PSYCHOPATHOLOGY AND ATTENTIONAL BIAS TO THREAT

PSYCHOPATHOLOGY AND ATTENTIONAL BIAS TO THREAT:

A CONCURRENT AND LONGITUDINAL INVESTIGATION

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Lay Abstract

People with higher anxiety levels pay more attention to threatening information than neutral information, compared to people with lower anxiety levels. Relatively few studies have investigated the long-term relation between attentional bias to threat and symptoms of mental disorder. Our study investigated the concurrent and longitudinal relations between attentional bias to threat and symptoms of anxiety, depression, and social anxiety.

We found that anxiety, depression, and social anxiety in the 30s were concurrently related to greater attentional bias to threat. Additionally, anxiety and depression in the 20s were longitudinally related to greater attentional bias to threat 10 years later. Moreover, people with high anxiety and high attentional bias to threat were more likely to experience social anxiety in the future than people with high anxiety but low attentional bias to threat. Therefore, attentional bias to threat might have a critical role in the development and/or persistence of some mental disorders.

Abstract

Individuals with high anxiety levels from clinical and non-clinical populations tend to exhibit an attentional bias where they selectively allocate more attention to threat stimuli than neutral stimuli, in comparison to individuals with lower anxiety levels. However, longitudinal studies investigating the relations between attentional bias to threat and symptoms of anxiety, depression, and social anxiety—some of the most common mental disorders—are scarce.

Using a concurrent and longitudinal design, we investigated the relations between attentional bias to threat and symptoms of anxiety, depression, and social anxiety; concurrently in adulthood (the 30s) as well as longitudinally between young adulthood (the 20s) and adulthood (the 30s). We also investigated whether attentional bias to threat in the 30s moderated and/or mediated the relation between symptoms of psychopathology in the 20s and the same symptoms in the 30s.

We found significant concurrent correlations between attentional bias to threat and greater symptoms of anxiety, depression, and social anxiety in the 30s. We also found positive longitudinal correlations between attentional bias to threat in the 30s and symptoms of anxiety (approached significance) and depression (significant) in the 20s. Thus, greater symptoms of internalizing-related psychopathology were associated with greater attentional bias to threat.

Attentional bias to threat did not mediate the relation between early psychopathology and later psychopathology, but it did moderate the relation between anxiety in the 20s and social anxiety nearly a decade later. In individuals with greater attentional bias to threat, early anxiety was significantly associated with and predicted greater future social anxiety, but this was not the case for individuals with lower attentional bias to threat. Hence, attentional bias to threat may have a critical role in internalizing-related psychopathology, and interventions targeting it may

have preventative and therapeutic potential for mitigating the likelihood of the development

and/or persistence of internalizing-related psychopathology.

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Declaration of Academic Achievement

The current study investigated the concurrent and longitudinal associations between symptoms of psychopathology and attentional bias to threat in adults. Rei Jamalifar, the Master's graduate student, conceptualized the research questions, conducted a literature review on the topic, conducted data analyses, and wrote the thesis manuscript. Dr. Louis Schmidt, the principal investigator and co-supervisor, conceptualized the experimental design and provided feedback and guidance on all drafts of the thesis manuscript. Dr. Bruce Milliken, the co-supervisor, also conceptualized the research design and provided feedback on thesis manuscript drafts. Moreover, Dr. Randi McCabe, supervisory committee member, provided guidance on data analyses and research conceptualization. Lastly, members of the Child Emotion Laboratory at McMaster University were responsible for data collection.

Introduction

Have you heard of the expression: "What you pay attention to becomes your life"? In the busy, technologically advanced 21st century, people are constantly surrounded by and bombarded with various types of information. It makes sense that the information that people pay attention to significantly impacts their mood, thoughts, behaviors, and ultimately, their lives on a daily basis. People often consciously choose to pay attention to information that they find important, interesting, or relevant to their lives. But what if some of us have an unconscious bias to pay more attention to the negative information in our environment?

Specifically, individuals with high anxiety levels from clinical and non-clinical populations tend to exhibit an attentional bias where they selectively allocate more attention to threatening and negative stimuli in comparison to neutral or positive stimuli, when compared to individuals with relatively low anxiety levels (Bantin et al., 2016; Bar-Haim et al., 2007; Bradley et al., 2000; de Voogd et al., 2016; Kuckertz et al., 2014; Maidenberg et al., 1996; Matsumoto, 2010; Musa et al., 2003; Neubauer et al., 2013; Pergamin-Hight et al., 2015; Reinecke et al., 2011; Schofield et al., 2012). It is imperative to further explore attentional bias to threat in individuals with high anxiety levels because attentional biases may have a crucial role in the development and maintenance of anxiety disorders.

Anxiety-Related Attentional Bias to Threat

In the extant literature, anxiety-related attentional bias to threat has been operationally defined in two ways: within-subject attentional bias to threat and between-subject attentional bias to threat (Bar-Haim et al., 2007). Within-subject attentional bias to threat refers to the significant difference between the attention oriented to threat stimuli versus the attention oriented to neutral stimuli in individuals with high anxiety levels (Bar-Haim et al., 2007). Between-subject

attentional bias to threat refers to the significant difference between the attention allocation pattern of individuals with high versus low anxiety levels when presented with threat stimuli and neutral stimuli (Bar-Haim et al., 2007). Individuals with high anxiety levels tend to display between-subject and within-subject attentional bias to threat (Bantin et al., 2016; Bar-Haim et al., 2007; Bradley et al., 2000; de Voogd et al., 2016; Kuckertz et al., 2014; Maidenberg et al., 1996; Matsumoto, 2010; Musa et al., 2003; Neubauer et al., 2013; Pergamin-Hight et al., 2015; Reinecke et al., 2011; Schofield et al., 2012). On the other hand, individuals with relatively low anxiety levels either demonstrate no attentional bias to threat (Fox et al., 2001; Maidenberg et al., 1996; Matsumoto, 2010) or demonstrate an attentional bias away from threat (Bradley et al., 2000; Monk et al., 2004; Musa et al., 2003).

Attentional bias to threat has been observed in children (Bar-Haim et al., 2007; Dalgleish et al., 2001; Dudeney et al., 2015; Hadwin et al., 2003; Kelly et al., 2016; Moradi et al., 1999; Taghavi et al., 2003) and in adults (Bar-Haim et al., 2007; Kuckertz et al., 2014; Maidenberg et al., 1996; Neubauer et al., 2013; Reinecke et al., 2011). Attentional bias to threat has also been found in individuals with a variety of anxiety disorders such as generalized anxiety disorder (Bradley et al., 1999; Mogg & Bradley, 2005; Rinck et al., 2003; Taghavi et al., 2003), posttraumatic stress disorder (Buckley et al., 2000; Dalgleish et al., 2001; El Khoury-Malhame et al., 2011a; Moradi et al., 1999), social anxiety disorder (Amir et al., 2009b; Bantin et al., 2016; Kuckertz et al., 2014; Neubauer et al., 2013), panic disorder (Maidenberg et al., 1996; McNally, 1999; Reinecke et al., 2011), and obsessive-compulsive disorder (Bradley et al., 2016; da Victoria et al., 2012; Moritz et al., 2009; Summerfeldt & Endler, 1998). Overall, individuals display greater attentional bias to threat toward their disorder-specific threat stimuli in comparison to other disorders' threat stimuli (Pergamin-Hight et al., 2015). Moreover, the effect

size of attentional bias to threat is similar across all of the aforementioned anxiety disorders (*d* = .45), suggesting that attentional bias to threat may be a core component of all anxiety disorders (Bar-Haim et al., 2007).

Interestingly, many researchers have been able to use attention bias modification (ABM), a computerized cognitive training technique designed to reduce participants' attentional bias to threat, to decrease stress reactivity (Bar-Haim et al., 2011; Dennis & O'Toole, 2014; Grafton et al., 2014) and alleviate anxiety symptoms (Amir et al., 2009a; Amir et al., 2009b; Hallion & Ruscio, 2011; Kuckertz et al., 2014; MacLeod & Clarke, 2015). The reduction in anxiety symptoms after the reduction of attentional bias to threat provides further evidence that attentional bias to threat may be one of the causal factors that contributes to anxiety symptomology.

In their meta-analysis, Bar-Haim et al. (2007) established that even if the next 11,339 studies exploring the existence of attentional bias to threat in individuals with high anxiety levels find non-significant results, this phenomenon does not lose its robust statistical significance. Hence, Bar-Haim et al. (2007) concluded that publication bias is not of concern regarding the existence of attentional bias to threat. More recently, however, some researchers have questioned the role of attentional bias to threat in the development and maintenance of anxiety disorders (Heeren et al., 2015; Kruijt et al., 2019; McNally, 2019) because various studies failed to find attentional bias to threat in individuals with high anxiety levels (Boettcher et al., 2013; Boettcher et al., 2014; de Lijster et al., 2019; Enock et al., 2014; Julian et al., 2012; McNally et al., 2013; Naim et al., 2018). The inconsistency in the presence of attentional bias to threat in the extant literature may be due to some studies' inadequate statistical power (small sample size), publication bias (Kruijt et al., 2019), and questionable task reliability (Cisler et al., 2009; Kruijt

et al., 2019; MacLeod et al., 2019). Moreover, it is possible that certain measurement methodologies are more effective at capturing attentional bias to threat in specific anxiety disorders. Hence, the use of different measurement methodologies as well as the use of samples from populations with different types and different severities of anxiety symptomology may contribute to the observed inconsistency in findings. The disparities in the literature reveal a need for further exploration of attentional bias to threat.

Theoretical Cognitive Frameworks of Attentional Bias to Threat

Biased processing of emotionally-valenced information can create cognitive vulnerability to psychopathology (Mathews & MacLeod, 2005). Specifically, attentional bias to threat is considered to have a central role in the development and/or maintenance of anxiety disorders (Amir et al., 2009b; Bar-Haim et al., 2007; Bradley et al., 2016; El Khoury-Malhame et al., 2011a; Mogg & Bradley, 2005; Reinecke et al., 2011). There are multiple theoretical frameworks that explain the cognitive mechanisms underlying anxiety and attentional bias to threat.

According to the cognitive-motivational framework (Mogg & Bradley, 2018), anxiety and attentional bias to threat are caused by the imbalance between bottom-up processes responsible for motivational salience evaluation/detection and top-down processes responsible for goal-directed cognitive control. Mogg and Bradley (2018) posit that individuals with high levels of anxiety have over-reactive threat salience-evaluation mechanisms (bottom-up processes), which when activated, may render goal-directed cognitive control mechanisms (top-down processes) ineffective or maladaptive.

According to the schema-based information processing model of anxiety (Beck & Clark, 1997; Beck et al., 1985), one's schema network greatly influences one's attention, interpretation, and recollection of information. This cognitive theory posits that individuals with high levels of

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anxiety have schemata biased toward threat, which consequently bias their information processing mechanisms toward threat at all levels of information processing, including automatic and strategic processes (Beck & Clark, 1997; Beck et al., 1985).

Two similar cognitive models of selective processing in anxiety by Mathews and Mackintosh (1998) and Mogg and Bradley (1998) posit that attention toward threat stimuli involves an intensity threshold; below the threshold, the stimulus is ignored, and above the threshold, the stimulus is attended to. It was predicted that relatively severe-intensity threats would be attended to by individuals with low and high levels of anxiety, whereas relatively moderate-intensity threats would be attended to only by individuals with high levels of anxiety (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998); this prediction was experimentally supported by Wilson and MacLeod (2003). Hence, attentional bias to threat in individuals with high anxiety levels can be attributed to having a lower cognitive threshold for threat intensity compared to individuals with low levels of anxiety (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Wilson & MacLeod, 2003).

Lastly, the multi-process model of cognitive vulnerability to anxiety (Ouimet et al., 2009) postulates that individual differences in associative processing (bottom-up activation of associated concepts) and rule-based processing (top-down rational evaluation of factual relations between concepts) collectively influence information processing biases. This model suggests that the strength of threat-related associations and the specific strategy used to invalidate threat-related associations together impact attention orientation, engagement, disengagement, avoidance, and interpretation of threat information, which contribute to the etiology and maintenance of various anxiety disorders (Ouimet et al., 2009).

