, youths with separation anxiety disorder, posttraumatic stress disorder, generalised anxiety disorder, social phobia, specific fears, high and low shy children, and high and low anxious children. Methodology varied greatly between studies; however, overall results indicate anxious youths demonstrate discordance or biased perception regarding their physical anxiety symptoms. There was some evidence that anxious youths have an elevated autonomic response to stress, and some evidence that they demonstrate a blunted physiological flexibility to stress, with less evidence that anxious youths have chronic hyperarousal. We discuss implications of the review's findings and future directions.

Hypothalamic-Pituitary-Adrenal Axis, Autonomic Nervous System and Youth Anxiety: A Systematic Review

Anxiety disorders remain one of the most prevalent psychiatric disorders in the general population (Albano, Chorpita, & Barlow, 2003; Alonso et al., 2004; Lawrence et al., 2015; Slade et al., 2009). According to a European six-country survey, anxiety disorders were the most common disorders (6%) experienced in the preceding 12 months, with 13.6% of respondents reporting a lifetime history of an anxiety disorder (Alonso et al., 2004). In the Australian population, 1 in 7 adults have experienced an anxiety disorder in the past 12 months (Slade et al., 2009). Prevalence rates from a recent report of the Second Australian Child and Adolescent Survey of Mental Health and Wellbeing indicated 6.9% of children (4–11 years) and 7% of adolescents (12–17 years) had one or more anxiety disorders (i.e., social phobia [SP]: 2.3%, separation anxiety disorder [SepA]: 4.3%, generalised anxiety disorder [GAD]: 2.2%, obsessive-compulsive disorder [OCD]: 0.8%; Lawrence et al., 2015). Given the debilitating effects of anxiety disorders affecting youth and adult populations, researchers have conducted numerous investigations to better understand the nature of anxiety disorders and develop prevention and treatment programs.

Anxiety is generally conceptualised as comprising of three components that contribute to and maintain anxiety disorders: cognitive components, e.g. attention and thought processes related to fear and threat appraisal; behavioural components or responses to threat, e.g. threat avoidance or safety behaviours; and a physiological component, which relates to physiological responses to the perceived threat e.g. racing heart, restlessness. Adult and child literature has demonstrated differences between individuals with anxiety disorders or anxiety symptoms and non-anxious counterparts on these three components (for reviews, see Ellis & Hudson, 2010; Kashdan & Herbert, 2001; Spence & Rapee, 2016; Stapinski, Abbott, & Rapee, 2010; Wong & Rapee, 2016). However, the majority of anxiety research has focused on cognitive and behavioural processes, and developing interventions targeting those processes in anxious youths and adults (Hudson, 2005; Lampe, 2009; Kendall & Peterman, 2015; Ponniah & Hollon, 2007). In contrast, research on anxiety physiology has been scant and has provided inconsistent findings, particularly concerning the physiological profile of children and adolescents with anxiety disorders.

Specific cognitive models, developed for some of the individual anxiety disorders, have incorporated the three components of anxiety (Clark, 1986; Clark & Wells, 1995; Sandin, Sánchez-Arribas, Chorot, & Valiente, 2015; Wells, 1999; Wells & Carter, 2001). Reflecting the similarities across anxiety disorders, there are many similarities across the models that describe the interaction of cognitive, behavioural and physiological components or symptoms. For example, Clark and Well's tripartite cognitive model of social anxiety disorder (SAD) implicates physiological arousal as a target for a socially anxious individual's maladaptive monitoring. The individual's heightened sensitivity or awareness towards these bodily sensations further contributes to the maintenance of the disorder (Clark & Wells, 1995; Rapee & Heimberg, 1997). Similarly, cognitive factors such as heightened sensitivity and catastrophic misinterpretations of physical sensations are associated with the severity of panic disorders (PD; Sandin et al., 2015).

Most anxiety disorders are accompanied by acute physical symptoms such as excessive sweating, dry mouth, heart palpitations, chills, hot flushes, and blushing (Ehlers & Clark, 2000; Langeland & Olff, 2008; Wilhelm & Roth, 2001). According to the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM–V; American Psychiatric Association [APA], 2013) and the *International Statistical Classification of Diseases and Related Health Problems* (10th ed.; ICD-10; World Health Organisation [WHO], 2016), physical symptoms are key diagnostic presentations of various anxiety disorders (Wilhelm & Roth, 2001). For example, a GAD diagnosis requires the presence of at least three symptoms from six symptoms (including restlessness or muscle tension) for more days than not over the past 6 months (APA, 2013) or at least four out of 22 physical symptoms must be present, and one from four autonomic arousal symptoms (heart palpitations, sweating, trembling, dry mouth; WHO, 2016). Therefore, physiological reactivity is a critical part of anxiety disorders that has a role in symptom expression and maintenance of disorders.

Despite the importance of physiological symptoms and arousal in cognitive models and diagnostic criteria, our understanding of the role of physiological processes and reactivity in anxiety disorders is limited, especially in children and adolescents. There is mixed consensus on whether anxious individuals experience (a) a dysregulated physiological response in general, (b) an abnormal physiological response in reaction to a threat, or alternatively, (c) a normal physiological reactivity but inaccurately perceive their physiological responses as being more dangerous or threatening than non-anxious individuals (Krämer et al., 2012). Past research has focused mostly on subjective reports rather than objective measurements, particularly in child and adolescent studies. Objective physiological measures can accurately record physiological responses and trajectories in anxious individuals, and examine differences in somatic perception among anxious individuals. Past research has reported discordance between objective and subjective measures of physical arousal in anxious adults and children. For example, Mauss, Wilhelm, and Gross (2003) found that high socially anxious adults reported greater levels of subjective anxiety after two public speaking tests compared to adults who were low socially anxious, despite both groups experiencing similar levels of physiological activity and habituation to the stressors. Other studies have reported on the discordance between subjective self-reports of arousal and actual physiological response to anxiety in adults (Edelmann & Baker, 2002; Gerlach, Mourlane, & Rist, 2004; Gramer, Schild, & Lurz, 2012) and in children (Anderson & Hope, 2009; Kirsch, Wilhelm, & Goldbeck, 2015; Miers, Blöte, Sumter, Kallen, & Westenberg, 2011). It is thought that greater anxiety sensitivity (Anderson & Hope, 2009) and self-focused attention (Gerlach et al., 2004) leads anxious individuals to catastrophize minute physical symptoms and believe that their anxiety is visible to others and that visibility is a source of embarrassment (Anderson & Hope, 2009). Hence, highlighting the discrepancy between individuals' exaggerated perception of physical arousal and actual physiological response may help individuals to train their subjective reports to closely align with reality or challenge their physical experience of anxiety, leading to clinical improvements (Thomas, Aldao, & De Los Reyes, 2012).

The aim of this study was to conduct a systematic literature review on the physiological reactivity in anxious and non-anxious children and adolescents and examine the similarities and differences between anxious and non-anxious youths on physiological reactivity and physiological dysregulation. The aim was also to investigate whether specific physiological response patterns are unique to individual anxiety disorders, and if there is evidence of discordance in anxious youths. To begin, we describe the physiological systems and measures associated with physiological reactivity (mostly conducted in adults).

Physiology

Recent studies have focused on two physiological systems that are associated with stress and anxiety and how these two systems influence the body's stress response: the *autonomic nervous system* (ANS) and the *hypothalamic-pituitary-adrenal* (HPA) axis.

Autonomic Nervous System

The ANS moderates and influences the individual's physiological response to stress and is divided into the *sympathetic nervous system* and *parasympathetic nervous system*. The sympathetic nervous system is responsible for preparing certain organs for vigorous activity – increasing sweat, breathing, heart rate, and blood pressure. The sympathetic nervous system also has sole control over the sweat glands, adrenal glands, and muscles that constrict blood vessels and cause hairs to stand up. The sympathetic nervous system also inhibits the functioning of other organs such as the stomach and intestines, thus decreasing digestion. Conversely, the parasympathetic nervous system works to create homeostasis, where the body is at rest and organs such as the stomach can continue the digestive process. Thus, if the sympathetic nervous system increases heart rate, the parasympathetic nervous system will work to decrease it. Whilst there is a tendency to treat the two systems as dichotomous and bifurcated systems where they are responsible for separate body organs and have polar opposite (antagonistic) functions, it is now accepted that the sympathetic and parasympathetic nervous system can simultaneously influence or moderate the cardiovascular system (Berntson, Quigley, Norman, & Lozano, 2016; Porges, 1992, 2007). Many studies have shown abnormal reactivity or responses to stress and anxiety, indicated by increases in heart rate, blood pressure, or skin conductance levels for example. However, literature also suggests that altered physiological responses are tightly associated with anxiety disorders, and not just a response to a stressor (Edgar, Keller, Heller, & Miller, 2007).

Friedman (2007) proposed that chronic ANS dysregulation is strongly associated with anxiety presentation. Individuals with anxiety disorders have a “faulty” and inflexible autonomic response both in the absence and presence of stressors, coined restricted autonomic flexibility (Friedman, 2007). Friedman suggested a clinically anxious individual, relative to a non-anxious individual, would demonstrate heightened sympathetic activity and weaker parasympathetic activity at rest, but in the face of stress, would not exhibit the usual increased sympathetic activity and diminished parasympathetic activity. Lastly, the anxious individual’s body recovers more slowly, relative to the non-anxious, once the stressor has passed (Friedman, 2007). Indeed, adults with social anxiety (SAD) show increased sympathetic activity and diminished parasympathetic activity (Barlow, 2002). As discussed below, a variety of measures represent aspects of autonomic activity.

Electrodermal Activity Measures. Galvanic skin conductance, the most commonly used measure of electrodermal activity, has been well documented and measured in many physiology studies (Kreibig, 2010). The sympathetic nervous system solely influences electrodermal activity and generally, differences in electrodermal activity are found for differing levels of anxiety or stress response. Individuals with SAD are characterised with increased skin conductance levels (Barlow, 2002) and one study demonstrated induced state anxiety was associated with greater skin conductance levels (Smith, Bradley, & Lang, 2005). In this study, undergraduate students were exposed to a series of pleasant, neutral and unpleasant pictures and sustained exposure to the unpleasant pictures elicited more skin conductance responses than the neutral and pleasant pictures. This increase in skin conductance was greater for adults who reported higher state anxiety during and after exposure to the unpleasant stimuli (Smith et al., 2005). Similarly, a meta-analysis conducted by Pole (2007) showed that adults with post-traumatic stress disorder (PTSD) exhibited elevated skin conductance levels at rest and elevated reactivity to a stressor.

Cardiovascular Measures. Multiple studies have examined heart rate, heart rate variability and other cardiovascular measures (e.g. blood pressure) in association with anxiety and stress. However, because both the sympathetic and parasympathetic nervous system can stimulate the heart (Porges, 1992), cardiovascular measures must be carefully chosen to reflect the autonomic branches under investigation or be discussed in relation to the correct branch system (Berntson et al., 2016).

Heart Rate. Heart rate is the number of heart beats per minute (Berntson et al., 2016) and is reflective of physiological arousal. Other indices include *pre-ejection period* and *heart period*, also known as *interbeat interval* (the period between heart beats). Studies have shown that anxiety or stress increases heart rate (Nater et al., 2005) and it is the most commonly reported cardiovascular physiology measure (Kreibig, 2010). Adults with PTSD demonstrated abnormally high levels of heart rate at rest compared to adults with no trauma history (Pole, 2007). Psychosocial stressors, such as the Trier Social Stress Test (TSST, Kirschbaum, Pirke, & Hellhammer, 1993; TSST-C; Buske-Kirschbaum et al., 1997), also significantly increases adult heart rate (Nater et al., 2005). Other popular cardiovascular measures include; *blood pressure*, *mean arterial pressure*, *systolic* and *diastolic blood pressure*, all reflecting sympathetic nervous system activity (Kreibig, 2010).

Heart Rate Variability. Heart rate variability is another popular index of ANS regulation, representing the changes in duration of time between one heartbeat to the next (Allen, Chambers, & Towers, 2007). It represents the sympathetic and parasympathetic influences on the heart rate and represents cardiac flexibility (Porges, 2007). There are two beat-to-beat variability patterns or periods; the fast or high-frequency band (above 0.14 Hz) which is associated with spontaneous breathing (also known as respiratory sinus arrhythmia) and a slow or low-frequency band (between 0.04 and 0.14 Hz) (Malpas, 2002; Porges, 2007). Low-frequency heart rate variability is rarely assessed, attributable to the fact physical movements introduce error variance (Fox, Schmidt, Henderson, & Marshall, 2007). However, stressor tasks significantly increase low-frequency power and decrease high-frequency power: the ratio of low-frequency/high-frequency increases in response to stress (Nater et al., 2005).

Vagal Tone/Respiratory Sinus Arrhythmia. Vagal tone represents the activity of the vagus nerve (Berntson et al., 2016) and, by extension, represents the functional state of the parasympathetic nervous system. As researchers cannot directly measure vagal tone, they can instead measure high-frequency heart rate variability in association with the respiratory cycle, giving rise to *respiratory sinus arrhythmia* (Porges, Doussard-Roosevelt, & Maiti, 1994).

Greater variability or flexibility in vagal tone in response to fearful stimuli is associated with healthy individuals relative to patients (Porges, 1992). Studies also reported that higher respiratory sinus arrhythmia levels in adults is related to decreased negative affect in response to stressors (Fabes & Eisenberg, 1997) and adults who were highly socially anxious had poorer respiratory sinus arrhythmia modulation (Movius & Allen, 2005).

Salivary Alpha-Amylase. Salivary alpha-amylase is an enzyme secreted by the salivary glands and reflects autonomic activation, and more specifically reflects the sympathetic nervous system's activity (Nater & Rohleder, 2009). Bosch, de Geus, Veerman, Hoogstraten, and Nieuw Amerongen (2003) reported associated increases in sympathetic activity and decreases in parasympathetic activity with increased alpha-amylase in response to a stressor. One of the earliest studies on salivary alpha-amylase and stress found a relationship between amylase activity and the frequency and severity of critical life events, suggesting that stress in everyday life contributed to altered physiological response (Bosch et al., 1998). A review by Nater and Rohleder (2009) reports on multiple studies that found increased alpha-amylase in many psychological and socially stressful conditions, and support salivary alpha-amylase as a useful indicator of stress. Despite three studies (Hill-Soderlund et al., 2008; Morrison, Haas, Shaffner, Garrett, & Fackler, 2003; Schäffer et al., 2007) failing to find the expected salivary alpha-amylase increase to a stressor, the studies in Nater and Rohleder's review show support for alpha-amylase as a useful indicator of stress. In line with other studies examining physiological responses to stress, Nater et al. (2005, 2006) used the standardised TSST and found that adults who completed the mock job interview and mental arithmetic task had significantly higher levels of salivary alpha-amylase than adults in the rest condition. Furthermore, adults with SAD showed elevated levels of salivary alpha-amylase compared to healthy controls (van Veen et al., 2008). However, Almela et al. (2011) found there were no differences in salivary alpha-amylase levels between the stress and control conditions using a healthy adult population. A more recent study reported adults with SP had similar salivary alpha-amylase levels as healthy controls after stress exposure (Klumbies, Braeuer, Hoyer, & Kirschbaum, 2014). Despite the inconsistent evidence in the adult literature, this review will investigate salivary alpha-amylase in the youth population.

The Hypothalamic-Pituitary-Adrenal Axis

The hypothalamic-pituitary-adrenal axis is a neuroendocrine system responsible for coordinating the body's response to stressors by initiating a cascade of different hormones. The hypothalamic release of *corticotrophin releasing hormone* stimulates the anterior pituitary gland to release *adrenocorticotropic hormone* which stimulates the adrenal cortex to release *cortisol* into the bloodstream (Sapolsky, Romero, & Munck, 2000). The HPA axis and cortisol play critical roles in supporting normal physiological functioning, such as influencing diurnal cortisol cycles. An efficient and adaptive HPA axis would be able to protect the individual against environmental stressors by sensing danger and controlling individual systems in the HPA axis through regulation, activation and termination (Koss, Cummings, Davies, & Cicchetti, 2017). However, the HPA axis is much slower to respond to stress or threats compared to the fast and flexible ANS. McEwen (1998) proposed that excessive or prolonged stress is associated with the dysregulation of the HPA axis and abnormal cortisol activity. According to allostatic load theory, chronic or repetitive stress results in either hyperactivity or hypoactivity in the HPA axis (McEwen & Seeman, 1999). When at rest a hyperactive HPA axis is characterised by elevated levels, and when exposed to an acute stressor or threat, demonstrates an intensified reactivity peak and prolonged return to pre-stressor levels (Koss et al., 2017). Conversely, a hypoactive HPA axis shows a decreased sensitivity to acute stressors, resulting in lower levels reactivity, commonly described as blunted or flattened reactivity (Koss et al., 2017). This downregulation in the HPA axis is the body's copying mechanism against repetitive stress and excessive elevations of cortisol production (Fries, Hesse, Hellhammer, & Hellhammer, 2005). Condren, O'Neill, Ryan, Barrett, and Thakore (2002) reported that SP adults and their same age- and sex-matched controls did not differ in baseline cortisol levels, but SP adults showed HPA hyperactivity (indexed by cortisol levels) in response to two cognitive-social stressors. Interestingly, corticotrophin levels were also examined and no differences in baseline corticotrophin were found between clinical and controls, nor did the stressor tasks increase corticotrophin levels (Condren et al., 2012). Furthermore, a meta-analysis by Dickerson and Kemeny (2004) found that socio-evaluative tasks and other tasks that have an element of uncontrollability produced greater cortisol reactivity in adults. The authors also reported that noise exposure and emotion induction such as films was not associated with elevated cortisol. Cortisol concentrations can be sampled from blood plasma, urine and saliva; the latter can be gathered non-invasively and is the more popular substance.

Review Aims

Numerous studies have explored physiological arousal in adults, with and without an anxiety disorder, but little research has examined anxious children and adolescents' physiological responses to anxiety, and the findings available to date often conflict with each other. A recent review by Siess, Blechert, and Schmitz (2014) explored the relationship between anxiety and physiology in socially anxious children. The current study extends previous research by focusing on the physiology of child and adolescent anxiety more broadly and the differences in physiological responses in youths with different anxiety disorders and symptoms. Specifically, we examined the literature to understand, firstly, whether anxious youth have a different basal physiological profile compared to non-anxious youth, and secondly, whether anxiety symptoms or disorders in youth are associated with abnormal physiological response to stressful and anxiety-provoking stimuli.

Methods

Using the PsycINFO database, all articles available until April 2017 were searched using the terms psychophysiolog*, physiolog*, anxi*, social anxi*, general* anxi*, youth*, child* and adolescen*. The inclusion criteria were (1) human participants with the age range of 5–17 years, (2) publication as peer-reviewed journal articles in the English language, (3) reported on children's and adolescents' physiological responses to stress/anxiety or (4) reported on physiological differences between children and/or adolescents who had either clinical anxiety diagnosis (or significant anxiety problems) or no mental health issues. For example, studies whose samples included 'high shy', 'low shy' or 'behavioural inhibited' children were included. Studies that reported on physiological measures other than those closely linked to the HPA or ANS system were excluded from the review list, such as genetic or brain neurochemistry physiology. Studies with age ranges that extended to ages 4 or 18 years were not excluded. Relevant articles identified from reference lists and authors' own knowledge on the area were added to the literature list for full-text assessment.

Results

The initial search identified 533 articles based on the search terms. Article titles and abstracts were screened and excluded from full-text assessment if the article: 1) did not focus on anxiety or include an anxiety measure, 2) did not meet the age criteria, 3) did not include an objective physiological measure, 4) was not a peer reviewed journal article, or 5) reported only on other physiology parameters, for example genetics or neurophysiology. An additional 20 articles identified from reference lists were added to the 160 articles for full-text review to closely assess each study's relevance to the key search terms, and whether the study had met inclusion criteria and reported on either children's and adolescents' physiological responses to stress or physiological differences between children/adolescents with varying symptoms of anxiety. In total, 104 articles were included in the current review, which were published from

1967 to 2017 (see Figure 1). While the majority of articles focused on children with anxiety disorders, four articles explored the relationship between test anxiety and children/adolescent's physiology, and three articles reported on the effects of hospitalisation or surgery anticipation on children's physiology. While the majority of studies were cross-sectional, there were 14 longitudinal studies.

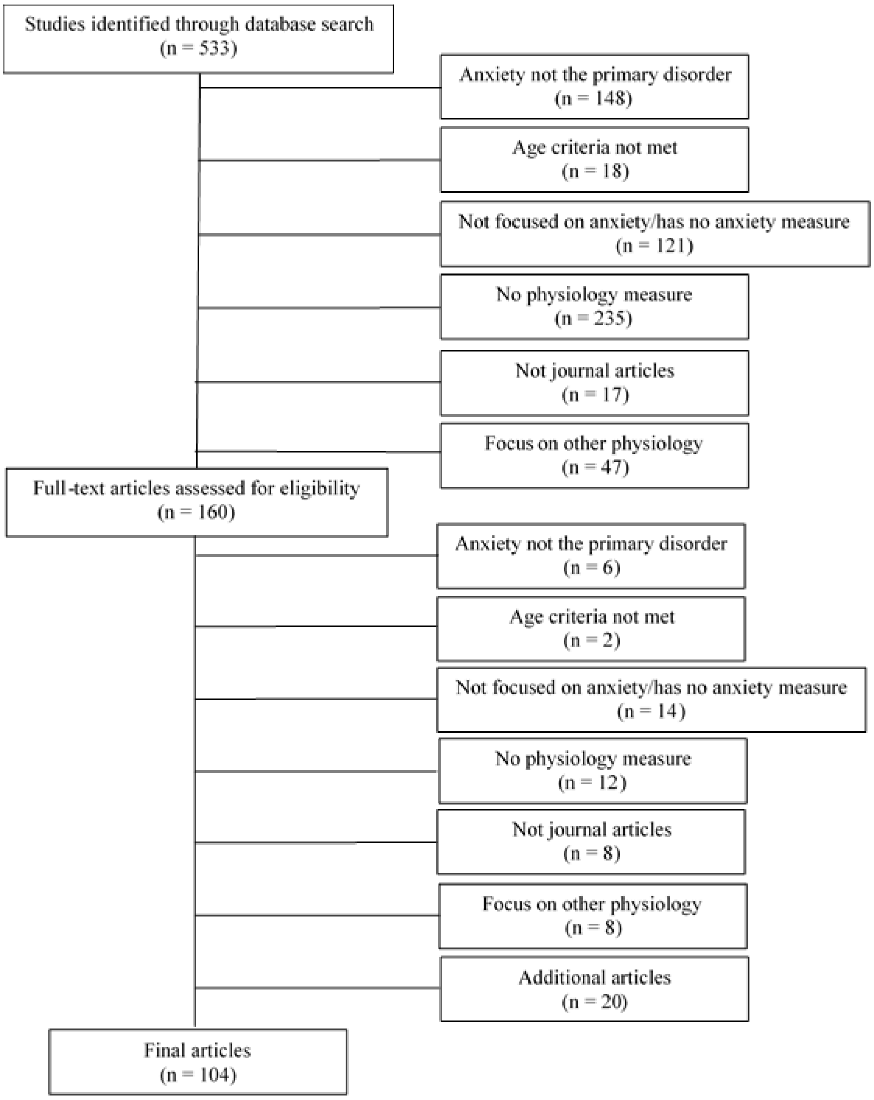

Figure 1. *Flow Chart of Studies Selection Process*

Stressor Induction Methods

The identified literature included a broad range of different study designs, methodologies, sample population and physiology parameters. The majority of studies focused on stress response by inducing stress using physical challenges, social evaluative tasks, and cognitive challenges. Common physically challenging tasks included voluntary hyperventilation (Kossowsky, Wilhelm, & Schneider, 2013), the action of standing up from a sitting position (Greaves-Lord et al., 2007), stepping up and down stairs (Asbrand, Blechert, Nitschke, Tuschen-Caffier, & Schmitz, 2016), and the hand-grip challenge (Matthews, Manuck, & Saab, 1986). Common socio-evaluative stressors included vocabulary tests, recounting stories, presenting a speech to an audience (live vs recorded, same-aged/sex peers vs adults), participating in a parent-child conflict discussion, and judgement and rejection from peers. A variation of the socio-evaluative stressor is the peer rebuff challenge in which youths gave a speech, then were told that the judges (same-aged peers) rated their speech performance poorly, and then were given the opportunity to present their disagreement to the judges (Kaeppler & Erath, 2017).

The most common cognitive challenges were mental arithmetic tasks (e.g. Dieleman et al., 2014; Scott & Weems, 2014) and other tasks employed a trace-mirror task (Stroud et al., 2009), spatial memory recall test (Kagan, Snidman, Zentner, & Peterson, 1999) and a tangram puzzle task (Alkozei, Creswell, Cooper, & Allen, 2015). Many studies utilised the commonly used Trier Social Stress Task adapted for children and adolescents, which required the participants to give a speech and perform serial subtraction in front of strangers (Buske-Kirschbaum et al., 1997). Nederhof, Marceau, Shirtcliff, Hastings, and Oldenhinkel (2015) used a similar paradigm, the Groningen Social Stress Test, developed by Bouma Riese, Ormel, Verhulst, and Oldehinkel (2009).

The Behavioural Approach Task (BAT) features in a number of studies which recorded youths’ approach latency to a box (supposedly containing an animal) after given specific primed information (Field & Price-Evans, 2009; Reynolds, Field, & Askew, 2014). The BAT was also used to test the efficacy of exposure therapy for children with specific phobias by comparing whether cardiovascular and subject distress measures during the BAT improved after therapy (Benoit Allen, Allen, Austin, Waldron, & Ollendick, 2015). A separation task from a parent was used when examining stress in children with SepA (Kossowsky, Wilhelm, Roth, & Schneider, 2011). A few studies required participants to passively listen to unpleasant audio stimuli (El-Sheikh, Harger, & Whitson, 2001), or watch stressful or non-stressful videos and pictures (Balle, Tortella-Feliu, & Bornas, 2013; Fischer & Kutina, 1976). In general, the majority of these tasks were associated with elevated physiological stress responses (e.g. greater skin conductance, elevated heart rate or magnitude). Cognitive and social performance tasks such as speech performances, mental arithmetic and conversing with strangers were the most popular stress induction method. However, it is not clear which of these tasks may be more appropriate for measuring physiological reactivity than others, as reactivity to the different types of tasks are often not compared and some studies did not include pre- and post-task anxiety measures. There is also a question of whether tasks should be disorder-specific and closely resemble real-life scenarios.

A number of studies examined youths' physiology at rest. These studies required participants to be measured whilst sitting (Henje Blom, Olsson, Serlachius, Ericson, & Ingvar, 2010), in supine position (lying down; Wetter & El-Sheikh, 2012) and standing up (orthostatic challenge; Greaves-Lord et al., 2007). Other studies explored how different therapies, programs, task instructions, priming and conditioning may elicit differing physiological response profiles in youths. For example, Zaichkowsky and Zaichkowsky (1984) gave the experimental group a relaxation training program, Melamed, Dearborn and Hermecz (1983) gave hospitalised children either an informative procedural video or an unrelated film the night before surgery, and two studies utilised fear conditioning and extinction paradigms and documented the subsequent physiological responses (Waters &

Kershaw, 2015; Waters & Pine, 2016). Overall, there was substantial variation between studies in the physiological parameters used, and this variation was reflected in the significant and non-significant results.

Cardiovascular Studies

Within the 104 identified studies, 72 studies reported on the following cardiovascular parameters: heart rate, heart rate variability (low-frequency and high-frequency/respiratory sinus arrhythmia), vagal tone, interbeat interval, pre-ejection period, mean arterial pressure, systolic and diastolic blood pressure and total peripheral resistance. A few studies reported on a group of cardiovascular parameters as a cardiac index, as well as other sympathetic and parasympathetic parameters. A few studies measured multiple cardiovascular parameters but only found significant differences in one parameter across groups (Kristensen, Oerbeck, & Torgersen, 2014; Schmitz, Tuschen-Caffier, Wilhelm, & Blechert, 2013). Other studies measured multiple parameters and reported significant associations between anxiety or anxiety disorders for one parameter, but no associations for the other. For example, Monk et al. (2001) reported that anxious children had significantly higher basal heart rate than healthy children, while no such difference was found for basal heart rate variability. Contrary to Monk et al.'s findings, Henje Blom et al. (2010) reported no association between anxiety disorders and basal heart rate, but showed anxious children had significantly lower heart rate variability compared to healthy children.

