ATTENTION BIASES AND EXECUTIVE CONTROL IN SEVERE WEATHER PHOBIA: AN ERP STUDY

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ATTENTION BIASES AND EXECUTIVE CONTROL

IN SEVERE WEATHER PHOBIA: AN ERP STUDY

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Abstract: Severe Weather Phobia is the excessive and unreasonable fear or anxiety regarding severe weather events. Literature on this topic is largely limited to case studies and no study has aimed to document potential maintenance factors. Utilizing models from other anxiety disorders, worry and attention biases may be investigated as potential maintenance factors. The current investigation aimed to determine whether attention biases towards pictorial (Study 1) and written (Study 2) stimuli are present within severe weather anxiety. Study 1 also aimed to evaluate whether engaging in worry regarding an upcoming severe weather event modulates attention biases using event related potentials. Results of Study 1 indicated that engaging in worry did result in increased anxiety regarding an upcoming severe weather threat; however, this increase in anxiety was present in those with and without elevations in trait severe weather anxiety. This study failed to observe any attentional biases within severe weather anxiety. Similarly, no attention biases were observed in Study 2. Overall, results of Study 1 and 2, generally, failed to support hypothesized attention biases to both pictorial and written stimuli. These results could suggest that those with severe weather anxiety do not present attentional biases similar to those observed in other anxiety disorders; however, a potentially more likely explanation is that the valance, arousal, and intensity of the stimuli presented in the paradigms were not robust enough to elicit an anxious response or bias in attention. A wider variety of severe weather stimuli should be investigated to determine which stimuli and at what intensity results in attention biases, increases in state anxiety, and psychological arousal. Once stimuli are developed, investigations into their impact on executive function and psychophysiology can be pursued.

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CHAPTER I

INTRODUCTION

Severe Weather Phobia is the excessive and unreasonable fear or anxiety regarding severe weather, which falls within the Natural Environment (i.e., phobia of water, heights, and storms) category of Specific Phobia (APA, 2013; Westefeld, 1996). Natural Environment Specific Phobia's prevalence rates fall between 8.9% and 11.6%, whereas diagnosable weather-related anxiety falls around 2% - 3% (Klainknecht & Smith, 2002; LeBeau et al., 2010). Although only a small portion of the population meets diagnostic criteria, a large percentage (40% - 76%) of the population reports some level of excessive anxiety or worry regarding storms (Coleman, Newby, Multon, & Taylor, 2014; Westefeld, Less, Ansley, & Yi, 2006). With increasing severe weather-related events, the American Psychological Association Task Force on the Interface between Psychology and Global Climate Change (2010) encouraged researchers to investigate the etiology, mechanisms, and treatment of fears related to weather. Although there is a push to document weather-related anxiety, a dearth of research regarding this topic remains.

Initial evidence of severe weather anxiety is documented in case studies (Liddell & Lyons, 1978; Wang, 2000). In reviewing these cases, the authors describe individuals with excessive and uncontrollable anxiety regarding storms. These individuals also engage in avoidance of weather events, excessive checking and monitoring of weather events, and excessive safety behavior use. Liddell and Lyons (1978) and Wang (2000) report experiences of uncontrollable anxiety, shaking, screaming, crying, hot/cold flashes, palpitations, sweating, and difficulty breathing during the threat of inclement weather. Although some fear and avoidance towards significant weather events is adaptive, the anxiety, avoidance, and functional impairment related to any weather event (e.g., cloud formation, moderate wind gusts, rain) often seen in Severe Weather Phobia is disproportional to the risk and is dysfunctional (Klainknecht et al., 2002).

Westefeld (1996) claimed the term "Severe Weather Phobia" and defined it as the "intense, debilitating, unreasonable fear of severe weather," with an emphasis on severe thunderstorms or tornadoes. Using this definition, Westefeld interviewed individuals with self-reported Severe Weather Phobia and found that a majority of subjects engage in excessive monitoring of weather, distressing anticipatory anxiety 5+ days before a potential weather event, and significant worry about weather that often leads to physiological symptoms (e.g., rapid breathing, sweating), restlessness, and inability to concentrate.

In an attempt to understand Severe Weather Phobia outside of a clinical population, Westefeld and colleagues (2006) asked 138 university students to rank how they experienced symptoms of anxiety (e.g., dizziness, shortness of breath, heart pounding, panic, helplessness, difficulty sleeping) related to severe thunderstorms and tornadoes. Results revealed that approximately 20% of the sample indicated at least a moderate degree of anxiety and 76% reported a bit of fear. A portion (21%) of the sample indicated frequent palpitations, sweating, panic, helplessness, obsessive thoughts, anxiety and avoidance towards severe weather. Although diagnostic criteria were not evaluated, it is clear that severe weather anxiety is prevalent, albeit at a sub-clinical level. Using a geographically more diverse MTurk population, Coleman and colleagues (2014) found that 10% of the sample reported having a fear of severe weather either in the "extreme" or "quite a bit" range. Some researchers have turned to using experimental methods to evaluate severe weather anxiety. Only two studies experimentally manipulated state anxiety by having participants engage in a virtual reality severe thunderstorm (Nelson, Vorstenbosch, & Antony, 2014; Krause et al., 2018). These two studies found that those with higher severe weather anxiety (Nelson et al., 2014) and those that engage in more safety behaviors (Krause et al., 2018) during severe weather events experienced significantly more anxiety during the storm simulation.

This collection of studies suggests that severe weather phobia is a dimensional construct with a large portion of the population experiencing some levels of excessive anxiety towards storms, whereas a smaller portion experience clinically significant symptoms. Prevalence rates and frequently observed symptomology have been documented, but investigation of the maintenance factors and their causal mechanisms have yet to be investigated in Severe Weather Phobia. Incorporating information from existing models and maintenance factors observed in other specific phobias may help provide context to the maintenance and mechanisms of Severe Weather Phobia. Two processes of interest are worry and attentional biases.

Worry is defined as the perseverative verbal-linguistic thought process aimed at problem solving (Borkovec, Robinson, Pruzinsky and DePree, 1983; Wells, 1995). Models of worry propose that, although individuals with high levels of worry report the benefit of this process, it is a maladaptive preparation and emotion regulation strategy (Wells, 1995). Hirsch and Colleagues (2012) suggest worry is both a habitual (automatic) and an intentional (controlled) process that may begin as an intentional problem-solving technique and insidiously become a more habitual response to a stressor (Hirsch & Matthews, 2012). This habitual response is thought to lead to decreased cognitive control, which leads to even further decreased ability to control one's worry (Eysenck et al., 2007; Hayes, Hirsch, & Matthews, 2008). Although no studies of Severe Weather Phobia specifically investigate worry, many studies document the presence of uncontrollable and excessive worry or anxious thought (Liddell et al., 1978; Nelson et al., 2014; Watt & DiFrancescantonio, 2012; Westefeld, 1996).

Attentional biases are the preferential attention allocation towards threat-related stimuli as opposed to non-threat-related stimuli (Cisler & Koster, 2010). Commonly observed in anxiety, threatening information receives prioritization (e.g., Beck & Clark, 1997; see Bar-Haim et al., 2007) due to its relevance to the individual's fear. Attentional biases are posited to maintain anxiety by limiting the content of information that is processed, thereby escalating anxiety symptoms and decreasing focus on non-threatening aspects (Cisler & Koster, 2010), which may hinder habituation. Attentional biases within severe weather phobia have yet to be documented, but studies investigating other specific phobias (e.g., spider, snake, social anxiety- formally social phobia) imply that attentional biases in anxiety may be trans-diagnostic.

The impact and influence of worry and attentional biases can be understood using the Attentional Control Theory (Eysenck et al., 2007). This theory proposes that anxiety and associated functional impairments are partially maintained due to preferential allocation of resources, which occupies valuable and limited cognitive resources. Specifically, this preferential processing (bottom-up) aimed at evaluating and addressing the threat consumes mental resources, thereby decreasing mental resources allocated to process other non-threat-related tasks (top-down). Since worry and attentional biases are targets of this preferential bottom-up processing, they will result in decreased top-down processing which impairs effective executive function. For example, manipulations in worry (vs. distraction or relaxation) often lead to decreased cognitive performance, which is even further amplified in those with trait anxiety or worry (e.g., Borkovec et al., 1983; Hayes et al., 2008). Additionally, the presentation of threat-related information often results in increased attentional bias towards that threat, leading to decreased cognitive performance (e.g., Kindt & Brosschot, 1997; Mattia, Heimberg, & Hope, 1993; Pineles, & Mineka, 2005; Spector, Pecknold, & Libman, 2003). Mattia and colleagues (1993) found similar results where anxiety specific threat cues (e.g., “stupid”, “failure”) led to decreased executive function performance for those with anxiety compared to non-threat cues and when compared to a non-anxious group. It appears that both worry and attentional bias manipulations influence cognitive performance, neither of which have been investigated in Severe Weather Phobia.