Measurement of Attentional Bias to Threat

Dot-Probe Paradigm

The predominant method of measuring attentional bias to threat is using the dot-probe paradigm (MacLeod et al., 1986). In this cognitive task, two stimuli (words or images) simultaneously appear on a computer screen. Each stimulus can have a threatening, neutral, or positive valence, and when two of them are presented together, they may be of the same or of different valences. The two stimuli are briefly presented on the screen, and then a visual probe replaces one of the stimuli. Participants must make a two-alternative discrimination response (i.e., press a specific button on a keyboard) to the probe based on its location. In the case of presenting a threat stimulus with a neutral stimulus, individuals with high anxiety levels tend to exhibit a faster reaction time when the probe appears in the previous location of the threat stimulus (Bantin et al., 2016; Kuckertz et al., 2014; MacLeod et al., 1986; MacLeod & Clarke, 2015; Salemink et al., 2007). This result suggests that individuals with high anxiety levels selectively orient their attention to threat stimuli compared to neutral stimuli. The observed attentional bias to threat seems to be due to higher and quicker engagement with threat stimuli (i.e., hypervigilance) as well as difficulty disengaging from threat stimuli (Cisler et al., 2009). Moreover, the dot-probe paradigm allows for the measurement of attention to (vigilance) and attention away from (avoidance) threat stimuli through the calculation of bias scores. Bias scores are determined by calculating the difference between the mean response time in incongruent trials and the mean response time in congruent trials; incongruent trials are trials in which the probe appears in the previous location of the neutral stimulus, whereas congruent trials are trials in which the probe appears in the previous location of the valenced stimulus. A positive bias

score reflects vigilance favouring the valenced stimuli, and a negative bias score reflects avoidance of the valenced stimuli.

Emotional Stroop Task

Another measurement technique of attentional bias to threat is the emotional Stroop task (Williams et al., 1996). In the emotional Stroop task, participants must quickly name the colour of neutral and emotionally-valenced words while ignoring the words' semantics (Williams et al., 1996). Individuals with high anxiety levels are slower in naming the colour of threat words in comparison to neutral words relative to individuals with low anxiety levels (Becker et al., 2001; Moradi et al., 1999; Richards et al., 2000; Williams et al., 1996). This result suggests that individuals with high anxiety levels orient more attention to the meaning of threatening words.

Visual Search Paradigm

The visual search paradigm (Treisman & Gelade, 1980) can also be used to measure attentional bias to threat. In this paradigm, individuals with high anxiety levels are faster at locating a threatening stimulus among neutral distractors in comparison to a positive stimulus among neutral distractors relative to individuals with low anxiety levels (Byrne & Eysenck, 1995; de Voogd et al., 2016; Gilboa-Schechtman et al., 1999; Matsumoto, 2010). This finding suggests that individuals with high anxiety levels are hypervigilant toward threat.

Eye Tracking

Beyond using cognitive stimulus-response tasks to assess attentional bias to threat, eye tracking technology has also been used to measure attentional bias to threat (Clauss et al., 2022). Eye tracking technology has demonstrated that individuals with high anxiety levels have faster reflexive orienting and higher vigilance toward threat stimuli (Armstrong & Olatunji, 2012; Bradley et al., 2000; Clauss et al., 2022; Felmingham et al., 2011), higher maintenance of vision

and attention on threat stimuli (Clauss et al., 2022; Lazarov et al., 2016; Lazarov et al., 2021), and difficulty disengaging from threat stimuli during visual search tasks (Armstrong & Olatunji, 2012; Schofield et al., 2012).

Physiological Correlates of Attentional Bias to Threat

Attentional bias to threat is associated with multiple physiological measures. It corresponds with higher skin conductance responses upon observing threat stimuli (Felmingham et al., 2011), indicating higher sweat gland secretion and sympathetic nervous system activation due to emotional arousal (Ekman et al., 1983). Attentional bias to threat also correlates with higher activation of the amygdala (in an emotional face matching task; El Khoury-Malhame et al., 2011b). The amygdala is a brain region involved in threat detection (Ohman, 2005), fear expression (Davis, 1992), and the pathophysiology of anxiety disorders (Anand & Shekhar, 2003).

Using electroencephalogram (EEG) technology, individuals with high anxiety levels demonstrate faster latencies and higher amplitudes in their early components of event-related potentials (ERPs) upon observing threat stimuli compared to individuals with low anxiety levels (Bar-Haim et al., 2005; Li et al., 2005). This finding suggests that threat stimuli elicit higher mobilization of attentional resources in individuals with high anxiety levels (Bar-Haim et al., 2005). Attentional bias to threat is also associated with right frontal brain EEG asymmetry (i.e., higher relative activation in the right frontal cortex) at rest (Grimshaw et al., 2014; Miskovic & Schmidt, 2010), during an emotional Stroop task (Avram et al., 2010; Herrington et al., 2005), and during a stressful speech task (Pérez-Edgar et al., 2013). This is in line with previous research, which indicates that right frontal brain EEG asymmetry is associated with fear (Coan et al., 2001; Tomarken et al., 1990) and withdrawal motivation (Harmon-Jones, 2003), whereas left

frontal brain EEG asymmetry is associated with happiness (Coan & Allen, 2003; Davidson et al., 1990; Wheeler et al., 1993) and approach motivation (Harmon-Jones, 2003). Right frontal brain EEG asymmetry is also correlated with a higher risk for psychopathology (Coan & Allen, 2004).

Attentional Bias to Threat and Psychopathology: Concurrent and Longitudinal Relations

Anxiety

Despite the robust evidence for a concurrent association between attentional bias to threat and anxiety (Bantin et al., 2016; Bar-Haim et al., 2007; Bradley et al., 2000; de Voogd et al., 2016; Kuckertz et al., 2014; Maidenberg et al., 1996; Matsumoto, 2010; Musa et al., 2003; Neubauer et al., 2013; Pergamin-Hight et al., 2015; Reinecke et al., 2011; Schofield et al., 2012), very few studies have investigated the predictive relation between attentional bias to threat and anxiety in the long term. Some studies demonstrate that attentional bias to threat longitudinally predicts anxiety after 1 year (Bardeen & Daniel, 2018) as well as after 3 months (Osinsky et al., 2012). However, some other studies demonstrate that there is no significant association between attentional bias to threat at baseline and anxiety at follow-up, which was approximately between 6 months to 3 years after baseline (Briggs-Gowan et al., 2016; Dodd et al., 2020; Nozadi et al., 2016; Price et al., 2016; White et al., 2017).

Interestingly, even though some of the aforementioned studies found that attentional bias to threat by itself does not predict anxiety, their results revealed that attentional bias to threat moderates the longitudinal relation between behavioral inhibition (a risk factor for internalizing psychopathology; Clauss & Blackford, 2012) and later anxiety in childhood and adolescence (Dodd et al., 2020; Nozadi et al., 2016; White et al. 2017). Moreover, attentional bias to threat has been found to moderate the longitudinal relation between shyness (a risk factor for psychopathology; Findlay et al., 2009) and resting frontal EEG asymmetry (another risk factor

for psychopathology; Coan & Allen, 2004) in an adult population (Hassan & Schmidt, 2021). Therefore, the combination of attentional bias to threat and another risk factor of psychopathology may significantly increase one's vulnerability to psychopathology.

Most longitudinal studies investigating the longitudinal relation between attentional bias to threat and anxiety did so in child or adolescent populations, in which they did not find a direct predictive association between attentional bias to threat and anxiety (Briggs-Gowan et al., 2016; Dodd et al., 2020; Nozadi et al., 2016; Price et al., 2016; White et al., 2017). To our knowledge, the studies by Bardeen and Daniel (2018) and Osinsky et al. (2012) are the only studies that directly assessed the longitudinal association between attentional bias to threat and anxiety in adult populations, both of which found a significant predictive association. The scarcity of longitudinal studies and their conflicting findings highlight the critical need for more longitudinal research investigating the predictive relation between attentional bias to threat and anxiety. This research strategy will allow us to further our understanding of the mechanisms underlying the etiology and maintenance of anxiety.

Social Anxiety

There is strong evidence supporting a concurrent relation between attentional bias to threat and social anxiety symptoms (Abend et al., 2018; Amir et al., 2009b; Bantin et al., 2016; Kuckertz et al., 2014; Morrison, 2014; Neubauer et al., 2013; Roy et al., 2008). However, longitudinal research investigating the predictive relation between attentional bias to threat and social anxiety is lacking. Using a longitudinal design, Henricks et al. (2022) and Morrison (2014), surprisingly, did not find a significant predictive association between attentional bias to threat and social anxiety in adolescents after 2 years or young adults after 9 months, respectively. To our knowledge, no study has investigated the predictive relation between attentional bias to

threat and social anxiety symptoms in an adult population. This highlights the crucial need for more longitudinal research on the long-term association between social anxiety and attentional bias to threat.

Depression

The findings in the extant literature are conflicting with regards to the concurrent association between attentional bias to threat and depressive symptoms. Some studies have found attentional bias to threat in individuals with depressive symptoms (Mathews et al., 1996; Mogg et al., 1995; Sears et al., 2011) and individuals with a history of depression (Sears et al., 2011). Moreover, Hommer et al. (2014) found that attentional bias to threat positively correlated with the severity of depressive symptoms. On the other hand, some evidence suggests that individuals with depression do not demonstrate attentional bias to threat (Elgersma et al., 2018; Mogg & Bradley, 2005; Mogg et al., 1993), and there is no concurrent association between attentional bias to threat and depressive symptoms (Struijs et al., 2021). A meta-analysis of 29 empirical studies found that individuals with depressive symptoms demonstrate significant attentional bias toward sad stimuli and a trending attentional bias toward threat stimuli (Peckham et al., 2010). Interestingly, there is also evidence for individuals with depressive symptoms demonstrating attentional bias away from positive stimuli (Peckham et al., 2010; Sears et al., 2011). These findings suggest that depressive symptoms are more strongly associated with an attentional bias away from positive information as well as an attentional bias to sad information as opposed to threatening information.

With regards to comorbid depression and anxiety, Hommer et al. (2014) found that attentional bias to threat existed in individuals with depression alone as well as individuals with comorbid anxiety and depression. Some other studies, however, have found that individuals with

co-occurring anxiety and depression do not demonstrate attentional bias to threat (Bradley et al., 1995; Elgersma et al., 2018; Struijs et al., 2021; Taghavi et al., 1999), suggesting that depression comorbidity in anxiety may impede the manifestation of attentional bias to threat. In their meta-analysis, Bar-Haim et al. (2007) found that the inclusion of participants with co-occurring anxiety and depression symptoms did not modulate attentional bias to threat, suggesting that depression comorbidity in anxiety does not impede the manifestation of attentional bias to threat.

With regards to the longitudinal relation between attentional bias to threat and depression, longitudinal studies are scarce. Struijs et al. (2021) found no predictive relation between attentional bias to threat and depressive symptoms in adults after 5 years. However, Osinsky et al. (2012) found a significant predictive relation between attentional bias to threat and depressive symptoms after 3 months in adults, which was moderated by the short allele of the 5-HTTLPR serotonin transporter gene; the 5-HTTLPR short allele is a risk factor for developing depressive psychopathology under stress (Karg et al., 2011). Surprisingly, Price et al. (2016) found that attentional bias away from threat (threat avoidance), instead of attentional bias to threat, predicted greater depressive symptoms after 2 years in adolescents. Lastly, although there is evidence for a concurrent association between depressive symptoms and attentional bias away from positive stimuli, Elgersma et al. (2019) were not able to find a predictive association between attentional bias away from positive stimuli and the probability of depression recurrence after 2 and 4 years in adults. Given the conflicting findings in the literature as well as the small number of longitudinal studies conducted to date, more longitudinal studies are needed to firmly establish the longitudinal relation between attentional bias to threat and depressive symptoms.

The Current Study

Significance

Longitudinal studies investigating prospective associations between attentional bias to threat and symptoms of anxiety, social anxiety, and depression—some of the most common mental disorders—are quite scarce, especially in adult populations. The current study extends our knowledge about attentional bias to threat by investigating the concurrent relations and the longitudinal relations (in approximately a 10-year timeframe) between attentional bias to threat and symptoms of psychopathology in adults. This enhances the literature's understanding of the role of attentional bias to threat in the development and maintenance of psychopathology in adults, and it may inform prevention and intervention programs such as attention bias modification (ABM). The findings of the current study also provide valuable insight into the underpinnings of anxiety, social anxiety, and depression. Lastly, to our knowledge, this study is the first to explore the longitudinal relation between attentional bias to threat and symptoms of psychopathology with a longer than a 5-year timeframe by exploring nearly a 10-year timeframe.

Primary Goals

The current study had three primary goals. The first goal was to investigate the concurrent associations between attentional bias to threat and psychopathological symptoms (i.e., anxiety, social anxiety, and depression) all measured concurrently in adulthood (i.e., the 30s). In line with previous studies in the literature, we predicted that symptoms of anxiety and social anxiety would significantly correlate with greater attentional bias to threat. We made no prediction regarding the association between attentional bias to threat and symptoms of depression since the literature presents inconclusive findings regarding this association.