Cardiovascular Reactivity at Rest

In summary, most of literature indicated that basal heart rate and heart rate variability are unreliable measures of anxiety severity or reactivity, and there is little support for differences in anxiety on basal heart rate for anxious and non-anxious youth. The majority of the literature indicates that basal cardiovascular parameters were not significant indicators of anxiety, and that there were no associations between anxiety symptoms and basal heart rate (Greaves-Lord et al., 2007; Hammar, Campbell, & Huffine, 1968; Yeragani, Radhakrishna Rao, Pohl, Jampala, & Balon, 2001), and no differences in basal heart rate between healthy controls and children with anxiety disorders (Alkozei et al., 2015; Dorn et al., 2003; Henje Blom et al., 2010; Gonzalez, Moore, Garcia, Thienemann, & Huffman, 2011; Kossowsky et al., 2011), high anxious and low anxious children (Weems, Zakem, Costa, Cannon, & Watts, 2005), high socially anxious and low socially anxious children (Schmitz et al., 2013), high shy and low shy children (Miers et al., 2011; Schmitz, Blechert, Krämer, Asbrand, & Tuschen-Caffier, 2012), SAD children, high shy children and healthy controls (Anderson, Veed, Inderbitzen-Nolan, & Hansen, 2010). However, there were also several studies that reported significant associations between anxiety, anxiety disorders and heart rate measures, however the direction of these findings vary (Asbrand et al., 2016; Beidel, 1991; Henje Blom et al., 2010; Krämer et al., 2012; Mezzacappa et al., 1997; Monk et al., 2001; Schmitz, Krämer, Tuschen-Caffier, Heinrichs, & Blechert, 2011). These studies indicate anxious children were characterised by elevated autonomic arousal at rest evidenced by higher heart rates (and higher skin conductance levels) (Asbrand et al., 2016; Krämer et al., 2012; Schmitz et al., 2011), and SP children showed chronically elevated heart rates throughout experimental procedures (baseline, during and after the stressor task) compared to healthy children (Krämer et al., 2012). A few studies suggested anxious children were characterised by lower heart rate variability (Henje Blom et al., 2010; Sharma, Balhara, Sagar, Deepak, & Mehta, 2011), however, not all did so (Monk et al., 2001).

Regarding parasympathetic nervous activity, all the studies that reported significant associations between anxiety and basal vagal tone or respiratory sinus arrhythmia described a negative relationship (El-Sheikh, Keiley, Erath, & Dyer, 2013; Greaves-Lord et al., 2007; Schmitz et al., 2011; Scott & Weems, 2014; Sharma et al., 2011). One study found that low respiratory sinus arrhythmia at rest characterises children with high behavioural inhibition sensitivity (Balle et al., 2013) and predicts internalising symptoms for girls later in childhood (Wetter & El-Sheikh, 2012). Yet, some studies reporting no differences in basal respiratory sinus arrhythmia or vagal tone between youths with differing anxiety disorders and healthy controls (Alkozei et al., 2015; Asbrand et al., 2016; Henje Blom et al., 2010; Kirsch et al., 2015). Basal respiratory sinus arrhythmia was not associated with anxiety symptoms (El-Sheikh et al., 2001; Greaves-Lord et al., 2010; Mezzacappa et al., 1997), shyness (Schmidt, Fox, Schulkin, & Gold, 1999) and mothers' reports of youths' internalising problems (Hane & Barrios, 2011). Thus, lower resting vagal tone or respiratory sinus arrhythmia seemingly characterises clinically anxious children, but further investigations are required to confirm this.

Very few studies examined blood pressure (systolic and diastolic) and mean arterial pressure at rest in comparison to studies investigating other cardiovascular measures. Three studies suggested that, in comparison to healthy controls, children with anxiety disorders have higher systolic blood pressure (Dorn et al., 2003), elevated mean arterial blood pressure (Kossowsky et al., 2011), and showed higher levels of diastolic blood pressure as an infant with high reactive temperaments (Kagan et al., 1999). Yet, other studies reported no association between blood pressure and anxiety or anxiety disorders (Beidel, Turner, & Trager, 1994; Hammar et al., 1968; Henje Blom et al., 2010). Altogether, these studies suggest blood pressure and mean arterial pressure at rest are not reliable predictors of anxiety or anxiety disorders in youths.

Cardiovascular Reactivity to a Stressor

As noted above, the studies varied significantly in the methods used to induce stress and anxiety in youths. Collapsing the studies together, the results can be grouped into three main findings, of which some are incompatible with other findings. One group of results suggest that there is no association between abnormal heart rate reactivity to stress and anxiety or anxiety disorders. The second group of findings suggests anxiety disorders are associated with an elevated heart rate reactivity to a stressor task. Lastly, anxious youths demonstrate a blunted heart rate response and recovery to stressor tasks, compared to normal heart rate reactivity in non-anxious youths. The first group of results is associated with the most amount of evidence.

Most studies failed to find associations between heart rate reactivity to stressor tasks and anxiety or anxiety disorders (Allwood, Handwerger, Kivilghan, Granger, & Stroud, 2011; Beidel et al., 1994; Field & Price-Evans, 2009; Hane & Barrios, 2011; Leen-Feldner, Feldner, Bernstein, McCormick, & Zvolensky, 2005; Schmitz et al., 2011; Young, Bunnell, & Beidel, 2012). There were no differences in heart rate reactivity to stressor tasks between non-anxious and SP children (Anderson & Hope, 2009), between high shy and low shy children (Miers et al., 2011; Schmitz et al., 2012), and between SAD children, high shy children and healthy children (Anderson et al., 2010). In one study, although high shy children (vs. low shy) were more concerned about being visibly anxious during the two social stressors, this was unrelated to actual heart rate activity (Schmitz et al., 2012). Furthermore, Beidel's (1988) finding that test anxious children showed greater heart rate reactivity towards a vocabulary test and oral reading task could not be reproduced (Beidel et al., 1994). Similarly, Leen-Feldner et al. (2005) replicated Monk et al.'s (2001) hyperventilation study but discovered that anxiety sensitivity scores (which predicted post-challenge anxiety and panic symptoms) were unrelated to heart rate reactivity. Two other studies examined heart rate reactivity to stressor tasks and found heart rate reactivity profiles did not differ between anxiety disordered and healthy children (Gonzalez et al., 2011) nor was parent-reported GAD symptoms associated with response profiles that included high or moderate heart rate reactivity (Turpyn, Chaplin, Cook, & Martelli, 2015). These studies altogether suggest heart rate reactivity to stressors does not differentiate anxious from non-anxious youths.

Yet, a few studies indicate heart rate reactivity to a stressful task can discriminate between anxious and healthy children (Beidel, 1988; Fischer & Kutina, 1976; Monk et al., 2001). Elevated heart rate during a social stressor task was associated with more concurrent internalising problems in adolescent boys (Nederhof, et al., 2015). Other studies reported a positive association between anxiety and elevated heart rate in anticipation to and during a stressor (Hastings, Zahn-Waxler, & Usher, 2007; Kossowsky et al., 2011; Li & Lopez, 2006; Matthew et al., 1986). Past research showed that anxious children had higher heart rates prior to, during and after a stressor task, such as a speech task, and reported more subjective anxiety compared to non-anxious children (Matthew et al., 1986). This finding was replicated by Schmidt et al.'s (1999) speech task study, where high and moderate shy children showed greater heart rate reactivity than low shy children. Altogether, these studies illustrate that anxious youths are characterised by an elevated heart rate response immediately prior to and during a stressor task, as well slower heart rate recovery post-task.

Conversely, evidence suggests anxious or shy children are characterised by a blunted heart rate reactivity to stress. Children with SP demonstrated a blunted heart rate reactivity in anticipation to, during and after the TSST-C, and although the task did not produce differing heart rate reactivity profiles between SP children and healthy children, SP children showed slower heart rate recovery from the task (Schmitz et al., 2011). Other studies have demonstrated slower heart rate recovery post-task in anxious children (Krämer et al., 2012; Schmitz et al., 2013) and greater heart rate recovery in non-anxious children (Alkozei et al., 2015). Children with SP also exhibited a slower increase in heart rate to the task compared to healthy children (Krämer et al., 2012). Lower heart rate during the speech task was associated with higher levels of post-speech anxiety (Hastings et al., 2007). Thus, blunted heart rate reactivity to stress may characterise either all anxious children with varying anxiety disorders, or only SP children in the face of social stressors.

From the identified literature, a few studies have used heart rate as an outcome measure for treatment and therapies (Armstrong, Collins, Greene, & Panzironi, 1998; Benoit Allen et al., 2015; Eisen & Silverman, 1998; Tsai, Friedman, & Thomas, 2010; Zaichkowsky & Zaichkowsky, 1984), and to examine the effects of information bias paradigms (Lester, Field, & Muris, 2011). Two studies reported that reduced heart rate was associated with relaxation training (Zaichkowsky & Zaichkowsky, 1984) and tailored therapy (Eisen & Silverman, 1998). However, most studies showed no improvement or reduction in heart rate after various therapies and programs (Armstrong et al., 1988; Klein-Heßling & Lohaus, 2002) despite decreases in subjective distress, behavioural avoidance and anxiety after therapies (Bacow, May, Choate-Summers, Pincus, & Mattis, 2010; Benoit Allen et al., 2015).

Studies that manipulated information and stimuli also produced mixed findings. Children exhibited higher heart rates when placing their hands in and out of boxes that supposedly contained an animal after vicarious learning about scare-paired and unpaired animals (Reynolds et al., 2014), whilst Field and Price-Evans (2009) reported that elevated heart rates when approaching the box was associated with boxes paired with threatening information (vs positive or no information). Except for studies conducted by Balle et al. (2013) and Weems et al. (2015), the effects of fearful visual or auditory stimuli on heart rates do not differentiate between healthy children, children with anxiety disorders (Leen-Feldner, Zvolensky, & Feldner, 2004; Turner, Beidel, & Epstein, 1991; Williams & Woodruff-Borden, 2015). The effects of unpleasant stimuli on heart rates also did not differentiate between adolescents with either high or low exposure to community violence (Cooley-Quille, Boyd, Frantz, & Walsh, 2001). Furthermore, Balle et al. (2013) reported that healthy children demonstrated a more flexible heart rate reactivity in response to a passive viewing task than children with high levels of behavioural inhibition. Given the inconsistent findings regarding heart rate reactivity and anxiety, there is insufficient evidence to support heart rate reactivity as a reliable measure of therapy outcomes and effects of information manipulation.

Very few studies investigated parasympathetic cardiovascular reactivity and anxiety, of which a minority reported significant associations (Beidel, Fink, Turner, 1996; El-Sheikh et al., 2013; Kossowsky et al., 2011; Schmidt et al., 1999; Schmitz et al., 2011). However, most studies did not find abnormal parasympathetic cardiovascular response to various stressor tasks in children with PTSD (Kirsch et al., 2015), children with SAD (Asbrand et al., 2016) and healthy non-disordered children (Aldao, McLaughlin, Hatzenbuehler, & Sheridan, 2014; Kaeppler & Erath, 2017). Similarly, of the studies that examined sympathetic cardiovascular reactivity (blood pressure, mean arterial pressure, systolic and diastolic blood pressure and pre-ejection period), the majority found no evidence of abnormal sympathetic cardiovascular reactivity in anxiety disordered children (Allwood et al., 2011; Anderson & Hope, 2009; Beidel, 1988; Beidel et al., 1994; Gerra et al., 1992; Nederhof et al., 2015; Stroud et al., 2009). Overall, parasympathetic and sympathetic cardiovascular reactivity to stressors are not associated with anxiety or anxiety disorders in youths.

Electrodermal Sympathetic Activity Studies

Twenty-eight studies measured electrodermal activity in youths under the guise of various terms such as skin conductance level, skin conductance response, skin conductance reactivity, sympathetic skin response, palmar sweat index, and electrodermal sympathetic index. Eight studies also measured non-specific skin conductance fluctuation. As previously stated, electrodermal activity is innervated by the sympathetic nervous system. Overall, the findings suggest anxious youths are not characterised with an abnormal electrodermal physiology at rest. Most studies examining basal electrodermal activity found no differences between anxious and non-anxious youths (Kossowsky et al., 2013), between high shy and low shy children (Schmitz et al., 2013), high anxious and low anxious youths (Weems et al., 2005), or between selective mute children, social phobic children and healthy controls (Young et al., 2012). Despite some studies providing evidence that basal electrodermal activity is associated with anxiety (El-Sheikh et al., 2013; Schmitz et al., 2011), the majority of the literature suggests no relationship between anxiety and basal electrodermal profiles between anxious and non-anxious individuals.

Regarding electrodermal reactivity to stressors, the majority of studies report mixed evidence as to whether abnormal electrodermal response to stressful or anxiety-provoking tasks are associated with anxiety. The findings suggest children with anxiety disorders are characterised by an autonomic hyperarousal response to stress, demonstrated by greater electrodermal activation (Asbrand et al., 2016; Bakker, Tijssen, van der Meet, Koelman, & Boer, 2009; Myllyneva, Ranta, & Hietanen, 2015; Young et al., 2012), and that clinically anxious children demonstrate a distinct electrodermal pattern, a decline and increase in skin conductance during a fear acquisition paradigm (Turner et al., 1991) and extinction paradigm (Waters & Pine, 2016). In contrast, other studies reported no association between anxiety and abnormal electrodermal reactivity to stressor tasks, as demonstrated in studies examining children with PTSD and children with trauma history and no PTSD (Kirsch et al., 2015), anxious and non-anxious youths (Kossowsky et al., 2011, 2013), high shy and low shy children (Miers et al., 2011; Schmitz et al., 2013), social phobic children and healthy controls (Schmitz et al., 2011) and high anxious and low anxious children (Weems et al., 2005). However, it is too early to conclude that anxious youths, or youths with anxiety disorders show an abnormal electrodermal response to stressor tasks. Unlike other physiology studies, the electrodermal studies that found a significant association reported the same direction, that anxious individuals exhibit elevated skin conductance responses.

Salivary Alpha-Amylase Studies

Only five studies examined salivary alpha-amylase in relation to anxiety and anxiety disorders in youths, of which four studies examined a non-clinical youth population. These four studies also examined cortisol as both cortisol and salivary alpha-amylase. Interestingly, adolescents showed a sustained salivary alpha-amylase response to a peer-rejection stressor (children showed no significant change from baseline), and both adolescents and children showed no changes in salivary alpha-amylase response to the mental arithmetic and mirror tracing task (Stroud et al., 2009). Replicating Stroud et al.'s study design and methods, Allwood et al. (2011) reported that salivary alpha-amylase reactivity was associated with trait anxiety and physiological anxiety. These two studies suggest sympathetic nervous system reactivity is associated with anxiety elicited by stressors in non-clinical sample populations and that basal salivary alpha-amylase can differentiate between high anxious and low anxious children. However, Krämer et al.'s (2012) study failed to show any differences in salivary alpha-amylase reactivity to the two stressor tasks between healthy children and SP children. In fact, SP children reported significantly higher subjective anxiety from the stressors and both groups showed a significant salivary alpha-amylase increase from baseline to the social stressor (Krämer et al., 2012). Two other studies found that age appears to influence the effect of anxiety on salivary alpha-amylase and other physiological parameters (El-Sheikh et al., 2005, as cited in Granger et al., 2006; Stroud, Handwerger, Kivilghan, Granger, & Niaura, 2005, as cited in Granger et al., 2006). Salivary alpha-amylase may be associated with anxiety in healthy youths, however additional research is needed to clarify the role of salivary alpha-amylase in anxiety disorders, and test for differences between anxious and non-anxious youths.

HPA-Axis – Cortisol Studies

Thirty-three studies measured cortisol (salivary, urinary and plasma) in youths, of which five studies took frequent morning samples to document *cortisol awakening response* and one study recorded *diurnal cortisol profile*s (Dieleman, van der Ende, Verhulst, & Huizink, 2010; Dieleman et al., 20154Kallen et al., 2008; Oskis, Loveday, Hucklebridge, Thorn, & Clow, 2009; Nelemans et al., 2014). One study measured plasma adrenocorticotrophic hormone (Gerra et al., 1992).

The literature remains inconclusive regarding the relationship between anxiety in youths and basal cortisol levels. Of the 14 studies that reported on basal cortisol profiles, anxiety disorders and internalising symptoms, 64% of studies reported no significant relationships between basal cortisol profiles, anxiety and internalising problems (Allwood et al., 2011; Dieleman et al., 2010; Dorn et al., 2003; Kallen et al., 2008; Martel et al., 1999; Oskis et al., 2009; Schmidt et al., 1999; Tennes & Kreye, 1985; Williams et al., 2013). Although no differences on cortisol awakening response profiles were found between anxious children and a general population group, Dieleman et al. (2014) reported that children with anxiety disorders had significantly lower basal cortisol levels than their general population counterparts. Regarding cortisol awakening response, five studies reported no association between anxiety disorders and cortisol awakening response profiles (Dieleman et al., 2010, 2015; Kallen et al., 2008; Oskis et al., 2009; Nelemans et al., 2014). However, Kallen et al. found that girls with low MASC scores had higher cortisol awakening response than girls who score high on the measure, yet there were no differences between patients with GAD, SepA, SP and specific phobia disorders. It is possible cortisol awakening response cannot differentiate between separate anxiety disorders. Yet some longitudinal studies found basal cortisol levels and cortisol awakening response may signal an individual's risk or propensity to developing anxiety disorders (Laurent, Gilliam, Wright, & Fisher, 2015; Nelemans et al., 2014; Pfeffer, Altemus, Heo, & Jiang, 2007; Schiefelbein & Susman, 2006). In another study, morning cortisol levels at age 3–4 were associated with a heightened cortisol response to stressor tasks and sustained elevation, in turn predicting anxiety symptoms at ages 9–10 (Laurent et al. 2015). Further, girls whose basal cortisol levels greatly increased over 14 months reported more generalised anxiety and social anxiety symptoms (Scheifelbein & Susman, 2006). Klimes-Dougan, Hastings, Granger, Usher, and Zahn-Waxler (2001) reported that female adolescents had an elevated midday and late afternoon cortisol profile when compared with males, particularly for female adolescents with no disorder. There is no foregone conclusion on whether anxious individuals are characterised with a specific cortisol profile, but it is clear developmental and gender effects play a role. Altogether, these studies suggest future research should examine youths with a range of anxiety symptoms and disorders, and have more frequent measurement throughout many years to better track basal cortisol profiles.

The research exploring youths' cortisol reactivity to stressor tasks suggests that internalising problems and anxiety disorders are not associated with an abnormal cortisol response to stress, however it is too early to conclude direction and interaction effects with other physiological systems. A number of studies found no differences in cortisol reactivity to a stressor between non-anxious and anxious youths (Dorn et al., 2003; Krämer et al., 2012; Martel et al., 1999), between non-anxious children and children with early life stress (Burkholder, Koss, Hostinar, Johnson, & Gunnar, 2016), between high, middle and low shy children (Schmidt et al., 1999) and high and low shy children, even though high shy children reported more nervousness prior to the speech task (Miers et al., 2011). Interestingly, cortisol levels in SP children remained the same before and after the stressor task and there were no differences between SP children and healthy controls on cortisol reactivity (Krämer et al., 2012). Conversely, other studies reported that anxious youths exhibit a heightened cortisol response to a stressful task relative to non-anxious children. High cortisol reactivity to a parent-child conflict discussion task predicted internalising problems and anxiety disorders in children 6 months later, however the study used children from outpatient clinics and there was no comparison group (Granger, Weisz, McCracken, Ikeda, & Douglas, 1996). Elevated cortisol response and greater pre-ejection period reactivity was associated with greater numbers of internalising problems in 16–19 year old boys (Nederhof et al. 2015). Additionally, low cortisol reactivity predicts internalising problems in boys and girls (Nederhof et al., 2015). Oddly, only SP children with high trait anxiety showed an elevated cortisol response to a social stressor; state anxiety was unrelated (van West, Claes, Sulon, & Deboutte 2008). In stark contrast, a reduced cortisol response to stressors predicted internalising and anxiety symptoms in adolescents (Klimes-Dougan et al., 2001). The mixed directions of these significant associations between cortisol reactivity and various anxiety measures and disorders is perplexing, and further research should clarify if anxiety is associated with high or low cortisol reactivity to stressor tasks.

Objective Measures and Youth Perception of Physiological Arousal

Many studies reported a discordance (or synchrony-desynchrony) between anxious youth's subjective reports of anxiety and objective physiological measures. These studies, utilising a variety of physiological parameters, showed no physiological differences between anxious and non-anxious youths, despite the anxious group reporting more subjective anxiety and physiological symptoms (Anderson & Hope, 2009; Beidel et al., 1994; Kirsch et al., 2015; Kossowsky et al., 2013; Kristensen et al., 2014; Stroud et al., 2009; Waters & Kershaw, 2015). Anderson and Hope (2009) reported that although SP children reported greater subjective anxiety from the tasks, there were no differences between SP and non-anxious children in heart rate reactivity to two stressor tasks. This lack of correspondence between physiological reactivity and subjective anxiety was also found in other studies examining high shy and low shy children (Miers et al., 2011; Schmitz et al., 2012) and children with social anxiety, high shy children and healthy controls (Anderson et al., 2010). High shy children reported more subjective nervousness and sweatier palms than low shy children, even though there were no group differences in heart rate, skin conductance and cortisol levels during, before and after the speech task (Miers et al., 2011). Children with high social anxiety worried more about symptom visibility and perceived their heart rate much higher than children with low social anxiety when receiving heart rate feedback via speaker—however this was unrelated to actual heart rate before and during the stressor (Schmitz et al., 2012). Discordance was also found in children with PTSD who reported greater anxiety before and during exposure to a trauma script than children with a trauma history but no PTSD: there were no sympathetic and parasympathetic differences between groups during the study (Kirsch et al., 2015).

Adolescents reported less anxiety after receiving a mindfulness therapy program compared to those who received the control program, however both groups did not differ in cortisol levels at baseline or follow-up, nor did cortisol levels change pre- and post-therapy (Sibinga et al., 2013). This finding of subjective anxiety and stable cortisol levels has been reported by Krämer et al. (2012), who found the same discordance for salivary alpha-amylase and heart rate. This was also supported by Dieleman et al. (2010) and might explain Spies, Margolin, Susman, and Gordis's (2011) findings. Spies et al. reported that adolescents with low internalising symptoms showed greater cortisol reactivity and associated subjective distress to a stressful discussion task, but no such association was found for adolescents with higher internalising symptoms. Some caveats with this study is that the authors did not include other anxiety inventories to capture disorder symptoms and state/trait anxiety. Altogether, these studies support the notion that youths with anxiety disorders or other anxiety-related symptoms and problems demonstrate discordance between their subjective distress and physiological response to stressors.

Discussion

There are many diverse findings and results within this field of research, which likely relate to different methodologies, parameters measures, and population samples examined across the studies. Overall, the studies together indicate that resting heart rate, heart rate variability and blood pressure (systolic, diastolic blood pressure, mean arterial pressure) are not reliable indicators of anxiety in youths, and further investigations are required to clarify whether low respiratory sinus arrhythmia (or lower vagal tone) is associated with anxiety. The results also indicate that cardiovascular measures such as respiratory sinus arrhythmia and blood pressure reactivity to stress are unreliable indicators of anxiety or anxiety disorders in youth. However, a substantial proportion of studies examining heart rate reactivity to stress produced three findings: 1) anxiety or anxiety disorders are not associated with abnormal heart rate reactivity to stress; 2) youths with anxiety disorders demonstrate elevated heart rate reactivity to a stressor task relative to non-anxious youths; and 3) anxious youths demonstrate a blunted heart rate reactivity and recovery to stressor tasks, relative to non-anxious youths. Although most studies did conclude no association between anxiety disorders and abnormal heart rate reactivity to stress, there were equally similar support for the other two findings, thus no firm conclusions can be drawn. Overall, anxiety is not associated with resting electrodermal activity and there is mixed evidence for anxiety being characterised with abnormal electrodermal reactivity. Roughly half of the studies reported greater electrodermal stress reactivity associated with anxiety, whilst the other half reported no association. Preliminary youth studies indicate salivary alpha-amylase does not appear to be associated with anxiety disorders, but may be associated with anxiety symptoms in a healthy general population sample of youths. There is mixed support for the associations between anxiety and basal cortisol levels, and between anxiety and cortisol stress reactivity. Discordance between self-reported distress and physiological stress have been documented by some studies, reporting that anxious and non-anxious youths exhibit similar physiological stress responses; however anxious youths reported significantly greater subjective distress relative to non-anxious youths.

Studies such as Young et al. (2012) indicate that to elicit the strongest physiological response in anxious youths, the stressor tasks should be disorder-specific, e.g. separation task for children with SepA. This review also found many physical tasks are not sufficiently anxiety-provoking and do not reflect activities that are normally feared, e.g. public speaking, interaction with a stranger. However, the voluntary hyperventilation challenge is a pragmatic procedure for examining physiological stress in youths with PD as it mimics panic and anxiety attack symptoms (Leen-Feldner et al. 2005).

Lastly, the multifaceted nature of autonomic physiology in anxious and non-anxious youths are not well captured as 65 studies measured only one or two physiological parameters, and 16 studies measured numerous cardio-related autonomic parameters but ignored other autonomic parameters such as electrodermal activity. Studies that utilised relevant stressor tasks and broadly assessed autonomic and neuroendocrine systems more often reported differences on certain physiological parameters between groups of disordered children and healthy counterparts (e.g. Dieleman et al., 2014, Kossowsky et al., 2011; Nederhof et al., 2015; Schmitz et al., 2011; 2013; Stroud et al., 2009).

Literature Gaps and Future Directions

Significant methodological limitations were present in most studies, for example, many studies measured a singular physiological parameter when measuring multiple parameters would better capture the multifaceted nature of the autonomic nervous system. For example, in Nederhof et al.'s (2015) study, they found that increased heart rate was due to unique interactions between respiratory sinus arrhythmia (parasympathetic) and pre-ejection period (sympathetic) occurring within individuals and the authors stressed that future physiological studies must incorporate sympathetic and parasympathetic measures to best understand the effect. Future studies should endeavour to measure physiological parameters that represent the physiological systems outlined earlier (i.e. skin conductance, respiratory sinus arrhythmia) as to better capture overall physiological stress reactivity. Some studies used only parent reports of children's anxiety, however some studies have indicated poor correspondence between parent and child reports of anxiety (Greaves-Lord et al., 2007) and therefore future studies should include both parent and child reports.

The systematic review found some suggestions that individual differences in anxiety sensitivity and behavioural inhibition are important in mediating the effects found (Leen-Feldner et al., 2004, 2006), and so future studies should control for these factors. For example, a study reported that anxiety sensitivity mediated the relationship between subjective anxiety and physiological reactivity in response to a hyperventilation task—adolescents with high anxiety sensitivity and showed greater heart rate response reported high levels of post-challenge anxiety (Leen-Feldner et al., 2006). Investigating unique and related aspects of anxiety may further shed light on the mixed evidence.

Within the identified studies, the sample population varied in sample size, age range, and in heterogeneity—both offer strengths and limitations to the ecologically validity and generalisability of a study. For example, Weems et al. (2005) noted that dividing 49 children into groups according to anxiety levels had severely minimized sample size and that the wide age range may have masked any effects of anxiety on physiology. Determining whether physiological responses differ across ethnicity, gender, and age can create an informed platform on which researchers can better interpret findings. Another common drawback is the lack of control groups for comparison (Bacow et al., 2010; Granger, Weisz, & Kauneckis, 1994; Waters & Kershaw, 2015). Including another group of healthy children might reveal an atypical response unique to anxiety disorders.