A common way to measure these executive function deficits is by using cognitive tasks, such as the Stroop task. The Emotional Stroop is an extension of the traditional Stroop color-word test (Stroop, 1935), in which participants are shown a series of words (e.g., house, chair), including those with emotional relevance (e.g., needle, spider, tornado). These words are presented in various colors (i.e., red, green, blue) and participants are asked to name the color in which the words are printed, while ignoring the meaning of the word. Researchers reported finding increased interference (e.g., reaction times) during trials that presented emotionally salient words compared to neutral words (e.g., Amir et al., 1996; Bar-Haim et al., 2007). These results suggest that disorder-specific emotionally salient words reveal a level of attentional bias, which compromises effective and efficient responses. These slower responses are theorized to represent a level of interference within perceptual processing (Hock & Egeth, 1970) and response production (Keele, 1972).

Variations of the Emotional Stroop task are frequently used to assess the presence of attentional or perceptual biases within anxiety disorders (e.g., Amir et al., 1996; Bar-Haim et al., 2007; Cisler et al., 2011; Dresler et al., 2009; Ruiter & Brosschot, 1994; Williams et al., 1996). Researchers frequently document slower reaction times in those with anxiety disorders during trials with anxiety-related printed words (e.g., Bar-Haim et al., 2007). Research also documents anxiety specific word effects (Cisler et al., 2011), where trauma related words appear to uniquely impact those with PTSD, and social related words impact those with social anxiety. These results suggest that the presence of attentional biases and interference of word stimuli requires the words to be emotionally salient to the participant’s idiographic anxiety. It is believed that these attentional biases and interferences are present as a result of the disorder specific stimuli receiving processing priority, which results in inefficient processing and completion of the Stroop task (Derakshan & Eysenck, 2009). In alignment with the Attentional Control Theory, it is thought that threat-related distractors capture attentional resources for those with anxiety, which decreases resource allocation to complete the color naming, leading to ineffective task completion.

Another common cognitive task used to assess executive function is the Flanker task (Eriksen & Eriksen, 1974). Participants are shown an array of letters or symbols (e.g., <<<<<, or HHHHH) and are told to pay attention to and identify the middle stimulus while ignoring the stimuli to the left and right flanks. Executive function is measured by how well participants can ignore distracting information (Eriksen & Eriksen, 1974; Paquet & Craig, 1997). It is frequently found that participants are slower and make more errors during trials with conflicting distractor information, which is often exacerbated for those with anxiety and after anxiety and threat manipulations (Chen et al., 2016; Dennis & Chen, 2009; Pacheco-Unguetti, Acosta, Callejas, & Lupianez, 2010; Taylor et al., 2019; White & Grant, 2017).

For example, Dennis and Chen (2009) presented a Flanker task where, prior to each Flanker trial, either a threatening or non-threatening face was presented. Results found that the trials with the threatening information modulated attention for those with higher levels of trait social anxiety and led to poorer performance, which was not observed in those with low social anxiety. Together, these studies demonstrate that threat-related distractors can hinder task performance. It is believed that those threat-related distractors capture attentional resources for those with anxiety, which decreases resource allocation, leading to ineffective task completion.

An advantage of using the Flanker and other cognitive tasks is the ability to collect Electroencephalography (EEG). Researchers often use event-related potentials (ERPs) to determine attentional resource allocation during Flanker tasks (e.g., Folstein & Van Petten, 2008). Many researchers use the N2 as a measure of recruitment of cognitive control and processing of the matched and mismatched cues during the Flanker task (Folstein & Van Petten, 2008; Luck, 2014) and find modulations of the N2 across anxiety levels and threat manipulations (Dennis & Chen, 2009; Kanske & Kotz, 2010; Luck, 2014; Owens et al., 2015). For example, researchers have substituted the traditional Flanker stimuli (i.e., "H" "I" or arrows) with threat-related words and found modulations in the N2 (Alguacil, Tudela, & Ruz, 2013; Kanske & Kotz, 2010; Li et al., 2014; Zhang et al., 2019), such that trials that contain threat/emotional information within the Flanker stimuli show increased amplitudes in the N2, which has shown to be enhanced for those with trait anxiety (Chen et al., 2016; Owens et al., 2015). Specifically, those with anxiety may recruit attentional resources to threat-related distractors, thus leaving less resources to effectively complete the task.

Although multiple case studies have documented the prevalence and behavioral features of Severe Weather Phobia, no research has evaluated potential maintenance factors. Furthermore, no study has attempted to evaluate the mechanisms behind those maintenance factors. Based on the dearth of research on Severe Weather Phobia, the current two studies aimed to 1) identify psychological and physiological responses to the threat of severe weather, 2) determine how worry may maintain that response, and 3) document attentional biases, their underlying neural mechanisms, and executive function deficits within Severe Weather Phobia. By documenting cognitive and neural processes within Severe Weather Phobia, researchers may better understand how attentional biases are influenced by worry within this presentation. Furthermore, this may help explain how individuals with severe weather anxiety show functional impairment and are unable to experience habituation of their fears.

Study 1 utilized a threat induction and worry manipulation to induce weather-related anxiety. EEG data were collected for those with high and low trait levels of storm anxiety during a Flanker task to document cognitive and attentional impairment. It was believed that using threat-related distractors prior to the Flanker task would lead to an attentional bias, which would result in a decrease in available cognitive resources to the upcoming Flanker stimuli. Therefore, presenting both threat and non-threat-related images prior to the Flanker stimuli would allow researchers to determine how task-irrelevant threat leads to subsequent deficits in executive function engagement (i.e., N2) during the Flanker stimuli. Luck (2014) reports that N2 effects towards matching and mismatching information only when that information is attended. Therefore, modulations in N2 activity may depend on how those with Severe Weather Phobia preferentially attend to task-irrelevant information.

Due to predictions from the Attentional Control Theory, Study 1 had two hypotheses. 1) Individuals with higher storm anxiety would show increased anxiety related to the storm threat, which would be exacerbated in the worry condition. 2) Individuals with higher storm anxiety would show a decreased N2 response to trials proceeded by threat-related distractors (suggesting increased resources allocation to threat), which would be exacerbated in the worry condition.

Study 2 utilized an Emotional Stroop task to assess the presence of storm related attentional biases in those with elevations in severe weather anxiety. Storm-related words were presented along with non-storm related words to determine whether these threat-related words capture attention, thus impeding efficient responding in the task. Within the same Attentional Control Theory framework, Study 2's hypothesis was that individuals with higher storm anxiety would show increased interference leading to longer reaction times to trials with threat-related words (suggesting increased resources allocation to threatening meaning of the word).

CHAPTER II

STUDY 1 METHODOLOGY

Participants

Participants were recruited from the undergraduate student population at a Midwestern University using an online recruitment system. Participants received course credit for participation. All participants in the online recruitment system completed a pre-screener question used in previous research (Krause et al., 2018; Nelson et al., 2014) to screen for severe weather anxiety. Based on cutoff criteria recommended and those used in previous studies (Krause et al., 2018; Nelson et al., 2014), an extreme groups sampling approach was used. Participants with a pre-screener score of 0 or a 2 or above were recruited for the in-lab study. This pre-screener technique has shown to reliability differentiate and predict severity of severe weather anxiety (Krause et al., 2018; Nelson et al., 2014). From the total eligible population, 32 were recruited for the in-lab portion. Participants completed the Storm Fear Questionnaire (SFQ; Nelson & Antony, 2013; Nelson et al., 2014), which was used to split participants into high ($N = 19$) and low anxiety ($N = 13$) groups. One standard deviation above the mean of the original standardization sample (cutoff = 7.61, $M = 4.06$, $SD = 3.55$) was used as the cutoff to split the high and low anxiety group (Nelson et al., 2014). An a-priori power analysis (Cohen, 1988) using effect sizes found in previous studies on attention biases in anxiety ($\eta 2 = .14$-$.24$ Dennis & Chen, 2009; Judah, et al., 2013) suggested a total of 52 individuals would be needed to achieve adequate power ($\beta = .80$, $\alpha = .05$). Due to COVID-19 safety precautions, only 32 participants were recruited for the in-lab portion of the study, which resulted in potentially underpowered analyses.

Materials

Storm Fear Questionnaire (SFQ; Nelson & Antony, 2013; Nelson et al., 2014). The SFQ is a 15-item questionnaire aimed to measure cognitive, affective, and behavioral aspects related to storm phobia in adults. Participants rated how much statements (e.g., "I worry about storms more than other people") related to them on a Likert scale (0 = "not at all true" to 4 = "almost always true"). The 15 items were summed to create an overall storm fear score. The SFQ shows adequate convergent and discriminant validity as well as test-retest reliability and internal consistency (Cronbach's α = .95; Krause et al., 2018) and adequate internal consistency for the current sample (Cronbach's α = .92).

Manipulation Checks. Manipulation checks adapted from previous literature (e.g., Mills et al., 2014) were used to assess for self-reported state anxiety before the auditory stimuli. Participants reported state anxiety level on a scale from 0 (no anxiety at all) to 10 (the worst anxiety I have ever felt). To conceal the intention of this manipulation check, participants were also asked to rate their current level of happiness, sadness, fearfulness, joyfulness, surprise, relaxation, and stress.