The second goal of the current study was to investigate longitudinal associations between psychopathological symptoms (i.e., anxiety and depression) in young adulthood (i.e., the 20s) and attentional bias to threat measured approximately 10 years later in adulthood (i.e., the 30s). We predicted that anxiety symptoms would prospectively predict greater attentional bias to threat after nearly a decade. We again made no prediction for the relation between attentional bias to threat and depressive symptoms due to the conflicting findings in the literature.

The third goal of the current study was to investigate whether attentional bias to threat measured in adulthood moderated and/or mediated the relation between psychopathological symptoms (i.e., anxiety, social anxiety, and depression) in young adulthood and the same psychopathological symptoms in adulthood. We predicted that psychopathological symptoms in the 20s would correlate with the same psychopathological symptoms nearly 10 years later in the 30s. We further predicted that attentional bias to threat in adulthood would moderate and mediate the relation between symptoms of anxiety and social anxiety in the 20s and symptoms of anxiety and social anxiety in the 30s, respectively. We made no prediction regarding the moderation or mediation of attentional bias to threat for the relation between depression in the 20s and depression in the 30s.

Methods

Participant Overview

Participants were from a larger longitudinal birth cohort study investigating the psychological and physical health outcomes of extremely low birth weight (ELBW) infants and normal birth weight (NBW; control group) infants born between 1977 and 1982 in central-west Hamilton, Ontario, Canada (Saigal et al., 1984). The current study used the data of NBW participants who had participated in data collection at the young adulthood assessment (i.e., early

20s; ages 22 – 26) as well as the adulthood assessment (i.e., early 30s; ages 30 – 35).[1] The decision to only use the data of NBW participants and exclude ELBW participants was made to increase the generalizability of the findings to a wider healthy, nonclinical population.

Out of 133 NBW (control) participants who participated in data collection at the young adulthood assessment, 94 participants (i.e., 70.7%) returned approximately 10 years later for data collection at the adulthood assessment. We conducted t-tests to assess whether participant attrition was related to any study variables. Out of all study variables, only two variables were related to participant attrition. Firstly, more male participants were lost to attrition than female participants ($t = 2.1$, $df = 70.2$, $p = .04$), and secondly, more participants with lower household incomes in their 20s were lost to attrition than participants with higher household incomes in their 20s ($t = 3.4$, $df = 79.0$, $p = .001$). All other study variables measured at the young adulthood assessment (i.e., age, number of chronic diseases, depressive symptoms, and anxiety symptoms) were not related to attrition.

Out of the 94 participants who participated in data collection at the adulthood assessment, 85 participants (i.e., 90.4%) successfully participated in the dot-probe task. We were unable to successfully collect dot-probe data from 9 out of the 94 participants due to equipment problems with the computer used for the dot-probe task.

Additional exclusion criteria were applied to the aforementioned 85 participants for number of chronic conditions. Chronic conditions were defined as health issues including visual impairments, neurosensory impairments, coordination impairments, and other disabilities. In order to increase the generalizability of the sample and the findings, an exclusion criterion of 3 standard deviations above and below the mean of number of chronic conditions in the 30s were

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[1] For the sake of brevity, the early 20s and the early 30s age groups will be referred to as the 20s and the 30s age groups, respectively.

used. No participant had a number of chronic conditions lower than 3 standard deviations below the mean. Only two participants who had a number of chronic conditions higher than 3 standard deviations above the mean were excluded. Moreover, one participant had an attentional bias to threat score that was 3 standard deviations above the mean level of attentional bias to threat. This participant was treated as an extreme outlier and was removed from further analyses.

Our final sample consisted of 82 adults ($n_{male} = 32$; $M_{age} = 23.64$ years, $SD_{age} = 1.08$ years, age range = 22 – 26 years; $M_{household\ income} = \$92,708.68$; $SD_{household\ income} = \$70,682.44$), approximately 88% of which were from a Caucasian background, who came back for data collection approximately 10 years later ($n_{male} = 32$; $M_{age} = 32.48$ years, $SD_{age} = 1.41$ years, age range = 30 – 35 years; $M_{household\ income} = \$80,808.82$; $SD_{household\ income} = \$41,740.23$).

Procedure

Participants were assessed at two time points: once in young adulthood (the 20s) and once in adulthood (the 30s) at McMaster University's Child Emotion Laboratory. Participants received a thorough explanation of the study procedures and signed consent forms prior to data collection. All participants were compensated with $100 for their time and participation. Study procedures received ethics clearance by the Hamilton Health Sciences Research Ethics Board.

The dot-probe task was used at the adulthood assessment to measure attentional bias to threat, while self-report questionnaires were used at the young adulthood assessment as well as the adulthood assessment to measure psychopathological symptoms.

Please note that in order to facilitate replication, transparency, and consistency, the present study adopted the use of language consistent with the methods section of two other papers published from our lab, which also used the dot-probe paradigm: Hassan and Schmidt (2021) and Tang et al. (2017). Hence, there is considerable overlap between the present study's

methods section and the methods description of these two papers, which explored research questions involving attentional bias to threat and other outcome variables in participants from the aforementioned larger longitudinal birth cohort study.

Measures

Attentional Bias in the 30s

Participants completed a dot-probe task (MacLeod et al., 1986), the predominant method of measuring attentional biases, at the adulthood assessment (in the 30s). They completed the dot-probe task in a dimly lit and sound-attenuated room at McMaster University's Child Emotion Laboratory. The stimuli used for the dot-probe paradigm were images of four models (two males and two females) demonstrating happy (positively-valenced), neutral (no valence), and angry (negatively-valenced) facial expressions. These images were selected from the NimStim Set of Facial Expressions (Tottenham et al., 2009). The Adobe Photoshop software (version 10.0) was used to match all images in their contrast and luminance. All images were displayed to participants on a computer screen in full RGB colour with a resolution of 234x300-pixel and a refresh rate of 75 Hz. Participants were positioned approximately one meter away from the computer screen, and the E-Prime software (version 1.2) was used to carry out the paradigm.

Participants were given one 8-trial practice block prior to completing two 64-trial experimental blocks. At the beginning of all trials, a fixation cross was displayed by itself in the centre of the screen for 500 ms. Afterwards, two images simultaneously appeared side-by-side for 104 ms. The two images in each trial were from the same model; one image expressed a neutral facial expression and the other expressed an emotionally-valenced facial expression (happy or angry). The display duration of 104 ms was selected because shorter stimuli-displaying durations, such as 104 ms, in the dot-probe paradigm are associated with greater reliability and

larger effect sizes in detecting attentional biases (Bar-Haim et al., 2007; Miskovic & Schmidt, 2012). After the 104 ms display duration of the stimuli, an asterisk, acting as the visual probe, replaced one of the two stimuli on the left or right side of the screen and remained on the screen for a maximum of 1500 ms. Participants were told to make a two-alternative discrimination response (i.e., press a specific button on a keyboard) to the probe indicating whether it appeared on the right or left side of the screen. Participants were also told to respond as quickly and accurately as they could. As soon as the participant responded to the probe, the next trial was prompted to begin. If the participant did not respond for 1500 ms after the probe had been displayed, the program was set up to automatically initiate the next trial.

Each of the two 64-trial experimental blocks consisted of 32 angry-neutral stimuli pairings and 32 happy-neutral stimuli pairings. The order of trials/stimuli in each block was randomized for each participant. The blocks were programmed to be balanced by displaying valenced stimuli, angry or happy stimuli, with an equal likelihood (i.e., 50%) on the right or left side of the screen. The likelihood of the probe appearing on the right or left side of the screen was also equal (i.e., 50%). Additionally, there was an equal likelihood (i.e., 50%) of each trial being congruent (probe appearing in the previous location of the valenced stimulus) and being incongruent (probe appearing in the previous location of the neutral stimulus).

The dot-probe paradigm can be used to measure attention to (vigilance) and attention away (avoidance) from valenced stimuli through the calculation of bias scores. Bias scores are determined by calculating the difference between the mean response time in incongruent trials (probe appearing in the previous location of the neutral stimulus) and the mean response time in congruent trials (probe appearing in the previous location of the valenced stimulus). Hence, the formula used to calculate attentional bias scores was: *Attentional Bias Index = Mean Response*

Time in Incongruent Trials – Mean Response Time in Congruent Trials. A positive bias score reflects vigilance favouring the valenced stimuli, and a negative bias score reflects avoidance of the valenced stimuli. When calculating attentional bias scores in the current study, only response times from correctly-responded trials were used. Moreover, we excluded response times that were less than 150 ms as they were considered random or anticipatory responses.

Anxiety and Depression in the 20s and the 30s

Anxiety and depression were measured at both the young adulthood assessment (in the 20s) and the adulthood assessment (in the 30s) using the Young Adult Self-Report (YASR; Achenbach, 1997) questionnaire. The YASR is one of the widely-used self-report Achenbach series of assessments of adaptive functioning, behavioral problems, and psychopathology called the Achenbach System of Empirically Based Assessments (ASEBA; Rescorla & Achenbach, 2004). The YASR is a 130-item questionnaire derived from the Child Behavior Checklist (CBCL; Achenbach, 1991) to assess internalizing and externalizing problems in young adults. Specifically, the YASR can be used to obtain scores on DSM-oriented scales, which include internalizing scales (i.e., anxiety problems, depressive problems, avoidant personality problems, and somatic problems) as well as externalizing scales (i.e., attention deficit/hyperactivity problems and antisocial personality problems; Achenbach et al., 2005). The current study only used participants' scores on YASR's DSM-oriented scales of anxiety problems and depressive problems.

Participants were provided with a series of items and asked to rate how much each item described them over the recent 6 months on a 3-point scale (options included not true, somewhat or sometimes true, and very true or often true). Sample items from the anxiety scale include "I am nervous or tense", "I worry a lot", and experiencing "Heart pounding or racing without

known medical cause" (Achenbach, 1991). Sample items from the depression scale include "I cry a lot", "I feel worthless or inferior", "There is very little that I enjoy", and "I am unhappy, sad, or depressed" (Achenbach, 1991). These items were scored on a 3-point scale (0 = not true, 1= somewhat or sometimes true, 2 = very true or often true). Moreover, we found good internal consistency in the present study's YASR anxiety scale (α = .73 in the 20s, α = .82 in the 30s) as well as the YASR depression scale (α = .88 in the 20s, α = .88 in the 30s).

Social Anxiety in the 30s

The widely used self-report Social Phobia Inventory (SPIN; Connor et al., 2000) was used at the adulthood assessment (in the 30s) to measure participants' social anxiety levels. Participants were provided with a series of statements (17 items) and were asked to indicate how much each mentioned problem has bothered them during the most recent week on a 5-point scale (options included not at all, a little bit, somewhat, very much, and extremely). Sample items from this scale include "Parties and social events scare me", "I avoid talking to people I don't know", and "Being embarrassed or looking stupid are among my worst fears" (Connor et al., 2000). These items were scored on a 5-point scale (0 = not at all, 4 = extremely). Lastly, the SPIN demonstrated good internal consistency in the present study (α = .93).

Data Analyses

All statistical analyses were completed using R (v4.2.2; R Core Team, 2022) and RStudio software (v2023.3.1.446; Posit Team, 2023).

Correlation Analyses

Pearson correlations were used to investigate the concurrent and longitudinal relations between attentional bias to threat in the 30s and psychopathological symptoms (i.e., anxiety, depression, and social anxiety) in the 20s as well as the 30s. Pearson correlations were also used

to investigate (1) the concurrent relations between different psychopathological symptoms measured in the 20s, (2) the concurrent relations between different psychopathological symptoms measured in the 30s, and (3) the longitudinal relations between psychopathological symptoms measured in the 20s and in the 30s. The 'cor.test' function in the R package of 'stats' (R Core Team, 2022) was used to conduct the correlation analyses.

Moderation Analyses

Linear regression models were used to investigate whether attentional bias to threat in the 30s moderated the relation between psychopathological symptoms (i.e., anxiety, depression, and social anxiety) in the 20s and the same psychopathological symptoms nearly 10 years later in the 30s. These models addressed the question of whether attentional bias to threat, the moderator, significantly influenced the strength and/or direction of the association between psychopathological symptoms in the 20s and the same psychopathological symptoms nearly 10 years later in the 30s.

In all moderation models, participants' age, sex, number of chronic health conditions, and household income in the 30s were entered as covariates. In these models, the outcome variable was one specific type of psychopathology (i.e., anxiety, depression, or social anxiety) in the 30s, and the predictor variables were the same type of psychopathology in the 20s, attentional bias to threat in the 30s, and the interaction of these two variables. Notably, due to a lack of a social anxiety scale at the young adulthood assessment (in the 20s), anxiety (i.e., general anxiety) in the 20s was used as an approximate index of early social anxiety. Consequently, anxiety in the 20s was treated as the predictor variable in the moderation model with the outcome variable of social anxiety in the 30s.