Future studies should carefully select appropriately aversive, arousing and stressful tasks that are ecologically valid. As demonstrated by Asbrand et al. (2016) and Young et al. (2012), strong abnormal or heightened autonomic response is elicited by disorder-specific tasks, and future studies should incorporate both disorder-specific and non-disorder-specific tasks. A physical exercise task such as stepping up and down or standing up (orthostatic challenge) may not significantly increase state anxiety and could mask any modest physiological and cognitive differences between individuals with varying anxiety disorders and anxiety-related dimensions. Arguably, the physical exertion and cognitive elements involved in a stepping task are not the same components activated when youths approach and perform an anxiety-provoking task like an impromptu speech—it is hard to believe a stepping task is comparable to worry about a school exam or public speaking. Furthermore, Greaves-Lord et al. (2010) noted that participants’ heart rate increased and respiratory sinus arrhythmia levels decreased as participants stood up (orthostatic challenge) from a sitting position. Future researchers who use tasks that require participants to stand up or move around must carefully consider this, especially if participants were sitting during baseline measurements.

Researchers should also examine the elements involved in stressor tasks and carefully decide which tasks are appropriate for hypothesis testing. Some researchers consider the mental arithmetic task (serial subtraction) a cognitively challenging task, and Stroud et al. (2009) argued that public speaking and mental arithmetic tasks are performance-oriented rather than socio-evaluative, despite participants performing both tasks in front of an audience or experimenter, and thus have an inherent socio-evaluative element. Future studies should aim to eliminate socio-evaluation elements from cognitive or physical tasks, and tests of cognitive/physical capabilities from socio-evaluative tasks. As different tasks are likely to elicit differing developmental physiological responses amongst disordered individuals

(Asbrand et al., 2016; Young et al., 2012), future studies should also aim include a variety of stressor tasks that are disorder-specific and non-disorder-specific.

An important issue raised by Alkozei et al. (2015) is that control participants may approach the stressor tasks with a level of excitement and determination to perform well, rather than respond with anxiety, fear or distress. Some studies varied in the amount of threat participants perceived, e.g. participants were told to perform in front of a live audience of peers or adults or that the performance would be recorded and later evaluated judged by peers or adults. One study allowed mothers to accompany the child during stressor tasks, potentially lessening the child's anxiety levels (Alkozei et al., 2015). These individual and methodological differences may influence the child's perceived threat and it would be worthwhile to include mastery motivation measures in future studies.

Studies that reported discordance between self-reported distress (and physical arousal) and actual physiological responses implicate the perception of physiological arousal as an important target for anxiety treatment. Drawing an individual's attention to the stark contrast between self-reports and objective measures of physical arousal would enable a more accurate perception of their physical arousal and use prior information to challenge negative cognitions (Anderson & Hope, 2009; Siess et al., 2014; Thomas, Aldao, & De Los Reyes, 2015). Further work is required to explore the phenomena of discordance in youths, and to investigate if individual differences influence discordance, or whether discordance is unique to certain anxiety disorders more so than others.

The length of physiological assessment varied greatly across studies, which may have contributed to non-significant findings. Several studies only measured physiology from baseline to the end of the stressor (Reynolds et al., 2014; Wild, Freeston, Heary, & Rodgers, 2014) and others measured physiology intermittently (Gonzalez et al., 2011), thus losing potential data that could indicate dysregulated physiology. To capture the physiological differences in anxious and non-anxious children, or the general physiological response to stress, future studies should also include easier collection methods, continuous physiology measures throughout the tasks, ecologically valid stressors, and a recovery measurement phase; the length of the recovery phase should also be relevant to the physiological phenomena.

Review Strengths and Limitations

To our knowledge, this paper presents a current update and overview of research on physiological differences in children and adolescents with anxiety disorders. The focus on both autonomic and endocrine differences, as well as perceptual differences, offered a more comprehensive than other reviews (e.g. Siess et al., 2014) on the physiological component of anxiety disorders in children and adolescents.

One of the limitations of this review was excluding studies that reported on respiration. Respiration is closely associated with respiratory sinus arrhythmia (Berntson et al., 2016; Grossman & Taylor, 2007) and innervated by the ANS (Kreibig, 2010), and attention was often drawn to controlling respiration rate during voluntary hyperventilation tasks or when measuring respiratory sinus arrhythmia/vagal tone (Aldao et al., 2014; Kossowsky et al., 2013; Scott & Weems, 2014). In the reviewed studies, respiration was not a common physiological parameter measured, but this was likely due to omitting ‘respiration’ from initial search terms. The search terms also focused primarily on social anxiety, generalised anxiety, and used the general encompassing term of “psychophysiology” and “physiology”. A more comprehensive collection of physiological studies on youth populations would have emerged had all anxiety disorders and relevant physiological parameters been actively included in the search terms, and expanding to other databases, e.g. MEDLINE. However, this review was produced to precede experimental research examining children with anxiety disorders and their perception of physical arousal during stressful tasks.

Conclusion

Within this review, we found evidence that anxious youths have a biased perception towards their somatic symptoms. There was some evidence for autonomic (or physiological) hyperarousal, and conversely some evidence for blunted physiological reactivity in anxious youths in response to stress. However, there was less evidence to support chronic hyperarousal in anxious individuals, as most studies did not find physiological differences between anxious and non-anxious youths at rest. Multiple physiological parameters and multiple comparison groups are required to understand the physiology of anxiety in children and adolescents both at rest, and towards ecologically valid stressors. The phenomena of discordance has promising applications in anxiety therapies, where therapists can highlight an anxious individual’s disconnect between subjective experience and physical arousal.

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Abstract

Despite the high prevalence of anxiety disorders affecting children and adolescents (Lawrence et al., 2015), the physiology of anxiety in anxious youths is poorly understood. Adult studies, diagnostic criteria and cognitive models of anxiety disorders indicate the importance of physiology in characterising and maintaining anxiety disorders. However, it is less clear whether physiological arousal to anxiety-provoking stressors can distinguish between youths with and without anxiety, and whether anxious youths report abnormal physiological arousal in general or to disorder-specific stressors. This study investigated the differences between anxious and non-anxious children and adolescents on self-reported state anxiety and physical symptoms across different stressor tasks, and examined whether task specificity predicted differences in youths' physical symptoms and state anxiety. Clinically anxious youths (n = 27, aged 7–14 years) and healthy controls (n = 23, aged 7–17 years) completed a series of tasks (speech, interaction, tangram), rating their state anxiety and physical symptoms after each task. Participants completed additional self-report measures on their automatic thoughts, anxiety symptoms, social phobia and perfectionism. Results suggested that across all tasks, anxiety and physical symptoms differed between youths with social anxiety, other anxiety disorders, and no disorder. The social tasks were associated with heightened state anxiety and physical symptoms across all participants. There was some evidence of disorder-specific tasks eliciting stronger responses, specifically social anxiety measures predicting stronger responses in social tasks. The results may explain why individuals with social anxiety have poorer outcomes in standard anxiety treatment.

Keywords: social anxiety disorder, anxiety disorder, physiology, stress, children, adolescents

Comparing Youths' Self-Reports of Somatic Symptoms to Disorder-Specific and Non-Disorder-Specific Stressors

Anxiety disorders remain some of the most prevalent psychiatric disorders globally (Alonso et al., 2004; Slade et al., 2009) and are highly prevalent among Australian children and adolescents (Lawrence et al., 2015; Rapee, Schniering, & Hudson, 2009). Cognitive processes (e.g. threat appraisal), behavioural processes (e.g. avoidance or stressful endurance) and increased physiological arousal underlie and maintain anxiety disorders. Physiological arousal or reactivity interacts with cognitive and behavioural processes leading to an increased awareness of and arousal to the perceived threat (Clark & Wells, 1995). While research has shown individuals with anxiety have distorted cognitive and behavioural processes, it is less clear whether physiological arousal can differentiate youths with anxiety disorders from those without. Many adult studies and some child studies have reported conflicting evidence of heightened autonomic arousal or restricted physiological flexibility to stress. Recent studies have shown differences in subjective self-reports and objective measures of physical arousal between anxiety-disordered individuals and healthy controls. However, relative to adult studies, few studies have examined children's and adolescents' perceived physiological arousal to various stressors, and whether this differs between anxiety-disordered youths and healthy counterparts.

Physiology in Cognitive Theories of Anxiety Disorders

Physiological arousal and processes are prominent features in contemporary aetiological models of anxiety and anxiety disorders. For example, Clark and Watson's (1991) tripartite model of anxiety and depression asserts that anxiety and depression are different manifestations of an underlying vulnerability and differ along three dimensions: positive affect, negative affect, and physical hyperarousal. Watson et al. (1995a, 1995b) contend that physical hyperarousal (or physical symptoms) is specific to anxiety, with some research supporting this theoretical framework (e.g. Anderson, Veed, Inderbitzen-Nolan, & Hansen, 2010; Cannon & Weems, 2006; Chorpita, Albano, & Barlow, 1998; Dieleman, van der Ende, Verhulst, & Huizink, 2010), however, this model may not accurately capture the diversity of anxiety disorders (Brown, Chorpita, & Barlow, 1998; Greaves-Lord et al., 2007). Brown et al. reported that physical (or autonomic) arousal was strongly associated with Generalised Anxiety Disorder (GAD), Panic Disorder (PD) with or without Agoraphobia, but not associated with Obsessive-Compulsive Disorder (OCD) nor Social Phobia (SP) in adults. This implies that physiological arousal may differ between anxiety disorders, however, little research has examined this, especially in child samples.

Other cognitive models of anxiety disorders include physiological processes which contribute to and maintain anxiety disorders (Clark, 1986; Clark & Wells, 1995; Sandin, Sánchez-Arribas, Chorot, & Valiente, 2015; Wells & Carter, 1999, 2001). These models suggest that an anxious individual's maladaptive attention and monitoring generates hyperawareness or sensitivity towards bodily phenomena that they then often interpret as threatening, thus maintaining or exacerbating anxiety. For example, Wells and Carter (1999, 2001) proposed that individuals with GAD may interpret somatic symptoms—racing heart and sweating—as evidence of an impending "mental breakdown". Similarly, according to Clark and Wells' (1995) cognitive model of Social Anxiety Disorder (SAD), an individual's heightened sensitivity towards their physical symptoms draws them to misinterpret or exaggerate the physical symptoms and potentially believe these symptoms are visible to others, which becomes a source of embarrassment (Anderson & Hope, 2009), thus ultimately maintaining the disorder (Rapee & Heimberg, 1997). Clearly the role of physiological symptoms in the development and maintenance of anxiety disorders is important.

Physical Symptoms in Anxiety Disorders

Physical (or somatic) symptoms of anxiety form part of the key diagnostic criteria for most anxiety disorders in both the *International Statistical Classification of Diseases and Related Health Problems* (10th ed.; ICD-10; World Health Organisation [WHO], 2016) and the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM-V; American Psychology Association [APA], 2013; Wilhelm & Roth, 2001). For example, to meet DSM-5 diagnosis for GAD, anxiety and worry must be associated with at least three of six symptoms: restlessness, easily fatigued, difficulty concentrating, irritability, muscle tension, and sleep disturbance for a duration of at least 6 months (APA, 2013). Similarly, ICD-criteria for GAD require at least four out of 22 physical symptoms to be present, of which one must be either heart palpitations, sweating, trembling/shaking or a dry mouth. The requirement for the presence of physical symptoms occurs for both adults and children with anxiety disorders.

Research has demonstrated that somatic complaints are prevalent among youths (children and adolescents) with anxiety disorders (Ginsburg, Riddle, & Davies, 2006), who also report more symptoms than non-anxious youths (Beidel, 1991; Kristensen, Oerbeck, Torgersen, Hansen, & Wyller, 2014). Ginsburg et al. found the most frequently reported somatic symptoms among 128 youths with anxiety disorders were restlessness (74%), stomach aches (70%), blushing (50%), palpitations (48%), muscle tension (45%), sweating (45%), and trembling/shaking (43%). Additionally, older children (12+ years) reported more somatic symptoms than younger children (6–11 years; Ginsburg et al., 2006). Similarly, Kendall and Pimentel (2003) found that 9–11-year-old children reported fewer symptoms than 11–13-year-old children. It is unclear whether these age-based differences are because older children experience more physical symptoms or because they become more cognisant of their symptoms as they age. The latter seems more likely. Kendall and Pimentel (2003) reported disagreement between child and parent reports of children’s physical symptoms, whereby parents reported more symptoms than their children and these endorsements did not differ with respect to children's ages, suggesting that older children identified more physical symptoms. Yet, despite the importance of physiological symptoms in diagnostic tools and prevalence of physiological complaints, our understanding of the role of physiological mechanisms in anxiety disorders is limited, especially in regard to children and adolescents.

Physiological Dysregulation in Anxiety

Despite abundant literature, it is unclear whether anxious individuals—particularly youths—experience abnormal or dysregulated physiology in general, or only show a dysregulated physiological response to specific threats (Krämer et al., 2012). Physiological theories have proposed that anxious individuals exhibit chronically elevated autonomic arousal in the absence and presence of stressors, a pattern termed *restricted autonomic flexibility* (Friedman, 2007; Porges, 2007; Thayer & Lane, 2000). Friedman (2007) suggested that anxious individuals have an inflexible autonomic response at rest and towards stressors, and that they would not exhibit the usual increased sympathetic nervous system activity nor decreased parasympathetic activity in comparison to non-anxious individuals. Friedman (2007) further proposed anxious individuals' bodies would recover more slowly after the stressor has ended, relative to non-anxious individuals. In a large Dutch cohort study, Greaves-Lord et al. (2010) found restricted autonomic flexibility predicted anxiety levels in adolescent girls two years later. Other child studies found clinically anxious individuals and high anxious individuals at risk exhibiting a diminished, blunted or restricted physiological/ autonomic flexibility in response to laboratory stressors (Balle, Tortella-Feliu, & Bornas, 2013; Schmitz, Krämer, Tuschen-Caffier, Heinrichs, & Blechert, 2011; Schmitz, Tuschen-Caffier, Wilhelm, & Blechert, 2013). In Siess, Blechert, and Schmitz's (2013) systematic review, socially anxious youths (both clinical and non-clinical samples) exhibited a restricted physiological response to social stressors. Therefore, there is evidence that anxious youths have restricted physiological response to stress, mimicking the findings from adult samples (Hoehn-Saric & McLeod, 2000; Hoehn-Saric, McLeod, Funderburk, & Kowalsky, 2004; Hoehn-Saric, McLeod, & Hipsley, 1995; Hoehn-Saric, McLeod, & Zimmerli, 1989, 1991).

Yet a competing alternative physiological response profile has been reported to characterise clinically anxious youths—*heightened autonomic arousal* (Asbrand, Blechert, Nitschke, Tuschen-Caffier, & Schmitz, 2016; Young, Bunnell, & Beidel, 2012). In Siess et al.'s (2013) review, only studies that examined test anxiety, high shyness or high social anxiety in youths found elevated autonomic reactivity—this profile was not found in studies examining participants diagnosed with SAD. Furthermore, Young et al. (2012) found partial evidence for autonomic arousal—children with SP showed significantly elevated electrodermal reactivity to a social stressor, and differed significantly on heart rate compared to controls. However, Alkozei, Creswell, Cooper, and Allen (2015) reported no autonomic differences between children with and without an anxiety disorder at rest and during stressor tasks. Due to the inconsistent findings and conflicting theories, little consensus has been reached on the physiological profile of a clinically anxious youth, nor is it clear if physiological profiles can reliably differentiate between youths with different anxiety disorders. It is also unclear if anxious children exaggerate the severity of their symptoms, or actually experience severe somatic symptoms.

Interoceptive Awareness

Several studies have shown *interoceptive awareness* (recognition of bodily sensations) is associated with various anxiety disorders in adults: panic disorder (Ehlers, Mayou, Sprigings, & Birkhead, 2000; Eley, Stirling, Ehlers, Gregory, & Clark, 2004; Wald & Taylor, 2005; White, Brown, Somers, & Barlow, 2006), social anxiety/phobia (Pineles & Minneka, 2005), generalised anxiety disorder (Hoehn-Saric et al., 2004; McLeod, Hoehn-Saric, & Stefan, 1986), anxiety-specific arousal symptoms (Dunn et al., 2010), trait anxiety and anxiety symptoms (Richard & Bertram, 2000). Adults with PD (Ehlers et al., 2000), children with panic symptoms (Eley et al., 2004) and children with SAD (Anderson & Hope, 2009) also showed heightened awareness of internal physiological cues e.g. heartbeat. However, the above studies focused on cardiac perception when other physiology measures are available. Moreover, interoceptive awareness of physiological symptoms does not necessarily equate to an accurate perception of real-time physiological response. Individuals may perceive a change in physiological arousal, but inaccurately perceive the degree of change (McLeod et al., 1986). Very few child studies have actively examined interoceptive awareness or explored differences in self-reported physical arousal in anxious youths.

Physiological Discordance

Krämer et al. (2012) suggested that anxious individuals inaccurately perceive their physical arousal during stressful situations and recent research corroborates this claim. Adult studies, utilising objective physiological measures and subjective reports of arousal collected before, during and after stressor tasks, reported poor or no associations between objective and subjective measures (Hoehn-Saric et al., 2004; Jamieson, Nock, & Mendes, 2013; McLeod et al., 1986). Discordance between objective and subjective measures of arousal have also been demonstrated in many child and adolescent studies: anxious youths reported higher levels of perceived symptoms when facing a feared task, contrary to objective physiological measures that demonstrate similar physiological arousal in anxious and non-anxious youths (Anderson & Hope, 2009; Kirsch, Wilhelm, & Goldbeck, 2015; Klumbies, Braeuer, Hoyer, & Kirschbaum, 2014; Kristensen et al., 2014; Mauss, Wilhelm, & Gross, 2003; Miers, Blöte, Sumter, Kallen, & Westenberg, 2011; Stroud et al., 2009; Wilhelm, Gerlach, & Roth, 2001). Edelmann and Baker (2002) compared the self-reports and objective measures of physiological arousal (heart rate, skin conductance) between social phobics, clinically anxious and non-anxious controls across four stressor tasks (riding an exercise bike, mental arithmetic, social conversation, mental imagery task). There were no physiological differences between the three groups and all groups generally had inaccurate self-reports. However, despite showing similar physiological reactivity, SP participants reported higher heart rates during tasks involving social threats and both clinically disordered groups endorsed higher ratings of a racing heart during the imagery task and higher ratings of sweaty hands during the conversation (Edelmann & Baker, 2002). In a novel study, Schmitz, Blechert, Krämer, Asbrand, and Tuschen-Caffier (2012) gave children heart rate feedback either via a speaker (in a public condition) or headphones (private condition) whilst delivering a speech. Schmitz et al. reported that high anxious children perceived their heart rate to be greater than low anxious children in both conditions despite having similar heart rates. These studies support the concept of discordance between subjective experience and actual physiological reactivity that characterises anxious individuals, particularly those with SP or SAD, which is more pronounced when the stressor targeted their main fear. The mounting evidence highlights the role of cognition and somatic perception in anxiety disorders, and that self-reported physical arousal is potentially a more reliable predictor of anxiety than actual physiological reactivity, which has potential clinical benefits.

Effects of Content/Disorder-Specific Stimuli

Research suggests that interpretation biases in anxious individuals may be content- or disorder-specific. Content- or disorder-specific stimuli may elicit stronger physiological reactions in anxious individuals which could account for the conflicting evidence regarding physiological reactivity to stressors, and explain non-significant findings in studies that hypothesised restricted physiological response or heightened autonomic arousal. Anxious patients show stronger physiological reactions to disorder-specific stimuli than non-anxious controls, and this has been demonstrated in patients with GAD (Hoehn-Saric et al., 1989), OCD (Hoehn-Saric et al., 1995), and PD (Hoehn-Saric et al., 1991). Content-specificity also influences the interpretations made by socially anxious individuals—e.g. SAD individuals had more negative interpretations about social situations compared to non-anxious individuals, yet those groups did not differ in interpretations for non-social situations (Gramer, Schild, & Lurz, 2012; Huppert, Foa, Furr, Filip, & Mathews, 2003; Miers, Blöte, Bögels, & Westenberg, 2008; Voncken, Bögels, & de Vries, 2003; Wilson & Rapee; 2005). Bögels, Sneider, and Kindt (2003) examined children with GAD, specific phobia and SAD, and compared their interpretations of situations specific to each disorder. The study found that SAD children reported significantly more negative interpretations to disorder-specific scenarios than children with specific phobia or GAD. Partial support was found for content-specificity in children with specific phobia who reported significantly more negative interpretations associated with disorder-specific scenarios than SAD children, but did not differ from GAD children. However, there were no differences on interpretations between the three groups on GAD-specific scenarios. The authors suggested this may be due to overlapping worries associated with specific phobia and SAD (Bögels et al., 2003). Miers et al. found that highly socially anxious adolescents were significantly more likely to rate negative interpretations of social situations as coming to mind than those with average levels of social anxiety, and no difference was found for non-social situations, after controlling for negative affect in participants. However, this study could not examine whether interpretation bias for social situations is specific to social anxiety compared to other anxiety disorders.

Future research will need to determine whether eliciting anxiety and stress increases individuals' awareness of their bodily sensations and symptoms, and whether anxious individuals have poor perception of the severity of these symptoms, and clarify the nature of anxious individuals' physiological reactivity to stressors. Further research should also investigate whether youths' physiological arousal and perception of physiological arousal is specific to stressors related to the youths' fears or psychopathology. For instance, it would be informative to examine whether children with social anxiety have a more heightened perception of their physical arousal during stressful social tasks than other stressful non-social tasks, and whether awareness of physical arousal differs between disordered groups.

The Present Study

Based on existing research on content-specificity and physiological symptoms associated with anxiety, the present study aims to answer two research questions; first, are there differences in self-reported arousal (state anxiety) and physical symptoms between anxious and non-anxious youths across different stressor tasks, and second, does task specificity uniquely predict differences in physiological symptoms and state anxiety. Conducted in a laboratory setting, children and adolescents completed two socio-evaluative tasks and one cognitive task, and reported on the frequency and severity of physical symptoms and anxiety that occurred during the tasks. It was hypothesised that:

1. Physical symptoms and state anxiety will differ between youths diagnosed with primary social anxiety disorder (SAD), youths with other primary anxiety disorders (OAD), and healthy controls (ND).
2. Physical symptoms and state anxiety will differ on task type, in that youths with social anxiety will report greater state anxiety and more physical symptoms to the social tasks than the non-social task. There will be no differences on both measures between the youths with social anxiety and youths with other anxiety disorders on the non-social task. Overall, all anxiety groups will be more aroused than the non-disordered youths across the tasks, and the non-disordered youths will endorse fewer physical symptoms and less state anxiety across all tasks.
3. Social fears, as measured by the child MiniSPIN, CATS social threats and SCAS social anxiety scores, will provide unique contributions to state anxiety and physical

symptoms associated with the social tasks, over and above SCAS general anxiety, perfectionism and CATS personal failure scores.

4. Non-social fears related to CATS personal failure and self-prescribed perfectionism will provide unique contributions to state anxiety and physical symptoms associated with the non-social tasks as reported by youths with anxiety disorders when controlling for social fears.

Methods

Participants

The two recruitment streams produced a total of 54 study participants (see Table 2 for sample characteristics). The clinical group comprised 27 participants. These participants (*M* = 9.21 years, *SD* = 1.97, age range of 7–14 years) had a current primary anxiety disorder based on the Anxiety Disorder Interview Schedule 4th edition parent and child version (ADIS-IV-C/P; Silverman & Albano, 1996). Participants were excluded if the child was at current risk of harm, an inpatient, was receiving concurrent psychological therapy, had a diagnosis of Autism Spectrum Disorder, required significant assistance within the classroom or was not enrolled in mainstream schooling. The participants and their parents were required to have English literacy, and participants taking psychotropic medications were required to be stabilised on their medication for one month prior. The primary anxiety diagnoses were as follows: Social Anxiety Disorder (*n* = 16, 59.3%), Generalised Anxiety Disorder (*n* = 4, 8.0%), Specific Phobia (*n* = 3, 11.1%), Anxiety Disorder not otherwise specified (*n* = 3, 11.1%), and Separation Anxiety Disorder (*n* = 1, 3.7%). There were also two participants (with either generalised anxiety or separation anxiety disorder) who had social anxiety as a secondary diagnosis.

The control group comprised 23 participants (*M* = 10.7, *SD* = 2.93, age range 7–17 years) who did not meet criteria for any mental disorders based on the ADIS-IV-C/P. Controls were recruited via social media advertisements circulated through the Psychology Department and the Centre for Emotional Health at Macquarie University, Sydney. We also advertised through the Neuronauts Brain Science Club for children and parents interested in participating in research. The participants and their parents were also required to have adequate English literacy skills. Participants seeking psychological treatment at the time were excluded. The control participants received $30 reimbursement for their participation.

Initially there were 54 participants, however, four participants were removed from data analysis. Three clinical participants were removed as the primary disorder diagnosis was not an anxiety disorder, and one community participant was removed due to responder fatigue (e.g. giving straight-line responses).

Materials

Anxiety Disorders Interview Schedule

Psychopathology was screened using the semi-structured Anxiety Disorders Interview Schedule 4th edition parent/child version (ADIS-IV-C/P; Silverman & Albano, 1996) adapted for the Diagnostic and Statistical Manual – Fifth Edition (DSM-V; American Psychiatric Association, 2013). Both the child and parent versions were conducted either face-to-face session for clinical participants or via telephone for control participants. Interviews were conducted by clinical psychologists and clinically trained postgraduate students who received training on ADIS administration and regular supervision. Interrater reliability using the ADIS-C/P has been demonstrated in our clinic to be adequate (Lyneham, Abbott, & Rapee, 2007; Rapee, Barrett, Dadds, & Evans, 1994) and telephone delivery has been found to be as reliable as face-to-face delivery (Lyneham & Rapee, 2005).

Children's Automatic Thoughts Scale

The Children's Automatic Thoughts Scale (CATS; Schniering & Rapee, 2002) is a 20-item questionnaire designed to measure children and adolescents' automatic thoughts. Participants were asked to indicate the frequency they experienced each thought over the past week using a 5-point scale from 0 (*Not at all*) to 4 (*All the time*). The current study used only two subscales of the original measure: social threat (CATS-ST) and personal failure (CATS-PF). Schniering and Rapee (2002) reported adequate internal consistency for both subscales was high, with a coefficient alpha of .92 for social threat and .92 for personal failure. Schniering and Rapee (2002) also reported test-retest correlations for social threat was .78 at 1 month and .73 at 3 months, and for personal failure was .80 at 1 month and .74 for personal failure. These psychometric properties were considered adequate (Schniering & Rapee, 2002) and were successfully replicated by Schniering and Lyneham (2007). In the current sample, internal reliabilities were adequate (CATS-ST α = .97, CATS-PF α = .97).

Spence Children's Anxiety Scale

The Spence Children's Anxiety Scale (SCAS; Spence, 1998) was administered to parents and children to assess child current anxiety symptoms. Responders were asked to rate the frequency of anxiety symptoms over the past four weeks using a 4-point scale from 0 (*Never*) to 3 (*Always)*. The Child SCAS consists of 44 items and the Parent version consists of 38 items, and produced a total score and six subscale scores in line with the DSM-IV criteria for panic/agoraphobia, social anxiety (social phobia), separation anxiety, generalised anxiety, obsessive-compulsive disorders and fear of physical injury. In the current study, internal consistency was considered acceptable, and child scores ranged from 2–68, and parent scores ranged from 0–54. The SCAS has demonstrated good reliability and concurrent validity (Spence, 1998). In the current study, only the social anxiety, generalised anxiety and total scores were relevant. Internal consistencies of SCAS scores were adequate in the current sample (Child SCAS Total α = .93, Child SCAS-SAD α = .84, Child SCAS-GAD α = .82; Parent SCAS Total α = .94, Parent SCAS-SAD α = .87, Parent SCAS-GAD α = .85).