After the auditory stimuli and worry manipulation, participants completed the same manipulation check questionnaire as before the auditory stimuli. In addition, to assess the participants level of engagement during the worry manipulation they rated (i) the amount of time during the manipulation that they were thinking about the prompts, (ii) the amount of time during the manipulation they spent thinking about the storm threat (on a 10-point scale ranging from Never to Nearly the whole time).

Auditory Stimuli. To induce anxiety regarding storms, a version of the National Weather Service alert was played over the computer speakers in front of the participant. This audio was based on those used in previous studies (Perreault, Houston, & Wilkins, 2014) and using the language in traditional National Weather Service Severe Weather alerts. The audio included the following phrases, *"The national weather service in Norman has issued a tornado warning for*

North Central Payne County in North Central Oklahoma, South Noble County in North Central Oklahoma. National weather service meteorologists and storm spotters were tracking a large, and extremely dangerous tornado located 9 miles south west of Stillwater, moving north east at 40 miles an hour. This is a tornado emergency for North Langston, Lake Carl Blackwell, Lake McMurtry, and Stillwater. In addition to a tornado, large and destructive hail up to tennis ball size is expected with this storm. Locations impacted include Langston, Lake Carl Blackwell, Lake McMurtry, Stillwater, Morrison, and Glencoe. This is an extremely dangerous and life-threatening situation. If you cannot get underground go to a storm shelter, or an interior room of a sturdy building now. Take cover now in a storm shelter, or in an interior room of a sturdy building. Stay away from doors and windows. Do not wait, take cover now." Participants were told to imagine that this threat is imminent and going to affect the participant's current location.

Worry Manipulation. After the auditory stimulus was played, participants completed a worry manipulation based on those used in previous research (Hinrichsen & Clark, 2003; Mills, Grant, Judah, & White, 2014; Vassilopoulos, 2005; Wong & Moulds, 2011). Participants were then split into two conditions; worry or distraction. Participants in the worry condition saw six prompts on the computer that each lasted for 60 seconds, in which they were told to think about the severe weather event (1. a particular severe storm that where you did not feel safe, 2. the potential of the severe storm indicated on the radio, 3. how you are going to feel during the upcoming potential severe storm, 4. all the things that could go wrong during the upcoming severe storm, 5. the worst thing that could happen during the severe storm, and 6. what would happen to you, family, or friends if this worst fear came true). Participants in the distraction condition were asked to think about non-anxious stimuli (1. a boat slowly crossing the Atlantic, 2. the layout of a typical classroom, 3. the shape of a large black umbrella, 4. the movement of an electric fan on a warm day, 5. leaves falling from a tree, and 6. the layout of your childhood house).

Open Affective Standardized Image Set Images (OASIS; Kurdi, Lozano, & Banaji, 2017). Eight severe weather-related images (e.g., Lightning, Tornadoes; Thunderstorms, Tornado damage) and 8 non-severe weather-related images (e.g., Street, Keyboard, Camping) were selected from the Open Affective Standardized Image Set Images (OASIS; Kurdi, Lozano, & Banaji, 2017). These images are a subset of a larger data set that have been rated on valence and arousal dimensions. Severe weather-related images were matched for brightness and luminosity (Knebel et al., 2008; Kurdi, Lozano, & Banaji, 2017), such that the severe weather images and control images did not differ in brightness, t(14) = -.323, p = .752, or in luminosity t(14) = -.367, p = .719. All images were presented in the same center location and shared the same dimensions. Based on the standardization sample, the severe weather images (M = 3.09, SD = .94) are significantly more negative (valence) than the control images (M = 4.40, SD = 1.08) t(14) = -.2.584, p = .022. The severe weather images (M = 4.61, SD = .41) are significantly more physiologically arousing (arousal) than the control images (M = 2.94, SD = .47) t(14) = 7.465, p < .001. These images were presented in a randomized order. Image identification numbers are I230, I475, I825, I833, I848, I850, I851, I852, I806, I449, I74, I29, I619, I111, I421, and I445.

Flanker task. Participants completed a Flanker task (Eriksen & Eriksen, 1974) based on Dennis and Chen (2009) and Tillman and Wiens (2011) (See Figure 1). Participants sat in front of a computer to complete the Flanker task. Each trial began with either a threat-related or non-threat-related image for 50 ms. Participants then saw a fixation cross "+" appear in the middle of the screen for an average of 500 ms. (ISI varied from 450 to 550 ms.), which signals the upcoming flanker stimuli. Participants then saw a row of 5 simple arrows (e.g., < < < < <) for 200 ms. Participants were told to either press the right or left trigger on a game pad controller to indicate whether the middle arrow is pointing right or left. On congruent trials (i.e., < < < < < and > > > > >), all of the arrows are facing the same direction, whereas on incongruent trials (i.e., < < > < < and > > < > >), the target arrow is facing one direction while the flanking arrows are facing the opposite direction. After the flanker stimuli was presented, participants saw a blank screen for about 1750 ms. (ITI varied from 1500 to 2000 ms.). To ensure a reliable N2, ERPs trials (1024) were broken into 4 blocks (256) (Clayson & Larson, 2013). Based on previous research and psychometric properties of the N2 and Flanker task, a ratio of roughly 45% incongruent and 55% congruent trials was used (Clayson & Larson, 2013). Trials within each block showed each image 16 times (7 times for incongruent and 9 times for congruent) and were randomized based on trial and image type. Participants completed 24 practice trials with response feedback to ensure they understood the task.

Procedure.

All procedures were approved by the Institutional Review Board. After informed consent, participants completed the SFQ online and then electrodes were attached to measure EEG, electrocardiographic (ECG), and electrooculography (EOG). Baseline physiological data were collected for 5 minutes while the participant sat still with their eyes closed. Participants were then told to imagine that severe weather was approaching the location of the participant and the national weather service just issued a statement. The National Weather Service alert audio was played and the participant engaged in either the worry or distraction condition. Participants then completed the Flanker task.

Physiological Recording. EEG, ECG, and EOG data were collected with an Active II system (BioSemi, Amsterdam, The Netherlands) using 32 channels (Fp1, Fp2, AF3, AF4, F7, F3, FZ, F4, F8, FC5, FC1, FC2, FC6, T7, C3, CZ, C4, T8, CP5, CP1, CP2, CP6, P7, P3, PZ, P4, P8, PO3, PO4, O1, OZ, and O2) in the traditional 10/20 positioning. EEG data were sampled at 250Hz. Two electrodes (Common Mode Sensor active and Driven Right Leg passive) are incorporated into the electrode cap and used as online references. Electrodes were placed behind the left and right ears in the mastoids and were used for offline references (Luck, 2005). Using a standard 2-lead configuration (Andreassi, 2007), an electrode was placed approximately 6 inches below the left armpit and on the right trapezius to measure ECG. To record blinks and eye movement (EOG), an electrode was place one centimeter below the left eye, and one centimeter to the left and right of the outer canthus of each eye.

Physiological Data Preparation. EEG data were processed using EEGLAB version 12 (Delorme & Makeig, 2004) and ERPLAB version 3 (Lopez-Calderon & Luck, 2010). A band-pass filter (.1 – 35Hz) was applied to filter the data along with a 60Hz notch filter. Data were re-referenced to the average of the mastoids (Luck, 2005). An independent-components analysis (ICA) was used to correct for ocular artifact in the data. TTL signals generated by the stimuli presentation computer were used to mark the onset of the stimuli presentation. EEG data were epoched from 200 ms. before and 600 ms. after the flanker stimuli. The N2 was measured in a window of 200 – 350 ms. after stimulus presentation at the FZ electrode site (Dennis & Chen, 2009; Luck, 2014). Trials that included eye movement or blinks during the trial or during the baseline measures were excluded. Individuals were excluded from analyses if they have 25 percent or more trials rejected (N = 6).

Analytic Strategy. The current study used a mixed design with a between-subject factor of Weather anxiety (High Weather Anxiety[HWA], Low Weather Anxiety[LWA]) and within-subject factors of Worry manipulation (worry, distract), Task type (Congruent, Incongruent), and Distractor stimuli type (Weather threat-related, Non-weather threat-related) on N2 amplitude as the outcome. Therefore, the data were analyzed using a repeated measures factorial ANOVA. To assess the manipulation-check questions a 2 (Weather anxiety; HWA, LWA) x 2 (Manipulation; Worry, Distraction) x 2 (Time; T1, T2) mixed model ANOVA was used to determine the impact of the worry manipulation on state anxiety. A series of 2 (Weather anxiety; HWA, LWA) x 2 (Manipulation; Worry, Distraction) mixed model ANOVA's were used for the (i) the amount of time during the manipulation that they were thinking about the prompts, (ii) the amount of time during the manipulation they spent thinking about the storm threat. Mauchley's test was used to assess sphericity, in which the Greenhous-Geisser correction was used in cases when sphericity is violated. When examining pairwise comparisons, the Bonferroni adjustment was used when necessary to follow up significant interactions. For continuity in the sample characteristics across analyses, the final sample excluded the participants with 25 percent or greater trials rejected in the data set. The full sample was investigated for the manipulation check, error rate, and reaction time results. Much of these results revealed a similar pattern and a footnote is used to indicate any differences between using the full sample (N = 32) and the reduced sample (N = 26). [1]

[1] Inclusion of trait worry (Penn State Worry Questionnaire), PTSD symptoms (PTSD Checklist of DMS-5), and daily weather events as control variables (covariates) results in an identical pattern of results as presented in the results section.