The 'lm' function in the R package of 'stats' (R Core Team, 2022) was used to conduct regression analyses. Moreover, the 'interact_plot' function and 'sim_slopes' function in the R package of 'interactions' (Long, 2019) were used to create interaction plots and conduct simple slopes analyses for the interactions, respectively.

Mediation Analyses

The 'mediate' function in the R package of 'mediation' (Tingley et al., 2014) as well as the 'mediate' function in the R package of 'psych' (Revelle, 2023) were used to conduct causal mediation analyses. The mediation analyses evaluated whether attentional bias to threat in the 30s (the mediator) was the mechanism through which psychopathology in the 20s (the predictor variable) was related to psychopathology nearly 10 years later in the 30s (the outcome variable).

In all mediation models, participants' age, sex, number of chronic health conditions, and household income in the 30s were entered as covariates. In these models, the outcome variable was one specific type of psychopathological symptoms (i.e., anxiety, depression, or social anxiety) in the 30s, the predictor variable was the same type of psychopathological symptoms in the 20s, and the mediator variable was attentional bias to threat in the 30s. Notably, due to a lack of a social anxiety scale at the young adulthood assessment (in the 20s), anxiety (i.e., general anxiety) in the 20s was used as an approximate index of early social anxiety. Consequently, anxiety in the 20s was treated as the predictor variable in the mediation model with the outcome variable of social anxiety in the 30s.

Covariates

We statistically controlled for the effects of participants' age, sex, number of chronic health conditions, and household income on psychopathological symptoms and attentional bias to threat by considering them as covariates in all of our moderation and mediation models. This

decision was made to account for any relation that may exist between either psychopathological symptoms or attentional bias to threat and any of the following variables: age, sex, household income (socioeconomic inequalities), and chronic health conditions.

Results

Descriptive Statistics

Table 1 presents the means, standard deviations, and ranges for all study variables.

Correlation Analyses

Table 2 presents the zero-order Pearson correlations between attentional bias to threat and symptoms of psychopathology in the 20s as well as the 30s. These correlations have also been illustrated using scatterplots in Figure 1. Attentional bias to threat in the 30s was significantly and positively correlated with the three types of psychopathology concurrently measured in the 30s: anxiety ($r = .21$, $p = .033$), depression ($r = .22$, $p = .048$), and social anxiety ($r = .19$, $p = .045$). Hence, symptoms of anxiety, depression, and social anxiety were concurrently associated with greater attentional bias to threat in adulthood (the 30s). Additionally, anxiety in the 20s was positively associated with attentional bias to threat approximately 10 years later in the 30s ($r = .16$, $p = .081$), although this relation was a statistical trend. Moreover, depression in the 20s was significantly and positively associated with attentional bias to threat 10 years later in the 30s ($r = .28$, $p = .011$). Hence, higher levels of anxiety and depression in young adulthood were associated with greater attentional bias to threat (i.e., vigilance toward threat) approximately 10 years later in adulthood.

The zero-order Pearson correlations in Table 3 present (1) the concurrent correlations between different symptoms of psychopathology measured in the 20s, (2) the concurrent correlations between different symptoms of psychopathology measured in the 30s, and (3) the

longitudinal correlations between symptoms of psychopathology measured in the 20s and the 30s. The concurrent correlation between different symptoms of psychopathology measured in the 20s was significant: anxiety – depression ($r = .73$, $p < .001$). The concurrent correlations between different symptoms of psychopathology measured in the 30s were also significant: anxiety – depression ($r = .80$, $p < .001$), anxiety – social anxiety ($r = .56$, $p < .001$), and depression – social anxiety ($r = .50$, $p < .001$). Moreover, all longitudinal correlations between anxiety measured in the 20s and psychopathological symptoms measured 10 years later in the 30s were significant: anxiety – anxiety ($r = .61$, $p < .001$), anxiety – depression ($r = .55$, $p < .001$), anxiety – social anxiety ($r = .54$, $p < .001$). Lastly, all longitudinal correlations between depression measured in the 20s and symptoms of psychopathology measured approximately 10 years later in the 30s were significant: depression – depression ($r = .69$, $p < .001$), depression – anxiety ($r = .63$, $p < .001$), depression – social anxiety ($r = .56$, $p < .001$). These results indicated that the symptoms of psychopathology measured in this study were concurrently and longitudinally associated with each other, and they remained relatively stable across nearly a 10-year period.

Multivariate Analyses: Partial Correlation and Multiple Regression Analyses

Two types of multivariate analyses, partial correlation analyses and multiple regression analyses, were conducted[2] to further investigate the unique associations between attentional bias to threat and each type of psychopathology (anxiety, depression, and social anxiety), while controlling for one another's effects. We assessed these multivariate analyses for data measured in young adulthood (the 20s) and adulthood (the 30s), separately.

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[2] The partial correlation analyses were conducted using the 'pcor.test' function in the R package of 'ppcore' (Kim, 2015), and the multiple regression analyses were conducted using the 'lm' function in the R package of 'stats' (R Core Team, 2022).

Upon conducting multivariate analyses for the adulthood measures, all associations (anxiety – attentional bias to threat, depression – attentional bias to threat, and social anxiety – attentional bias to threat) while controlling for another type of psychopathology also measured in the 30s were non-significant (ps > .10). Upon conducting multivariate analyses for the young adulthood measures, the association between depression and attentional bias to threat while controlling for anxiety remained significant (r = .25, β = 1.09, ps = .03), suggesting that depression in the 20s uniquely predicted attentional bias to threat (i.e., vigilance toward threat) nearly a decade later independent of anxiety in the 20s. However, interestingly, the association between anxiety in the 20s and attentional bias to threat in the 30s while controlling for depression in the 20s was non-significant (ps > .10).

Moderation Analyses

Attentional bias to threat in the 30s did not significantly moderate the relation between anxiety in the 20s and anxiety in the 30s (β = .01, p = .33; Table 4), indicating that attentional bias to threat did not interact with anxiety in young adulthood to predict anxiety later in adulthood. Similarly, attentional bias to threat in the 30s did not significantly moderate the relation between depression in the 20s and depression in the 30s (β = .01, p = .25; Table 5), indicating that it did not interact with depression in young adulthood to predict depression in adulthood. However, attentional bias to threat in the 30s did significantly moderate the relation between anxiety (i.e., general anxiety) in the 20s and social anxiety in the 30s (β = .10, p = .03; Table 6, Figure 2), indicating that attentional bias to threat interacted with anxiety in young adulthood to predict social anxiety in adulthood.[3] Hence, attentional bias to threat significantly

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[3] It is important to note that anxiety (i.e., general anxiety) measured in the 20s was used as a predictor variable in this model with the outcome variable of social anxiety in the 30s, as an approximate index of social anxiety, due to a lack of a social anxiety scale at the young adulthood assessment (in the 20s).

influenced the strength of the association between anxiety in the 20s and social anxiety in the 30s. It is important to note that participants' age, sex, number of chronic health conditions, and household income in the 30s were entered as covariates in each of the aforementioned moderation models.

We conducted a simple slopes analysis for the significant moderation/interaction effect found in predicting social anxiety in the 30s (Figure 2) to break down and interpret the moderation effect. This was done by computing the slope of the regression line for the association between anxiety in the 20s (the predictor variable) and social anxiety in the 30s (the outcome variable) when the value of attentional bias to threat in the 30s (the moderator variable) was held constant at 1 standard deviation above the mean (vigilance toward threat) and at 1 standard deviation below the mean (avoidance of threat). Upon conducting the simple slopes analysis, we found that when the value of attentional bias to threat was low (relatively high avoidance of threat), the slope of the regression line for the association between anxiety in the 20s and social anxiety in the 30s was not significantly different from 0 ($\beta = .74$, $p = .46$). This indicates that in individuals who had a relatively low attentional bias to threat (high avoidance of threat), anxiety in the 20s was not significantly associated with social anxiety in the 30s. However, when the value of attentional bias to threat in the 30s was high (relatively high vigilance toward threat), the slope of the regression line for the association between anxiety in the 20s and social anxiety in the 30s was positive and was significantly different from 0 ($\beta = 3.31$, $p < .01$). Hence, in individuals who had a relatively high attentional bias to threat (high vigilance toward threat), anxiety in their 20s was significantly associated with and predicted greater social anxiety in their 30s. Another way of interpreting this moderation effect is that

increases in attentional bias to threat (vigilance toward threat) amplified the relation between early anxiety and later social anxiety measured across a decade.

Mediation Analyses

Attentional bias to threat in the 30s did not mediate the relation between symptoms of psychopathology in the 20s and symptoms of psychopathology in the 30s (Figure 3). Firstly, attentional bias to threat did not mediate the relation between symptoms of anxiety in the 20s and anxiety in the 30s ($\beta = .02$, 95% CI = -.01 – .07, $p = .16$; Table 7, Figure 3). Secondly, attentional bias to threat did not mediate the relation between symptoms of depression in the 20s and depression in the 30s ($\beta = .01$, 95% CI = -.04 – .05, $p = .88$; Table 8, Figure 3). Thirdly, attentional bias to threat did not mediate the relation between symptoms of anxiety in the 20s and social anxiety in the 30s ($\beta = .08$, 95% CI = -.06 – .31, $p = .18$; Table 9, Figure 3).[4] As mentioned previously, all mediation models included participants' age, sex, number of chronic health conditions, and household income in the 30s as covariates.

Statistical Analyses with Attentional Bias to Happiness

We conducted statistical analyses to investigate the associations between attentional bias to happiness and psychopathology in order to investigate whether the observed associations were specific to threatening and negatively-valenced stimuli. All zero-order correlations between attentional bias to happiness and psychopathology (anxiety, depression, and social anxiety) measured in the 20s and in the 30s were non-significant ($ps > .10$). All moderation analyses demonstrated that attentional bias to happiness in the 30s did not moderate the relation between symptoms of psychopathology in the 20s and the same symptoms of psychopathology later in the

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[4] It is important to note that anxiety (i.e., general anxiety) measured in the 20s was used as a predictor variable in this model with the outcome variable of social anxiety in the 30s, as an approximate index of social anxiety, due to a lack of a social anxiety scale at the young adulthood assessment (in the 20s).

30s (ps > .10), indicating that attentional bias to happiness did not interact with psychopathology in young adulthood to predict psychopathology later in adulthood. Lastly, attentional bias to happiness in the 30s did not mediate the relation between symptoms of psychopathology in the 20s and the same symptoms of psychopathology later in the 30s (ps > .10).

Discussion

The current study investigated (1) concurrent and longitudinal relations between attentional bias to threat and symptoms of psychopathology (i.e., anxiety, depression, and social anxiety) as well as (2) whether attentional bias to threat moderated and/or mediated the relation between psychopathology in young adulthood (the 20s) and the same type of psychopathology approximately a decade later in adulthood (the 30s). We found that zero-order Pearson correlations between symptoms of psychopathology and attentional bias to threat were predominantly statistically significant. However, when multivariate analyses (i.e., partial correlation analyses and multiple regression analyses) were performed to investigate the same relations while controlling for one other type of psychopathology, the associations were predominantly no longer statistically significant.

Moreover, out of the three moderation models, only one model's moderation effect reached statistical significance. Attentional bias to threat in the 30s significantly moderated the relation between anxiety in the 20s and social anxiety in the 30s; greater attentional bias to threat (i.e., vigilance toward threat) amplified the relation between anxiety in the 20s and social anxiety nearly a decade later. Additionally, we found that attentional bias to threat in the 30s did not mediate the relation between psychopathology in the 20s and the same type of psychopathology later in the 30s. It is also important to note that all statistically significant findings were specific to threatening and negatively-valenced stimuli because no significant correlations, partial

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correlations, moderation effects, or mediation effects were found with regards to attentional bias to happy, positively-valenced stimuli.

Correlation Analyses

Attentional Bias to Threat and Anxiety

In line with our prediction, we found that anxiety in the 30s was significantly and concurrently correlated with greater attentional bias to threat in the 30s. There is an abundance of evidence in the literature supporting the concurrent association between attentional bias to threat and symptoms of anxiety (Bantin et al., 2016; Bar-Haim et al., 2007; Bradley et al., 2000; de Voogd et al., 2016; Kuckertz et al., 2014; Maidenberg et al., 1996; Matsumoto, 2010; Musa et al., 2003; Neubauer et al., 2013; Pergamin-Hight et al., 2015; Reinecke et al., 2011; Schofield et al., 2012). However, despite the robust evidence, there is some skepticism regarding the existence of attentional bias to threat as well as its association with anxiety (Heeren et al., 2015; Kruijt et al., 2019; McNally, 2019) due to the inability of various studies to find attentional bias to threat in individuals with high anxiety levels (Boettcher et al., 2013; Boettcher et al., 2014; de Lijster et al., 2019; Enock et al., 2014; Julian et al., 2012; McNally et al., 2013; Naim et al., 2018). Our findings further support the notion that symptoms of anxiety are associated with threat-related cognitive processes, reducing the skepticism regarding this relation in the literature.