Mini-Social Phobia Inventory

The 3-item Mini-Social Phobia Inventory (MiniSPIN; Connor, Kobak, Churchill, Katzelnick, & Davidson, 2001) is an abbreviated version of the 17-item Social Phobia Inventory (SPIN; Connor et al., 2000). Both child and parent were asked to rate how true the three items were from 1 (*Not at all)* to 5 (*Extremely*). The following items were “Fear of embarrassment causes me (my child) to avoid doing things or speaking to people”, “I (My child) avoids activities in which I am (he/she is) the centre of attention” and “Being embarrassed or looking stupid are among my (my child’s) worse [sic] fears”. The Mini-SPIN cut-off of 6 or greater has demonstrated 90% accuracy in diagnosing presence of generalised social anxiety disorder in an adult population (Connor et al., 2001) and demonstrated good psychometric properties in an adolescent general population (Ranta, Kaltiala-Heino, Rantanen, & Marttunen, 2012). Internal consistency for the current sample was adequate (child α = .86, parent α = .95).

State Anxiety Rating

Adapted from the State Anxiety Rating (SAR) from Rapee and Abbott (2007), a 6-item measure was administered at the end of each stressor task to assess children’s state anxiety in relation to the task. Originally created for speech tasks, the items were also amended for the interaction and tangram task (e.g., “I felt like stopping the speech”, “I felt like stopping the conversation”). The items focused on feelings of worry, escaping, shyness/embarrassment, anxiety/fear, wanting to stop the task, and hiding. Participants indicated whether they experienced the above statements on a 5-point Likert-type scale from 0 (*Not at all*) to 4 (*Extremely*). If participants did not complete or attempt the stressor task, they completed the SAR imagining they had completed the task. Total SAR scores ranged from 0 to 24. For the purposes of the current study, the SAR acted as a manipulation check to see if the tasks increased state anxiety in the participants. Internal consistency was previously reported as .96 for the original 10 items. For the current study, internal consistency was conducted twice per stressor task: The Cronbach's alpha based upon participants who completed the real SAR version was compared against the Cronbach's alpha of a singular SAR variable, comprising real and imagined SAR responses. As there were no large differences between the two values for each stressor task, it was decided to combine the real and imagined SAR responses into a singular SAR variable for later analyses. Internal consistency of the 6 items in the current sample were as follows: SAR-Speech $\alpha = .93$; SAR-Interaction $\alpha = .93$; SAR-Tangram $\alpha = .92$.

Self-Report Measure of Physical Symptoms

The Self-Report Physical Symptom Questionnaire (SRSQ) was developed for this study and measured the extent to which participants experienced 10 physical symptoms or sensations during the experimental stressor tasks (see Table 1). Each physical symptom was rated on a 5-point Likert-type scale from 0 (*Not at all*) to 4 (*Extremely*). Similarly, if participants did not complete or attempt the task, they completed the SRSQ imagining that they had completed the task. Although we did not conduct a pilot test, we collated the symptoms from an unpublished study that had recorded the frequency of physical symptoms endorsed by anxious children. The same method was used to investigate the internal consistency of the SRSQ, i.e. internal consistency was conducted twice per stressor task, with one test examining only real SRSQ responses, and the other test examining both real and imagined responses as a singular SRSQ variable. As there were no marked differences between the two values for each stressor task, the real and imagined SRSQ responses were combined into one variable. The internal consistency are as follows: SRSQ-Speech α = .93; SRSQ-Interaction α = .95; SRSQ-Tangram α = .92.

Table 1. The 10-item Self-Report Measure of Physical Symptoms

Did you feel funny in your stomach
Did you feel butterflies in your stomach
Was your heart racing or beating really fast/hard
Did you feel shaky in your arms or legs
Did you feel tingly in your arms or legs
Did you feel like you were going to faint
Did you feel dizzy or light-headed
Did you have a dry mouth like you needed a drink of water
Did you feel tightness in your throat
Did you feel suddenly very hot?

Child-Adolescent Perfectionism Scale

The updated Child-Adolescent Perfectionism Scale (CAPS; Flett et al., 2016) was designed to measure Self-Oriented Perfectionism (SOP) and Socially Prescribed Perfectionism (SPP) among child and adolescent populations. The measure consists of 22 items (e.g., "I try to be perfect in everything I do", "My family expects me to be perfect") and participants were asked to rate how true each statement was for them using a 5-point Likert-type scale 1 (*False*) to 5 (*Very true of me*). Flett et al. argued SOP is the exceptionally high standards directed towards the self, while SPP is a combination of having high standards, being driven to achieve these standards, and responses to outcomes. The internal consistency for the current sample was adequate (Total α = .83, SOP α = .82, SPP α = .72).

Stress Induction Tasks

The study used three stressor tasks: a speech task, an interaction task and a tangram puzzle task. The two social tasks (speech and interaction task) were based upon the tasks and instructions developed by Dodd et al. (2011) and the tangram task was adapted from Hudson and Rapee (2001). Only the speech task required the parent to be present with their child.

The speech task started with the parent, child and experimenter in the room, with a pen and paper placed on a table in front of the child. Participants were asked to prepare a speech (2-minutes duration for 7–12-year-olds; 3-minutes for 13–17-year-olds) about a topic of their choice. Participants were informed they could change topics during the speech if they liked, but that their speech would be video recorded and later evaluated by two clinic staff. Parents were told they could help their child during the three minutes available for speech preparation but only if their child needed help. The experimenter left the room and returned after three minutes, then the parent was asked to leave the room. The experimenter instructed the participants to stand and face the camera. The experimenter also stated "I will sit here next to the camera. I will remain neutral throughout the speech. Remember, we will be recording you while you give your speech so two clinic staff can later mark you on how well you do. I will let you know when the (two/three) minutes have passed so keep talking until I tell you to stop. You can start". At the start of the task, if a participant did not speak for more than 10 seconds, the experimenter provided the following prompts in order, waiting 10 seconds between prompts or between participants' responses: "Would you like to talk about a movie you saw recently?", "Would you like to talk about something you did recently – your last holiday?", "Would you like to talk about something you are learning at school?" If the participant did not respond to the third prompt within 10 seconds, the experimenter terminated the task and thanked the participant for their efforts. If a participant requested their parent to stay or if the experimenter thought a participant would not attempt the speech without their parent, the parent was instructed to sit next to the confederate, to remain neutral and make no physical or verbal distractions.

The interaction task required participants to hold a 3-minute conversation with an adult confederate, aged in their 20s. The participants could talk about anything with the confederate, but were also instructed to get to know the confederate as well as possible and to ask questions. The participants were told that the conversation would be video recorded and later judged by two clinic staff. The confederate was instructed to act neutral, respond minimally to the participants, and to glance at them every 10 seconds. If a participant did not speak for 10 seconds, the confederate could use three prompts, one at a time at 10-second intervals: e.g. “I see”, “Hmm”, “Ok”. If the participant had not spoken for a further 10 seconds, three open-ended statements were used one at a time: e.g. “It’s a nice day today”, “I wonder how long we’ve been here”, “I’m not sure what I’ll do after this”. If the participant did not speak for another 10 seconds, the confederate asked three questions: “What kind of movies do you like/books do you like to read”, “Do you have any hobbies?”, “What did you do at the weekend?” If the participant had not spoken for 10 seconds after the last prompt, the confederate left the room, and the experimenter returned to terminate the task.

The tangram task was a cognitive task, designed to be difficult, and challenged participants to solve tangram puzzles for a prize reward. Participants were asked to solve as many puzzles as possible within a time limit (3 minutes for 7–10-year-olds, or 5 minutes for 11–17-year-olds). Participants were told they would not be video-recorded during the challenge and that the more puzzles they solved, the more prizes they would get. For example, 7–10-year-old children were told they would receive a small prize for solving one tangram puzzle within 3 minutes, and two small prizes if they solved four puzzles within the time limit. Participants were also told the experimenter would knock on the table for every minute that passed. If a participant did not attempt to solve the puzzle for 10 seconds, was visibly frustrated or struggling, the experimenter could use up to three prompts (four prompts for 7–9 year olds), one at a time: e.g. “Remember you can always try a different shape if this one is too hard", "You still have some time left, keep going", "How about you have a go at one of the other ones". If the participant did not respond within 10 seconds to the last prompt, the experimenter terminated the task and thanked the participant for their efforts.

Procedure

This study was conducted as part of a randomised controlled trial for the treatment of child and adolescent anxiety. The study was approved by Macquarie University Human Research Ethics Committee. Before participation, all children and their parents provided written and informed consent. Although all children and parents completed a diagnostic interview, the same online questionnaire pack and attended the research session, the order of the research study components differed between groups. For control participants, the diagnostic interview was conducted first to confirm the absence of mental health issues before proceeding to the online questionnaires and then attending the research session. Clinical participants completed the online questionnaires first, and then attended a face-to-face assessment, followed by the research session.

During the research session, both parent and child completed the same experimental tasks. At the end of each stressor task, participants completed the SAR and SRSQ. If participants did not complete or attempt the task, they were asked to complete questionnaires imagining that they had completed the task. This allowed responses to the items designed to assess for anxiety awareness of physical symptoms. Participants completed the CAPS last. The experimenters running the research sessions were instructed to remain neutral throughout the research session, and give minimal responses or encouragement.

Due to research protocol required for the parent study, full randomisation of the tasks was not possible, instead the speech and interaction task were randomly completed first, followed by the tangram task for all participants regardless of group status. Hence, the order of tasks was either a) speech, interaction, tangram, or b) interaction, speech, tangram.

Statistical Analyses

We performed statistical analyses using IBM SPSS 24. To answer the first two hypotheses, we used a mixed model analysis, otherwise known as multilevel linear modelling (MLM) or hierarchical linear modelling (Howell, 2013; Tabachnick & Fidell, 2013). We also conducted hierarchical multiple regressions and simple multiple regressions.

Visual inspection of histograms, Q-Q plots and P-P plots, and Shapiro-Wilks statistics showed that many of our measures violated assumptions of normality and there were outliers. Square root transformations improved Child SCAS-GAD and Child SCAS Total measures. Although Child SCAS-GAD had a significant Shapiro-Wilks statistic overall, when inspecting normality of the measure between diagnosis groups, only one group violated assumptions but was also approaching non-significance. Log10 transformations improved Child SCAS-SAD, CAPS-SOP, CAPS total score and Child MiniSPIN measures. Child SCAS-SAD and Child MiniSPIN improved overall but still violated assumptions of normality overall. When inspecting Shapiro-Wilks statistics for Child SCAS-SAD between diagnosis groups, only one group violated assumptions but was approaching non-significance. Inverse transformations improved CATS-ST slightly, and Log10 improved CATS-PF by removing some outliers, but there were still some violations of normality for both measures. Square root transformation improved Parent SCAS-SAD and Parent SCAS-GAD measure best, however there still violations of normality and outliers. Lastly, although square root transformations worked best for Parent MiniSPIN, the measure was kept untransformed as it was not needed for hypothesis testing. Only CAPS-SPP and Parent SCAS Total were left untransformed.

As the mixed model analysis can deal with violations of assumptions (normality distribution, independence of errors), unequal sample sizes, and tolerate missing values, we proceeded with using the analysis technique (Tabachnik & Fidell, 2013). However, residual plots reveal assumptions of normality, linearity and homoscedascity were violated for state anxiety and physical symptoms for all three tasks. Square root transformations improved SAR and SRSQ responses for each task. There were fewer outliers but still some violations of normality when inspecting Shapiro-Wilks by diagnosis groups. All analyses were conducted with a *p*-value significance less than .05.

While all community participants completed the three tasks, a small proportion of clinical participants were too anxious to complete the speech task (N = 5, 18%) and interaction task (N = 3, 11%), and therefore provided ratings based on imagining how they would have felt if they completed the tasks. The internal reliabilities of the SAR and SRSQ responses for the real ratings minus the imagined ratings did not vary substantially from the combined (real and imagined) SAR and SRSQ responses; hence, we decided to combine real and imagined responses together for subsequent analyses. Furthermore, although the tasks could not be fully counterbalanced, the mixed model ANOVAs accounts for task order.

Results

Sample Characteristics

Table 2 details sample characteristics and demographics by recruitment streams. As child's age, child's gender, family setting, family's ethnicity and family's gross weekly income violated assumptions of normality and homogeneity of variances, the non-parametric Mann Whitney U-Test was conducted to compare differences between the clinical and control groups. There were no significant age differences between the clinical and control groups (U = 223, p = .085, two-tailed), and no significant difference in gender between the clinical and control groups (U = 309.5, p = .982, two-tailed). Similarly, no differences between the clinical and control groups were found for family structure (U = 276, p = .103, two-tailed), family's ethnicity (U = 299, p = .790, two-tailed), and family's gross weekly income (U = 273, p = .460, two-tailed).

Table 2. Sociodemographic Characteristics of the Sample by Recruitment Streams

	Clinical Group (*n* = 27) No. (% within group)	Control Group (*n* = 23) No. (% within group)
Gender (male)	14	13
Family income, AU$/year		
52, 000 – 124, 799	10 (37.0%)	6 (26.1%)
124, 800 – 207, 888	8 (29.6%)	5 (21.7%)
208, 000 – 332, 799	5 (18.5%)	12 (52.3%)
> 332, 800	4 (14.8%)	0
Family Structure		
Two parents	24 (88.9%)	23 (100%)
Single parent	3 (11.1%)	0
Ethnicity		
Oceanian	18 (66.7%)	15 (65.2%)
European	6 (14.8%)	5 (8.7%)
Asian	1 (3.7%)	2 (4.3%)
Other	2 (3.7%)	1 (4.3%)
Principal diagnosis		
Generalised anxiety disorder	4 (8.0%)	0
Social anxiety disorder	16 (59.3%)	0
Separation anxiety disorder	1 (3.7%)	0
Specific phobia	3 (11.1%)	0
Anxiety disorder not otherwise specified	3 (11.1%)	0
No diagnosis	0	23 (100%)
Received stable psychopharmacological medicine	2 (7.4%)	0

Note: Oceanian (e.g. Australian, Aboriginal, Torres Strait Islander, New Zealander, Solomon Islander, Papua New Guinean, Samoan, Tongan), European (North-West European, e.g. British, Irish, Austrian; Southern and Eastern European, e.g. Italian, Maltese, Spanish), Asian (South-East Asian, e.g. Lao, Thai; North-East Asia, e.g. Chinese, Taiwanese, Japanese), Other (People of the Americas, e.g. American, Argentinian, Brazilian; North African and Middle Eastern, e.g. Egyptian, Iraqi, Lebanese).

Descriptive results were calculated for the three diagnostic groups (see Table 3): No Disorder (ND; M = 10.70 years, SD = 2.93, range of 7–17 years), Other Anxiety Disorder (OAD; M = 9.27 years, SD = 1.55, range of 7–12 years), and primary Social Anxiety Disorder (SAD; M = 9.25 years, SD = 2.30, range of 7–14 years). Assumptions of normality and homogeneity of variances were violated for child's age and gender, family structure, ethnicity and income. When considering differences in demographics between SAD, OAD, and ND groups, Kruskal-Wallis tests revealed that there were no statistically significant differences between the three groups on child's gender, $\chi^2(2) = 1.749$, $p = .417$, child's age, $\chi^2(2) = 3.072$, $p = .215$, family's ethnicity, $\chi^2(2) = 0.697$, $p = .706$, and family's gross weekly income, $\chi^2(2) = 1.341$, $p = .512$. However, the groups did differ significantly on family structure, $\chi^2(2) = 11.089$, $p = .004$.

Table 3. Sociodemographic Characteristics of the Sample by Diagnosis Group

	SAD (*n* = 16) No. (% within group)	OAD (*n* = 11) No. (% within group)	ND (*n* = 23) No. (% within group)
Gender (male)	10 (62.5%)	4 (36.4%)	12 (52.2%)
Family Income, AU$/year			
52, 000 – 124, 799	6 (37.5%)	4 (36.4%)	6 (26.1%)
124, 800 – 207, 999	3 (18.8%)	5 (45.5%)	5 (21.7%)
208, 000 – 332, 799	5 (31.3%)	0	12 (52.2%)
> 332, 800	2 (12.5%)	2 (18.2%)	0
Family Structure			
Two parents	16 (100%)	8 (72.7%)	23 (100%)
Single parent	0	3 (27.3%)	0
Ethnicity			
Oceanian	10 (62.5%)	8 (72.7%)	15 (65.2%)
European/Asian/Other	6 (37.5%)	3 (27.3%)	8 (34.7%)
Principal diagnosis			
Generalised anxiety disorder	0	4 (36.4%)	0
Social anxiety disorder	16 (100%)	0	0
Separation anxiety disorder	0	1 (9.1%)	0
Specific phobia	0	3 (27.3%)	0
Anxiety disorder not otherwise specified	0	3 (27.3%)	0
No diagnosis	0	0	23 (100%)
Received stable psychopharmacological medicine	2 (12.5%)	1 (9.1%)	0

Overview of Anxiety Measures

To compare if correspondence between Child and Parent SCAS total scores was affected by the child's age, a hierarchical linear regression was performed with transformed variables. All assumptions of the linear regression were met. We found that child's age did not affect the correspondence between the Child and Parent SCAS reports, $\Delta R^2 = .02$, $\Delta F(1, 47) = 2.478$, $p = .122$. Child's age also did not influence the correspondence between Child and Parent MiniSPIN scores, $\Delta R^2 = .01$, $\Delta F(1, 47) = 1.088$, $p = .302$. After removing child age from the model, parent reports explained 66% of the variance in Child MiniSPIN scores, $R^2 = .657$, adjusted $R^2 = .651$, $F(1, 48) = 91.948$, $p = .000$. Parent SCAS explained 65% of variance in Child SCAS reports, $R^2 = .645$, adjusted $R^2 = .637$, $F(1, 48) = 87.041$, $p = .000$.

Table 4. Percentages of the Top 5 Physical Symptoms Endorsed by Diagnosis Groups During Stressor Tasks.

Top 5 symptoms	**Diagnosis Group**
	SAD (*n* = 16)
Stomach feeling funny	14 (54%)
Butterflies in stomach	14 (54%)
Increased heart rate	14 (54%)
Feeling hot	14 (54%)
Shaky arms/legs, Dizziness*	13 (54%)
	OAD (*n* = 11)
Butterflies in stomach	9 (82%)
Stomach feeling funny	8 (73%)
Tight throat	6 (55%)
Feeling hot	6 (55%)
Increased heart rate, Shaky arms/legs, Dizziness, Dry Mouth*	4 (36%)
	ND (*n* = 23)
Stomach feeling funny	12 (52%)
Increased heart rate	11 (48%)
Feeling hot	10 (43%)
Butterflies in stomach	9 (39%)
Tingly arms/legs	8 (35%)
Note: * Symptoms were endorsed equally	

To check that the anxiety measures were closely associated with one another, a correlation table was produced using Spearman’s Rho using the untransformed variables: most were non-parametric. Table 5 shows that many variables were moderately correlated with each other as expected. There was a strong correlation between CATS-PF and CATS-ST ($r_s = .85$, $p = .000$, two-tailed, $N = 50$). As expected, there was a strong positive correlation between the SAR and SRSQ rating for the speech task ($r_s = .79$, $p = .000$, two-tailed, $N = 48$), and a strong positive correlation between SAR and SRSQ rating for the interaction task ($r_s = .89$, $p = .000$, two-tailed, $N = 48$). There was a moderate correlation between the SAR and SRSQ rating for the tangram task ($r_s = .54$, $p = .000$, two-tailed, $N = 50$). Table 4 reports the top five symptoms endorsed by the three disorder groups.

Table 5. Spearman's Rank Order Correlations of Untransformed Child and Parent MiniSPIN, Child and Parent SCAS, CATS, CAPS, SAR and SRSQ Ratings

Scale	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. CATS Social Threat	—																	
2. CATS Personal Failure	.85**	—																
3. Child MiniSPIN	.76**	.62**	—															
4. Parent MiniSPIN	.67**	.58**	.81**	—														
5. CAPS Self-Oriented	.16	.09	.20	.04	—													
6. CAPS Socially Prescribed	.22	.38**	.28*	.22	.41**	—												
7. CAPS Total	.25	.27	.30*	.14	.89**	.76**	—											
8. Child SCAS-SAD	.81**	.70**	.85**	.80**	.27	.34*	.38**	—										
9. Child SCAS-GAD	.76**	.72**	.56**	.57**	.09	.07	.11	.71**	—									
10. Child SCAS Total	.73**	.74**	.65**	.66**	.06	.20	.16	.77**	.91**	—								
11. Parent SCAS-SAD	.72**	.61**	.78**	.92**	.09	.22	.18	.83**	.64**	.72**	—							
12. Parent SCAS-GAD	.54**	.58**	.52**	.65**	–.03	.05	.00	.55**	.77**	.77**	.70**	—						
13. Parent SCAS Total	.61**	.60**	.59**	.75**	–.08	.08	–.02	.62**	.78**	.83**	.81**	.92**	—					
14. SAR-Speech	.54**	.56**	.61**	.59**	–.01	.18	.08	.65**	.64**	.65**	.53**	.46**	.51**	—				
15. SAR-Interaction	.56**	.58**	.57**	.62**	–.04	.23	.08	.70**	.60**	.62**	.62**	.45**	.50**	.75**	—			
16. SAR-Tangram	.37***	.34**	.50**	.50**	–.09	.11	.02	.45**	.40**	.43**	.47**	.39**	.44**	.59**	.54**	—		
17. SRSQ-Speech	.59**	.58**	.50**	.58**	–.09	.15	.01	.66**	.64**	.63**	.58**	.46**	.52**	.79**	.77**	.60**	—	
18. SRSQ-Interaction	.52**	.54**	.56**	.63**	.00	.27	.11	.69**	.64**	.65**	.68**	.57**	.60**	.70**	.89**	.46**	.80**	—
19. SRSQ-Tangram	.17	.19	.25	.37**	–.09	.19	.02	.32*	.25	.35*	.37**	.30*	.36*	.40**	.50**	.54**	.54**	.50**

Note: ** p < 0.01 (2-tailed), * p < 0.05 (2-tailed)

Hypotheses Testing

Hypothesis 1 and 2

To investigate whether physical symptoms and state anxiety differed between youths with no anxiety disorder, youths diagnosed with primary social anxiety disorder, and youths with other primary anxiety disorders, a 3 x 3 mixed model ANOVA was conducted twice. Diagnosis group was the between-subjects factor (SAD, OAD, HC), task was the within-subjects factor (speech, interaction, tangram) and square root transformed SAR and SRSQ were the DVs. Furthermore, child's sex and gender, family structure, family ethnicity and family's gross income were included as covariates. Multivariate outliers were not an issue in the final model with SAR as the DV, as the Mahalanobis distance did not exceed the critical $\chi 2$ for $df = 3$ (at $\alpha = .001$) of 16.266. Similarly, Mahalanobis distance did not exceed the critical $\chi 2$ for $df = 2$ (at $\alpha = .001$) of 13.816 for any cases in the final model of the SRSQ. Tolerance and variance inflation factor (VIF) values indicated multicollinearity was not an issue for both final models. Intraclass correlations from a null model indicated individual differences accounted for 54% of variance in SAR and 60% of variance in SRSQ.

To determine the most concise model, we performed a series of multilevel models. First, a null model was performed where SAR was entered as the DV, and subject was entered as a random effect. Next, a full model examined SAR by diagnosis and task with additional covariates (e.g. child's sex, child's gender, family structure, family ethnicity, and family gross weekly income). This model was significantly better than the null model which only included intercepts (i.e. differences among subject), $\chi 2(15, N = 150) = 516.577 - 461.082 = 55.495$, $p = .001$. These predictors as a group improved the model beyond that produced considering variability in individuals. Task and diagnosis were significantly associated with SAR, and only child's sex was significantly associated. The interaction between task and diagnosis was non-significant, $F(4, 107) = 1.08$, $p = .37$. As child's sex was significant, an additional model inspected whether there were any interactions between sex, task and diagnosis, with none of the interactions approaching significance. A final model was proposed in which only two fixed predictors (task, diagnosis) and one covariate (child's sex) was examined. The final model did not significantly differ from the full model, $\chi2(8, N = 150) = 468.512.577 - 461.082 = 7.43$, $p > .05$. Table 6 summarises the three models.

Table 6. Comparison of Multilevel Models for transformed SAR and SRSQ by Task and Diagnosis

Model	**–2 Log Likelihood**	**df**	**χ^2 Difference Test**
SAR			
Null	516.577	2	
Full	461.082	17	M1 – M2 = 55.495*
Final	468.512	9	M3 – M2 = 7.43
SRSQ			
Null	543.278	2	
Full	495.019	17	M1 – M2 = 48.259*
Final	504.405	8	M3 – M2 = 9.386

Note: *p < .001

Beginning with state anxiety from the stressor tasks, we obtained a significant main effect child's sex, $F(1, 139) = 6.775$, $p = .01$. Compared to male participants ($M = 1.85$, $SD = 0.14$), females ($M = 2.34$, SD = 0.14) across groups and tasks reported higher SAR ($t = 2.603$, $p = .010$). We also obtained a significant main effect for diagnosis groups, $F(2, 139) = 43.892)$, $p = .000$. The ND group ($M = 1.16$, $SD = 0.14$) reported significantly less SAR across tasks than did the SAD group ($M = 3.14$, $SD = 0.17$), ($t = -9.261$, p .000). The OAD group ($M = 1.96$, $SD = 0.20$) also reported significantly less SAR across tasks than did the SAD group ($t = -4.511$, $p = .000$). Pairwise comparisons indicate the OAD group reported higher SAR across groups than the ND group, $p = .003$. Lastly, we found a significant main effect for task, $F(2, 110) = 13.790$, $p = .000$. Across groups, the speech task ($M = 2.40$, $SD = 0.18$) was associated with a SAR increase of 0.96 compared to the tangram task ($M = 1.45$, $SD = 0.14$), ($t = 4.291$, $p = .000$). The interaction task was also associated with a 0.99

increase in SAR across groups compared to the tangram (t = 4.384, p = .000). Pairwise comparisons reveal that the speech and interaction task did not differ from each other on SAR (p = 1.00). Trends of the transformed SAR means by diagnosis and task can be seen in Figure 1.

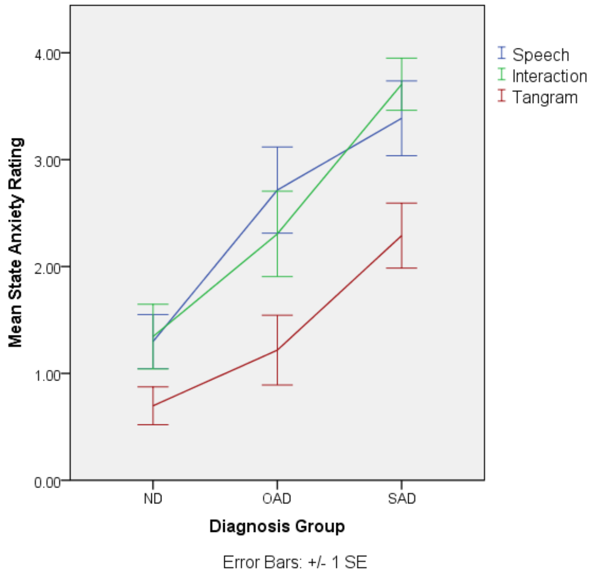

Figure 1. Mean State Anxiety Ratings (Square Root Transformed) of Each Stressor Task by Group

A similar procedure was conducted to determine the best-fit model for SRSQ (see Table 5). We compared a null model with subject as a random effect and SRSQ as the DV against the full model. The full model is identical to the full model conducted earlier, except we examined transformed SRSQ instead. The full model was significantly better than the null model, $\chi^2(15, N = 150) = 543.278 - 495.019 = 48.259$, p = .001. Both ask and diagnosis were significantly associated with SRSQ, however, the interaction between task and diagnosis was not significant, $F(4, 107) = 1.08$, p = .37. No covariates were associated with SRSQ. A final model included only task and diagnosis as predictor variables. The final model did not significantly differ from the full model, $\chi^2(9, N = 150) = 504.405 - 495.019 = 9.386$, $p > .05$.