CHAPTER III

STUDY 1 RESULTS

Manipulation Check. Results for self-reported anxiety indicated a main effect for Time, $F(1,22) = 7.40$, $p = .012$, $\eta p2 = .25$, such that T1 ($M = 1.68$, $SE = .28$) showed lower anxiety compared to T2 ($M = 2.45$, $SE = .31$). This main effects appear to be driven by a significant interaction between Time and Worry Manipulation, $F(1,22) = 7.41$, $p = .012$, $\eta p2 = .26$, suggesting that there were no differences in anxiety between the T1 ($M = 1.63$, $SE = .40$) and T2 ($M = 1.63$, $SE = .44$) in the distraction group, but those who engaged in worry group indicated more anxiety at T2 ($M = 3.28$, $SE = .42$) than at T1 ($M = 1.73$, $SE = .38$), $p = .001$. Additionally, there was a main effect of Weather anxiety, $F(1,22) = 4.92$, $p = .037$, $\eta p2 = .18$, such that the HWA group ($M = 2.63$, $SE = .35$) showed higher anxiety compared to the LWA group ($M = 1.50$, $SE = .37$) overall.[2]

Results of the analysis on the amount of time during the manipulation that they were thinking about the prompts indicated no significant main effects or interactions, suggesting that all groups were equally engaged in the worry and distraction prompts.

Results of the analysis on the amount of time during the manipulation they spent thinking about the storm threat indicated a main effect of Worry Manipulation, $F(1, 22) = 9.31$, $p = .006$, $\eta p2 = .30$, such that participants in the worry group ($M = 6.80$ $SE = .65$) spent more time thinking about the storm threat than those in the distraction group ($M = 3.75$, $SE = .67$). These results support that those in the worry manipulation were engaging in thoughts regarding the

[2] Results of the full sample ($N = 32$) revealed no main effect of severe weather anxiety, but all other effects for self-reported anxiety maintained the same pattern as the reduced sample ($N = 26$).

severe storm threat, whereas those in the distraction condition were indeed engaging in more distraction.

Error Rates. Results of the Flanker error rates indicated a main effect of Task type, $F(1, 22) = 9.35$, $p = .006$, $\eta p2 = .30$, such that participants made more errors on the incongruent trials ($M = 1.99$, $SE = .58$) than the congruent trials ($M = .34$, $SE = .06$). No other main effects or interactions were significant. To further understand these null findings which assessed a specific aim of the study, the patterns of group means were evaluated. Visual inspection of the pattern of means revealed that the error rates between the trials with threatening and non-threatening stimuli were similar across manipulation and weather anxiety groups.

Reaction Times. Results of the reaction times indicated a main effect of Task type, $F(1, 22) = 114.97$, $p < .001$, $\eta p2 = .84$, such that participants responded slower on the incongruent trials ($M = 517.99$ ms., $SE = 8.67$) than on the congruent trials ($M = 465.89$ ms., $SE = 10.59$). There was a significant 3-way interaction between Task type, Worry manipulation, and Distractor stimuli type, $F(1, 22) = 5.07$, $p = .035$, $\eta p2 = .19$. Follow-up analyses revealed no significant pairwise comparisons. Visual inspection of the means indicated a unique pattern of results between the worry and distraction groups (See Figure 2). Within the worry group the trials with threat stimuli showed longer reaction times in the congruent trials compared to the neutral trials, whereas the trials with neutral stimuli showed longer reaction times in the incongruent trials. This pattern was reversed in the distraction group, such that the trials with threat stimuli showed shorter reaction times in the congruent trials, whereas the trials with neutral stimuli showed shorter reaction times in the incongruent trials.

There also was a significant 3-way interaction between Task type, Weather anxiety, and Distractor stimuli type, $F(1, 22) = 4.70$, $p = .041$, $\eta p2 = .18$. Follow-up analyses revealed a marginally significant difference between the threat ($M = 466.68$ ms., $SE = 14.29$) and neutral ($M = 461.83$ ms., $SE = 15.26$), $p = .083$, in the congruent conditions for those with elevated severe weather anxiety, which was not observed in other group and condition combinations (See Figure

3). General observation of the pattern of means indicated a similar unique pattern of results between the HWA and LWA groups. Within those with HWA, the trials with threat stimuli showed shorter reaction times in the congruent trials, whereas the trials with neutral stimuli showed longer reaction times in the incongruent trials. This pattern was reversed in those with LWA, such that the trials with threat stimuli showed shorter reaction times in the congruent trials compared to the neutral trials, whereas the trials with neutral stimuli showed shorter reaction times in the incongruent trials. [3]

N2. Results of the N2 analyses indicated a main effect of Task type, F(1, 22) = 6.39, p = .019, ηp2 = .23, such that participants had a larger N2 in the incongruent trials (M = 2.15, SE = 1.06) than the congruent trials (M = 4.00, SE = .91). No other main effects or interactions were significant. To further investigate these potentially underpowered results, the pattern of means and standard errors were evaluated to determine if the pattern of the means resembled the hypothesized effects (See Figure 4). Visual inspection of the pattern of means revealed similar means between those with and without severe weather anxiety in both the threat and neutral trials within the distraction group. However, within the worry group the individuals with elevations in severe weather anxiety showed a larger N2 compared to the low weather anxiety group for only the trials with threatening images. Moreover, this elevated N2 was the largest observed across the groups, trials, and conditions. Although this pattern was observed, relatively elevated standard errors (range: 1.31 – 2.36) accompanied these means, which may have contributed to the non-significant effects (See Figure 5 for visual representation of N2 waveform).

[3] Results of the full sample (N = 32) revealed no main significant interactions for error rates, but did reveal a main effect of Task type in a similar pattern as the reduced sample (N = 26), potentially suggesting unstable interaction effects or Type 1 error.

CHAPTER IV

STUDY 2 METHODOLOGY

Participants

Participants were recruited from the undergraduate student population at a Midwestern University using an online recruitment system. Participants received course credit for participation. All participants in the online recruitment system completed a pre-screener question used in previous research (Krause et al., 2018; Nelson et al., 2014) to screen for severe weather anxiety. Based on cutoff criteria recommended and used in these studies (Krause et al., 2018; Nelson et al., 2014), an extreme groups sampling approach was used. Participants with a pre-screener score of 0 or a 2 or above were recruited for the online study. Those who were recruited ($N = 86$) for the online portion completed Storm Fear Questionnaire (SFQ; Nelson & Antony, 2013; Nelson et al., 2014), which was used to split participants into high ($N = 40$) and low ($N = 45$) anxiety groups. One standard deviation above the mean of the original standardization sample (cutoff = 7.61, $M = 4.06$, $SD = 3.55$) was used as the cutoff to split the high and low anxiety group (Nelson et al., 2014). A power analysis (Cohen, 1988) using effect sizes found in previous studies on attention biases in anxiety in Stroop tasks ($\eta2 = .24 - .38$ Cisler et al., 2011; Judah et al., 2013) suggested a total of 84 individuals was needed to achieve adequate power ($\beta = .80$, $\alpha = .05$).

Materials

Storm Fear Questionnaire (SFQ; Nelson & Antony, 2013; Nelson et al., 2014). Similar to Study 1, the SFQ is a 15-item questionnaire aimed to measure cognitive, affective, and behavioral aspects related to storm phobia in adults. The 15 items were summed to create an overall storm fear score (Cronbach's $\alpha = .92$).

Emotional Stroop task. Participants completed an Emotional Stroop task based on Amir and colleagues (1996) and Dresler and colleagues (2009). Participants sat in front of their computers and completed the task online. The task was programmed in Psychopy software and presented to participants using the online Pavlovia platform. Each trial began with a fixation cross "+" in the middle of the screen for an average of 1000 ms (ISI varied from 950 to 1050 ms.) (See Figure 6). Participants then saw a word printed in either red, green, or blue text, in which they were asked to identify the color in which the words are printed as quickly as possible. The word was presented for 100 ms. and then a blank screen was presented until a response was made. Participants used the arrow keys (left, down, right) on their computer keyboard to indicate which color the words are printed in. The left, down, and right keys each were assigned a color (red, green, blue, respectively).

The printed words were chosen from the Affective Norms for English Words (ANEW) database (Bradley & Lang, 1999). Four weather threat-related (tornado, storm, lightning, flood), four neutral (waterfall, sleep, sunrise, honey), and four positive words (affection, brave, holiday, happy) where chosen from the larger stimuli array. These stimuli were chosen to match for frequency of word use in the English language, length of each word, and general stimuli characteristics. Each word was presented in each color 8 times, which resulted in each of the 12 words being presented 24 times (288 total trials). The presentation of stimuli was randomized for each participant. Participants completed 24 practice trials with response feedback to ensure they understood the task prior to the beginning of the task. The words "piano", "cabinet", "chair", and "desk" were used in the practice trials.