In line with our prediction, anxiety in the 20s had a positive longitudinal association with attentional bias to threat nearly a decade later; this longitudinal association, however, only approached statistical significance ($p = .08$). To our knowledge, relatively few studies have investigated the longitudinal relation between anxiety and attentional bias to threat. There appear to be five longitudinal studies in child/adolescent populations and two in adult populations. All

five studies investigating this association in children/adolescents have reported statistically non-significant findings (Briggs-Gowan et al., 2016; Dodd et al., 2020; Nozadi et al., 2016; Price et al., 2016; White et al., 2017). However, the two studies investigating this association in adults found that attentional bias to threat prospectively predicted anxiety after 3 months (Osinsky et al., 2012) as well as after 1 year (Bardeen & Daniel, 2018). The current longitudinal study was unique because it investigated whether anxiety prospectively predicted attentional bias to threat in adults across nearly a decade, a timeframe that has not been previously examined. Hence, the current study contributes unique findings to the extant literature, further supports the existence of a positive association between anxiety and attentional bias to threat in adults, and alleviates skepticism regarding this association by demonstrating that anxiety positively and prospectively correlated with attentional bias to threat after nearly a decade in adults. It is important to mention that this prospective association only approached statistical significance, which may have been due to insufficient statistical power.

Overall, the positive concurrent and longitudinal correlations between anxiety and attentional bias to threat in adults were expected and were in line with the general consensus in the literature. These findings were also in line with, and can be explained by, cognitive theories regarding attentional bias to threat in anxiety, which posit that individuals with relatively high anxiety levels have over-reactive threat salience-evaluation mechanisms (Mogg & Bradley, 2018), have biased schemata and information processing mechanisms toward threat (Beck & Clark, 1997; Beck et al., 1985), and have lower cognitive thresholds for threat intensity (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998).

Attentional Bias to Threat and Depression

We made no a priori predictions regarding the concurrent association between attentional bias to threat and symptoms of depression because the current literature demonstrates inconclusive evidence for attentional bias to threat in depression. Interestingly, we found that depression in the 30s was significantly correlated with greater attentional bias to threat in the 30s. In the extant literature, some studies found statistically significant and positive concurrent associations (Hommer et al., 2014; Mathews et al., 1996; Mogg et al., 1995; Sears et al., 2011), some studies found statistically non-significant concurrent associations (Elgersma et al., 2018; Mogg & Bradley, 2005; Mogg et al., 1993; Struijs et al., 2021), and a meta-analysis found a statistically trending concurrent association (Peckham et al., 2010). The current study extends the extant literature and adds support to studies that also found a significant and positive concurrent association between depression and attentional bias to threat.

We made no a priori predictions regarding the longitudinal correlation between attentional bias to threat and depression due to the inconsistent findings in the current literature regarding this association. In the current study, depression in the 20s had a significant prospective association with greater attentional bias to threat nearly a decade later. In the extant literature, studies investigating the longitudinal association between depression and attentional bias to threat are scarce, and the few that exist have conflicting findings. One study found no prospective association in adults after 5 years (Struijs et al., 2021). Another study found a positive and significant association where attentional bias to threat prospectively predicted depression after 3 months in adults (Osinsky et al., 2012). Two other studies found significantly greater attentional bias to threat in individuals with a history of depression in comparison to individuals who never had depression (Elgersma et al., 2018; Sears et al., 2011). Surprisingly,

one study found that attentional bias away from threat (avoidance), rather than attentional bias to threat (vigilance), predicted greater levels of depression after 2 years in adolescents (Price et al., 2016). The current longitudinal study adds a unique finding to the literature where depression prospectively predicted greater levels of attentional bias to threat nearly a decade later in adults. This finding is in line with the longitudinal findings of Elgersma et al. (2018) and Sears et al. (2011), which found that individuals with a history of depression exhibited greater attentional bias to threat than individuals with no history of depression.

The current findings suggest that attentional bias to threat is not specific to anxiety. Rather, it may be a cognitive manifestation of a more general construct of internalizing-related problems, which include anxiety and depression. In the current study, individuals with greater symptoms of depression selectively allocated more attention to threat stimuli. It is likely that similar to anxiety, symptoms of depression also associate with hypervigilance toward threat stimuli as well as difficulty disengaging from threat stimuli. Hence, the theoretical frameworks that explain the association between anxiety and attentional bias to threat may extend to depression as well. For instance, the cognitive-motivational framework of anxiety (Mogg & Bradley, 2018) may extend to depression; individuals with greater depression may have over-reactive threat salience-evaluation mechanisms. Moreover, the two cognitive models of selective processing in anxiety by Mathews and Mackintosh (1998) and Mogg and Bradley (1998) may also extend to depression; individuals with greater depression may have lower cognitive thresholds for threat intensity, causing them to find threat stimuli in the current study to be more potent and salient compared to individuals with lower levels of depression. These theories may explain why we observed this significant positive correlation between depression and attentional

bias to threat. Moreover, the findings from the current study may be relevant to future research regarding cognitive models of depression.

Attentional Bias to Threat and Social Anxiety

In line with our prediction, we found that social anxiety in the 30s was significantly and concurrently correlated with greater attentional bias to threat in the 30s. In the literature, there is robust evidence supporting the concurrent association between social anxiety and attentional bias to threat using images of faces as stimuli (Abend et al., 2018; Amir et al., 2009b; Bantin et al., 2016; Kuckertz et al., 2014; Morrison, 2014; Neubauer et al., 2013; Roy et al., 2008). However, as previously mentioned, some researchers have expressed skepticism with regards to the existence of attentional bias to threat and its relation with anxiety (Heeren et al., 2015; Kruijt et al., 2019; McNally, 2019). The findings from the current study extend the literature and support the notion that there is a significant and positive association between social anxiety and attentional bias to threat, alleviating the uncertainty regarding this association.[5]

Correlations between Measures of Psychopathology

In line with our predictions, symptoms of psychopathology concurrently correlated with each other, indicating that symptoms of psychopathology measured in the current study have a considerable degree of co-occurrence. Moreover, as expected, symptoms of psychopathology in the 20s were significantly correlated with the same symptoms of psychopathology nearly a decade later. This finding suggests that symptoms of psychopathology remain relatively stable across a decade in adulthood and may involve stable, trait-like characteristics. Additionally, in line with our predictions, symptoms of psychopathology were longitudinally correlated with each other nearly a decade later. These findings indicate that having symptoms of psychopathology in

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[5] The current study did not investigate the longitudinal relation between social anxiety and attentional bias to threat 10 years later due to the lack of a social anxiety scale at the young adulthood assessment (in the 20s).

young adulthood seems to be a risk factor for experiencing similar and different symptoms of psychopathology later in adulthood.

Attentional Bias to Threat and the Co-occurrence of Anxiety and Depression

The significant concurrent and longitudinal correlations between depression and attentional bias to threat were unexpected and worthy of further discussion. In the current study, there was a strong correlation between depression and anxiety in the 20s ($r = .73$, $p < .001$) as well as in the 30s ($r = .80$, $p < .001$), indicating that anxiety and depression were often co-occurring symptoms. The high degree of comorbidity of anxiety and depression is well-documented in the literature (Gorman, 1996; ter Meulen et al., 2021) and is consistent with the current findings. With regards to the manifestation of attentional bias to threat and the comorbidity of anxiety and depression, some studies in the literature suggest that individuals with co-occurring symptoms of depression and anxiety still exhibit attentional bias to threat (Bar-Haim et al., 2007; Hommer et al., 2014), and some studies suggest that the addition of depression to anxiety impedes the manifestation of attentional bias to threat (Bradley et al., 1995; Elgersma et al., 2018; Struijs et al., 2021; Taghavi et al., 1999). The findings from the current study support Bar-Haim et al. (2007) and Hommer et al. (2014) by finding positive associations between attentional bias to threat and both anxiety and depression despite participants' co-occurring symptoms of anxiety and depression.

Multivariate Analyses: Partial Correlation and Multiple Regression Analyses

Given the co-occurrence of depression and anxiety, we considered the idea that the high comorbidity in our sample may have influenced our findings. For this reason, we conducted multivariate analyses (partial correlation analyses and multiple regression analyses) to assess the relation between depression and attentional bias to threat while controlling for anxiety, and vice

versa. As mentioned in the results section, the findings from the multivariate analyses yielded statistically non-significant correlations[6], except for the longitudinal correlation between depression in the 20s and attentional bias to threat in the 30s while controlling for anxiety in the 20s, which remained significant. It is possible that the results of the multivariate analyses were not adequately precise because we likely lacked the sufficient statistical power to adequately isolate the unique variance contribution of depression and anxiety to attentional bias to threat, especially since depression and anxiety were highly correlated. It is also plausible that the zero-order correlations between psychopathology and attentional bias to threat were significant and meaningful but not robust enough to remain significant when other types of psychopathology were also controlled for.

Although the multivariate findings may have been influenced by insufficient statistical power and other factors discussed later, the surviving longitudinal correlation between depression and attentional bias to threat after controlling for anxiety was important to interpret. Why did depression in the 20s uniquely and prospectively predict attentional bias to threat nearly 10 years later?

It is possible that individuals with previous negative experiences of depressive symptoms have a heightened vulnerability to exhibit attentional bias to threat in the future. The heightened vulnerability to attentional bias to threat may be unique to previous experiences of depression, rather than concurrent experiences, since two other studies similarly found greater attentional bias to threat in individuals with a history of depression in comparison to individuals with concurrent symptoms of depression (Elgersma et al., 2018; Sears et al., 2011). The attentional bias to threat found in individuals with previous experiences of depressive symptoms may be due

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[6] The statistical explanation behind the findings of the multivariate analyses is explored in-depth in the next sub-section of the discussion section under the heading of "Comparing Bivariate Analyses to Multivariate Analyses".

to decreased prefrontal activity and prolonged amygdala activity, which have been found in individuals with a history of depression when faced with stress and have also been found to increase vulnerability to future depressive episodes (De Raedt & Koster, 2010). It is also possible that individuals with previous experiences of depression feel fearful and threatened by the possibility of having another depressive episode, causing them to have higher vigilance toward threat and/or difficulty disengaging from threat-related stimuli (Elgersma et al., 2018). Thus, previous experiences of depression may heighten one's vulnerability to attentional bias to threat, which in turn may elevate one's vulnerability to recurrent episodes of depression or other internalizing-related psychopathology.

One may ask why anxiety did not have a statistically significant longitudinal or concurrent correlation with attentional bias to threat after controlling for depression. We speculate that we lacked the sufficient statistical power to detect the true significance of these relations. With regards to the longitudinal correlations, anxiety and depression in the 20s were strongly and concurrently correlated with each other, and the strength of the prospective relation between anxiety and attentional bias to threat ($r = .16$) was smaller than the strength of the prospective relation between depression and attentional bias to threat ($r = .28$), allowing for only one relation to remain statistically significant when controlling for the other. With regards to the concurrent relations, anxiety and depression in the 30s were strongly and concurrently correlated with each other, and the strength of the concurrent relation between anxiety and attentional bias to threat ($r = .21$) was almost equal to the strength of the concurrent relation between depression and attentional bias to threat ($r = .22$), leading to both correlations becoming statistically non-significant after controlling for one another.

Comparing Bivariate Analyses to Multivariate Analyses

Multivariate analyses, partial correlation analyses and multiple regression analyses, were conducted to better understand the unique associations between attentional bias to threat and each type of psychopathology (anxiety, depression, and social anxiety) while controlling for each other's effects. We assessed these multivariate analyses for data measured in young adulthood (the 20s) and adulthood (the 30s), separately. In the paragraphs below, bivariate analyses (zero-order correlations and simple linear regressions) are being compared to multivariate analyses (partial correlation analyses and multiple regression analyses) when a control variable was added.

As mentioned in the results section, bivariate associations between attentional bias to threat and each type of psychopathology (anxiety, depression, and social anxiety) were found to be predominantly significant (Table 2, Figure 1). However, upon conducting multivariate analyses (partial correlation analyses and multiple regression analyses), the same associations while controlling for the effect of another type of psychopathology were found to be predominantly no longer statistically significant.