The 3 x 3 mixed model ANOVA produced a significant main effect for diagnosis group, $F(2, 144) = 32.127$, p = .000. The ND group (M = 0.94, SD = 0.17) reported significantly less SRSQ across tasks than the SAD group (*M* = 3.00, *SD* = 1.96), (*t* = -8.001, *p* = .000). Similarly, the OAD group (*M* = 1.70, *SD* = 0.24) reported significantly less SRSQ across tasks than the SAD group (*t* = -4.305, *p* = .000). Pairwise comparisons showed the ND group reportedly significantly less SRSQ across tasks than OAD (*p* = .034). We also obtained a significant main effect for task, *F*(2, 104) = 10.966, *p* = .000. Compared to the tangram task (*M* = 1.18, *SD* = 0.18), the speech task (*M* = 2.11, *SD* = 0.21) was associated with a SRSQ increase of 0.94 across all groups (*t* = 3.478, *p* = .001). Across groups, the interaction task (*M* = 2.34, *SD* = 0.21) significantly increased in SRSQ by 1.16 compared to the tangram task (*t* = 4.289, *p* = .000). Pairwise comparisons show that interaction and speech did not differ significantly on SRSQ (*p* = 1.00). Both the speech and interaction, compared to the tangram task, were associated with increased physical symptoms across all groups (*p* = .001–.002). Figure 2 displays the trends of the transformed SRSQ means by diagnosis and task.

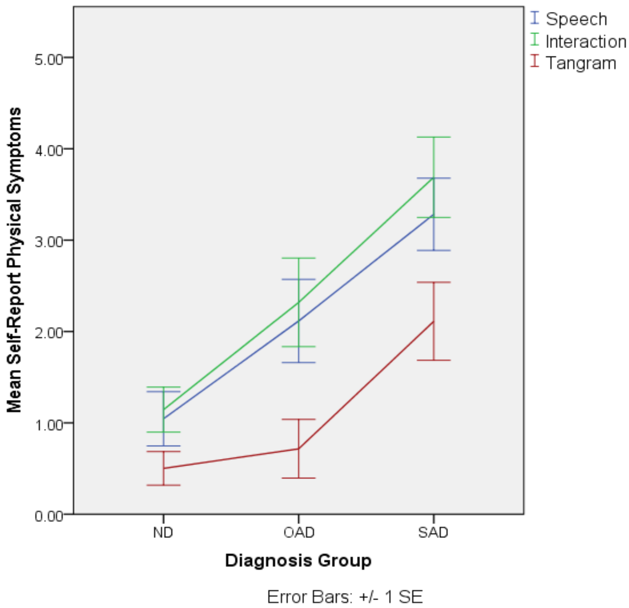

Figure 2. Mean Physical Symptoms (Square Root Transformed) of Each Stressor Task by Group

Additional paired samples *t* tests with an α of .05 were conducted to check if the ND group reported similar levels of distress (square root transformed SAR) to the speech task (*M* = 1.30, *SD* = 1.21), the interaction task (*M* = 1.34, *SD* = 1.45) and the tangram task (*M* =

0.70, *SD* = 0.85). Compared to the tangram task, the ND group reported .64 units of distress, 95% CI [0.06, 1.23], more to the interaction task, $t(22) = 2.301$, $p = .031$, and large Cohen's $d = 2.14$. The ND group also reported .60 units of distress, 95% CI [0.10, 1.10], more to the speech task than the tangram task, $t(22) = 2.505$, $p = .02$, and large Cohen's $d = 3.13$. There were no differences in SAR between the speech and interaction tasks as reported by the ND group, $t(22) = -0.199$, $p = .844$.

Hypothesis 3

Hierarchical multiple regressions (MRA) were performed to estimate the proportion of variance in state anxiety and physical symptoms associated with social tasks (speech and interaction) that can be accounted for by the Child MiniSPIN, CATS Social Threats and Child SCAS Social Anxiety over and above perfectionism (CAPS), Child SCAS General Anxiety, and CATS Personal Failure. Four hierarchical MRAs were performed, each assessing state anxiety and physical symptoms to the speech and interaction task using transformed variables. First, several assumptions were evaluated for each hierarchical MRA. We conducted a brief preliminary screening with initial runs of each model using the untransformed predictor and dependent variables. Scatterplots of residuals against predicted DV scores indicate many assumptions of regression were violated. Boxplots indicated most variables were positively skewed, leptokurtic and had outliers. All four models were run again with transformed variables. For each model, tolerance and VIF values were acceptable, thus multicollinearity was not an issue. Multivariate outliers were not an issue, as the Mahalanobis distance did not exceed the critical χ^2 for $df = 6$ (at $\alpha = .001$) of 22.458 for any cases. Independence of error is assumed for all models as Durbin-Watson statistic was within acceptable range, $1.5 < d > 2.5$. The normal P-P plot indicated assumptions of normality, linearity and homoscedasticity of residuals have been met for all four models.

State Anxiety Rating – Speech Task. On step 1 of the hierarchical MRA, Child SCAS Generalised Anxiety, CATS Personal Failure and CAPS total score accounted for a significant 46% of the variance in state anxiety from the speech task, $R^2 = .455$, $F(3, 46) = 12.784$, $p = .000$. For step 2, transformed Child SCAS Social Anxiety, Child MiniSPIN and CATS Social Threat were added to the regression equation, did not significantly account for additional variance, $\Delta R^2 = .087$, $\Delta F(3, 43) = 2.710$, $p = .057$. In total, Model 2 explained 54% of the variance in state anxiety during the speech task, $R^2 = .541$, adjusted $R^2 = .477$, $F(6, 43) = 8.460$, $p = .000$. Only Child SCAS General Anxiety emerged as a significant predictor in Model 2, $t(43) = 2.446$, $p = .019$. Unstandardised (B) and standardised (β) regression coefficients, and squared semi-partial (or part) correlations (sr^2) for each predictor on each step of the hierarchical MRA are reported in Table 7.

State Anxiety Rating – Interaction Task. On step 1, Child SCAS-GAD, CATS-PF and CAPS total accounted for a significant 41% of the variance in state anxiety from the interaction task, $R^2 = .410$, $F(3, 46) = 10.643$, $p = .000$. For step 2, Child SCAS-SAD, Child MiniSPIN and CATS-ST were added to the regression equation, and accounted for an additional 13% of the variance, $\Delta R^2 = .128$, $\Delta F(3, 43) = 6.533$, $p = .001$. Overall, Model 2 explained 54% of the variance in state anxiety during the interaction task, $R^2 = .537$, adjusted $R^2 = .473$, $F(6, 43) = 8.323$, $p = .000$. Furthermore, Child SCAS-SAD emerged as the only significant predictor in Model 2, $t(43) = 2.781$, $p = .008$ (see Table 7).

Table 7. Hierarchical Multiple Regressions of Predictor Variables on State Anxiety and Physical Symptoms for Speech and Interaction Tasks.

Model **Variable**	***B* [95% CI]**	**β**	***sr*²**
State Anxiety – Speech Task			
Step 1			
Child SCAS-GAD	0.88 [0.38, 1.37]	0.56	.15
CAPS Total	–0.66 [–4.15, 2.84]	–0.04	.01
CATS-PF	0.48 [–0.55, 1.51]	–0.15	.00
Step 2			
Child SCAS-GAD*	0.67 [0.12, 1.22]	0.43	.06
CAPS Total	–1.99 [–5.56, 1.59]	–0.13	.01
CATS-PF	0.51 [–0.64, 1.66]	0.16	.01
Child SCAS-SAD	1.22 [–0.78, 3.22]	0.29	.02
Child MiniSPIN	1.01 [–0.62, 2.64]	0.24	.02
CATS-ST	1.17 [–0.35, 2.70]	0.31	.03
State Anxiety – Interaction Task			
Step 1			
Child SCAS-GAD	0.70 [0.17, 1.24]	0.44	.09
CAPS Total	–0.73 [–4.47, 3.02]	–0.05	.00
CATS-PF	0.83 [–0.27, 1.93]	0.26	.03
Step 2			
Child SCAS-GAD	0.35 [0.22, 0.92]	0.22	.02
CAPS Total	–2.91 [–6.61, 0.79]	–0.19	.03
CATS-PF	0.79 [–0.40, 1.98]	0.25	.02
Child SCAS-SAD*	2.85 [0.78, 4.92]	0.66	.08
Child MiniSPIN	–0.09 [–1.77, 1.60]	–0.02	.00
CATS-ST	1.17 [–0.41, 2.75]	0.30	.02
Physical Symptoms – Speech Task			
Step 1			
Child SCAS-GAD	0.56 [0.01, 1.11]	0.33	.05
CAPS Total	–1.38 [–5.27, 2.51]	–0.08	.01
CATS-PF	1.38 [0.24, 2.52]	0.41	.07
Step 2			
Child SCAS-GAD	0.29 [0.33, 0.91]	0.17	.01
CAPS Total	–3.11 [–7.16, 0.95]	–0.19	.03
CATS-PF*	1.48 [0.16, 2.80]	0.44	.06
Child SCAS-SAD*	2.61 [0.27, 4.95]	0.56	.06
Child MiniSPIN	–0.56 [–2.40, 1.28]	–0.12	.00
CATS-ST	1.01 [–0.78, 2.80]	0.24	.02
Physical Symptoms – Interaction Task			
Step 1			
Child SCAS-GAD	0.70 [0.09, 1.31]	0.40	.07
CAPS Total	–0.41 [–4.2, 3.89]	–0.02	.00
CATS-PF	0.99 [–0.28, 2.25]	0.28	.03
Step 2			
Child SCAS-GAD	0.38 [–0.28, 1.05]	0.22	.02
CAPS Total	–2.58 [–6.89, 1.73]	–0.15	.02
CATS-PF	1.23 [–0.18, 2.63]	0.35	.04
Child SCAS-SAD*	2.87 [0.38, 5.36]	0.58	.07
Child MiniSPIN	0.18 [–1.78, 2.14]	0.04	.00
CATS-ST	1.82 [–0.09, 3.72]	0.42	.04

Note. CI = confidence interval.
* $p < .05$.

Physical Symptoms – Speech Task. On step 1, Child SCAS-GAD, CATS-PF and CAPS total accounted for 45% of the variance in physical symptoms from the speech task, $R^2 = .452$, $F(3, 44) = 12.096$, $p = .000$. For step 2, Child SCAS-SAD, Child MiniSPIN and CATS-ST were added to the regression equation, and did not significantly account for additional variance, $\Delta R^2 = .07$, $\Delta F(3, 41) = 2.015$, $p = .127$. In total, Model 2 accounted for 52% of the variance of physical symptoms to the speech task, $R^2 = .522$, adjusted $R^2 = .453$, $F(6, 41) = 7.474$, $p = .000$. In Model 2, CATS-PF emerged as a significant predictor, $t(41) = 2.263$, $p = .029$. The Child MiniSPIN also emerged as a significant predictor, $t(41) = 2.252$, $p = .030$ (see Table 7).

Physical Symptoms – Interaction task. On step 1, Child SCAS-GAD, CATS-PF and CAPS total score accounted for 39% of the variance in physical symptoms from the interaction task, $R^2 = .386$, $F(3, 44) = 9.214$, $p = .000$. For step 2, Child SCAS-SAD, Child MiniSPIN and CATS-ST were added to the equation, and significantly accounted for additional variance, $\Delta R^2 = .120$, $\Delta F(3, 41) = 3.325$, $p = .029$. In total, Model 2 accounted for 51% of the variance in physical symptoms to the interaction task, $R^2 = .506$, adjusted $R^2 = .434$, $F(6, 41) = 7.000$, $p = .000$. Only Child SCAS-SAD emerged as a significant predictor in Model 2, $t(41) = 2.868$, $p = .025$. Interestingly, CATS-ST was approaching significance as a predictor, $t(41) = 1.928$, $p = .061$ (see Table 7).

Hypothesis 4

Lastly, to examine whether CATS Personal Failure and Self-Prescribed Perfectionism scores would provide unique contributions to state anxiety ratings and physical symptoms associated with non-social tasks as reported by anxiety-disordered youths, two simple multiple regressions were conducted. We conducted a preliminary screening of initial regression models using untransformed variables. Normal P-P plots of regression standardised residuals and scatterplots of residuals against predicted DV scores indicate many assumptions of regression were violated. The two models were conducted again with the transformed variables. Both models produced acceptable tolerance and VIF values: multicollinearity was not an issue. Mahalanobis distance did not exceed the critical χ^2 for df = 2 (at α = .001) of 13.816 for any cases. The normal P-P plot of Regression standardised residuals and scatterplot of standardised predicted values against standardised residuals greatly improved. Assumptions of independence of errors, normality, linearity, and homoscedasticity of residuals have been met for the models.

In anxiety-disordered youths, the CATS-PF and CAPS-SPP scores accounted for a non-significant 2% variance of physical symptoms during the tangram task, R^2 = .020, adjusted R^2 = -.062, $F(2, 24)$ = 0.246, p = .784, and accounted for a non-significant 0.3% variance in anxiety to the tangram task, R^2 = .003, adjusted R^2 = .003, $F(2, 24)$ = 0.033, p = .968.

Discussion

Overview of Findings

The present study aimed to investigate if there were any differences between non-disordered children, children with social anxiety, and children with other anxiety disorders on self-reported state anxiety and physical symptoms across two socio-evaluative tasks and one non-social task. Our second research aim was to investigate whether task specificity uniquely predicts differences in physiological symptoms and state anxiety. Results supported aspects of hypothesis 1 and 2, supported hypothesis 3, and failed to support hypothesis 4.

Regarding the effect of task on state anxiety, both the speech and interaction task were more arousing than the tangram task across all groups. As expected, the anxiety ratings from the speech and interaction task did not differ across groups. Across all tasks, the SAD group reported more distress than OAD, who also reported more distress than ND. State anxiety in both social tasks could be explained by measures of social threat and social anxiety severity, with Child SCAS social anxiety emerging as a significant predictor of state anxiety ratings from the interaction task. Although the Task x Diagnosis interaction was non-significant, Figure 1 portrays a trend where the ND group found the tasks were equally distressing more so than the other groups. Figure 1 also shows the social tasks were more distressing than the non-social task in both OAD and SAD groups, even though the OAD groups did not have social anxiety as the primary disorder. This could be explained by generalised anxiety emerging as a significant predictor of state anxiety from the speech task.

Turning to the effect of tasks on physical symptoms, across all groups, both the speech and interaction task elicited more physical symptoms than the tangram task. The effects of the speech and interaction task on physical symptoms did not differ across groups. Across all tasks, the SAD group reported more physical symptoms than OAD, who reported more physical symptoms than ND. Child SCAS Social Anxiety emerging as a significant predictor for both tasks could explain the effect of social tasks on physical symptoms. The task x diagnosis interaction was non-significant, but Figure 2 shows that the ND and OAD group reported similar physical symptoms on the tangram task. Figure 2 also shows social tasks were more distressing than the non-social task in both OAD and SAD groups. This could be explained by personal failure emerging as a significant predictor of state anxiety from the speech task.

These results are intriguing as emerging research suggests that social anxiety is harder to treat and is associated with worse treatment outcomes in generic anxiety treatment programs. Furthermore, this study's results indicate social anxiety has different symptomology severity in that there was heightened anxiety and increased physical symptoms elicited by both social and non-social tasks compared to other anxiety disorders and no pathology. This may also explain why social anxiety has poorer treatment outcomes.

However, these results may have been exacerbated by other secondary anxiety disorders and so the results might have been driven by the comorbidity with generalised anxiety or other anxiety disorders. Another possibility is that youths with social anxiety truly exhibited a heightened physiological response in general that makes exposure more difficult to practise and the avoidance behaviour more persistent.

Interestingly, girls reported more state anxiety than boys across all groups and all tasks, but this was not observed with physical symptoms. It is possible that both girls and boys are equally aware of physical symptoms, but girls may be more cognisant of the cognitive aspects of anxiety than boys. To examine whether this is the case, future studies will need to repeat a similar study with a larger sample and examine the effects of age as well, as younger children have more difficulty conceptualising and explaining their anxiety and current state of wellbeing than adolescents.

In both social tasks, the social phobia/threat variables (Child SCAS Social Anxiety, Child MiniSPIN, CATS Social Threat) explained unique variance in youths' anxiety arousal and physical symptoms over and above generalised anxiety, perfectionism and personal failure, with explained variance ranging from 51–54%. In comparison, we found no evidence that personal failure and self-prescribed perfectionism accounted for anxiety and physical symptoms associated with the non-social or social task in anxiety-disordered youths: regression analyses indicated they did not account for any variance.

Despite many studies examining children's and adolescents' physiological reactivity to stressor tasks, there has been little research actively examining children's awareness of physical arousal induced by various stressor tasks. The majority of studies that measure self-reported physiological arousal investigate objective measures in conjunction. Of the few studies that actively investigate objective physiological arousal, even fewer will include subjective self-reports of arousal. This is a crucial flaw for those studies as failing to include measures of arousal, anxiety or stress before and after a stressor means researchers cannot confirm nor deny that the stressor has successfully induced anxiety or stress in participants, and if the stressor affected participants differently.

Limitations

The study sample was small for the types of analyses conducted which may have affected the power of statistical analyses: it may have determined the non-significant interaction effects we tested. Tachbachnik and Fiddell (2013) recommended that for MLM, a sample size of at least 60 is ideal. The diagnosis group sample sizes were small and unbalanced and although the MLM can cope with unbalanced groups, the non-normal distributions of various measures by diagnosis may have negatively affected the findings. The different age ranges between groups may have masked any effects of the stressor task on the anxiety measures. We also did not account for the effects of secondary anxiety diagnoses, which may have influenced the non-significant interactions and non-significant results testing for hypothesis 4. However, only two OAD participants had social anxiety as a secondary diagnosis, and this seems unlikely to have been an issue. Sample sizes of diagnostic groups were already small and statistical power would probably have decreased if we attempted to control for secondary anxiety disorders. This might explain the OAD group reporting distress and physical symptoms from the social tasks more than expected. Not all social elements could be eliminated from the tangram task. Although the experimenter clearly stated there would be no recordings made during the tangram task, the researcher was always present in the room. This may have evoked socio-evaluative or social threat cognitions, and influenced our null results. However, all participants reported the least anxiety and physical symptoms to the tangram task, so we believe that the procedure was adequate for our aims. However, it is a further limitation that in the control group, the three tasks differed in distress severity—the social tasks were significantly more distressing than the non-social task. Ideally the distress induced by the three tasks would have been equal in the control group.

One limitation of this study was the absence of using physiological recording/ measurements. Recording actual physiological reactivity to stressors would help clarify whether the participants were merely reporting the physical sensations they were aware of, or grossly overestimated the severity of physical symptoms. Unfortunately, based upon the current results, it cannot be determined if youths overestimate physical sensations to disorder-/content-specific stressors. Interpretation of results is advised as assumptions of independence of errors were violated when conducting the MLM.

Future Direction

Future research will need to incorporate physiological measurements to examine differences in physiological reactivity for different social and non-social tasks in social and non-social disordered children and adolescents. Previous research has neglected to include physiological measurements of arousal and instead relied purely on self-reports. Similarly, previous studies neglected to check whether participants were sufficiently aroused and anxious whilst measuring physiological reactivity. These shortcomings are unideal (Kendall & Pimentel, 2003) and future studies should examine both physical and subjective reports of anxiety. Future studies can also examine the trajectory of physical and subjective anxiety in anticipation to, during and after stressor tasks, and compare any differences between socially and non-socially anxious youths. Furthermore, a variety of ecologically valid tasks should be included as well non-disorder-specific tasks.

Conclusion

State anxiety and physical symptoms, across social and non-social tasks, differed between youths with primary social anxiety disorder, youths with other primary anxiety disorders, and youths with no anxiety disorder. Different task type affected how youths responded. The social tasks were associated with heightened state anxiety and physical symptoms across all participants. Social anxiety accounted for unique contributions to state anxiety and physical symptoms associated with the social tasks, over and above general anxiety, perfectionism and personal failure. Personal failure and self-prescribed perfectionism did not predict anxious youths' state anxiety and physical symptoms associated with the non-social task. Future studies will need to improve on this study by including larger sample sizes and various physiological measures, and examining the effects of secondary anxiety disorders, gender, and age.

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Appendix A

Table 8. Descriptive Information of Reviewed Studies

Study	Sample Size, Age	Sample description	Anxiety Measure	Stressor type; study design	Physiology	Findings	Limitations
Cameron, McKay, Susman, Wynne-Edwards, Wright, & Weinberg, 2017	146 adolescents (74 males, 73 females) (*M* = 14.50, range of 13-16 years)	60% European-Canadian	STAI; Spielberger, 1988	Three conditions; FSS-A (Frustration Social Stressor for Adolescents); TSST-T (Trier Social Stress Test for Teenagers; Kudielka et al., 2007) and low stress	Salivary cortisol	The FSS-A protocol elicited increased cortisol stress responding and induced significant greater state anger and state anxiety than the low-stress condition. There were no differences between in cortisol change scores (Time 0 to Time 45min) between FSS-A and TSST-T.	Did not specifically report on cortisol patterns between the three experimental conditions in relative to state and trait anxiety
Kaeppler & Erath, 2017	123 children (50% male) (*M* = 12.03, *SD* = .64)	58.5% European Americans, 35% African-Americans, and 6.5% other	SAS-A; La Greca & Lopez, 1998 Two-item context-specific anxiety measure	Two socio-evaluative tasks; peer evaluation and peer rebuff	SCLR RSA	SCLR and RSA were not correlated. Nearly all participants showed increase in SCL during peer-evaluative stress period. Fifty-five% of participants showed reduction in RSA from pre-task to peer-evaluative stress period, the remaining 45% showed an increased RSA response. Social anxiety scores is associated with lower social competence at lower SCL, but not at higher SCL	Used a community sample, findings may not generalise to clinical population
Koss, Cummings, Davies, & Cicchetti, 2017	240 mother-father-child triads (122 males, 118 females) (*M* = 13. 08, *SD* = .53)	Family triads taking part in longitudinal study, recruited from South Bend, IN and Rochester, NY; USA. 73.8% White, 17.4% African American, 4.4% Hispanic, 4.4% biracial/multiracial/other	RCMAS; Reynolds & Richmond, 1978	Triadic Family Problem-Solving Task (FPST)	Salivary Cortisol	Four distinct patterns of adolescent behaviours were identified. Physiologically reactive adolescents had elevated cortisol pre-task and increased cortisol reactivity than other children. PR adolescents also showed concurrent increasing anxiety levels	Sample population largely represented stable, functioning families.
Asbrand, Blechert, Nitschke, Tuschen-Caffier, & Schmitz, 2016	57 children 30 SAD (63 % female) (*M* = 10.9, *SD* = 1.32) 27 HC (70.4% female) (*M* = 11.1, *SD* = 1.44)	Participants were recruited through advertisements in schools, treatment facilities and local newspapers as part of a larger German research project	Kinder-DIPS; Schneider et al. 2009 ADIS-C; Silverman & Nelles, 1988 SASC-R; La Greca & Stone, 1993 CBCL; Achenbach & Edelbrock, 1991	Two physical stress tasks: Orthostatic task and stepping task	SCL HR RSA	No differences in baseline cortisol between SAD and HC groups. SAD group had a higher elevated HR throughout the procedure compared to HC group, however both groups showed elevated HR at orthostatic and stepping task. SAD children had greater SCL activation during the ambulatory session. Higher trait social anxiety predicted higher tonic HR arousal SAD group showed signs of tonic autonomic hyperarousal (higher HR and SCL)	Could not eliminate emotional response to procedure. Control group may have elevated subclinical fears Many of the SAD children had comorbid diagnosis with other anxiety disorders

Bilsky, Feldner, Knapp, Rojas, & Leen-Felder, 2016	108 adolescents (59 males, 59 females) (*M* =15.69, *SD* = 1.24, range of 12-17 years)	All participants endorsed positive history of cigarette smoking. 85% Caucasian American, 8.4% African American, 4.7% Native American/Alaskan Native, 1.9% Other	CASI; Silverman, Fleisig, Rabian & Peterson, 1991 SR-A; Bilsky, et al., 2016	Physical stress task: Voluntary Hyperventilation Procedure	SCL	SCL and self-reported anxiety increased significantly from baseline to post-challenge across all genders and smoking history.	Study does not reflect natural development of panic symptoms or naturalistic symptoms of bodily arousal. Did not assess nicotine withdrawal which could have affected anxiety sensitivity
Burkholder, Koss, Hostinar, Johnson, & Gunnar, 2016	79 children, (*M* = 9.83, *SD* = .55, range of 9-10 years) 39 ELS (20 female) 40 NA (20 female) 82 adolescents (*M* = 15.81, *SD* = .59, range of 15-16 years) 20 ELS (22 female) 42 NA (20 female)	ELS children adopted from Indo-Europe (n = 50), SE Asia (N = 25), Latin America (N = 3), Africa (N = 1). NA group based in major US Midwest metropolitcan	CASES; Burkholder et al., 2016 SAM; Bradley & Lang, 1994	TSST-C (Trier Social Stress Test for Children; Buske-Kirschbaum et al., 1997)	Salivary Cortisol	Cortisol reactivity did not correlate with self-reported stress for the TSST-C. Cortisol also did not correlate with observed anxiety expression. Children with ELS did not show larger cortisol responses or reported more stress than NA children.	Did not collect saliva sample at baseline or habituation. Did not explore or record all aspects of early life stress, current family stress and quality of life after adoption. Did not perform manipulation check
Ng & Lee, 2016	113 children (54 males, 69 females) (*M* = 11.25, *SD* = .52)	Singaporean children from low-to middle-SES in primary schools	STAI; Spielberger et al., 1980 STAI-C; Spielberger, 1973	Mental arithmetic task Two test conditions; high situational stress (negative feedback) vs low situational stress	Salivary Cortisol	High stress condition increased children's self-report state anxiety levels compared to low stress condition regardless of trait test anxiety. There was no significant elevation in cortisol from baseline to any post-test time points. There was a significant decrease from immediate post-test to 10-min post-test. Weak correlation between self-reported state anxiety and cortisol level.	May not have adequately sampled cortisol post-test. Socio-evaluative threat may not have been salient or age appropriate as a threat.
Waters & Pine, 2016	44 clinically anxious children (responders & non responders) Responders (*M* = 10.02, SD = 1.4) Non-responders (M = 10.01, SD = 1.6) 32 nonanxious children (*M* = 9.9, *SD* = 1.2)	84% Australian born 95% of anxious children had more than one anxiety disorder	ADIS-IV-C/P; Silverman & Albano, 1996 SCAS-C/P; Spence, 1998	Pavlovian conditioning and extinction task	SCL/R	Nonanxious children did not acquire conditioned negative evalution of the CS+ relative to the CS-, and displayed efficient physiological decline to the CSs during extinction. Similarly, anxious children who responded to CBT showed similar physiological decline to the CSs during extinction trials. Nonresponders showed no change in SCRs across extinction trials. Change in physiology but not evaluative measures during extinction predicted better treatment outcomes	Fear conditioning and extinction paradigm relied on an aversive tone US. The aversive stimuli used may produce differing physiological response for children with varying anxiety diagnosis