Procedure

All procedures were approved by the Institutional Review Board. After informed consent, participants completed the SFQ online on Qualtrics and then were directed to Pavlovia to complete the Emotional Stroop task. Upon completion of the Emotional Stroop task, participants were redirected to Qualtrics to be debriefed.

Data Preparation. Data cleaning procedures from Dresler and colleagues (2009) were used. Error rates were evaluated by determine the number of errors (i.e., pressing the wrong color button for a word) for each word group. Trials with errors and those with reaction times more or less than two SDs from the subject's mean were excluded from the reaction time calculation (Dresler et al., 2009) to ensure that trials with outliers of early responding and attentional disengagement do not skew the data. The remaining trials were averaged to obtain an average reaction time for each word condition.

Analytic Strategy. Study 2 used a mixed design with a between-subject factor of Weather anxiety (HWA, LWA) and a within-subjects factor of Word type (Weather, Neutral, Positive) on both error rates and reaction times. Therefore, the data were analyzed using a repeated measures factorial ANOVA. Mauchley's test was used to assess sphericity, in which the Greenhous-Geisser correction was used in cases when sphericity is violated. When examining pairwise comparisons, the Bonferroni adjustment was used when necessary to follow up significant interactions.[4]

[4] Inclusion of trait worry (Penn State Worry Questionnaire), PTSD symptoms (PTSD Checklist of DMS-5), and daily weather events as control variables (covariates) results in an identical pattern of results as presented for both error rates and reaction times.

CHAPTER V

STUDY 2 RESULTS

Error Rates. Results of the error rates data indicated no significant main effects or interactions. Visual inspection of the pattern of means (See Figure 7) revealed that the error rates for the positive (M = 6.50, SE = .52) and weather (M = 6.40, SE = .54) were slightly higher than the neutral words (M = 5.97, SE = .49).

Reaction Times. Results of the reaction time data indicated no significant main effects or interactions. Visual inspection of the pattern of means revealed that the reaction times for the HWA group (M = 610.09, SE = 16.12) were generally longer than the LWA group (M = 607.05, SE = 15.20). Additionally, the difference between the HWA group (M = 611.15, SE = 16.93) and the LWA group (M = 606.17, SE = 15.96) for the weather words was larger than the differences observed in the positive and neutral trials (See Figure 8).

CHAPTER VI

DISCUSSION

The aims of the current studies were to 1) identify psychological and physiological responses to the threat of severe weather, 2) determine how worry may maintain that response, and 3) document attentional biases, their underlying neurological mechanisms, and executive function deficits within Severe Weather Phobia. Generally, these studies share considerable conceptual overlap, in which they both aimed to test whether attentional biases are present by introducing distracting information that is threat-related into a cognitive paradigm. It was thought that threat-related information would selectively capture the attention of those with HWA thus leading to decreased performance on the tasks (Derakshan & Eysenck, 2009).

Study 1 utilized a Flanker task to document the presence of attentional biases in those with elevated severe weather anxiety and whether engaging in worry impacted these biases. It was hypothesized that 1) individuals with higher storm anxiety would show increased anxiety related to the storm threat, which would be exacerbated by the worry condition, and 2) individuals with higher storm anxiety would show a decreased N2 response to trials proceeded by threat-related distractors (suggesting increased resources allocation to threat), which would be exacerbated in the worry condition. Study 2 aimed to investigate attentional biases within severe weather anxiety by using an Emotional Stroop task. It was hypothesized that those with elevated severe weather anxiety would experience an attentional bias towards threat-related words, which would result in decreased performance. Those without elevated severe weather anxiety were not expected to experience attentional biases and not experience decreases in performance.

As the results of Study 1 and 2 are assessing the same conceptual question they will be discussed together. Results of Study 1 and 2, generally, failed to support hypothesized attentional biases to both pictorial and written stimuli. Indeed, the worry manipulation in Study 1 increased self-reported anxiety towards the severe weather threat, whereas the distraction manipulation did not. These results support previous findings that suggest engaging in worry or repetitive negative thinking increases anxiety (e.g., Borkovec et al., 1983; Mogg et al., 2010; Rapee & Hiemberg, 1997); however, this was not influence by individual's level of trait severe weather anxiety. In other words, the deleterious effect of worry on state anxiety towards severe weather does not seem to be unique to those with elevated trait severe weather anxiety. Early documentation of severe weather anxiety does report the presence of worry (Watt & DiFrancescantonio, 2012; Westefeld, 1996), yet the current study did not support the assertion that worry is a maintenance factor for those with severe weather anxiety. It possible that the frequency of uncontrollable and unplanned worry is common within those with severe weather anxiety, but that forcing individuals to engage in a single bout of worry resulted in everyone displaying the same increased anxiety. If this pattern is true, it would explain the negative effect that worry had on both those with and without severe weather anxiety and would be consistent with other maintenance factors for specific phobias (Kraft & Grant, 2020).

These findings are contradictory to those which have found that individuals with elevations in severe weather anxiety show increased anxiety after engaging in severe weather exposures (Krause et al., 2018; Nelson et al., 2014) compared to those without elevations in severe weather anxiety. Studies finding these effects utilized an immersive virtual reality experience including visual, auditory, and pallesthesia (vibration) cues. It is possible that the threat induction (auditory alert) and worry manipulation were not threatening enough or did not provide enough threatening cues to induce a meaningful level of severe weather anxiety or physiological arousal specifically for those with elevated severe weather anxiety. Moreover, the presence of severe weather is often accompanied by multiple threat cues (e.g., rain, humidity, lightning, thunder, media coverage, visual cues of a severe storm), whereas other phobias may not be paired with such a numerous number of preceding cues (e.g., spiders, needles, dogs). For example, an individual with spider phobia may encounter spiders with little to no preceding cues, whereas an individual with Severe Weather Phobia will likely experience a variety of cues preceding the threat. For this reason, it is possible that the intensity and variety of threat cues used in the current study resulted in both groups showing increased anxiety, in that those with severe weather anxiety to respond like those without severe weather anxiety (Dresler et al., 2009).

In terms of the distractors impact on task performance, results of both studies observed no significant differences in error rates. This pattern is consistent with previous literature on anxiety (Derakshan & Eysenck, 2009). This literature indicates that deficits in the effectiveness of performance (i.e., error rates) are not always observed for those with anxiety disorders. Instead, these theories postulate that individuals with elevated anxiety may require increased effort, such as reaction times or attentional recruitment, to complete the task effectively (Derakshan & Eysenck, 2009). A notable pattern of findings was observed when evaluating the trend in means for the Emotional Stroop task. This pattern indicated that the positive and weather words resulted in marginally more errors than the neutral, which may suggest a trend of emotionality effects. Although non-significant and representing minimal effect sizes, an emotionality effect, in which weather stimuli appears to be trending with positive emotional stimuli, is important to note for future research.

Collecting reaction times across both studies allowed for the investigation of deficits in efficiency where effectiveness deficits are absent. Results of the Emotional Stroop indicated no significant effects, but evaluation of the means suggested a slight trend, in which those with elevations in severe weather anxiety displayed slightly longer RT’s to weather words compared to those with lower weather anxiety. This pattern was not observed in the positive or neutral trials. Although non-significant, these trends align with previous studies documenting increased reaction time to trials that contain threatening information for those with anxiety (Bar-Haim et al., 2007; Cisler et al., 2011; Derakshan & Eysenck, 2009), which may indicate the presence of attentional biases to threaten stimuli in severe weather anxiety. A potential explanation for these non-significant, but trending, results is the stimuli. At the time of stimuli selection, minimal datasets existed which discussed the stimuli properties of English words. Weather related words were selected from a small number of words that pertained to weather events. Unfortunately, these words may not have been disorder specific enough and may not have been threatening enough to produce an anxiety response unique to those with severe weather anxiety.

Reaction time results observed the traditional congruency effects for the Flanker task, such that the incongruent trials resulted in increased reaction times compared to the congruent trials. Results also indicated multiple interactions with difficult to interpret effects. Specifically, these results potentially suggest that engaging in worry, or having increased severe weather anxiety, alters the pattern of responding to threatening and distractor stimuli within both congruent (i.e., easy or low cognitive load) and incongruent (i.e., difficult or higher cognitive load) tasks. Previous literature supports the presence of modulations in attention and performance during cognitive tasks as a result of cognitive and working memory load (e.g., Judah et al., 2013; White & Grant, 2017). For example, during increased working memory load, those with low levels of anxiety and worry display decreased processing of emotionally relevant stimuli, which was not observed in those with increased levels of anxiety and worry (White & Grant, 2017).

The results of Study 1 potentially suggest that, during trials with increased cognitive load (incongruent trials), those with elevations in weather anxiety showed longer reaction times for the trials with threat, compared to the trials with non-threat distractors. Whereas in those with lower severe weather anxiety, slower reaction times for the trials with threat were observed, relative to the trials with non-threat distractors. A potential interpretation is that those with lower levels of severe weather anxiety are less impacted by threat-related distractor stimuli when engaging in a task with higher levels of cognitive load, which may not be the case in those with elevated weather anxiety.