One possible explanation for finding statistically non-significant partial correlations involves how partial correlations are calculated. To compute the partial correlation for the relation between an outcome variable and a predictor variable while controlling for a second predictor variable (control variable)[7], we must statistically partial out the variance that the second predictor variable shares with the outcome variable as well as the variance that the two predictor variables jointly share with the outcome variable (Cohen et al., 2003). Hence, it is possible that

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[7] For the sake of clarity, we refer to the variables in this paragraph as the first predictor variable, the second predictor variable (control variable), and the outcome variable. However, correlation analyses are between variables that technically do not have predictor or outcome roles.

the joint variance that two types of psychopathology together shared with attentional bias to threat was very large, and by removing it in the partial correlation analyses, the unique overlap (partial correlation) between the first predictor variable and the outcome variable became non-significant.

Another plausible explanation for the predominantly non-significant multivariate analyses findings is the existence of interaction effects. However, upon conducting multiple regression analyses that included the interaction of two psychopathology predictor variables (both measured at the same age) in predicting attentional bias to threat, no significant interaction effects were found (ps > .10).

It is likely that we found predominantly statistically non-significant partial correlations (r) and simple linear regression coefficients (β) because we did not have sufficient statistical power given the sample size of 82. Sufficient statistical power is needed to adequately isolate the unique contribution of variance by each predictor variable and detect significant associations when variables are considered together. Low statistical power may have also been the reason behind finding non-significant interaction effects in the multiple regression models mentioned in the previous paragraph.

Additionally, it is possible that the bivariate associations found between attentional bias to threat and psychopathology through zero-order correlations and simple linear regressions were significant and meaningful but not strong or robust enough to remain significant when other variables were also considered through partial correlation and multiple regression analyses.

Lastly, another plausible explanation as to why previously significant findings from bivariate analyses became statistically non-significant when conducting multivariate analyses is the presence of high correlations (some degree of multicollinearity) between different types of

psychopathology measured at each assessment (Table 3). Partial correlation analyses can be used to compute how much variance one predictor variable uniquely shares with the outcome variable (while controlling for another predictor variable). When two predictor variables such as anxiety and depression are highly correlated, it is statistically challenging to accurately and precisely separate each predictor variable's unique variance overlap with the outcome variable from each other. Moreover, high correlation between two predictor variables inflates the variance and leads to greater standard errors, wider confidence intervals, and higher p-values when estimating partial correlation coefficients (r) as well as partial regression coefficients (β) (Daoud, 2017; O'Brien, 2007). This suggests that our partial correlation and multiple regression findings might have been less precise due to the potential influence of some degree of multicollinearity.

In summary, the bivariate associations between attentional bias to threat and psychopathology (anxiety, depression, and social anxiety) were predominantly significant, whereas the same associations controlling for one other type of psychopathology (measured in the same assessment) computed through multivariate analyses were predominantly statistically non-significant. The inconsistent findings suggest that there were other factors influencing the results, which may include a large variance overlap between the outcome variable and the two predictor variables, low statistical power, and some degree of multicollinearity. It is also plausible that the bivariate associations were significant and meaningful, but not robust enough to remain significant when other variables were also considered. Further investigation, especially with a larger sample size, is needed to compute more precise findings and gain a deeper understanding of the associations between attentional bias to threat and different types of psychopathology.

Moderation Analyses

Contrary to our prediction, attentional bias to threat in the 30s did not moderate the relation between anxiety in the 20s and anxiety in the 30s, indicating that attentional bias to threat did not interact with early anxiety to predict later anxiety in adulthood. Attentional bias to threat in the 30s also did not moderate the relation between depression in the 20s and depression in the 30s, indicating that attentional bias to threat did not interact with early depression to predict later depression in adulthood. We made no a priori predictions regarding the latter moderation model due to the extant literature's inconclusive findings regarding the association between depression and attentional bias to threat. However, given the significant concurrent and longitudinal correlations found between depression and attentional bias to threat in the current study, we later expected to find a significant moderation effect in predicting depression in the 30s, which we did not find. Moreover, in line with our prediction, attentional bias to threat in the 30s significantly moderated the relation between anxiety in the 20s and social anxiety in the 30s, indicating that attentional bias to threat interacted with early anxiety to predict later social anxiety in adulthood.[8]

The statistical analyses used in the present study were likely able to capture the significant moderation effect in the model with the outcome variable of social anxiety because this interaction effect was likely larger than the interaction effects in the models with the outcome variable of depression in the 30s as well as anxiety in the 30s. Moreover, these two moderation effects were likely found to be statistically non-significant due to insufficient power in the current study. In order to detect interaction effects, which are often smaller and more

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[8] Anxiety (i.e., general anxiety) measured in the 20s was used as a predictor variable in this model with the outcome variable of social anxiety in the 30s, as an approximate index of social anxiety, due to a lack of a social anxiety scale at the young adulthood assessment (in the 20s).

difficult to detect than main effects, a sample size of above 100 or even 200 is recommended (Brysbaert, 2019). Hence, we speculate that if we had sufficient statistical power, we would have found significant moderation effects in the models predicting anxiety in the 30s and depression in the 30s similar to the significant moderation effect found in the model predicting social anxiety in the 30s.

The current study's findings from the moderation analyses demonstrated that greater attentional bias to threat significantly moderated and amplified the association between anxiety in the 20s and social anxiety in the 30s. The simple slopes analysis demonstrated that when individuals had lower levels of attentional bias to threat (higher avoidance of threat), anxiety in the 20s was not significantly associated with social anxiety nearly a decade later. However, when individuals had higher levels of attentional bias to threat (higher vigilance toward threat), symptoms of anxiety in the 20s were significantly associated with and predicted greater symptoms of social anxiety nearly a decade later. Hence, the combination of attentional bias to threat and early anxiety predicted higher levels of social anxiety later in adulthood. Our findings suggest that as levels of attentional bias to threat increase, it becomes increasingly likely for a risk factor of psychopathology (i.e., early experiences of anxiety symptoms) to prospectively predict greater levels of psychopathology later on (i.e., later experiences of social anxiety symptoms). Fortunately, these findings also suggest that at lower levels of attentional bias to threat, it is less likely for a risk factor of psychopathology to prospectively predict greater levels of psychopathology later on. In other words, individuals with greater anxiety but lower attentional bias to threat were much less likely to experience later social anxiety when compared to individuals with greater anxiety and greater attentional bias to threat. This finding has substantial clinical implications because by lowering levels of attentional bias to threat using

prevention or intervention programs such as attention bias modification (ABM), it may be possible to reduce the chances of early psychopathology and/or risk factors of psychopathology leading to later psychopathology.

In the literature, some longitudinal studies found that attentional bias to threat moderated the prospective relation between early behavioral inhibition (a risk factor for internalizing psychopathology; Clauss & Blackford, 2012) and later anxiety in children/adolescents (Dodd et al., 2020; Nozadi et al., 2016; White et al., 2017). Another study found that attentional bias to threat moderated the longitudinal association between early shyness and later greater relative right frontal EEG activity, both of which are risk factors for psychopathology (Coan & Allen, 2004; Findlay et al., 2009), in adults (Hassan & Schmidt, 2021). The current study found that attentional bias to threat moderated the relation between early symptoms of anxiety, a risk factor for future psychopathology, and later symptoms of social anxiety in adults after nearly a decade. This finding extends the current literature and further supports the notion that the combination of attentional bias to threat and another risk factor for psychopathology increases one's vulnerability to experiencing symptoms of psychopathology in the future.

Mediation Analyses

Contrary to our prediction, attentional bias to threat in the 30s did not mediate the relation between symptoms of psychopathology (i.e., anxiety, depression, and social anxiety) in the 20s and the same symptoms of psychopathology nearly a decade later. This finding suggests that attentional bias to threat was not the mechanism through which symptoms of psychopathology in the 20s were related to symptoms of psychopathology nearly a decade later. To our knowledge, no other short- or long-term longitudinal study to date has investigated whether attentional bias to threat mediates the relation between early psychopathology and later psychopathology. Hence,

the current study contributes a unique finding to the literature by suggesting that attentional bias to threat may not have a mediating role in the association between early psychopathology and later psychopathology.

It is plausible that the mediating effect of attentional bias to threat on the relation between early psychopathology and later psychopathology was statistically non-significant because the true causal pathway was complex and could have been impacted by a variety of other factors not measured in the current study. These factors may include genetic factors, stress, traumatic life events, emotional regulation skills, personality factors, etc. For instance, theoretically, another factor such as receiving mental health treatment (i.e., psychotherapy and/or medication) or carrying the short allele of the serotonin transporter gene 5-HTTLPR may moderate and influence the strength/existence of the mediation effect—the short allele of the 5-HTTLPR gene has been found to be a risk factor for psychopathology (Karg et al., 2011) as well as a moderator for the relation between depression and attentional bias to threat (Osinsky et al., 2012).

Moreover, rather than accepting the null hypothesis, there is a possibility that our study was underpowered to detect the true mediation effect of attentional bias to threat. If that was the case, attentional bias to threat may be a part of the causal pathway from early psychopathology to later psychopathology. There is also a possibility that the mediation pathway involves attentional bias to threat leading to anxiety in the 20s, and anxiety in the 20s leading to anxiety in the 30s. However, in the current study, we did not measure attentional bias to threat in the 20s; hence, we could not investigate whether this was the case. Future longitudinal investigations with greater statistical power should be conducted to further investigate the mechanistic and causal pathways between attentional bias to threat, early psychopathology, and other possibly relevant factors in predicting later psychopathology.

Theoretical and Clinical Implications

The correlation analyses add a unique finding to the extant literature: symptoms of anxiety and depression in the 20s prospectively associate with greater attentional bias to threat nearly a decade later in the 30s, although the association with anxiety only approached statistical significance. The current study also found positive concurrent correlations between attentional bias to threat and symptoms of anxiety, depression, and social anxiety. The correlation findings regarding anxiety and social anxiety extend the current literature, support the existence of a positive association between anxiety and attentional bias to threat, and help to alleviate the uncertainty in the literature regarding this association. Moreover, the concurrent and longitudinal correlations found between depression and attentional bias to threat provide valuable insight for reconciling the conflicting and inconsistent findings in the literature regarding this association. These findings may also be relevant and have implications for future research and theories on cognitive models of depression.

Overall, we found evidence that self-reported symptoms of anxiety, depression, and social anxiety converged with and were correlated with the behavioral and cognitive measure of attentional bias to threat. The correlational findings suggest that attentional bias to threat is not specific to individuals with symptoms of anxiety and social anxiety, but also symptoms of depression, another internalizing-related disorder. It is possible that attentional bias to threat is a risk factor for developing internalizing-related psychopathology, and it is also possible that attentional bias to threat is a cognitive manifestation of internalizing-related psychopathology. What seems to be evident is that individuals with greater levels of anxiety, depression, and social anxiety selectively allocate more attention to threat, are hypervigilant toward threat, and may also have difficulty disengaging from threatening and negatively-valenced stimuli. The present

findings suggest that biased cognitive processing of emotionally-valenced information, specifically attentional bias to threat, may have a considerable role in the development and/or maintenance of internalizing-related psychopathology.

Upon conducting multivariate analyses to investigate the associations between attentional bias to threat and each type of psychopathology while controlling for another type of psychopathology, we found that previously significant bivariate associations were predominantly no longer statistically significant. The only correlation that remained statistically significant was the prospective correlation between depression in the 20s and attentional bias to threat in the 30s while controlling for anxiety in the 20s. Although our multivariate findings may have been influenced by inadequate statistical power and other previously mentioned factors, this surviving correlation between depression and attentional bias to threat was quite interesting.

Why did depression in the 20s uniquely and longitudinally predict attentional bias to threat nearly a decade later? Individuals with previous experiences of depressive symptoms may have an elevated vulnerability to exhibiting attentional bias to threat in the future. This vulnerability to attentional bias to threat may be unique to previous experiences of depressive symptoms, rather than concurrent symptoms, as two other studies found similar results— individuals with a history of depression exhibited greater attentional bias to threat than individuals with concurrent symptoms of depression (Elgersma et al., 2018; Sears et al., 2011). It is plausible that individuals with previous experiences of depressive symptoms feel threatened by the possibility of having another depressive episode in the future, causing them to exhibit attentional bias to threat (Elgersma et al., 2018). Therefore, previous symptoms of depression may predict and influence how individuals process and engage with the world around them years later, increasing their threat vigilance and possibly, their difficulty disengaging from threat. This

elevated vulnerability to attentional bias to threat may also increase their vulnerability to recurrent episodes of depression or other internalizing-related psychopathology.