Alkozei, Creswell, Cooper, & Allen, 2015	90 children 30 SAD (*M* = 9.30, *SD* = 1.62, range of 7-12 years) 30 other ANX (*M* = 9.40, *SD* = 1.50, range of 7-12 years) 30 NONANX (*M* = 9.36, *SD* = 1.40, range of 7-12 years)	Clinical children referred to anxiety clinic. NONANX were recruited via letters through schools and clubs. 80% of SA children met criteria for a secondary anxiety disorder	ADIS-IV-C/P SCAS-C/P	Three stressor tasks; social stress task, tangram task, cognitive stress task	HR RSA	No differences between groups on baseline HR and RSA, nor any differences between groups on HR and RSA reactivity in response to tasks. The groups did not differ on subjective anxiety during the task. NONANX showed greater HR recovery from both tasks than clinical children. Across groups, increases in state anxiety was associated with decreased HR and RSA reactivity during the cognitive task.	Stressors may be too mild: child was told no one would watch video apart from RA, mothers remained present with child. ANX group already visited the location of research assessment Speech task elicited excitement in control group, may have influenced physiology
Benoit Allen, Allen, Austin, Waldron, & Ollendick, 2015	98 children with Specific Phobia (46 females) (*M* = 9.07, *SD* = 2.07, range of 6-15 years)	Children from larger treatment studies. 86% Caucasian, 11% African-American, 2% Hispanic, 1% other ethinicities. 40 had animal phobias, 42 had natural environment phobias, 4 had situational phobias, 12 had phobias fit into other category. Sample also included participants with primary diagnoses of other disorders e.g. GAD, ADHD.	ADIS-IV-C/P; Silverman & Albano, 1996) BAT; based upon Öst et al., 2001 SUDS	Three hour therapy session of gradual exposure to phobic stimulus, followed by BAT	IBI	Post-treatment cardiovascular reaction was consistent with pre-treatment levels, despite post-treatment SUDS decreasing significantly during the BAT. Subjective distress correlated with change in behavioural avoidance, but neither was related with IBI	Lacking a control group or a waitlist condition. Phobic children were highly comorbid with other disorders – unclear of the potential effects.
Kirsch, Wilhelm, & Goldbeck, 2015	39 children 19 PTSD (10 females) (*M* = 12.71, *SD* = 3.3, range of 6-17 years) 20 children with trauma history but no PTSD (10 females) (*M* = 12.67, *SD* = 2.5, range of 6-17 years)	All children had a history of one or more traumatic event and could speak German	CAPS-CA; Nader, Kriegler, & Blake, 2002 Self-report anxiety questionnaire; Wilhelm, Schneider & Friedman, 2006	Exposure to 3-min neutral script, followed by 30-min idiosyncratic trauma script	SCL HR RSA NSF-Rate	PTSD group reported elevated anxiety at baseline and greater anxiety reactivity to the control group. No group differences were found for HR, RSA, SCL and NSF	Small sample size Great variability of trauma types and time since trauma. No additional group without history of traumatic events was included

Laurent, Gilliam, Wright, & Fischer, 2015	107 children (range of 3-6 years) 57 Foster children assigned to intervention 60 foster children with regular care 60 low-income community children	89% European American, 1% African American, 5% Latino, 5% Native american.	CSI; Gadow & Sprafkin, 1994	Cortisol sample collected over a period of 6 + years. In final assessment waves, child completed problem-solving stress task and TSST-C	Salivary Cortisol	OCD symptoms related to sustained cortisol elevation following the problem solving task. PTSD symptoms related to higher TSST-cortisol and sustained elevation following problem solving task. Specific Phobia symptoms related to higher TSST-C stress cortisol levels GAD symptoms related to higher cortisol levels during both tasks and had a flatter TSST-C stress response curve Morning cortisol levels were associated with cortisol response to the stressor tasks. Rising morning cortisol is a predictor of heightened cortisol during stress and/or sustained elevation following stress.	Did not directly explore childhood adversity
Myllyneva, Rante, & Hietanen, 2015	34 children 17 SAD (4 males) (*M* = 15.2, *SD* = 1.52, range 12-17 years) 17 HC (4 males) (*M* = 15.3, *SD* = 1.53, range 13-17 years)	SAD were recruited from Finnish hospital and HC were recruited from local schools.	K-SADS-PL; Kaufman, et al., 1997) SAM; Bradley & Lang, 1994	Two experimental tasks; in the first task participants were presented direct, diverted gaze or closed eyes, during the second task, participants could control presentation time of the two gazes	SCR	SAD group showed greater SCR to direct gaze than HC, and also reported higher arousal ratings compared to HC for the direct gaze.	No self-report state anxiety measures before and after the tasks.
Nederhof, Marceaus, Shirtcliff, Hastings, & Oldernhinkel, 2015	715 adolescents (50.9% females)	90.8% had Dutch Ancestry, participants were part of a general population study called TRAILS in the Netherlands	YSR; Verhulst, Van de Ende & Koot, 1997 CBCL; Achenbach & Rescorla, 2001 ASR; Achenbach et al., 2003	Groningen Social Stress Task (GSST; Bouma et al., 2009)	Salivary Cortisol HR HRV RSA PEP	Increased HR was associated with more concurrent internalising problems in boys, but not in girls. Boys with higher cortisol response and higher RSA had greater number of internalising problems between ages 16 and 19.	Did not have anxiety measure before and after stressor task
Turan, Tackett, Lechtreck, & Browning, 2015	153 children (74 females, 79 males) (*M* = 9.38, *SD* = 0.62, range of 8-11 years)	43 African American (black), 50 non-Hispanic White 60 Hispanic Primarily recruited from local public schools in an urban Southwestern community. Children could speak English, and did not have psychotic disorders, neurodevelopmental disorders, or mental retardation	EATQ-R; Ellis & Rothbart, 2001	TSST-C (Trier Social Stress Task for Children; Buske-Kirschbaum et al., 1997)	Salivary Cortisol & Testosterone	Children with higher parent reported trait negative affectivity had stronger cortisol-testosterone coupling for both genders. Cortisol and testosterone tended to rise and fall together during the procedure	Did not include child self-report measure of anxiety Did not include clinically anxious population
Turpyn, Chaplin, Cook, & Martelli, 2015	198 adolescents (49% female) (*M* = 13.3, *SD* = 1.9, range of 10-17 years)	63.6% European Americans (63.6%), 17.2% African-American, 8.6% Latin-American, 6.1% Asian American, 4.5% mixed/other.	DES-R; Izard, 1972 CSI; Gadow & Sprafkin, 199	Parent-Adolescent Interaction Task (PAIT)	HR reactivity	Four emotion regulation profiles were produced. Profile 1 included adolescents with higher HR reactivity and lower self-reported anxiety Profile 2 included adolescents who reported greater anxiety and anger levels, and had low HR reactivity.	Did not have an adolescent self-report of anxiety or psychopathology

Waters & Kershaw, 2015	34 clinically anxious children (TVI vs TAV) 18 TVI (7 female) (*M* = 10.3, *SD* = 1.63, range of 7-12 years) 16 TAV (8 female) (*M* = 9.7, *SD* = 1.40)	91% Australian born, all spoke English as first language. All participants met criteria for principal diagnoses, 12 social phobia, 7 SAD, 9 specific phobia, 6 GAD. All children had comorbid anxiety disorders. None were receiving psychological and pharmacological treatment at time of testing.	ADIS-IV-C/P SCAS-C/P SAM	Fear acquisition and extinction phase	SCR	TAV children showed larger SCR to aversive unconditioned stimulus and to non-reinforced stimuli during fear acquisition and to both CSs during fear extinction compared to TVI anxious children. No group differences were found in subjective ratings of valence and arousal of CSs. During extinction, TAV anxious children showed delayed recovery of SCRs to both CSs and reported higher subjective anxiety ratings after extinction compared to TVI anxious children.	No healthy control group for comparison
Williams & Woodruff-Borden, 2015	85 child-parent dyads (35 female) (M = 8.36; SD = 1.77, range of 5-12 years)	77 Caucasian American, 4 African American, 1 Asian, 3 mixed ethnicity.	SCARED-P; Birmaher, et al., 1995	Computer task presenting threating or neutral images	Cardiac Variability	Some evidence that cardiac responsiveness mediates the relationship between unsupportive parent emotion socialisation and child emotion regulation. No evidence that cardiac responses predicts anxiety symptoms	Only 51% of participants completed the computer task Did not include clinically anxious children. Majority of the sample experience relatively few anxiety symptoms
Aldao, McLaughlin, Hatzenbuehler, & Sheridan, 2014	168 adolescents (56% female) (*M* = 14.9, *SD* = 1.36, range of 13-17 years) Final sample of 157	Recruited heavily from low-SES neighbourhoods in MA, USA. 40.8% white, 18.34% black, 17.8% Hispanic, 7.7% Asian, 14.8% biracial/other	CRSW – Rumination subscale; Abela, Brozina & Haigh, 2002 PANAS – State version; Watson, Clark & Tellegen, 1988	TSST (Kirschbaum et al., 1993)	PEP RSA HR	TSST elicited significant decreases in PEP and significant increases in HR, but did not influence subjective negative affect. Rumination (higher scores) was associated with slower HR recovery post-TSST.	Did not explicitly measure anxiety (trait or state) Used singular social stressor task
Busso, McLaughlin, & Sheridan, 2014	78 adolescents (65% female) (*M* = 16.7, *SD* = 1.33, range of 14-19 years) Only 44 completed TSST 1 year prior to Boston Marathon 2013	Community-based sample living in the Boston metropolitan area at the time of the 2013 Boston Marathon. 45.5% White, 18.2% Asian, 11.7% Black, 5.2% Latino, 18.2% multi-racial, and 1.3% other	IES-6; Weiss, 2004 MASC; March et al., 1997	TSST completed 1 year prior to 2013 Boston Marathon None – adolescents reported on media exposure to the Boston Marathon terrorist attack	RSA PEP	PEP and RSA reactivity were not significantly associated with PTSD symptoms.	May have missed out on individuals with delayed PTSD symptoms Relied on self-report rather than structure clinical interview to measure PTSD

Dieleman et al., 2014	152 AD children (*M* = 10.2, *SD* = 1.5, range of 8-12 years) 200 GP (*M* = 10.1, *SD* = 1.5, range of 8-12 years)	AD children: 47 primary GAD, 29 primary SP, 57 primary SepAD, 19 primary Specific phobia GP children: 2 primary SP, 2 SepAD, 25 Specific phobia	DISC-P; Shaffer, 1998 ADIS-C; Silverman, 1996 CBCL; Achenbach, 2001 MASC; March et al., 1997 PAQ; Dieleman et al., 2010)	Cortisol collected throughout a one day. Mental arithmetic task, based upon TSST (Kirschbaum et al., 1993)	Diurnal cortisol profile and CAR SCL HR HRV-HF(RSA)	There were no differences between groups on CAR. AD children had a low cortisol profile at noon and evening compared to controls. AD children showed similar low basal cortisol prior to task. AD children showed heightened sympathetic functioning (SCL) at rest and during stress, and lower parasympathetic functioning (RSA) at rest compared to controls Anxious children who had higher anxiety load showed more elevated SCL in comparison to children with lower anxiety load. AD children exaggerated perceived arousal during rest compared to controls. But AD children with higher anxiety load reported less perceived arousal than AD children with low anxiety load. Children with high clinical load (3+ disorders) had lower basal cortisol levels, higher SCL and lower arousal after the task. Specific phobia could be identified from only heightened sympathetic activity.	Cortisol collection for diurnal cortisol profile was restricted to a single day collection. Lack of HRV and cortisol measures during stress task. Did not measure anxiety prior to task Did not measure physiological recovery
Kristensen, Oerbeck, Torgersen, Hansen, & Wyller, 2014	45 children (range of 7-13 years) 22 HC (11 males, 11 females) 23 ANX (12 females, 11 males)	All children were Caucasian. 1 PD, 9 SepAD, 8 Specific, 5 SP, 5GAD, 4 OCD. 6 children had two diagnosis, 1 child had 4 diagnoses	K-SADS-PL; Kaufman et al., 1997 MASC & MASC-10; March, 1997 State Anxiety - thermometer scale	Two physical stressor tasks; orthostatic challenge and isometric muscular exercise	HR SBP DBP MAP SI CI TPR HRV LF RSA	The AD group reported significantly more somatic symptoms than the HC group, but there were no differences in cardiovascular variables between the groups. There were no significant correlations between subjective and objective measures. Groups did not differ on state anxiety at the beginning of assessment.	Small sample size, wide distribution of anxiety disorders Did not repeate state anxiety measure after the stressor tests
Nelemans et al., 2014	184 adolescents (57% males) (*M* = 14.99, *SD* = 0.42, range of 14-16 years)	All participants were ethnically Dutch	SCARED Dutch version; Birmaher et al., 1997; Hale et al., 2005	Longitudinal; three cortisol samples taken in the morning, one day per year for 3 successive years.	Cortisol Awakening Response	Controlling for sex, adolescents with high and low CAR significantly differed in depressive symptoms, but not for anxiety symptoms	Used single day measurement across 3 years; more sampling across years would be a better procedure Generalisability
Reynolds, Field, & Askew, 2014	44 children (21 males, 23 females) (*M* - 8.43, *SD* = 0.76, range of 7-9 years) 41 children at 1 week follow-up 37 children at 1 month follow-up	Recruited from UK school	STAI-C; Spielberger et al., 1973 MASC-10; March et al., 1997 FBQ; Field & Lawson, 2003 BAT; Field & Lawson, 2003	Four tasks: vicarious learning, visual search task, BAT, nature reserve task	HR	Baseline HR did not differ between children with scared-paired and unpaired animals when approaching the box. Children with scared-paired animals had higher elevated HR when placing their hands in and out of the animal boxes. There were no changes in HR at any point of the behavioural task for children with happy-paired animals. Children's avoidance preferences correlated with their fear beliefs, but not with HR responses, which approached significance	Did not measure recovery phase for HR Unable to measure HR effects at follow-up as BAT could not be repeated

Scott & Weems 2014	80 children (51% female) (*M* = 13.88, *SD* = 1.95, range of 11-17 years)	Recruited from New Orleans and surrounds, US. 37.% African-American, 33.8% Euro-American, 23.8% Other/mixed, 5.% Hispanic.	ACQ-C; Weems et al., 2003 RCADS-C/P; Chorpita et al., 2000 RCMAS; Reynolds & Richmond, 1978	Three tasks: HR control task, mental arithmetic task, video-vignette task	HR SCL Temperature Respiration VT (RSA)	Children and parent reported anxiety was associated with increasing vagal tone from baseline to the cognitive stress task. Resting vagal tone during the video task and baseline were negatively associated with the anxiety measures and positively associated with anxiety control beliefs. Boys had a blunted vagal response and girls showed vagal withdrawal in response to the cognitive stress task	Cannot infer directionality
Wild, Freeston, Heary, & Rodgers, 2014	33 healthy children (low IU vs high IU) 17 low IU (5 male) (*M* = 13.10, *SD* = 0.51) 16 high IU (4 male) (*M* = 12.92, *SD* = 0.40)	Recruited from UK schools, all spoke English as first language.	IUS-C; Walker, 2009 POMSA; Terry, Lane, Lane & Keohane, 1999	Iowa Gambling Task (IGT; Bechara, Damasio, Daasio & Anderson, 1994)	EDA (SCL/SCR)	Adolescents with low IU reported lower levels of subjective anxiety to the task and had more flexible physiological response patterns. High IU group reported higher levels of anxiety and less flexible physiological response pattern.	Did not include recovery phase for EDA Appraisal measure included one question regarding anxiety – anxiety may not have been explored properly in the sample
Balle, Tortella-Feliu, & Bornas, 2013	40 adolescents 29 at-risk (8 males, 12 female) (*M* = 13.89, *SD* = 1.21) 20 HC (13 males, 7 females) (*M* = 13.45, *SD* = 1.32	Adolescents were Caucasian, from middle socioeconomic backgrounds.	K-SADS-PL; Kaufman et al., 1997 SPSRQ-J Punishment scale; Torrubia et al., 2008 PANAS-CY; Sandin, 2003 SCAS; Spence 1998	Two tasks: Children's Sustained Attention Task (CAST; Severa Cardo, 2006) with response costs, and exposure to 20 fear-relevant pictures (IAPS; Lang, Bradley & Cuthbert, 1999)	SCR HR NSF VT (RSA)	At-risk group (children with higher BIS sensitivity) showed lower vagal tone in baseline than the HC group. There were no group differences in SCL reactivity during the attention task. At-risk group showed more NCF responses than control group during baseline 2. The control group showed greater HR flexibility than at-risk group throughout the experimental conditions	Did not measure anxiety before and after stressor tasks
El-Sheikh, Keiley, Erath, & Dyer, 2013	151 children (128 females, 123 males) (*M* = 8.23, *SD* = 0.71 at Time 1)	Majority of children were prepubertal. 64% European American and 34% African American. Recruited through public school systems in the southeastern US. Overall Retention rate (Time 1-3) was 75%.	TSCC; Briere, 1996	Star tracing task	RSA SCL	Girls characterised with low RSA and low SCl at baseline or with increasing RSA and decreasing SCL in response to tracing task were susceptible to higher levels of anxiety from middle to late childhood in the context of marital conflict	Did not include measure of child's anxiety pre and post-task
Kossowsky, Wilhelm, & Schneider, 2013	49 SepAD children (51.0% female) (*M* = 8.3, SD = 2.5, range of 5-13 years) 21 CC (66.7% female) (*M* = 9.5, *SD* = 2.4, range of 5-14 years) 39 HC (48.7% female) (*M* = 9.9, *SD* = 2.3, range of 6-14 years)	Children were recruited through local psychologists, psychiatrists paediatricians or distributed flyers and advertisements	Kinder-DIPS; Neuschwander et al., 2013; Schneider et al., 2009 SCAI-C/P; In-Albon et al., 2013 *RCMAS-German*; Boehnke et al., 1986 *SASC-R – German*; Melfsen & Florin, 1997 *Subjective Ratings*; Wilhelm et al., 2005	Three tasks: separation task, mild video-supported social stressor and voluntary hyperventilation challenge	HR Heart Period Variability (HRV) SCL NSF-n	There were no significant differences between groups at baseline for physiological measures. During the hyperventilation task, SepAD group had greater HR reactivity compared to HC. There were no group differences in self-reported anxiety and panic symptoms in response to the VH task, suggesting increased HR was likely due to difficulty and effort in breathing regulation than anxious responding.	Single study site, limited demographic information

Sibinga et al., 2013	41 adolescent males (*M* = 12.5, range of 11-14 years) 22 MBSR 19 HT	95% African American. Recruited from a middle school for urban boys with financial need and academic potential	MASC SCL-90 R Anxiety subdomain; Derogatis, 1994	Two conditions; structured mindfulness program vs active control "health topics" program	Cortisol	Boys who received MBSR had less anxiety than HT boys following the programs. Cortisol levels was not statistically significantly different between groups at baseline or follow up. Cortisol level did not chance pre- and post-MBSR.	Very small sample size, reducing power to find group differences Generalisability issue Single study site
Schmitz, Tuschen-Caffier, Wilhelm, & Blechert, 2013	40 children 20 HSA (60% female) (*M* = 11.0, *SD* = 0.76 20 LSA (45% female) (*M* = 11.1, *SD* = 0.83)	Recruited via local newspapers and flyers in schools.	SASC-R; La Greca & Stone, 1993 CBCL; Achenbach, 1991 Self-reported anxiety measure	Socio-evaluative/speech stressor task	ESI (SCL, NSF-R) VSI/CI (HR, LF HRV HF HRV, LF/HF)	HSA group had greater levels of self-reported anxiety from baseline to anticipation compared to LSA group. HSA group exhibited lower cardiac sympathetic arousal relative to baseline values, e.g. they had lower HR reactivity from anticipation to the stress task, and slower HR recovery than LSA children. No differences found in ESI or other VSI measures across between groups and across phases	Singular social performance task in front of adults, will this generalise to other feared situations in childhood social anxiety
Williams et al., 2013	27 mother-child dyads (*M* = 9.13, *SD* = 1.41)	17 European American, 6 African American, 4 mixed ethnicity. 7 GAD, 4 SP, 4 SAD, 12 no disorder.	ADIS-C/P; Silverman & Albano, 2004	Cortisol samples taken at home for two consecutive days	Salivary Cortisol	Child's basal cortisol levels was not related to presence of an anxiety disorder	Small sample size groups
De Los Reyes, et al 2012	62 adolescents (*M* = 15.32, *SD* = 1.1, range of 14-17 years) 31 clinic-referred (11 males) 31 community control (11 males)	63% African American, 26% European, 3% Asian or Asian American, 3 % American Indian, 5% Hispanic, 6% Other.	MASC; March, 1997 LSAS-CA; Marsia-Warner et al., 2003	None – Baseline measurements taken	HRV	HRV at rest was not associated with MASC social anxiety scores, however HRV did discriminate between adolescents on whether they were clinic referred or community recruited.	Used one physiology measure Did not consider child's trait and state anxiety Small sample size
Krämer et al., 2012	41 SP (20 male) (*M* = 10.1, *SD* = 1.39) 40 HC (20 female) (*M* = 10.0, *SD* = 1.12)	All children were Caucasian. Children with SP were excluded if SP was not primary, or if comorbid with MDD, dysthymia or autism	Kinder-DIPS; Schneider et al., 2009 SPAI-C – German version; Melfsen et al., 2001 ISAAC; Schenider et al., 2005	TSST-C	Salivary Cortisol sAA HR	SP children exhibited increased subjective activity in response to TSST-C compared to HC, but not heightened reactivity in HR, sAA or cortisol. SP children had chronically elevated HR levels throughout the testing session. SP children showed slower increase in HR to the TSST-C and slower HR recovery. Both groups had significant increase in sAA in response to TSST-C but there were no group differences.	TSST-C does not encompass all social situations that cause anxiety in SP children

Schmitz, Blechert, Krämer, Asbrand, & Tuschen-Caffier, 2012	40 children (21 female, 19 male) 20 HSA (*M* = 11.0, *SD* = 0.76, range of 10-12 years) 20 LSA (*M* = 11.1, *SD* = 0.83, range of 10-12 years)	All participants were Caucasian. Recruited via advertisements	SASC-R; La Greca & Stone, 1993 CBCl; Achenbach, 1991 Subjective ratings of anxiety	Two social stressors; reading two stories to an audience Two conditions: Children heard elevated HR feedback privately (earpiece) or publicly (speakers in the room)	HR	There were no group differences in HR during baseline and stressor task. When HR was made public, HSA had more worries about symptom visibility than LSA children, but this was not related to actu al HR levels or interceptive accuracy. HSA group perceived their HR as higher than the LSA group, regardless of experimental condition.	Used only one physiology measure Small sample seize, all Caucasian sample Used only high or low socially anxious children, no clinically socially anxious chidlren
Wetter & El-Sheikh, 2012	246 children at Time 1 (123 males, 123 females) (*M* = 8.23, *SD* = 0.72, range of 6-20 years)	64% European American, 36% African American children. Community based sample	RCMAS; Reynolds & Richmond, 1978	Longitudinal study; baseline measurement in supine position	RSA	Girls with high RSA and low maternal internalising symptoms showed a steep decline in internalising symptoms from ages 8 to 10. Girls with low RSA and mothers with higher internalising symptoms had highest levels of internalising symptoms at age 10. African American children had significantly higher RSA levels compared to European American children	74% of participants retained from Time 1 to Time 3 Did not include diagnostic assessment for anxiety disorder Used only one physiological measure, with no stressor task Generalisability issue
Young, Bunnell, & Beidel, 2012	35 children 10 SM (4 males) (*M* = 7.00, *SD* = 1.78) 11 SP (5 males) (*M* = 8.82, *SD* = 2.04) 14 HC (9 males) (*M* = 8.86, *SD* = 1.46)	49% Caucasian, 26% African American, 14% Latino/a, 11% Asian/Indian	ADIS-C/P; Silverman & Albano, 1996 K-GAS; Shaffer et al., 1983 SPAI-C; Beidel, Turner & Morris, 1995	Two social interaction tasks; role plays with same-aged peer and recounting story to adult and child audience	SCL/R NSF HR SBP DBP	Both SM and SP groups reported higher levels of social anxiety than the CC group. There was no significant difference in baseline NSFs across the groups. SP children showed significantly greater number of SCRs during both tasks, particularly with role-plays. There were no differences of HR and BP between the groups across all phases.	Very small sample size Individual differences may have masked physiology effects of anxiety
Allwood, Handwerger, Kivilghan, Granger, & Stroud, 2011	56 HC youths (29 females, 27 males) (*M* = 12.0, *SD* = 2.4, range 7-16 years)	79% Caucasian, 7% African American, 9% Multi-racial, 5% other	CBCL; Achenbach 1991, Achenbach & Rescorla, 2001 RCMAS; Reynolds & Richmond, 1978, 2000 Task-related affect measure adapted from STAI-C; Spielberger et al., 1973	Two testing sessions: 1) habituation session, 2) three stressor tasks; performance oriented or peer-rejection task	Salivary Cortisol sAA HR SBP DBP	Children's self-report of anxious affect was associated with baseline sAA. Trait anxiety was associated with sAA changes to stressor task. HR and BP reactivity was not correlated with self-reported anxiety (RCMAS) Cortisol and cardiovascular measures could not differentiate between high and low stress participants	Small sample size. Used non-clinical population, limited variance in CBCL and RCMAS scores may increase risk of Type II errors

Gonzalez, Moore, Garcia, Thienemann, & Huffman, 2011	29 parent-child dyads (ANX vs NONANX) 16 ANX (10 male, 6 female) (*M* = 12.49, *SD* = 2.58) 13 NONANX (2 male, 11 female) (*M* = 11.36, *SD* = 2.78)	80.3% families were Caucasian, middle-high SES from California. 6 SP, 4 GAD, 2 OCD, 3 with specific, 2 SepAD. Comorbidity with another anxiety disorder was common	ADIS-IV-C/P; Silverman & Albano, 1996	Four tasks: joke task, conflict conversation, anxiety conversation, ambiguous situations	HR	Groups did not differ on baseline HR and HR did not significantly differ between the groups on any task. NONANX group showed similar positive HR change from baseline to threat and nonthreat tasks. ANX group showed significant HR increase from baseline to the conflict task and remained elevated up until recovery phase. All children's HR returned to baseline levels within the recovery phase	Very short recovery period (2 min) Used only singular physiology measure Did not include child measure of anxiety pre- and post- tasks.
Hane & Barrios, 2011	35 healthy children (21 male, 14 female) (*M* = 8.81, *SD* = 0.75, range of 8-10 years)	Recruited from elementary school in small, rural New England town.	CBCL; Achenbach & Rescorla	Interpretative bias to threat task	HR HRV VT(RSA)	No relationship was found between maternal reports of child internalising problems and anxiety and physiological responses (baseline and change)	Small sample size Community sample, so no clinical sample represented Largely drawn from European American sample (100% of mothers were Caucasian)
Kossowsky et al., 2011	49 SepAD children (51.0% female) (*M* = 8.3, SD = 2.5, range of 5-13 years) 21 CC (66.7% female) (*M* = 9.5, *SD* = 2.4, range of 5-14 years) 39 HC (48.7% female) (*M* = 9.9, *SD* = 2.3, range of 6-14 years)	Children were recruited through local psychologists, psychiatrists paediatricians or distributed flyers and advertisements	Kinder-DIPS; Neuschwander et al., 2013; Schneider et al., 2009 SAI-C/P; In-Albon et al., 2013 RCMAS-German; Boehnke et al., 1986 SASC-R – German; Melfsen & Florin, 1997 Subjective Ratings; Wilhelm et al., 2005	Focusing on separation task out of three tasks (separation task, mild video-supported social stressor and voluntary hyperventilation challenge) For the separation task, child was given either a low-anxiety or high-anxiety instruction	PEP RSA SCL NSFn HR MAP TPR	There were no baseline differences in physiology between the three groups, except for MAP where both clinical groups had elevated MAP compared to HC. SeAP children showed greater anxiety, restlessness and cardiovascular reactivity (increased HR and MAP) to the separation task. PEP levels in SeAP children did not recover to baseline levels after reunion with mother, unlike HC children whose PEP levels recovered to baseline levels.	No additional demographic information Did not perform manipulation check for high- and low-anxiety instructions
Lester, Field, & Murris, 2011	67 children (randomly assigned to positive/negative conditions) 34 positive condition (12 females, 22 males) 33 negative condition (17 females, 16 males)	Participants recruited from UK primary school	STAI-C-Trait; Spielberger et al., 1973 FSSC-R-SF; Ollendick, 1983 Visual Analogue Mood Scale BAT; Field & Lawson, 2003	Interpretation Bias Modification Paradigm followed by BAT	HR	Presenting positive or negative information influenced children's behavioural avoidance tendencies, but the information did not affect children's self-report anxiety or physiological responses to the BAT.	Used only one physiological measure Used a nonclinical sample, limiting generalisability to clinical population Did not have a control group or neutral condition.