A similar pattern was observed between the worry and distraction groups, also suggesting that engaging in worry may modulate the ability to separate from distracting information. Consistent with previous data (Hammel et al., 2011; Sari et al., 2017; White et al., 2020), a potential interpretation for these results is that engaging in worry resulted in a reduction in the traditional congruency effect for the trials with threat-related information, but not for the trials with non-threatening distractors. It is possible that the threat-related images were maintained in working memory during the Flanker task, resulting in a reduction in the traditional congruency effect. This was only present within the individuals who engaged in worry regarding the upcoming weather event, indicating that the combination of worry as a working memory load and the threat stimuli may have uniquely interrupted the traditional congruency effect. Notably, interpretation of these two 2-way interactions is cautionary as they represent an underpowered analysis, do not show significant follow-up analyses, and disappear when utilizing the full sample. Additionally, evaluation of the effects sizes within the these follow up analyses showed quite small effects ($\eta p2 < .10$) for all comparisons, suggesting limited interpretations as well.

Results of the Flankers task did indicate a traditional N2 effect, such that incongruent trials had an increased N2 relative to the congruent. This suggests that the Flanker task may have been a methodological sound paradigm; however, no modulations in the N2 were observed in relation to trait severe weather anxiety, severe weather threat cues, or worry manipulations. These findings suggest that severe weather anxiety and the included manipulations may not impact psychophysiological resource allocation. Inspection of the pattern of means revealed trends in the direction opposite of hypothesized effects. Specifically, those with elevations in severe weather anxiety displayed a slight increase in neural recruitment to the Flanker task, when weather related distractor stimuli were presented compared to the non-weather distractors and to those without elevations in severe weather anxiety. Although contradictory to hypothesized directions, this pattern is consistent with previous literature indicating increased neural recruitment in those with anxiety disorders to complete a task effectively (Derakshan & Eysenck, 2009). It is possible that those with elevated severe weather anxiety required increased N2 resources to effectively complete the task; however, these effects were underpowered, non-significant, were accompanied with relatively high standard errors, and should be interpreted with caution.

Whereas previous research has documented disorder specific performance effects for anxiety (e.g., Williams et al., 1996), results of these studies failed to support these hypotheses and did not find any distinct and stable attentional biases. Using similar paradigms, Dennis and Chen (2009) and Cisler and Colleagues (2011) found that trials with anxiety specific threatening information led to decreased performance in those with social anxiety. Furthermore, decades of research have documented attentional biases and hindered performance in those with anxiety in the presences of threatening information (Cisler & Koster, 2010; Lipp & Derakshan, 2005; Mogg & Bradley, 2006; Pishyar, Harris, and Menzies, 2004). These results could suggest that those with severe weather anxiety do not present attentional biases similar to those observed in other anxiety disorders; however, a potentially more likely explanation is that the valance, arousal, and intensity of the stimuli presented in the paradigms were not robust enough to elicit an anxious response or bias in attention.

Several limitations of these studies are noteworthy. Due to the unforeseen impact of COVID-19 and resulting safety procedures, data collection for Study 1 was significantly hindered. This resulted in the collection of only 32 of the proposed 52 suggested by the power analyses. Therefore, the analyses for Study 1 are likely underpowered and may suffer from Type 2 error. Although the SFQ shows predictive utility for severe weather anxiety in the development paper, strict psychometric analyses of the questionnaire were not used, substantive cutoffs or recommendations were not provided, and the generalizability of the items and factor structure to a Midwestern population is questionable. It is possible that an extreme groups approach was not effective to classify those with severe weather anxiety and official diagnoses are necessary. It is possible that those in the high group did not experience severe weather anxiety in a severe way; however, our means were higher in the development paper. The overall mean SFQ of Study 1 (M

= 11.41, SD = 10.82) and Study 2 (M = 9.78, SD = 9.50) were higher than the mean (M = 4.06, SD = 3.55) presented in the development paper (Nelson et al., 2014). It is possible that the items on the questionnaire may be assessing different constructs within different geographical regions. Another limitation is the use of online data collection for the Emotional Stroop task. Participants unique computer characteristics and settings (screen settings, brightness settings, window tab dimensions) can impact the validity of the task by adding difficult to control confounds. Finally, as noted above, very finite stimuli arrays are available that incorporate severe weather stimuli. The current study was limited to using the stimuli in those datasets which provide stimuli characteristics from a representative sample. For this reason, the stimuli may have been limited in the specificity, intensity, valance, and arousal, which could have resulted in hindered stimuli effects.

Based on the current findings, there are multiple avenues for future direction. Future research should investigate the generalizability of the SFQ across geographical regions to determine whether the presence of severe weather anxiety varies by geography and exposure to severe weather. A wider variety of severe weather stimuli should be investigated to determine which stimuli and at what intensity results in attentional biases, increases in state anxiety, and psychological arousal. Once stimuli are developed, investigations into their impact on executive function and psychophysiology can be pursued. It is entirely possible that severe weather anxiety does not present attentional biases or performance deficits within the Flanker or Emotional Stroop task, therefore future research should evaluate alternative paradigms which focus on separate executive functions (e.g., shifting, working memory, inhibition).

In summary, severe weather anxiety is a relatively rare condition, yet a large portion of the U.S. population experiences disruptive anxiety towards weather every year. The current studies aimed to expand the literature on severe weather anxiety by documenting attentional biases and the impact of worry on those biases. Results of these two studies did not find attentional biases for those with elevations in severe weather anxiety and revealed no unique impact of worry of severe weather anxiety. Although these studies were limited in a number of ways, they represent an important first step in the investigation of the mechanisms underlying severe weather anxiety.

REFERENCES

American Psychiatric Association. (2013). Diagnostic and statistical manual disorders (5th ed.). Washington DC: Author.

American Psychological Association Task Force on the Interface between Psychology and Global Climate Change. (2010).

Amir, N., Mcnally, R. J., Riemann, B. C., Burns, J., Lorenz, M., & Mullen, J. T. (1996). Suppression of the emotional Stroop effect by increased anxiety in patients with social phobia. Behaviour Research and Therapy, 34(11-12), 945-948.

Andreassi, J. L. (2007). Psychophysiology: Human behavior and physiological response. Mahwah, NJ: Lawrence Erlbaum.

Alguacil, S., Tudela, P., & Ruz, M. (2013). Cognitive and affective control in a flanker word task: common and dissociable brain mechanisms. Neuropsychologia, 51(9), 1663-1672.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & Van Ijzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. Psychological bulletin, 133(1), 1-24.

Beck, A. T., & Clark, D. A. (1997). An information processing model of anxiety: Automatic and strategic processes. Behaviour research and therapy, 35(1), 49-58.

Becker, E. S., Rinck, M., Türke, V., Kause, P., Goodwin, R., Neumer, S., & Margraf, J. (2007). Epidemiology of specific phobia subtypes: findings from the Dresden Mental Health Study. European Psychiatry, 22(2), 69-74.

Blaustein, M. (1991). Overview: natural disasters and psychiatric response. Psychiatric Annals, 21(9), 518-519.

Borkovec, T. D., & Inz, J. (1990). The nature of worry in generalized anxiety disorder: A predominance of thought activity. Behaviour research and therapy, 28(2), 153-158.

Borkovec, T. D., Robinson, E., Pruzinsky, T., & DePree, J. A. (1983). Preliminary exploration of worry: Some characteristics and processes. Behaviour research and therapy, 21(1), 9-16.

Bradley, M.M., & Lang, P.J. (1999). Affective norms for English words (ANEW): Instruction manual and affective ratings. Technical Report C-1, The Center for Research in Psychophysiology, University of Florida.

Campbell, D., Sanderson, R. E., & Laverty, S. G. (1964). Characteristics of a conditioned response in human subjects during extinction trials following a single traumatic conditioning trial. The Journal of Abnormal and Social Psychology, 68(6), 627.

Chen, S., Yao, N., Qian, M., & Lin, M. (2016). Attentional biases in high social anxiety using a flanker task. Journal of behavior therapy and experimental psychiatry, 51, 27-34.

Cisler, J. M., & Koster, E. H. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. Clinical psychology review, 30(2), 203-216.

Cisler, J. M., Wolitzky-Taylor, K. B., Adams Jr, T. G., Babson, K. A., Badour, C. L., & Willems, J. L. (2011). The emotional Stroop task and posttraumatic stress disorder: a meta-analysis. Clinical psychology review, 31(5), 817-828.

Clayson, P. E., & Larson, M. J. (2013). Psychometric properties of conflict monitoring and conflict adaptation indices: Response time and conflict N2 event-related potentials. Psychophysiology, 50(12), 1209-1219.

Coelho, C. M., & Purkis, H. (2009). The origins of specific phobias: Influential theories and current perspectives. Review of General Psychology, 13(4), 335-348.

Coleman, J. S., Newby, K. D., Multon, K. D., & Taylor, C. L. (2014). Weathering the storm: Revisiting severe-weather phobia. Bulletin of the American Meteorological Society, 95(8), 1179-1183.