In the current study, we found that greater attentional bias to threat in the 30s significantly moderated and amplified the association between anxiety in the 20s and social anxiety nearly a decade later in the 30s. It is likely that attentional bias to threat combined with other risk factors (e.g., past experience of psychopathological symptoms) increase the chances of experiencing greater symptoms of psychopathology in the future. Our findings suggest that individuals with greater anxiety but lower attentional bias to threat are much less likely to experience greater social anxiety later on in comparison to individuals with both greater anxiety and greater attentional bias to threat. This finding has clinical implications because interventions targeting attentional bias to threat have the potential to reduce the stability of psychopathological symptoms over time as well as lower the chances of risk factors of psychopathology leading to greater psychopathological symptoms in the future. In the literature, attention bias modification (ABM), a computerized cognitive training program designed to decrease attentional bias to threat, has been found to alleviate anxiety symptoms (Amir et al., 2009a; Amir et al., 2009b; Hallion & Ruscio, 2011; Kuckertz et al., 2014; MacLeod & Clarke, 2015) as well as reduce stress reactivity (Bar-Haim et al., 2011; Dennis & O'Toole, 2014; Grafton et al., 2014). ABM uses modified versions of the dot-probe paradigm or the visual search paradigm to cognitively train individuals in avoiding threat, disengaging from threat, and reducing hypervigilance toward threat. A recent meta-analysis found that the combination of ABM with cognitive behavioral therapy (CBT) was superior in reducing clinician-rated anxiety than CBT alone (Hang et al., 2021). Given the current study's findings and the literature on cognitive training, programs such as ABM, which reduce attentional bias to threat, have great therapeutic potential to decrease the

stability of psychopathology over time, especially when combined with standard treatments such as CBT. These cognitive training programs also have preventative potential; they may reduce the likelihood of risk factors of psychopathology leading to future psychopathology.

Lastly, we found that attentional bias to threat did not mediate the relation between early psychopathology (i.e., anxiety, depression, and social anxiety) and later psychopathology in adults. Hence, even though the moderation analyses indicate that attentional bias to threat amplifies the strength of the relation between early psychopathology and later psychopathology, the mediation analyses suggest that the underlying mechanisms are still an open empirical question.

Strengths, Limitations, and Future Directions

There were several strengths and limitations of the present study that are important points of discussion. The current study had a longitudinal design and covered a nearly 10-year time span. This allowed us to contribute unique and valuable findings to a body of literature that is currently lacking with regards to the longitudinal investigation of the relation between psychopathology and attentional bias to threat. The current study also used a behavioral measure, the dot-probe task, to index cognitive threat-related biases as well as widely-used and well-validated self-report measures of emotional and behavioral problems, the YASR and the SPIN. Notwithstanding these strengths, the current study also had a number of limitations that warrant discussion, which are discussed below.

First and foremost, although the current study's longitudinal design was one of its greatest strengths, the longitudinal design also came with the disadvantage of participant attrition, resulting in a relatively small sample size. This contributed to the current study possibly

lacking sufficient statistical power to adequately detect true significance in correlation, partial correlation, moderation, and mediation analyses.

Second, the current study's sample was relatively homogenous where participants were predominantly Caucasian and were all born between 1977 and 1982 in Hamilton, Ontario, Canada. These factors may decrease the generalizability of the findings to individuals from diverse ethnicities and different generation cohorts.

Third, the current study used self-report measures (i.e., the YASR and the SPIN) that demonstrated good internal consistency, but nevertheless all self-report measures may be subject to reporting biases caused by factors such as the social desirability bias, individual differences in reporting similar experiences, as well as participants' mood state at the time of measurement.

Fourth, the dot-probe task's test-retest reliability and internal consistency have been found to be low or moderate (Price et al., 2015, Schmukle, 2005; Staugaard, 2009). However, even though the dot-probe task does not show high reliability, groups with higher anxiety vulnerability and higher anxiety most often demonstrate relatively higher attentional bias to threat using the dot-probe task (Bantin et al., 2016; Bar-Haim et al., 2007; Kuckertz et al., 2014; MacLeod et al., 1986; MacLeod & Clarke, 2015; MacLeod et al., 2019; Salemink et al., 2007). Hence, it is posited that even though the dot-probe task cannot classify individuals in terms of their unique attentional pattern to threat (MacLeod et al., 2019), it can be used to differentiate between groups and investigate attentional biases in groups (Bar-Haim et al., 2007; MacLeod et al., 2019; Staugaard et al., 2009).

Fifth, we acknowledge that there likely were other factors influencing the relations between early psychopathology, attentional bias to threat, and later psychopathology, which were

not measured in the current study. Some potential examples include genetic factors, stress, traumatic life events, emotional regulation skills, and personality factors.

Sixth, the current study could not statistically control for whether participants were receiving mental health treatment (psychotherapy, medication, or both) because these data were not collected in the 20s or the 30s.

Seventh, due to a lack of a social anxiety scale at the young adulthood assessment (in the 20s), the current study used anxiety (i.e., general anxiety) in the 20s as an approximate index of social anxiety in the 20s for moderation and mediation analyses.

Lastly, the current study conducted analyses investigating the role of attentional bias to threat as a moderator and a mediator for the relation between psychopathology in the 20s and psychopathology in the 30s. Unfortunately, attentional bias to threat was only measured in the 30s at the same time as our outcome variables, symptoms of psychopathology in the 30s. The longitudinal design of the current study and the statistical analyses would have been improved by measuring attentional bias to threat at another time point (e.g., mid-late 20s) to investigate the causal pathway between early psychopathology in the 20s and later psychopathology in the 30s more comprehensively.

Future studies should investigate the longitudinal relation between attentional bias to threat and psychopathology using a larger and more diverse sample with measures of psychopathology and attentional bias to threat at least at three different time points, using different methods of indexing attentional bias to threat in addition to the dot-probe task. Future studies can also incorporate other measures such as genetic factors or participants' experience with mental health treatment to investigate more complex and comprehensive longitudinal models involving attentional bias to threat and psychopathology.

Conclusion

In the present study, symptoms of anxiety, depression, and social anxiety were concurrently associated with greater attentional bias to threat. Symptoms of anxiety and depression were also longitudinally associated with greater attentional bias to threat nearly a decade later, although the association with anxiety only approached statistical significance. Moreover, our findings demonstrated that although attentional bias to threat did not mediate the relation between early psychopathology and later psychopathology, it did moderate and amplify the relation between anxiety in the 20s and social anxiety in the 30s. These findings suggest that individuals with greater anxiety but lower attentional bias to threat were significantly less likely to experience greater social anxiety in the future than individuals with greater anxiety and greater attentional bias to threat. As such, interventions targeting attentional bias to threat may have preventative and therapeutic potential for reducing the risks of the development and/or the maintenance of internalizing-related psychopathology.

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Table 1. Mean, standard deviation, and range for study variables

Assessment	Variables	Mean	Standard deviation	Range
Young adulthood assessment (age 20s)	Age	23.64	1.08	22.02 – 26.36
	Household income	92,708.68	70,682.44	9,600.00 – 400,000.00
	Number of chronic conditions	1.88	1.72	0.00 – 9.00
	Anxiety	3.23	2.31	0.00 – 10.00
	Depression	6.04	4.47	1.00 – 20.00
Adulthood assessment (age 30s)	Age	32.48	1.41	29.96 – 34.94
	Household income	80,808.82	41,740.23	10,000.00 – 150,000.00
	Number of chronic conditions	1.68	1.57	0.00 – 7.00
	Anxiety	2.96	2.58	0.00 – 10.00
	Depression	4.50	3.94	0.00 – 18.00
	Social anxiety	12.99	10.83	0.00 – 51.00
	Attentional bias to threat	4.55	13.51	-30.98 – 43.57
	Attentional bias to happiness	2.19	13.13	-25.46 – 59.75

Note.   Age was measured in years.

Household income was measured in Canadian Dollars.

Table 2. Zero-order Pearson correlations between symptoms of psychopathology and attentional

bias to threat

Assessment	Symptoms of psychopathology	Attentional bias to threat (age 30s)
Young adulthood assessment (age 20s)	Anxiety	.16 *
	Depression	.28 **
Adulthood assessment (age 30s)	Anxiety	.21 **
	Depression	.22 **
	Social anxiety	.19 **

Note. *p = .08, **p < .05

Table 3. Zero-order Pearson correlations between symptoms of psychopathology: Concurrent

and longitudinal relations

	1	2	3	4	5
1. Anxiety in the 20s	-	.73 ***	.61 ***	.55 ***	.54 ***
2. Depression in the 20s	-	-	.63 ***	.69 ***	.56 ***
3. Anxiety in the 30s	-	-	-	.80 ***	.56 ***
4. Depression in the 30s	-	-	-	-	.50 ***
5. Social anxiety in the 30s	-	-	-	-	-

Note. $*p < .05$, $**p < .01$, $***p < .001$

Table 4. Moderation model: Interaction of anxiety in the 20s and attentional bias to threat in the 30s in predicting anxiety in the 30s

		β	Standard error (SE)	t	p
Covariates	Sex	0.72	0.54	1.32	.19
	Age	-0.16	0.18	-0.89	.38
	Number of chronic conditions	0.48	0.17	2.84	.006 **
	Household income	0.00	0.00	0.16	.87
Predictors	Attentional bias to threat in the 30s	-0.02	0.04	-0.54	.59
	Anxiety in the 20s	0.47	0.14	3.32	.002 **
	Attentional bias to threat in the 30s * Anxiety in the 20s	0.01	0.01	0.99	.33
Model characteristics		$R^2 = .47$			
		$F(7, 59) = 7.46$			
		$p < .001$ ***			

Note. All covariates were measured at the adulthood assessment (in the 30s).
*$p < .05$, **$p < .01$, ***$p < .001$

Table 5. Moderation model: Interaction of depression in the 20s and attentional bias to threat in the 30s in predicting depression in the 30s

		β	Standard error (SE)	t	p
Covariates	Sex	1.40	0.78	1.80	.08
	Age	0.06	0.26	0.22	.83
	Number of chronic conditions	0.61	0.25	2.41	.02 *
	Household income	0.00	0.00	-1.12	.27
Predictors	Attentional bias to threat in the 30s	-0.07	0.05	-1.38	.17
	Depression in the 20s	0.41	0.11	3.63	.0006 ***
	Attentional bias to threat in the 30s * Depression in the 20s	-0.01	0.01	1.15	.25
Model characteristics		$R^2 = .54$			
		$F(7, 58) = 9.66$			
		$p < .001$ ***			

Note. All covariates were measured at the adulthood assessment (in the 30s).
   *$p < .05$, **$p < .01$, ***$p < .001$

Table 6. Moderation model: Interaction of anxiety in the 20s and attentional bias to threat in the 30s in predicting social anxiety in the 30s

		β	Standard error (SE)	t	p
Covariates	Sex	1.50	2.59	0.58	.57
	Age	0.50	0.86	0.58	.56
	Number of chronic conditions	0.20	0.85	0.24	.81
	Household income	0.00	0.00	-1.21	.23
Predictors	Attentional bias to threat in the 30s	-0.25	0.17	-1.48	.14
	Anxiety in the 20s	1.67	0.67	2.48	.02 *
	Attentional bias to threat in the 30s * Anxiety in the 20s	0.10	0.04	2.20	.03 *
Model characteristics		$R^2 = .38$			
		$F(7, 58) = 5.01$			
		$p < .001$ ***			

Note. All covariates were measured at the adulthood assessment (in the 30s).
 *$p < .05$, **$p < .01$, ***$p < .001$

Table 7. Mediation model testing the mediation of attentional bias to threat in the 30s on the relation between anxiety in the 20s and anxiety in the 30s

	Simplified description of effect	Effect estimate	Standard error (SE)	t	df	p
Total effect of anxiety in the 20s on anxiety in the 30s	Effect of X on Y	c = 0.69	0.10	7.13	80	<.001 ***
Direct effect of anxiety in the 20s on anxiety in the 30s (accounting for the effect of attentional bias to threat)	Effect of X on Y while accounting for the Mediator	c' = 0.67	0.10	6.88	79	<.001 ***
Effect of anxiety in the 20s on attentional bias to threat	Effect of X on the Mediator	a = 0.91	0.65	1.77	80	.08
Effect of attentional bias to threat on anxiety in the 30s (accounting for the effect of anxiety in the 20s)	Effect of the Mediator on Y while accounting for X	b = 0.02	0.02	1.67	79	.10
Mediation effect	Effect of X on Y through the Mediator	ab = 0.02 (95% CI = -0.01 – 0.07)	–	–	–	.16

Note. This model consisted of the mediator variable of attentional bias to threat in the 30s, the predictor variable of anxiety in the 20s, and the outcome variable of anxiety in the 30s.

This mediation analysis model accounted for 4 covariates measured in the 30s: sex, age, number of chronic conditions, and household income.