Miers, Blöte, Sumter, Kallen, & Westenberg, 2011	66 HSA children (38 males, 28 females) (*M* = 13.32, *SD* = 2.04, range of 9-17 years) 61 LSA children (37 males, 24 females) (*M* = 12.70, *SD* = 2.35, range of 9-17 years)	Participants recruited from the Social Anxiety and Normal Development (SAND) study's (Westenberg et al., 2009) larger community sample. Majority of participants were white, Dutch adolescents from middle class families.	SAS-A; La Greca & Lopez, 1998 VAS; Davey et al., 2007	Two sessions; 1) participants completed questionnaires and informed of upcoming speech, 2) participants watched nature video, followed by speech task	Salivary Cortisol HR SCL	HAS group reported experiencing more subjective nervousness, higher HR and sweatier palms to the speech task than LSA. There were no group differences in physiological arousal (HR, SCL, Cortisol) across pre-speech, during speech, and recovery phase.	Used pre-recorded audience, may affect generalisability Social fears not formally assessed, so it unclear how many children fulfilled SP diagnosis
Sharma, Balhara, Sagar, Deepak, & Mehta, 2011	60 children 30 ANX (16 males, 18 females) (*M* = 12.12, *SD* = 2.76, range of 8-18 years) 30 HC (15 males, 15 females) (*M* = 11.66, *SD* = 2.50, range of 8-18 years)	44% of the AD group came from rural backgrounds. All controls recruited from urban areas. Controls were sex and age matched with the ANX children.	K-SADS STAIC SCARED	None – measured at resting state in supine position	BP HRV	Children with anxiety disorders showed lower resting VT and reduced HRV compared to nonanxious controls	Small sample size Heterogeneous range of anxiety disorders
Schmitz, Krämer, Tuschen-Caffier, Heinrichs, & Blechert, 2011	30 SP children (15 males, 15 females) (M = 10.1, SD = 1.24, range of 8-12 years) 26 HC children (15 males, 11 females) (M = 9.96, SD = 1.14, range of 8-12 years)	Children were recruited via community advertisements. SP children were excluded if SP was not the primary diagnosis or if they had a comorbid DSM-IV diagnosis of severe depression, dysthymia or autism	Kinder-DIPS; Schneider et al., 2008 SASC-R-German version; Melfsen & Florin, 1997	TSST-C	HR RSA ESI (SCL/NSFn/amplitude of NSFn) CSI	SP children showed higher HR and ESI (increase sympathetic), lower RSA (decreased parasympathetic) levels at baseline than HC children. SP children exhibited blunted RSA reactivity to the TSST-C, but there were no group differences in HR reactivity. SP showed slower HR recovery from stressor task	Small sample size Used only socio-evaluative tasks
Spies, Margolin, Susman, & Gordis, 2011	70 adolescents (32 females, 38 males) (*M* = 15.3, *SD* = .8)	Participants were part of a multi-wave project examining family conflict and children's adjustment and physiology. 41.4% Hispanic/Latino/multi-ethnic, 15.7% African American, 32.9% Caucasian, 10.0% Asian	YSR; Achenbach, 1991 YSRD; Spies et al., 2011	Conflictual family discussion task	Salivary Cortisol	There is an association between subjective distress and cortisol reactivity in adolescents without or low internalising symptoms. For adolescents with high internalising symptoms, there is no association between subjective distress and HPA reactivity.	Did not include measures of trait or state anxiety Used singular stressor task Small sample size
Anderson, Veed, Inderbitzen-Nolan, & Hansen, 2010	119 adolescents (SP vs HSA vs NONANX) 56 SP (26 males, 30 females) 57 HSA (32 male, 25 female) 45 NONANX (19 male, 26 female)	87.6% Caucasian, 4.1% African American, 0.6% Asian American, 2.9% Hispanic, 2.4% Native American, 2.4% biracial	ADIS-IV-C/P; Silverman & Albano, 1996 BAI; Beck et al., 1988 SAS-A; La Greca & Lopez, 1998 SPAI-C; Beidel et al., 1995 PANAS; Watson & 1988) SUDS	Social stressor (speech task)	HR	Neither social anxiety symptoms or self-reported physiological arousal was correlated with HR reactivity during any part of the 10-min speech. The groups did not differ significantly on HR reactivity and baseline HR SP group reported significantly higher SUDS ratings than the HAS group, and the HAS group reported significantly higher SUDS ratings than the NONANX group.	Used singular physiology measure No recovery measurements of HR taken, nor was HR measured during speech preparation.

Bacow, May, Choate-Summers, Pincus, & Mattis, 2010	20 children (Tx vs SM) (*M* = 15.25, *SD* = 1.22, range of 14-17 years)	Recruited from a large US city, with parents, pediatricians, school personnel, and other clinicians serving as primary referral sources	ADIS-IV-C/P; Silverman & Albano, 1997 SUDS BAT	Panic Control Treatment for Adolescents (Hoffman & Mattis, 2000) vs Self-monitoring condition BAT based upon 3 stressor tasks from PCT (Barlow & Craske, 1989), where Ss	HR	HR reactivity at pre- and post-treatment was unrelated with changes in SUDS ratings. Treatment may reduce participant's experience of anxiety but does not improve physiological arousal	Used only singular physiology measure No control group
Dieleman, van der Ende, Verhulst, & Huizink, 2010	225 children (*M* = 10.06, *SD* = 1.52, range of 8-12 years)	Drawn from a larger general population sample from the Netherlands	MASC; March et al., 1997 PAQ; Kallen, 2002	Three stressor tasks; mental arithmetic, public speaking and a computer task	Salivary Cortisol CAR	There was no association between anxiety problems and any of the cortisol measures There was a relationship between perceived arousal due to the task and anxiety problems	Used a general population sample, replication with clinical sample required
Henje Blom, Olsson, Serlachius, Ericson, & Ingvar, 2010	69 female adolescents with ANX and or MDD (*M* = 16.8, range of 14-19 years) 65 female HC (*M* = 16.5, range of 15-18 years) Final sample: 60 ANX, 53 HC	ANX recruited from outpatient clinic in Stockholm. HC recruited from schools.	DAWBA; Goodman et al., 2000 BAI; Osman et al., 2008 SDQ; Goodman, 2001	None – measured at resting state in sitting position	HRV LF RSA HR SBP DBP	There were no differences in HR, BPs between the groups. But HRV LF and RSA were significantly lower in the clinical sample than the healthy controls – this was partly explained by SSRI medication	Limited sample size for clinical group may explain lack of HRV difference between diagnostic subgroups
Greaves-Lord et al., 2010	965 children (47% males) (*M* 11.0, *SD* = 0.51, range of 10-13 years at first assessment)	Subsample from the TRAILS Study, Dutch cohort	RCADS; Chorpita et al., 2000	Orthostatic challenge (standing up)	HR RSA	HR increased and RSA decreased from baseline (supine) to the challenge (standing) Baseline measures (supine rest) did not predict anxiety scores at Wave 2, and no gender interaction was found. For girls, low RSA reactivity to the challenge significantly predicted anxiety 2 years later, but this not found for boys.	Samples from general population, anxiety severity was low
Tsai, Friedmann & Thomas, 2010	15 youths (8 girls, 7 boys) (M = 10.97, SD = 3.01, range of 7-17 years)	Hospitalised children. All children scored lower than 40 on the STAI-C-State	STAI-C-State anxiety subscale; Spielberger, 1970 CMFS; Broome et al., 1992	Two conditions: Treatment (Animal-Assisted Therapy) vs comparison intervention (puzzle task)	HR SBP DBP	Neither intervention reduce child's anxiety and medical fears. SBP decreased from before to after AAT.	Small sample size No additional information on child's mental health Physical activity/exertion to the two interventions may have masked anti-arousal effects of the AAT
Afifi, Afifi & Coho, 2009	112 parent-adolescent dyads (62 male children) (M = 16, range of 14-18 years)	Majority of participants were White, a US study	Self-reported anxiety measure	Parent-child discussion on divorce	SCL	Adolescents with divorced parents had greater self-reported anxiety than adolescents with non-divorced parents, but there were no differences between the groups on change in SCL. There was a significant correlation between SCL and self-reported anxiety across the groups.	Possible selection bias in participant recruitment Used only one physiology measure

Anderson & Hope, 2009	392 adolescents (17 males, 213 females) (M = 14.5, SD = 1.27, range of 13-17 years) 85 SP (42 males, 43 females) 307 HC	Recruited from local schools in a Midwestern US city	ADIS-IV-C/P; Silverman & Albano, 1996. BAI: Beck, Epstein, Brown & Steer, 1988 CASI; Silverman, Fleisig, Rabin & Peterson, 1991 SPAI-C; Beidel, Turner & Morris, 1995 SUDS	Two social stressors (speech and interaction task)	HR SBP DBP	There were no significant differences between anxious and non-anxious children on HR reactivity, SBP and DBP during both stressor tasks. SUDS showed that both tasks were anxiety-provoking for social phobic youths, but not for the non-anxious youth. Girls exhibited higher HR reactivity during the speech than did boys, regardless of diagnosis.	Used only social stressor tasks
Bakker, Tijssen, van der Meet, Koelman, & Boer, 2009	59 children 25 ANX (17 females) (*M* = 12.0) 9 siblings of ANX (3 females) (*M* = 10.5) 25 HC (15 females) (*M* = 12.7)	Recruited from out-patient clinic in the Netherlands.	ADIS-IV-C/P – Dutch (Silverman & Albano, 1996)	Exposure to random sound	SSR	Patients with an anxiety disorder and their non-affected siblings showed significantly larger sympathetic skin response to the startle sound compared to controls	Did not measure recovery period Did not measure children's stress and anxiety after sound exposure Small sample size
Field & Price-Evans, 2009	54 children (22 males, 32 females) (*M* = 7.49, *SD* = 1.05)	Participants predominantly Caucasian, from UK	CW-BIS-C; Field, 2006	Behavioural Avoidance Task	HR	Children's HR was significantly higher when approaching the box associated with verbal threat information than the box associated with positive and no information. Children's trait anxiety was a non-significant predictor of HR.	The CW-BIS-C had very low internal consistency
Oskis, Loveday, Hucklebridge, Thorn, & Clow, 2009	61 female adolescents (*M* = 13.9, *SD* = 2.7, range of 9-18 years)	All British born, healthy adolescents	STAI; Spielberger, 1970	None. Observational, cross-sectional design	CAR	There were no significant correlations between CAR and state or trait measures of anxiety. There was also no relationship between daytime cortisol levels and anxiety.	STAI scores where within normative range with no evidence of psychopathology. Saliva samples taken on two consecutive weekdays
Stroud et al., 2009	39 children (22 females) and 43 adolescents (20 females) (M = 12.5, SD = 2.5, range of 7-17 years)	75.5% Caucasian, 4% African American, 14.5% Hispanic, 6% mixed race/ethnicity, and 6% other. Healthy children	Self-reported Affect adapted from STAI-C; Spielberger et al., 1973)	Completed either a performance (public speaking, mental arithmetic, mirror tracing) or peer rejection (three exclusion challenges) stress session	Cortisol sAA SBp DBP HR	Adolescents showed sig. greater cortisol, sAA, SBP and DBP stress response relative to children. Developmental differences were most pronounced in the performance stress session for cortisol and DBP, and in the peer rejection session for sAA and SBP. Children showed higher levels of HR compared to adolescents for both stressors. However, the differences between adolescents and children evident for physiological stress responses were not mirrored by differences in affective responses to the stressors.	Missing pubertal data for 40% of the sample Did not directly measure anxiety
Kallen et al., 2008	99 children/ adolescents (53 males, 46 females) (*M* = 10.8, *SD* = 2.2, range of 8-16 years)	Recruited from outpatient clinics 33 GAD 24 SepAD 19 SP 18 Specific Phobia	ADIS-C; Silverman et al., 2001 MASC; March et al., 1997	None – baseline measurements taken in the morning, afternoon and evening	Salivary Cortisol CAR	There were no baseline differences in CAR or cortisol levels at noon or evening between the diagnosed anxiety groups. Girls with low MASC scores had higher CAR than girls with high MASC scores.	Used only clinical group, no comparison group with HC or low anxiety. Some subjects had comorbidity with other anxiety disorders. Lack of compliance was a significant methodological drawback

Price-Evans & Field, 2008	54 children (22 males, 32 females) (*M* = 7.49, *SD* = 1.05, range of 6-10 years)	Participants predominantly Caucasian, from UK	FBQ; Field & Lawson, 2003	Behavioural Avoidance Task	HR	A neglectful maternal parenting style moderates the verbal information pathway such that it significantly decreases the child's HR during the BAT.	Did not report on child's anxiety to the BAT Used only one physiology measure
van West, Claes, Sulon, & Deboutte, 2008	50 children 25 SP (14 male, 11 female) (M = 9.48, SD = 0.77, range of 6-12 years) 25 HC (20 male, 5 female) (M = 8.88, SD = 1.54, range of 6-12 years)	All participants spoke Dutch as first language. SP recruited from an outclinic and HC recruited from local Dutch schools	ADIS-C/P; Silverman & Albano, 1996 CBCL; Achenbach, 1991 STAI-C; Spielberger, 1973	Public speaking test from the TSST	Cortisol	SP showed elevated cortisol reactivity to the stressor, but this associated only with higher trait anxiety levels, not state anxiety.	Used only one physiology measure Small sample size, Gender not well balanced between groups.
Greaves-Lord et al., 2007	1027 adolescents (543 females, 494 males) (*M* = 11.0, *SD* = 0.5, range of 10-13 years)	Participants were Dutch born, part of a general population study called TRAILS, the Netherlands	CBCL; Achenbach et al., 2003 RCADS; Chorpita et al., 2000, 2005	None – measurements taken in supine and standing position	HR HRV LF HRV HF (RSA)	Parent reported anxiety problems anxiety problems were associated with lower RSA in the supine position. This was also found for child-reports but only in boys. HR was not associated with anxiety problems	Only measured children at rest.
Hastings, Zahn-Waxler, & Usher, 2007	55 adolescents (18 females) (*M* = 13.47, *SD* = .60)	Recruited from greater metropolitan area of NYC, US as part of a longitudinal wave study	MC; Kendziora et al., 1997 YSR; Achenbach, 1991 CBCL; Achenbach, 1991	Two social stressors (conversation and speech)	HR DBP SBP	Children's anxiety increased significantly after the conversation and speech. HR was significantly higher after both tasks than at baseline. Postspeech measures reveal greater anxiety was related with higher SBP and lower HR. Higher internalising scores was related to larger increases in DBP to the tasks, and larger increases in SBP to the speech. Mother's reports of internalising symptoms predicted greater HR increases to the conversation.	Youth and mother reports of problems were not correlated for internalising problems. Tasks were not counterbalanced No baseline obtained between the two tasks Could not continuously measure cardiac responses Not enough power to assess gender differences
Pervanidou et al., 2007	60 patients (40 males, 20 females) 40 controls (13 males, 27 females) (*M* = 10.70, *SD* = 2.46)	All participants were White	K-SADS-PL – PTSD; Kaufman et al., 1997 YSR; Achenbach, 1991 CBCL; Achenbach, 1991 CPTS-RI; Pynoos et al., 1987 STAI-C; Spielberger, 1973 IES; Horowitz et al., 1979	None – longitudinal study. Cortisol samples collected at hospital, 1 month and 6 months follow-up	Salivary Cortisol	23 children had PTSD at 1 month and 9 children at the 6 month evaluations. PTSD children at 1 month had higher cortisol concentrations, but this level normalises at 6 months.	All participants were White

Pfeffer, Altemus, Heo, & Jiang, 2007	45 bereaved children (49% female) (*M* = 8.9, *SD* = 2.9, range of 4 - 13 years) 34 nonbereaved children (56% female) (*M* = 9.3, *SD* = 2.5, range of 4 -14 years)	Recruited from metropolitan areas near NYC, after September 11, 2001 terrorist attacks. Predominantly White participants	K-SADS; Ambrosini & Dixon, 1996	None – longitudinal study, Cortisol samples taken 4 consecutive days	Salivary Cortisol	Bereaved children were more likely to have at least one psychiatric disorder, and higher rates of anxiety and mood disorders than non-bereaved children after the attacks. Bereaved children had significantly higher afternoon baseline cortisol than non-bereaved children. Bereaved children with PTSD, compared with bereaved children without a disorder, had lower afternoon baseline and greater afternoon suppression of cortisol. Children with GAD had significantly less morning cortisol suppression than children without psychopathology.	Just taking baseline measurements - did not test how children would respond to mild stressor
Leen-Feldner et al., 2006	124 adolescents (57 females) (*M* = 15.04, *SD* = 1.49)	Primarily healthy Caucasian children	ADIS-C; Silverman & Albano, 1996 CASI; Silverman et al., 1991 PANAS-C; Wilson et al., 1998 SUDS; Wolpe, 1958	Voluntary hyperventilation procedure	HR	Anxiety sensitivity moderated the relationship between challenge-related change in HR and post-challenge anxiety, such that high AS youths who experienced a relatively greater HR change reported the most anxious reactivity to the challenge. HR change was not strongly related to anxiety ratings among individuals with low AS.	Had only one physiology measure Used a community sample of healthy children with little diversity – not representative of clinical populations
Li & Lopez, 2006	106 children (73 males, 33 females) (*M* = 9.56, *SD* = 1.65, range of 7-12 years)	Convenience sample of Chinese children from Hong Kong, admitted to day surgery	CSAS-C; Lo & Lopez, 2004; Spielberger et al., 1973) CEMS; Lo & Lopez, 2005	None – cross sectional study, measurements taken within operating theatre but before anaesthesia induction	HR MAP SBP DBP	At the preoperative level, children showed high self-report, observed report levels of anxiety and higher MAP and faster HR. HR and MAP were significantly positively correlated with child and observer reports of anxiety.	Convenience sampling. No comparison for after the post-operation or follow up.
Schiefelbein & Susman, 2006	108 children 56 males (*M* = 12.72, *SD* = 1.32, range of 10-14 years) 52 females (*M*= 11.99, *SD* = 155, range of 9-14 years)	Predominantly Caucasian, community sample recruited from US	DISC; Costello et al., 1983	None – longitudinal study taking baseline measurements	Plasma Cortisol	For girls, greater cortisol increase across the year predicted higher social anxiety. There was no difference in cortisol between social anxiety and generalised anxiety children. Girls with higher cortisol levels reported more GA and SA symptoms.	Used the DISC to assess symptoms, rather than for diagnosis Girls may have shown more stress at blood-drawn samples Boys may have been more reluctant to disclose anxiety symptoms Used only one anxiety measurement tool
El-Sheikh et al., 2005, as cited in Granger et al., 2006	54 children (24 males, 30 females) (*M* = 8.86, *SD* = 0.28, range of 8-9 years)	Recruited from small south-eastern US city Healthy children with no acute or chronic physical illness, mental retardation. Learning disabilities and ADHD. 66% European American, 33% African American	WJ-III; Woodcock et al., 2011	Exposure to audiotaped argument Star-tracing task	RSA Salivary Cortisol sAA	Salivary cortisol, alpha-amylase and RSA remained stable across assessment times. No association between cortisol and alpha-amylase levels or reactivity. Children with higher levels of amylase showed vagal augmentation (deficits in vagal suppression). Girls who showed higher post-stress amylase had more healthy problems, social problems and aggression, while boys had more cognitive problems.	Did not include subjective anxiety measure before and after stressors

Leen-Feldner, Feldner, Bernstein, McCormick, & Zvolensky, 2005	151 adolescents (85 males, 66 females) (*M* = 14.93, *SD* = 1.50, range of 12-17 years)	Predominantly healthy Caucasian, children	ADIS-C; Silverman & Albano, 1996 CASI; Silverman et al., 1991 PANAS-C; Joiner et al., 1996 SUDS; Wolpe, 1958 API; Dillon et al., 1987	Voluntary hyperventilation procedure	HR SCL	Although the CASI scores predicted postchallenge ratings of anxiety and intensity of panic symptoms, it was not related with HR and SCL. There was no association anxiety sensitivity and physiological responses during the challenge.	Used a community sample, findings may not generalise to clinical population Challenge did not uniformly evoke panic symptoms across all children
Stroud, Handwerger, Kivilghan, Granger, & Niaura, 2005, as cited in Granger et al., 2006	29 children and adolescents (12 females, 17 males) (*M* = 1.21, *SD* = 2.4, range of 7-16 years)	Recruited though community postings and direct mail as part of larger study. Participants were healthy youths with no history of psychological, behavioural problems and current physical illness.	Self-reported affect	Two sessions: First session to acclimatise the child to lab setting. Second session contained 3 stressor tasks: speech and mental arithmetic task modified from TSST-C, and a mirror-tracing task	Salivary cortisol sAA HR SBP DBP	Increasing age was associated with sAA reactivity to stress. There was no relationship between cortisol and sAA. HR and DBP reactivity were not associated with sAA, but there was a positive relationship between SBP and sAA. Greater sAA reactivity was associated with decreases of feelings of relaxation and increases in feelings of fearfulness. Greater cortisol reactivity was associated with decreases in relaxation and happiness.	Cross-sectional Small sample size Not enough information on measures used
Weems, Zakem, Costa, Cannon, & Watts, 2005	49 children (55% female) (M = 11.1, SD = 3.3, range of 6-17 years)	Community sample, 55% African American, 27% Euro-American, 8% Hispanic, 10% mixed	RCADS-C/P; Chorpita et al., 2000; Spence, 1997 RCMAS; Reynolds & Richmond, 1978 ADIS-C Interference scale; Silverman & Albano, 1996 FSSC-R; Ollendick, 1983	Watched a video of fearful stimulus (large dog)	HR GSR (SCR)	There were no differences in HR between high and low anxious groups pre-video, but there were significant differences during and post-video segments. No significant differences in GSR between high and low anxious groups were found during baseline, during and post-video phase. HR response was strongly associated with children's report of anxiety symptoms. Parent's reports were not associated with GSR or HR response.	Cross-sectional Small sample size and wide age range
Leen-Feldner, Zvolensky, & Feldner, 2004	95 children (42 females, 53 males) (*M* = 14.9, *SD* = 1.8, range of 12-17 years)	Non-clinical population, predominantly caucasian	BIS/BAS; Carver & White, 1994 SAM; Bradley & Lang, 1994 SUDS; Wolpe, 1958	Two conditions: children instructed to either suppress anxiety or observe anxiety to fear-relevant pictures	HR SCL	Greater behavioural inhibition scores were related to the SUDS and SAM. There was a negative correlation between BIS scores and SCL, no correlation was found between BIS scores and HR.	Cross-sectional, used community sample
Dorn et al., 2003	42 children 14 with abdominal pain (9 females, 5 males) (*M* = 12.7, *SD* = 2.8) 14 ANX (9 females, 5 males) (*M* = 12.0, *SD* = 2.4) 14 HC (9 females, 5 males) (*M* = 12.6, SD ± 2.7)	Predominantly Caucasian.	STAIC K-SADS-PL; Kaufman et al., 1997 SCARED; Birmaher et al., 1997 CSI; Walker et al., 1991 CBCL; Achenbach, 1992	TSST-C	HR SBP DBP Cortisol	Mean baseline HR were not significantly different between groups. ANX group had a significantly higher baseline SBP than the HC group. There were no significant group differences in DBP and cortisol levels.	Did not measure anxiety before and after TSST-C Small sample size

Klein-Heßling & Lohaus, 2002	128 children (range of 9 – 12 years)	Recruited from schools in Germany	TAQ; Wieczerkowski et al., 1973 Scales on stress, somatic stress symptoms and coping strategies; Lohaus et al., 1996	Experimental design – two conditions of systematic relaxation training (PMR and imagination)	HR SCL Skin temperature	Results did not show considerable physiological or stress differences of training.	Children may not have extreme levels of anxiety or stress that would be corrected by the relaxation programs
Cooley-Quille, Boyd, Frantz, & Walsh, 2001	185 adolescents 89 High-exposure group (33 female, 56 male)(*M* = 15.72, *SD* = 1.39) 86 Low-exposure group (46 female, 40 male)(*M* = 15.16, *SD* = 1.12)	90% African American. Located in most crime-ridden district in mid-Atlantic Region, US	STAI-C; Spielberger, 1973 YSR; Achenbach, 1991 FSSC-R; Ollendick, 1983 LES-N; Sarason et al., 1978	Exposure to media violence film clips	HR	Adolescents exposure to high levels of community violence had lower baseline HR and more trait anxiety than those exposed to lower levels of community violence. There was no difference between the groups on physiological reactivity.	Only 33 participants gave physiology measurements, decreasing sample size and power. Did not measure self-report anxiety before and after the media violence film Did not include recovery period
El-Sheikh, Harger, Whitson, 2001	75 children 39 males (*M* = 9.9, *SD* = 1.3, range of 8-12 years) 36 females (*M* = 9.9, *SD* = 1.3, range of 8-12 years)	80% European American, 9,3% African American, 1.3% Hispanic, 2.7% Asian American, 6.7% non-classfied.	RCMAS; Reynolds & Richmond, 1978 CBCL; Achenbacj & Edelbrock, 1983	Exposure to conflict audio	VT Delta VT	Baseline VT and delta VT were not associated with internalising problems or RCMAS scores.	Did not measure child's anxiety before and after the stressor
Klimes-Dougan, Hastings, Granger, Usher, & Zahn-Waxler, 2001	195 adolescents (M = 13.66, SD = 1.51, range of 11-17 years) 43 INP 81 IEP 71 HC	A community sample recruited from Washington, US	DISC-IV; Shaffer et al., 2000 CBCL; Achenbach, 1991 YSR; Achenbach, 1991	Two social stressors (interaction and speech task), parent-child conflict discussion, and baseline measurements on a non-school days	Salivary Cortisol	Females showed elevated midday and late afternoon cortisol levels than males, particularly for HC adolescents. Anxiety symptoms were reported more by participants who showed cortisol reactivity patterns of increase-decrease or decrease-increase to the social stressors, and participants who showed a strong decrease to the conflict discussion. Gender was a moderating factor	Used only one physiology measure No state and trait anxiety before and after the stressors Only female confederates were used, may explain increased cortisol in boys
Monk et al., 2001	34 children 22 ANX (*M* = 12.8, *SD* = 2.9, range of 9-18 years) 12 HC (*M* = 13.7, *SD* = 2.9, range of 9-18 years)	The probands had either SepAD, OAD/GAD, PD or SP, and were recruited when presented for treatment. HC were recruited via advertisements	DISC; Jensen et al., 1995 API; Pine et al., 1998 Symptom ratings State Anxiety analogue scale	Voluntary hyperventilation challenge	HR HRV	ANX group had significantly higher HR at baseline after controlling for age and sex. There were no group differences in HRV at baseline. ANX showed less HR fluctuations during the baseline period and increases in HR during the stressor period. HC group showed significant decrease in HRV across baseline and in the early phases of the challenge.	Small sample size,