Cook, E. W., Hodes, R. L., & Lang, P. J. (1986). Preparedness and phobia: effects of stimulus content on human visceral conditioning. Journal of abnormal psychology, 95(3), 195-207.

Cook, M., & Mineka, S. (1989). Observational conditioning of fear to fear-relevant versus fear-irrelevant stimuli in rhesus monkeys. Journal of abnormal psychology, 98(4), 448-459.

Davey, G. C., & Craigie, P. (1997). Manipulation of dangerousness judgements to fear-relevant stimuli: Effects on a priori UCS expectancy and a posteriori covariation assessment. Behaviour Research and Therapy, 35(7), 607-617.

Davey, G. C., & Dixon, A. L. (1996). The expectancy bias model of selective associations: the relationship of judgments of CS dangerousness, CS-UCS similarity and prior fear to a priori and a posteriori covariation assessments. Behaviour Research and Therapy, 34(3), 235-252.

De Ruiter, C., & Brosschot, J. F. (1994). The emotional Stroop interference effect in anxiety: attentional bias or cognitive avoidance?. Behaviour Research and Therapy, 32(3), 315-319.

Delorme, A., & Makeig, S. (2004). EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. Journal of neuroscience methods, 134(1), 9-21.

Dennis, T. A., & Chen, C. C. (2009). Trait anxiety and conflict monitoring following threat: an ERP study. Psychophysiology, 46(1), 122-131.

Derakshan, N., & Eysenck, M. W. (2009). Anxiety, processing efficiency, and cognitive performance: New developments from attentional control theory. European Psychologist, 14(2), 168-176.

Dollinger, S. J. (1985). Lightning-strike disaster among children. British Journal of Medical Psychology, 58(4), 375-383.

Dresler, T., Mériau, K., Heekeren, H. R., & van der Meer, E. (2009). Emotional Stroop task: effect of word arousal and subject anxiety on emotional interference. Psychological Research PRPF, 73(3), 364-371.

Duncan-Johnson, C. C., & Kopell, B. S. (1981). The Stroop effect: Brain potentials localize the source of interference. Science, 938-940.

Eriksen, B.A., & Eriksen, C.W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. Perception & Psychophysics, 16, 143–149.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: attentional control theory. Emotion, 7(2), 336.

First, M. B., Spitzer, R. L., Gibbon, M., & Williams, J. B. W. (1996). Structured clinical interview for DSM-IV Axis I Disorders—patient edition (SCID-I/P, Version 2.0). New York: New York State Psychiatric Institute, Biometrics Research Department

Folstein, J. R., & Van Petten, C. (2008). Influence of cognitive control and mismatch on the N2 component of the ERP: a review. Psychophysiology, 45(1), 152-170.

Fyer, A. J. (1998). Current approaches to etiology and pathophysiology of specific phobia. Biological psychiatry, 44(12), 1295-1304.

Fyer, A. J., Mannuzza, S., Gallops, M. S., Martin, L. Y., Aaronson, C., Gorman, J. M., Liebowitz & Klein, D. F. (1990). Familial transmission of simple phobias and fears: a preliminary report. Archives of general psychiatry, 47(3), 252-256.

Greening, L., & Dollinger, S. J. (1992a). Adolescents' Perceptions of Lightning and Tornado Risks 1. Journal of applied social psychology, 22(10), 755-762.

Greening, L., & Dollinger, S. J. (1992b). Illusions (and shattered illusions) of invulnerability: Adolescents in natural disaster. Journal of Traumatic Stress, 5(1), 63-75.

Hammel, J. C., Smitherman, T. A., McGlynn, F. D., Mulfinger, A. M., Lazarte, A. A., & Gothard, K. D. (2011). Vagal influence during worry and cognitive challenge. Anxiety, Stress, & Coping, 24(2), 121-136.

Hayes, S., Hirsh, C., & Matthews, A. (2008). Restriction of working memory capacity during worry. Journal of Abnormal Psychology, 3, 712-717.

Hinrichsen, H., & Clark, D. M. (2003). Anticipatory processing in social anxiety: Two pilot studies. Journal of behavior therapy and experimental psychiatry, 34(3-4), 205-218.

Hirsch, C. R., Hayes, S., Mathews, A., Perman, G., & Borkovec, T. (2012). The extent and nature of imagery during worry and positive thinking in generalized anxiety disorder. Journal of Abnormal Psychology, 121(1), 238.

Hirsch, C. R., & Mathews, A. (2012). A cognitive model of pathological worry. Behaviour research and therapy, 50(10), 636-646.

Hock, H. S., & Egeth, H. (1970). Verbal interference with encoding in a perceptual classification task. Journal of Experimental Psychology, 83(2, Pt.1), 299–303.

Judah, M. R., Grant, D. M., Lechner, W. V., & Mills, A. C. (2013). Working memory load moderates late attentional bias in social anxiety. Cognition and Emotion, 27,502-511. http://dx.doi.org/10.1080/02699931.2012.719490

Judah, M. R., Grant, D. M., Mills, A. C., & Lechner, W. V. (2013). The Neural Correlates of Impaired Attentional Control in Social Anxiety: An ERP Study of Inhibition and Shifting. Emotion, 13(6), 1096-1106.

Kanske, P., & Kotz, S. A. (2010). Modulation of early conflict processing: N200 responses to emotional words in a flanker task. Neuropsychologia, 48(12), 3661-3664.

Keele, S. W. (1972). Attention demands of memory retrieval. Journal of Experimental Psychology, 93(2), 245–248.

Kindt, M., & Brosschot, J. F. (1999). Cognitive bias in spider-phobic children: Comparison of a pictorial and a linguistic spider Stroop. Journal of Psychopathology and Behavioral Assessment, 21(3), 207-220.

Kleinknecht, R. A., & Smith, K. B. (2002). Afraid of the Weather?. Weatherwise, 55(6), 14-20.

Knebel, J. F., Toepel, U., Hudry, J., Le Coutre, J., & Murray, M. M. (2008). Generating controlled image sets in cognitive neuroscience research. Brain topography, 20(4), 284-289.

Kraft, J. D., Grant, D. M., White, E. J., Taylor, D. L., & Frosio, K. E. (2019). Cognitive mechanisms influence the relationship between social anxiety and depression among college students. Journal of American college health, 1-7.

Krause, K. L., MacDonald, E. M., Goodwill, A. M., Vorstenbosch, V., & Antony, M. M. (2018). Assessing Safety Behaviors in Fear of Storms: Validation of the Storm-Related Safety Behavior Scale. Journal of Psychopathology and Behavioral Assessment, 40(1), 139-148.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). International affective picture system (IAPS): Technical manual and affective ratings. NIMH Center for the Study of Emotion and Attention, 1, 39-58.

Lipp, O. V., & Derakshan, N. (2005). Attentional bias to pictures of fear-relevant animals in a dot probe task. Emotion, 5(3), 365.

LeBeau, R. T., Glenn, D., Liao, B., Wittchen, H. U., Beesdo-Baum, K., Ollendick, T., & Craske, M. G. (2010). Specific phobia: a review of DSM-IV specific phobia and preliminary recommendations for DSM-V. Depression and Anxiety, 27(2), 148-167.

Lépine, J. P. (2002). The epidemiology of anxiety disorders: prevalence and societal costs. The Journal of clinical psychiatry, 63(14), 4–8.

Li, W., Jiang, Z., Liu, Y., Wu, Q., Zhou, Z., Jorgensen, N., Li, X., & Li, C. (2014). Positive and negative emotions modulate attention allocation in color-flanker task processing: evidence from event related potentials. Motivation and Emotion, 38(3), 451-461.

Liddell, A., & Lyons, M. (1978). Thunderstorm phobias. Behaviour Research and Therapy, 16(4), 306-308.

Lopez-Calderon, J., & Luck, S. J. (2014). ERPLAB: an open-source toolbox for the analysis of event-related potentials. Frontiers in human neuroscience, 8, 213.

Luck, S. J. (2005). Ten simple rules for designing ERP experiments. Event-related potentials: A methods handbook, 262083337.

Luck, S. J. (2014). An introduction to the event-related potential technique. MIT press.

Man, A. D., & Simpson-Housley, P. (1987). Factors in perception of tornado hazard: An exploratory study. Social Behavior and Personality: an international journal, 15(1), 13-19.

Mattia, J. I., Heimberg, R. G., & Hope, D. A. (1993). The revised Stroop color-naming task in social phobics. Behaviour Research and Therapy, 31(3), 305-313.

McNally, R. J. (1987). Preparedness and phobias: a review. Psychological bulletin, 101(2), 283-303.

Merckelbach, H., de Jong, P. J., Muris, P., & van Den Hout, M. A. (1996). The etiology of specific phobias: A review. Clinical Psychology Review, 16(4), 337-361.

Mills, A. C., Grant, D. M., Judah, M. R., & White, E. J. (2014). The influence of anticipatory processing on attentional biases in social anxiety. Behavior therapy, 45(5), 720-729.