$*p < .05, **p < .01, ***p < .001$

Table 8. Mediation model testing the mediation of attentional bias to threat in the 30s on the

relation between depression in the 20s and depression in the 30s

	Simplified description of effect	Effect estimate	Standard error (SE)	t	df	p
Total effect of depression in the 20s on depression in the 30s	Effect of X on Y	c = 0.61	0.07	8.84	80	<.001 ***
Direct effect of depression in the 20s on depression in the 30s (accounting for the effect of attentional bias to threat)	Effect of X on Y while accounting for the Mediator	c' = 0.60	0.07	8.38	79	<.001 ***
Effect of depression in the 20s on attentional bias to threat	Effect of X on the Mediator	a = 0.85	0.32	2.62	80	.01 *
Effect of attentional bias to threat on depression in the 30s (accounting for the effect of depression in the 20s)	Effect of the Mediator on Y while accounting for X	b = 0.01	0.02	0.23	79	.82
Mediation effect	Effect of X on Y through the Mediator	ab = 0.01 (95% CI = -0.04 – 0.05)	–	–	–	.88

Note. This model consisted of the mediator variable of attentional bias to threat in the 30s, the predictor variable of depression in the 20s, and the outcome variable of depression in the 30s.

    This mediation analysis model accounted for 4 covariates measured in the 30s: sex, age, number of chronic conditions, and household income.

    *$p < .05$, **$p < .01$, ***$p < .001$

Table 9. Mediation model testing the mediation of attentional bias to threat in the 30s on the

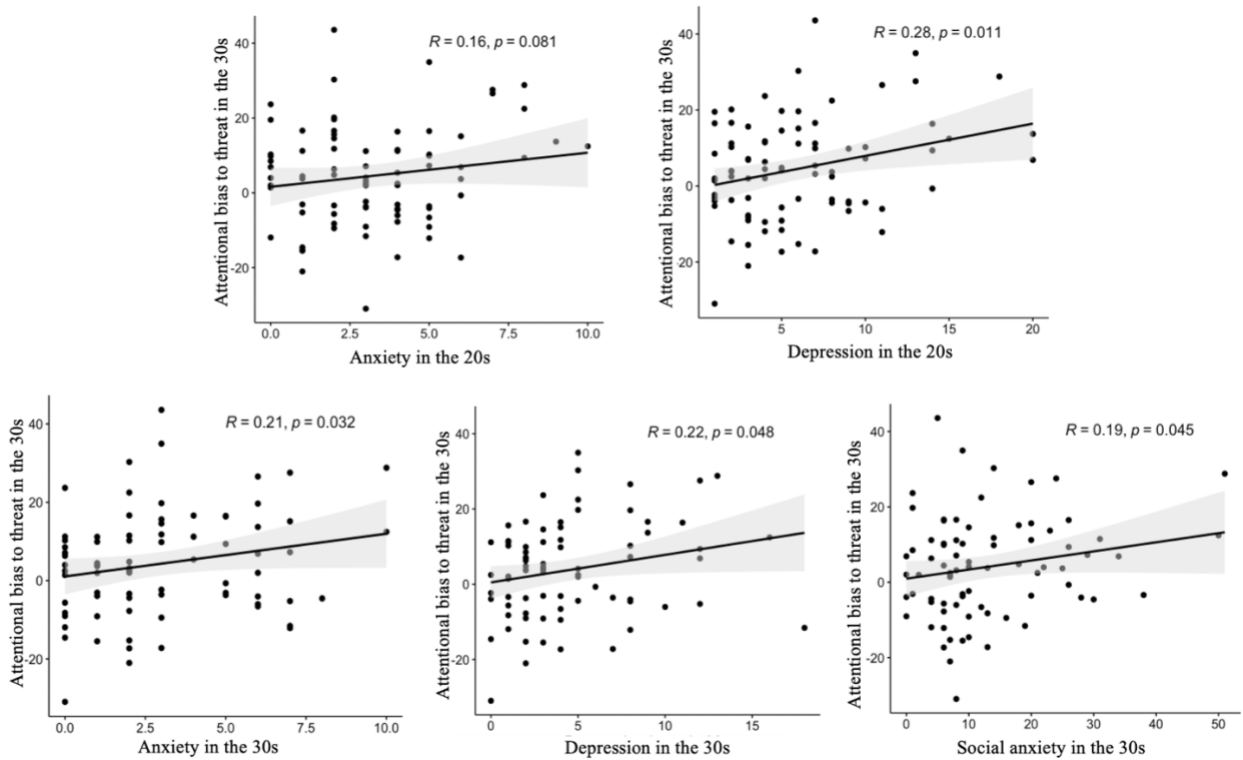relation between anxiety in the 20s and social anxiety in the 30s

	Simplified description of effect	Effect estimate	Standard error (SE)	t	df	p
Total effect of anxiety in the 20s on social anxiety in the 30s	Effect of X on Y	c = 2.58	0.44	6.04	80	<.001 ***
Direct effect of anxiety in the 20s on social anxiety in the 30s (accounting for the effect of attentional bias to threat)	Effect of X on Y while accounting for the Mediator	c' = 2.50	0.44	5.81	79	<.001 ***
Effect of anxiety in the 20s on attentional bias to threat	Effect of X on the Mediator	a = 0.91	0.65	1.77	80	.08
Effect of attentional bias to threat on social anxiety in the 30s (accounting for the effect of anxiety in the 20s)	Effect of the Mediator on Y while accounting for X	b = 0.09	0.08	1.56	79	.12
Mediation effect	Effect of X on Y through the Mediator	ab = 0.08 (95% CI = -0.06 – 0.31)	–	–	–	.18

Note. This model consisted of the mediator variable of attentional bias to threat in the 30s, the predictor variable of anxiety in the 20s, and the outcome variable of social anxiety in the 30s.

This mediation analysis model accounted for 4 covariates measured in the 30s: sex, age, number of chronic conditions, and household income.

*p < .05, **p < .01, ***p < .001

Figure 1. Scatterplots of the zero-order Pearson correlations between symptoms of

psychopathology and attentional bias to threat

Note. There is no graph illustrating the relation between attentional bias to threat and social anxiety in the 20s because social anxiety was not measured at the young adulthood assessment.
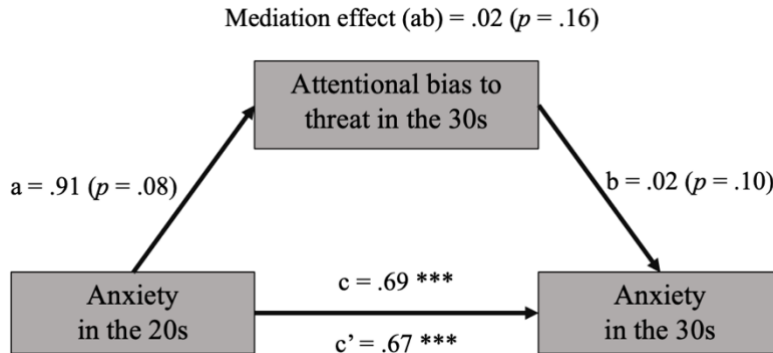
Figure 2. Interaction between anxiety in young adulthood (the 20s) and attentional bias to threat in adulthood (the 30s) in predicting social anxiety in adulthood (the 30s)
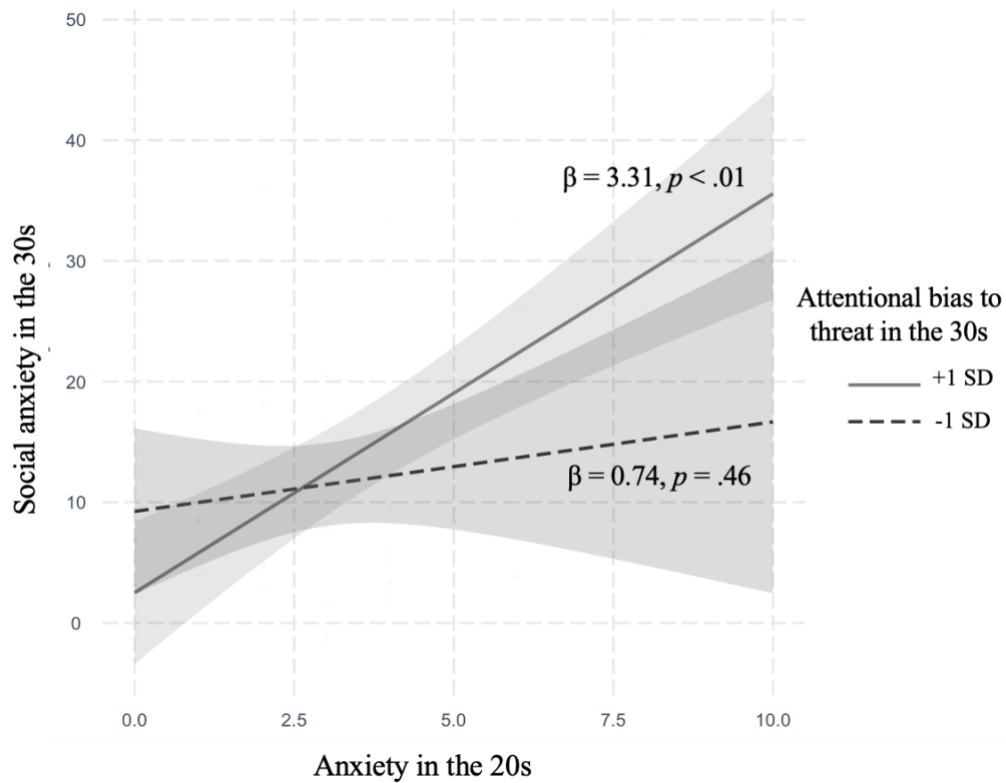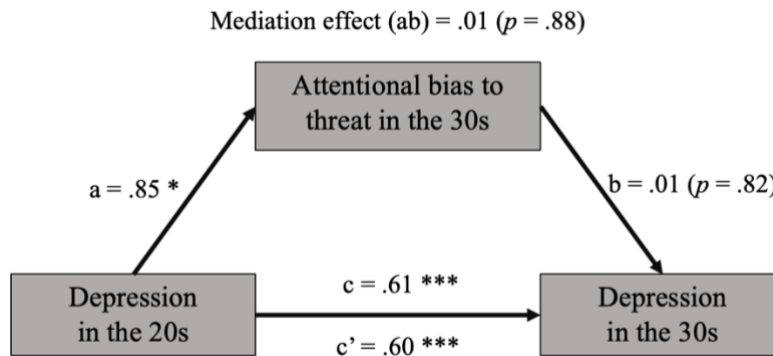

Note. Due to a lack of a social anxiety scale at the young adulthood assessment (in the 20s), anxiety (i.e., general anxiety) in the 20s was used as a predictor variable in this model as an approximate index of social anxiety.

Figure 3. Diagrams depicting the mediation analysis of models with the mediator variable of attentional bias to threat, different predictor variables of psychopathology in the 20s, and different outcome variables of psychopathology in the 30s
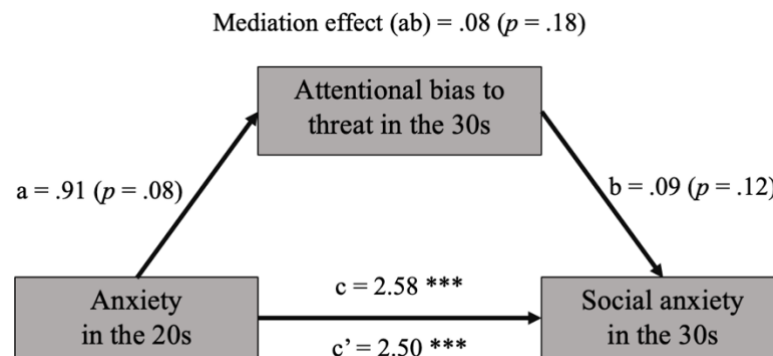
Mediation model for anxiety in the 30s

Mediation effect (ab) = .02 (p = .16)

Attentional bias to threat in the 30s

a = .91 (p = .08)   b = .02 (p = .10)

Anxiety in the 20s   c = .69 ***   Anxiety in the 30s
c' = .67 ***

Mediation model for depression in the 30s

Mediation effect (ab) = .01 (p = .88)

Attentional bias to threat in the 30s

a = .85 *   b = .01 (p = .82)

Depression in the 20s   c = .61 ***   Depression in the 30s
c' = .60 ***

Mediation model for social anxiety in the 30s

Mediation effect (ab) = .08 (p = .18)

Attentional bias to threat in the 30s

a = .91 (p = .08)   b = .09 (p = .12)

Anxiety in the 20s   c = 2.58 ***   Social anxiety in the 30s
c' = 2.50 ***

Note. Due to a lack of a social anxiety scale at the young adulthood assessment (in the 20s), anxiety (i.e., general anxiety) in the 20s was used as a predictor variable in the third mediation model as an approximate index of social anxiety.