Yeragani, Radhakrishna Rao, Pohl, Jampala, & Balon, 2001	22 children 7 ANX (2 females, 5 males) 15 HC (8 females, 7 males)	1 child diagnosed with Oad, 6 with SepAD	DSM-III-R; Spitzer et al., 1987	None – measured at resting state in supine position	HR QT variability	There were no group differences on HR baseline. ANX group had higher QT variability at baseline.	Small sample size
De Bellis et al., 1999	52 children 18 PTSD (8 females, 10 males) (*M* = 10.4, *SD* = 1.4, range of 8-13 years) 10 OAD/GAD (6 females, 4 males) (*M* = 10.9, *SD* = 1.3, range of 9-13 years) 24 HC (9 females, 15 males) (*M* = 10.5, *SD* = 1.1, range of 8-12 years)	Predominantly White	K-SADS-P; Chambers et al., 1985 K-SADS-E; Orvaschel & Puig-Antich, 1987 CBCl; Achenbach & edlebrock, 1983 CDC; Putnam & Peterson, 1994 GAF; Shaffer et al., 1983	None – observational, cross sectional study	UFC	PTSD excreted significantly greater concentrations of UFC than control, but not OAD subjects. Duration of maltreat experiences correlated with UFC.	Small sample size
Kagan, Snidman, Zenner, & Peterson, 1999	164 children (85 females, 79 males) (*M = 7.3*, range of 6-9.5 years) 43 with anxious symptoms 14 conduct/ADHD 107 HC	Middle- class, Caucasian participants, part of a larger longitudinal study sample.	ASQ; Kagan et al., 1999	Series of tests: modified stroop test, matching familiar figures test, reflex inhibition task, spatial memory recall task potentiated startle procedure	HR Temperature SBP DBP	Children who were classified as high reactive at 4 months were more likely to develop anxious symptoms than low reactive infants. High reactive who developed anxious symptoms showed higher DBP when sitting, and larger magnitude of cooling of surface temperature to the cognitive challenge than the high reactives who did not go on to develop anxious symptoms.90% of high reactive infants did not develop high fear and anxious symptoms.	Did not measure child’s trait or state anxiety during the tasks
Martel et al., 1999	48 female adolescents 27 SP (*M* = 15.6, *SD* = 1.5) 21 HC (*M* = 15.4, *SD* = 1.4)	Recruited via advertisement	ADIS-C; Silverman & Albano, 1995	Social stressor task from TSST and cortisol samples taken for 3 consecutive days	Salivary Cortisol	There were no differences between the HC and SP groups in cortisol levels immediately before or after the TSST. There were also no differences in cortisol levels during the 3 days between the groups.	No additional anxiety measure before and after social stressor. Post-task saliva collection occurred within 10 minutes after completing task. Did not attempt to measure recovery. Sample collection and noncompliance issues
Schmidt, Fox, Schulkin, & Gold, 1999	36 children 10 HSY (6 males, 4 girls) 16 MSY (7 males, 9 females) LSY (3 males, 7 females) 7-year olds	Primarily Caucasian, recruited from Washington DC area	CCTI; Buss & Plomin, Rowe & Plomin, 1977	Social stressor – speech task	HR Salivary Cortisol VT	HSY and MSY groups showed greater HR reactivity than LSY There were no group differences on cortisol measures (pre- and post-task) and VT (during baseline and stressor task)	Missing data on several physiological measures 70% of children classified as not shy were girls, suggesting maternal reports used differing gender norms Did not use child self-reports of anxiety

Eisen & Silverman, 1998	4 boys (M = 10.58, range of 8-12 years)	Children had principal diagnosis of Overanxious disorder (DSM-III-R) Referred to anxiety clinic in Miami area	ADIS-C/P; Silverman & Nelles, 1988 RCMAS; Reynolds & Richman, 1978 CNCEQ; Leitenberg, Yost &Carroll-Wilson, 1986 CASI; Silverman	Two treatment conditions: Cognitive response class treatment vs somatic response class treatment. Experimental participants received prescriptive treatment, control participants received nonprescriptive treatment	HR	Prescriptive intervention produced greater improvements than nonprescriptive intervention as shown by HR measures, and this was maintained at 6 months follow-up	Very small sample size Uses only one physiology measure Uses HR as a treatment outcome to assess intervention efficacy
Mezzacappa et al., 1997	175 male adolescents (*M* = 15.0, at the last assessment)	All participants Canadian, French-speaking and Caucasian	JIAP; Martin, 1981 SBQ; Kindlon et al., 1995, Trembley et al., 1991, 1994	Orthostatic challenge; longitudinal design over 5 years	HR HRV HRV LF RSA	Higher levels of anxiety were associated with increasing HR in both the supine and standing positions	Homogenous sample (age, sex, ethnicity) Missing cardiac data for 22 boys Did not control for time of day, time after meals, smoking history or substance consumption
Beidel, Fink, & Turner, 1996	150 children (75 males, 75 females) (*M* = 9.92, SD = 1.22, range of 7-12 years)	86.7% Caucasian; 11.3% African American; and 2.1% Asian American, Latin American, or Native American. Recruited from schools in US	ADIS-C/P; Silverman & Nelles, 1988 TASC; Sarason, 1975 STAI-C; Spielberger, 1973 CDCL; Achenbach, 1978; Achenbach & Edelbrock, 1979	Two tasks; vocabulary test and a social-stressor task (reading to an audience)	Pulse rate (HR) SBP DBP	Majority of subjects diagnosed with an anxiety disorder at initial assessment still showed significant symptoms at 6 month follow-up. Cardiovascular responses were stable at the 2 week follow-up but not at 6 month follow-up, except for SBP which was stable at 6-month follow-up	Could not obtain TASC data for 6 month follow up
Granger, Weisz, McCracken, Ikeda, & Douglas, 1996	64 children (34 males, 30 females) (*M* = 12.71, *SD* = 2.15, range of 9-17 years)	All children were recruited from outpatient clinics, seeking mental health services. 45.3% Caucasian, 26.6% Latino, 18.8% African-American, 9.3% mixed/other ethnic	DISC; NIMH, 1991 YSR; Achenbach, 1991 CBCL; Achenbach, 1991 SASC; La Greca et al., 1988 Self-Report Task Behavior Scores	Parent-child conflict discussion; longitudinal design	Salivary Cortisol	Cortisol response to the conflict discussion predicted children's internalising problem behaviours and anxiety disorders 6 months later.	Only had one physiology measure No control/non-referred group
Beidel, Turner, & Trager, 1994	62 children 31 TA 31 NTA	Each group had 18 African American and 13 white participants	ADIS-C/P; Silverman & Nelles, 1988 TASC; Sarason et al., 1960 STAIC; Spielberger, 1973 PSCS; Harter, 1982 SAM; Lang & Cuthbert, 1984	Two stressors; a vocabulary test and oral reading (social stressor)	HR SBP DBP	TA children had significantly higher TASC and trait anxiety scores than NTA children. TA children reported more anxiety than NTA for both taks, but there were no group differences on any physiological measure during baseline and stressor tasks. White children, regardless of group, had larger HR and SBP increases than African American children	Did not include recovery phase

Granger, Weisz, & Kauneckis, 1994	102 children/ adolescents (62 male, 40 female) (*M* = 12.08, range of 7-18 years)	Clinic referred participants 51% White, 20.6% Hispanic, 18.6% African American, 9.8% other.	CBCL; Achenbach, 1991 YSR; Achenbach, 1991 SASC; La Greca et al., 1988 Task related measures on social inhibition and anxious affect	Parent child conflict discussion	Salivary Cortisol	Cortisol reactivity correlated with trait social anxiety, trait social withdrawal and socially inhibited (internalising) behaviour during the discussion task.	Used only one physiology measure No control group for comparison No other stressor task to compare stress Did not account for parent's behaviours during the task No further information on children's diagnosis
Gerra et al., 1992	30 14-year-old adolescent girls 21 HC 9 with anxiety/frustration	Recruited from Italian high schools	AST-A (Busnelli et al., 1971)	Exercise step test	Plasma ACTH Plasma Cortisol HR BP	There were no group differences on HR and BP after physical exercise. There were no group differences on cortisol before and after the exercise. Plasma ACTH were similar for both groups are baseline and increased after exercise. The anxiety/frustration group had significantly higher ACTH levels after the exercise than the HC group	Small sample size Grouped adolescents with anxiety with adolescents with frustration
Beidel, 1991	47 children 18 SP (7 male, 11 female) (*M* = 10.6) 11 OAD/GAD (3 male, 8 female) (*M* = 10.0) 18 HC (7 male, 11 female) (*M* = 10.8)	Each group contained 11 White children, there were 7 African American children in the SP and HC group	ADIS-C/P; Silverman & Nelles, 1988 TASC; Sarason et al., 1958 STAI-C; Spielberger, 1973 SAM; Lang & Cuthbert, 1984	Two social stressors; a vocabulary test and story presentation task	Pulse Rate (HR)	SP group reported significantly higher trait anxiety and anxiety during the vocabulary test. The SP group had resting HR no different to the HC group, but significantly lower than OAD. SP group's HR significantly increased during the task (not significantly different to HC's HR increase) and remained elevated during the task. OAD children were more likely to show HR decrease from baseline to the behavioural task.	Used only one physiology measure Small sample size
Turner, Beidel, & Epstein, 1991	19 children 8 ANX (6 male, 2 female) (*M* = 9.0, range of 8-13 years) 11 HC (7 male, 4 female) (*M* = 9.7, range of 8-13 years)	All participants were Caucasian	CAS; Hodges et al., 1982 K-SADS; Last, 1986, Chambers et al., 1985 STAI-C; Spielberger, 1973 FSSC-R; Ollendick, 1983 SAM; Lang & Cuthbert, 1984	Exposure to either fearful visual or fearful auditory stimulus	HR SCL NSF	No significant differences between ANX and HC groups on STAI-C and FSSC-R. Both groups reported similar levels of distress to the stimuli. ANX had more NSF at baseline that HC. There were no significant main effects or group interactions for HR. HC's SCl decreased over time to the two stimuli. ANX showed decreasing SCL over the first several presentations, but increased gradually until the 20th exposure trial.	Small sample size, Task may have been too short to accurately detect changes in HR Did not include recovery phase
Armstrong, Collins, Greene, & Panzironi, 1988	30 children (12 male, 18 female) (range of 9-12 years)	Sampled from schools in West Virginia. All children reported significant levels of test anxiety	TASC; Sarason et al., 1960 FTR; Kelley, 1976 STAIC; Spielberger, 1973	Three treatment conditions; progressive muscle relaxation, positive visual imagery training and attention control condition All children completed an arithmetic test and grooved pegboard test	HR	All groups showed decreased HR from the 1st stress task to the 2nd task. FTR also decreased between the two tasks for all groups. HR remained steady during recovery phases, whilst FTR and state anxiety ratings decreased for all groups during the recovery phases.	The tasks may not have been sufficiently anxiety-provoking Very short recovery phases

Beidel, 1988	50 children (27 boys, 23 girls) 25 TA 25 HC (*M* = 9.1, range of 8-12 years)	Recruited from elementary school in Pennsylvania. All white children. 60$ of TA children met criteria for DSM-III anxiety	CAS; Hodges et al., 1982 TASC; Sarason et al., 1958	Two social stressor tasks; timed vocabulary test and oral reading	HR SBP DBP	No group differences in SBP and DBP were found during the procedure. TA showed higher HR reactivity during both stressors. HC showed an increase than a decrease in HR during the tasks (not significant, but trending)	No recovery phase for the physiological measures No self-report of anxiety pre- and post-task
Matthews, Manuck, & Saab, 1986	23 children 11 females (*M* = 15.5) 14 males (*M* == 15.3)	Participants were all Caucasian, enrolled in another study.	ASI; Siegel & Leitech, 1981 MYTH; Matthews & Angulo, 1980 STPI; Spielberger et al., 1983	A series of tasks; social stressor (public speaking – school assessment) and cognitive tasks (serial subtraction task, frustrating mirror trace task and handgrip task)	HR SBP DBP	Students generally showed elevations in all three cardiovascular measures prior, during and after speech relative to measurements taken during the next class. Anxious students showed higher SBP levels prior to the speech and at the signal of the speech task relative to the next class, whilst less anxious students showed a lesser effect. Anxious children also showed higher HR levels before and after their speech than the less anxious children. Anxious and less anxious children showed similar HR levels during the next class. HR and SBP increase was correlated with higher anxiety during the speech task	Could not take cardiovascular measures during the speech
Tennes & Kreye, 1985	70 children (38 males, 32 females) (*M* = 7.7, range of 6-9 years)	Predominantly Caucasian sample	TASC; Sarason et al., 1960	Two stressor tasks; cognitive test and reading test (social stressor)	Urinary Cortisol	No associations between test anxiety and cortisol was found. Although cortisol was significantly higher on test days than regular school days, it was not related to children's self-reports of test anxiety	No measure of trait or state anxiety Did not measure cortisol level after the test
Zaichkowsky & Zaichkowsky, 1984	24 experimental (12 males, 12 females) 19 control subjects (13 females, 6 males)	Fourth grade participants	STAI; Spielberger, 1973	No stressor. Relaxation training program given to experimental group. Self-report and physiological measure taken twice	HR Skin temperature	Groups did not differ at the start of the program. Experimental group showed significant reduction in HR, increase in skin temperature and reduction in state anxiety. Controls showed significant increase in skin temperature. There were no significant differences for state and trait anxiety between the groups throughout the experiment	Children were tested in a hotter, more humid room for post-test measurements, which may account for temperature increase
Melamed, Dearborn &Hermecz, 1983	58 children (range of 4-17 years)	Convenience sampling, inpatients coming for elective surgery in Florida, US	Hospital Fears Rating Scale adapted from FSS-FC; Scherer & Nakamura, 1969 ORSA; Melamed et al., 1976, Melamend & Siegel, 1975 BPC; Peterson, 1961	Two conditions: children received either an informative hospital procedure video or unrelated film the night before surgery	HR SBP DBP PSI	Children who saw the hospital-relevant film showed reduced sweating and reported less anxiety, but had higher SBP and DBP in the leap up to surgery. However, these children also were more compliant and had fewer complications following surgery. Age and experience also affects the amount of information acquired.	Small sample size Did not mention if the children's health before surgery affected cardiovascular system or other systems

Peterson & Shigetomi, 1981	66 children (35 females, 31 males) (M = 5.47, SD = 2. 06, range of 2-10 years)	All participants were white, and anticipating elective tonsillectomies in Utah, US	Parent report of Child Disposition Child Observational Rating Scale Behavior Checklist The Faces Scale; Venham, Bengston, & Cipes, 1977 Hospital Fears Rating Scale; Melamed & Siegel, 1975	Four experimental conditions: information, coping, modelling and modelling + coping	Pulse rate (HR) Temperature	The physiology measures did not correlate with other measures of anxiety.	Group differences and physiology variables were not discussed further in the report
Fischer & Kutina, 1976	96 10-year-old male children 32 LA 33 MA 30 HA	Recruited from 6 schools in Prague	CMAS; Castenada et al., 1956	Exposure to four film scenes depicting various injuries	HR	The LA group showed no change in HR variability during the least stressful and most stressful scenes, whilst the HA group showed low HR variability in and a sharp increase towards the end. The MA group showed elevated HR compared to LA group, and this remained stable throughout time. Mean HR values during the films showed differing trajectories according to groups, but there was an overall increasing trend throughout the film.	Only used one physiology measure. Did not measure state anxiety before and after the films. Did not measure HR recovery
Darley & Katz, 1973	20 male children	5th grade boys recruited from New Jersey, US. All participants were white	TASC; Sarason et al., 1960	A cognitive stressor with two conditions: game instruction vs test instruction	HR	Test anxiety was higher in the game condition than in the test group (this might reflect the influence of the experimental session) In the test condition, TA was negatively correlated with HR acceleration. In the game condition, TA was negatively correlated with HR deceleration	Only used one physiology measure Did not measure state or trait anxiety before and after stressor
Hammar, Campbell, & Huffine, 1968	69 adolescents (range of 11-19 years) 19 new patients (68% male, 32% female) (*M* = 14.2) 25 return patients (56% male, 44% female) (*M* = 14.7) 25 male residential (*M* = 13.2)	Recruited from a university clinic and boys' residential home in the US.	CMAS; Castaneda et al., 1956 AMEQ; Hammar et al., 1968	None – physiology measures taken in supine position	Pulse Rate (HR) SBP DBP	All three cardiovascular measures alone were no indicators of anxiety in a medical examination. They also did not distinguish between new and return clinic patients. However, there was a difference between the return patients and residential group on SBP levels, and a difference between new patients on residential group on DBP levels. New patients who also reported physiological symptoms had higher blood pressure	Residential group recruited from school with high incidence of behaviour problems.

Kondaš, 1967	23 TA children (*M* = 13.0, range of 11-15 years)	All children had stage fright	FSS; Wolpe & Lang, 1964	Four treatment conditions; control, autogenic training and relaxation, systematic desentisation, and presentation of items without relaxation. All groups exposed to social stressor (examination)	Perspiration (SCL)	Palmar perspiration reduced for some children after specific therapeutic treatment, and these treatments also reduced stage-fright and FSS scores.	Did not measure continuously throughout the actual stressor Used one physiology measure Did not measure child's state or trait anxiety before and after the stressor Did not have a control group Some methodological issues where some students had fewer treatment sessions

Notes: *ANX* Group with current anxiety disorder, *CC* Clinical controls with other anxiety disorders, *ELS* Group with Early Life Stress, *HA* High anxious group, *HC* Group with no lifetime diagnosis of mental disorder/healthy control, *HSY* High shy group, *HSA* Group with high socially anxious, *IEP* Group with internalising and externalising problems, *IN* Group with internalising problems, *IU* intolerance of uncertainty, *LA* Low anxious group, *LSY* Low shy group, *LSA* Group with low socially anxious, *MA* Moderate anxious group, *MSY* Moderate shy group, *NA* Non-adopted group, *NONANX* Group with no anxiety disorder, *NTA* Group with no test anxiety, *SAD* Group with social anxiety disorder, *SepAD* Group with separation anxiety disorder, *SM* Group with selective mutism, *SP* Group with social phobia, *TA* Group with test anxiety, *TAV* Threat avoidant, *Tx* Group undergoing treatment/therapy, *TVI* Threat vigilant;
ADIS-C Anxiety Disorder Interview Schedule for Children (Silverman & Nelles, 1988, Silverman, 1996; Silverman, Saavedra & Pina, 2001), *ADIS-IV-C/P* Anxiety Disorder Interview Schedule for Children/Parents (Silverman & Albano, 1996, 1997, 2004), *AST-A* Anxiety Score Test for Adolescents (Busnelli, Dall'Aglio, & Faina, 1971), *CAPS-CA* Clinician Administered PTSD Scale for Children and Adolescents (Nader, Kriegler, & Blake, 2002), *CAS* Child Assessment Schedule (Hodges, McKnew, Cytryn, Stern & Klinc, 1982), *DISC* Diagnostic Interview Schedule for Children (Shaffer, Fisher, Lucas, Dulcan & Schwab-Stone, 2000; Shaffer, 1998; Jensen, Roper & Fischer et al., 1995; National Institute of Mental Health, 1991; Costello, Edelbrock, Kalas, Dulcan & Flaric, 1983), *GAF/K-GAS* Kiddie – Global Assessment Scale (Shaffer, Gould & Brasic et al., 1983), *K-SADS* Child Schedule for Affective Disorders and Schizophrenia (Ambrosini & Dizxon, 1996), *K-SADS-P/L/E* Kiddie Schedule for Affective Disorders and Schizophrenia for School-Age Children – Present & Lifetime (Kaufman et al., 1997; Chambers, Puig-Antich, Hirsch, Paez, Ambriosini, Tabizi & Davies, 1985; Orvaschel & Puig-Antich, 1987; Last, 1986), *Kinder-DIPS* (Neuschwander, In-Albon, Adornetto, Roth, & Schneider, 2013; Schneider, Unnewehr & Margraf, 2008, 2009), *Structured Clinical Interview DSM-III-R* (Spitzer, Williams & Gibbon, 1987);
ACQ-C Anxiety Control Questionnaire for Children (Weems et al., 2003), *AMEQ* Adolescent Medical Examination Questionnaire (Hammar, Campbell & Huffine, 1968), *ASI* Adolescent Structured Interview (Siegel & Leitech, 1981), *ASR* Adult Self-Report (Achenbach et al., 2003), *ASQ* Anxiety Screener Questionnaire (Kagan, Snidman, Zentner & Peterson, 1999), *API* Acute Panic Inventory (Pine, Coplan, Papp et al., 1998; Dillon, Gorman, Leibowitz, Fyer & Klein, 1987), *BAI* Beck's Anxiety Inventory (Osman, Barios, Gutierrez, Williams & Bailer, 2008; Beck, Epstein, Brown, & Steer, 1988), *BAT* Behavioural Approach Test (Öst et al., 2001; Field & Lawson, 2003), *BPC* Behaviour Problem Checklist (Peterson, 1961), *CASI* Childhood Anxiety Sensitivity Index (Silverman, Fleisig, Rabian & Peterson, 1991), *CASES* Child and Adolescent Stress and Emotion Scale (Burkholder et al., 2016), *CBCL* Child Behavior Checklist (Achenbach, 1991; Achenbach & Edelbrock, 1991; Achenbach & Rescorla, 2001; Achenbach et al., 2003), *CCTI* Colorado Childhood Temperament Inventory (Buss & Plomin, 1984; Rowe & Plomin, 1977), *CDC* Child Dissociative Checklist (Putnam & Peterson, 1994), *CEMS* Children's Emotional Manifestation Scale (Lo & Lopez, 2005), *CMAS* Children's Manifest Anxiety Scale (Castaneda, McCandless & Palermo, 1956), *CMFS* Child Medical Fears Schedule (Broome, Lilis, McGahee & Bates, 1992), *CPTS-RI* Children's Posttraumatic Reaction Index (Pynoos, Frederick, Nader et al., 1987), *CRSW* Children's Response Styles Questionnaire, *CSAS-C* Chinese State Anxiety Scale for Children - Chinese version of *STAI-C* (Lo & Lopez, 2004), *CSI* Child Symptom Inventory (Gadow & Sprafkin, 1997), *CSI* Children's Somatization Inventory (Walker et al., 1991; Walker & Greene, 1989), *CW-BIS/BAS-C* Carver and White's Behavioural Inhibition and Behavioural Activation Scale – Child (Field, 2006; Meester, de Kanter & Timmerman, 2005; Carver & White, 1994), *DAWBA* Development and Wellbeing Assessment (Goodman, Ford, Richards, Gatward & Meltzer, 2000), *DES-R* Differential Emotions Scale – Revised (Izard, 1972), *EATQ-R* Early Adolescent Temperament Questionnaire – Revised (Ellis & Rothbart, 2001), *FSS-FC* Fear Survey Schedule for Children (Scherer & Nakamura, 1969; Wolpe & Lang, 1964), *FSSC-R* Revised Fear Survey Schedule for Children (Ollendick, 1983), *FSSC-R-SF* Revised Fear Survey Schedule for Children – Short Form (Ollendick, 1983), *FTR* Fear Thermometer Ratings (Kelley, 1976), *FBQ* Fear Beliefs Questionnaire (Field & Lawson, 2003), *IES* Impact of Events Scale (Horowitz, Wilner & Avarez, 1979), *IES-6* Impact of Events Scale – 6 (Weiss, 2004), *IUS-C* Intolerance of Uncertainty Scale (Walker, 2009), *ISAAC* Scales for Iconic Self-Assessment of Anxiety in Children (Schneider et al., 2005), *JIAP* Jesness Inventory of Adolescent Personality (Martin, 1981), *LES-N* Life Experiences Survey (Sarason, Johnson & Siegel, 1978), *LSAS-CA* Liebowitx Social Anxiety Scale for Children and Adolescents (Masia-Warner et al., 2003)
MASC, MASC-10 Multidimensional Anxiety Scale for Children and Version 10 (March, Parker, Sullivan, Stallings & Conners, 1997; March, 1997), *MC* Mood Checklist (Kendziora, Hastings & Klimes-Dougan, 1997), *MYTH* Matthews Youth Test for Health (Matthews & Angulo, 1980), *ORSA* Observer Rating Scale of Anxiety (Melamed, Meyer, Gee & Soule, 1976, Melamed & Siegel, 1975), *PANAS* Positive and Negative Affect Scale (Watson, Clark & Tellegen, 1988), *PANAS-C/Y* Positive and Negative Affect Schedule for Children and Youth (Sandin, 2003; Wilson, Gullone & Moss, 1998; Joiner, Cantanzaro & Laurent, 1996), *PAQ* Physiological Arousal Questionnaire (Kallen, 2002), *PAQ* Physiological Arousal Questionnaire (Dieleman, van der Ende, Verhulst, & Huizink, 2010), *POMSA* Profile of Mood States – Adolescents (Terry, Lane, Lane & Keohane, 1999), *PSCS* Perceived Competence Scale for Children (Harter, 1982), *RCADS-C/P* Revised Child Anxiety and Depression Scale (Chorpita et al., 2000, Chorpita et al., 2005; Spence, 1997), *RCMAS* Revised Children's Manifest Anxiety Scale (Reynolds & Richmond, 1978, 2000), *RCMAS – German version* (Boehnke, Silbereisen, Reynolds, & Richmond, 1986), *SAI-C/P* Separation Anxiety Inventory for Children and Parent (In-Albon, Meyer, & Schneider, 2013), *SAM* Self-Assessment Manikin (Bradley & Lang, 1994; Lang & Cuthbert, 1984), *SASC* Social Anxiety Scale for Children (La Greca, Dandes, Wick, Shaw & Stone, 1988), *SASC-R* Social Anxiety Scale for Children – Revised (La Greca & Stone, 1993), *SASC-R – German version* (Melfsen & Florin, 1997), *SAS-A* Social Anxiety Scale for Adolescents (La Greca & Lopez, 1998), *SBQ* Social Behavior Questionnaire (Kindlon et al., 1995; Trembley et al., 1991; Trembley, Pihl, Vitaro, & Dobkin, 1994, *Scales on stress experienced, somatic stress symptoms and coping strategies* (Lohaus et al., 1996), *SCARED-P* Screen for Child Anxiety Related Disorders (Birmaher et al., 1995, Birmaher et al., 1997), *SCAS-C/P* Spence Children's Anxiety Scale (Spence 1988; Spence 1998), *SCL-90 R* Symptom Checklist-90 R (Derogatis, 1994), *SDQ* Strengths and Difficulties Questionnaire (Goodman, 2001), *SPAI-C* Social Phobia and Anxiety Inventory for Children (Beidel, Turner & Morris, 1995), *SPAI-C – German version* (Melfsen et al., 2001), *SPSRQ-J* Sensitivity to Punishment and Sensitivity to Reward Questionnaire – Junior (Torrubia et al., 2008), *SR-A* Self-reported State Anxiety (Bilsky, et al., 2016), *Subjective Ratings* (Wilhelm et al., 2005), *STAI* State-Trait Anxiety Inventory (Spielberger, 1988, 1973), *STAI-C* State-Trait Anxiety Inventory for Children (Spielberger, Gorsuch, Lushene, Vagg & Jacobs 1973; Spielberger, Edwards, Montuori, Lushene & Platzek, 1973; Spielberger, 1970), *STAI-C – Chinese version* (Li & Lopez, 2004), *STPI* State-Trait Personality Inventory (Spielberger, Jacobs, Russell & Crane, 1983), *SUDS* Subjective Units of Distress Scale (Wolpe, 1958), *TAI* Test Anxiety Inventory (Spielberger et al., 1980), *TAQ* Trait Anxiety Questionnaire (Wieczerkowski et al., 1973), *TASC* Test Anxiety Scale for Children (Sarason, 1975; Sarason, Davidson, Lighthall, White & Ruebush, 1960; Sarason, Davidson, Lighthall & Waite, 1958), *TSCC* Trauma Symptoms Checklist for Children (Briere, 1996), *VAS* Visual Analogue Scale (Davey, Barratt, Butow & Deeks, 2007), *WJ-III* Woodcock-Johnson III Tests of Cognitive Abilities (Woodcock, McGrew & Maher, 2001), *YSR* Youth Self-Report (Verhulst, Van der Ende & Koot, 1997; Achenbach, 1991), *YSRD* Youth's Subjective Ratings of Distress (Spies, Margolin, Susman & Gordis, 2011);
BP blood pressure, *CAR* cortisol awakening response, *CI* cardiac index, *EDA* electrodermal activity, *ESI* electrodermal sympathetic index, *HR* heart rate, *HRV* heart rate variability, *IBI* interbeat interval, *MAP* mean arterial pressure, *NSF-R(N)* non-specific skin conductance fluctuation, *PEP* pre-ejection period, *PSI* palmar sweat index, *sAA* salivary alpha-amylase, *SCL* skin conductance level, *SCLR* skin conductance level reactivity, *SCR* skin conductance response, *SI* stroke index, *SSR* sympathetic skin response, RSA respiratory sinus arrhythmia, *TPR* total peripheral resistance, UFC urinary free cortisol, VSI vascular sympathetic index, *VT* vagal tone

Appendix B of this thesis has been removed as it may contain sensitive/confidential content