Mineka, S. (1987). A primate model of phobic fears. In Theoretical foundations of behavior therapy (pp. 81-111). Springer, Boston, MA.

Mineka, S., & Cook, M. (1993). Mechanisms involved in the observational conditioning of fear. Journal of Experimental Psychology: General, 122(1), 23-38.

Mogg, K., & Bradley, B. P. (2006). Time course of attentional bias for fear-relevant pictures in spider-fearful individuals. Behaviour research and therapy, 44(9), 1241-1250.

Mogg, K., McNamara, J., Powys, M., Rawlinson, H., Seiffer, A., & Bradley, B. P. (2000). Selective attention to threat: A test of two cognitive models of anxiety. Cognition & Emotion, 14(3), 375-399.

Mowrer, O. (1960). Learning theory and behavior.

Nelson, A. L., Vorstenbosch, V., & Antony, M. M. (2014). Assessing fear of storms and severe weather: Validation of the Storm Fear Questionnaire (SFQ). Journal of Psychopathology and Behavioral Assessment, 36(1), 105-114.

O'Toole, L. J., DeCicco, J. M., Hong, M., & Dennis, T. A. (2011). The impact of task-irrelevant emotional stimuli on attention in three domains. Emotion, 11(6), 1322.

Ollendick, T., Raishevich, N., Davis, T., III, Sirbu, C., & Ost, L. (2010). Specific phobia in youth: phenomenology and psychological characteristics. Behaviour Therapy, 41, 133–141.

Öst, L. G., & Hugdahl, K. (1981). Acquisition of phobias and anxiety response patterns in clinical patients. Behaviour Research and Therapy, 19(5), 439-447.

Owens, M., Derakshan, N., & Richards, A. (2015). Trait susceptibility to worry modulates the effects of cognitive load on cognitive control: An ERP study. Emotion, 15(5), 544.

Pacheco-Unguetti, A. P., Acosta, A., Callejas, A., & Lupiáñez, J. (2010). Attention and anxiety: Different attentional functioning under state and trait anxiety. Psychological science, 21(2), 298-304.

Paquet, L., & Craig, G. L. (1997). Evidence for selective target processing with a low perceptual load flankers task. Memory & cognition, 25(2), 182-189.

Perreault, M. F., Houston, J. B., & Wilkins, L. (2014). Does scary matter?: Testing the effectiveness of new National Weather Service tornado warning messages. Communication Studies, 65(5), 484-499.

Pineles, S. L., & Mineka, S. (2005). Attentional biases to internal and external sources of potential threat in social anxiety. Journal of abnormal psychology, 114(2), 314.

Pishyar, R., Harris, L. M., & Menzies, R. G. (2004). Attentional bias for words and faces in social anxiety. Anxiety, Stress & Coping, 17(1), 23-36.

Rapee, R. M., & Heimberg, R. G. (1997). A cognitive-behavioral model of anxiety in social phobia. Behaviour research and therapy, 35(8), 741-756.

Rozenkrants, B., & Polich, J. (2008). Affective ERP processing in a visual oddball task: arousal, valence, and gender. Clinical Neurophysiology, 119(10), 2260-2265.

Sari, B. A., Koster, E. H., & Derakshan, N. (2017). The effects of active worrying on working memory capacity. Cognition and Emotion, 31(5), 995-1003.

Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2003). Attention and emotion: an ERP analysis of facilitated emotional stimulus processing. Neuroreport, 14(8), 1107-1110.

Seligman, M. E. (1971). Phobias and preparedness. Behavior therapy, 2(3), 307-320.

Spector, I. P., Pecknold, J. C., & Libman, E. (2003). Selective attentional bias related to the noticeability aspect of anxiety symptoms in generalized social phobia. Journal of Anxiety Disorders, 17(5), 517-531.

Stinson, F. S., Dawson, D. A., Chou, S. P., Smith, S., Goldstein, R. B., Ruan, W. J., & Grant, B. F. (2007). The epidemiology of DSM-IV specific phobia in the USA: results from the National Epidemiologic Survey on Alcohol and Related Conditions. Psychological medicine, 37(7), 1047-1059.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. Journal of Experimental Psychology 18, 643–662.

Thorpe, S. J., & Salkovskis, P. M. (1995). Phobic beliefs: Do cognitive factors play a role in specific phobias?. Behaviour Research and Therapy, 33(7), 805-816.

Tillman, C. M., & Wiens, S. (2011). Behavioral and ERP indices of response conflict in Stroop and flanker tasks. Psychophysiology, 48(10), 1405-1411.

Vassilopoulos, S. (2005). Social anxiety and the effects of engaging in mental imagery. Cognitive Therapy and Research, 29(3), 261-277.

Wang, A. G. (2000). Storm phobia: a North Atlantic phenomenon. Nordic Journal of Psychiatry, 54(1), 67-68.

Watson, J. B., & Rayner, R. (1920). Conditioned emotional reactions. Journal of experimental psychology, 3(1), 1-14.

Watt, M. C., & DiFrancescantonio, S. L. (2012). Who's afraid of the big bad wind? Origins of severe weather phobia. Journal of Psychopathology and Behavioral Assessment, 34(4), 440-450.

Wells, A. (1995). Meta-cognition and worry: A cognitive model of generalized anxiety disorder. Behavioural and cognitive psychotherapy, 23(3), 301-320.

Westefeld, J. S. (1996). Severe weather phobia: an exploratory study. Journal of clinical psychology, 52(5), 509-515.

Westefeld, J. S., Less, A., Ansley, T., & Yi, H. S. (2006). Severe-weather phobia. Bulletin of the American Meteorological Society, 87(6), 747-750.

White, E. J., & Grant, D. M. (2017). Electrocortical consequences of image processing: The influence of working memory load and worry. Psychiatry Research: Neuroimaging, 261, 1-8.

White, E. J., Grant, D. M., Taylor, D. L., Kraft, J. D., & Frosio, K. E. (2020). The influence of state worry on covert selective attention and working memory for threatening stimuli: An ERP study. Psychology & Neuroscience. Advance online publication.

Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. Psychological bulletin, 120(1), 3-24.

Wittchen, H. U., Nelson, C. B., & Lachner, G. (1998). Prevalence of mental disorders and psychosocial impairments in adolescents and young adults. Psychological medicine, 28(1), 109-126.

Wong, Q. J., & Moulds, M. L. (2011). Impact of anticipatory processing versus distraction on multiple indices of anxiety in socially anxious individuals. Behaviour Research and Therapy, 49(10), 700-706.

Zhang, J., Wu, C., Yuan, Z., & Meng, Y. (2019). Differentiating emotion-label words and emotion-laden words in emotion conflict: an ERP study. Experimental brain research, 237(9), 2423-2430.

APPENDICES

APPENDIX A

FIGURES

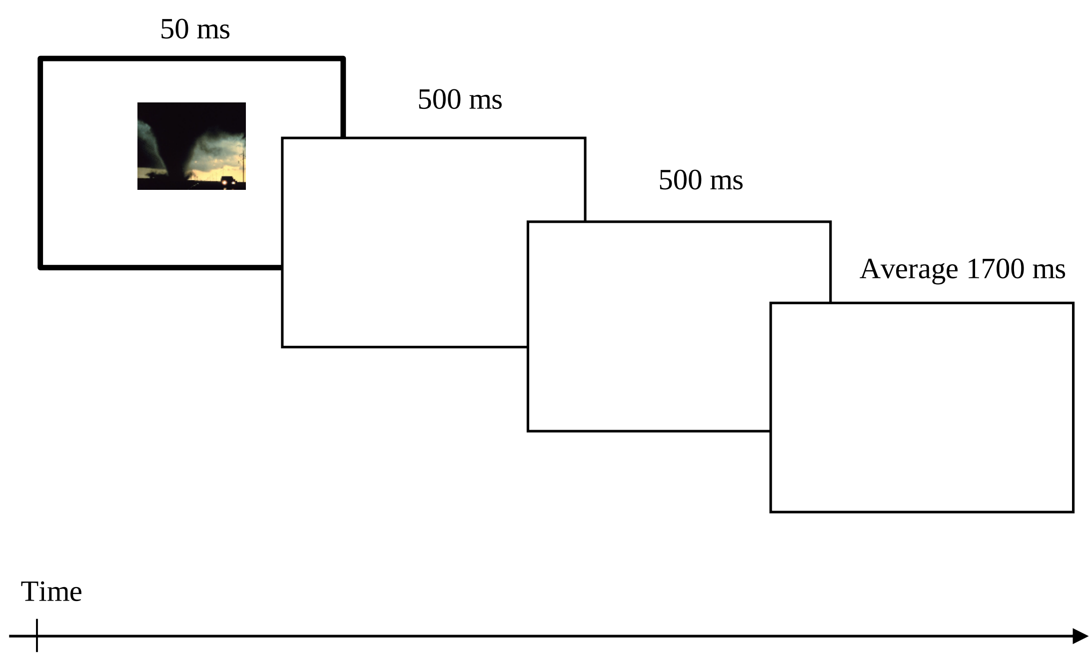


Figure 1. The Flankers

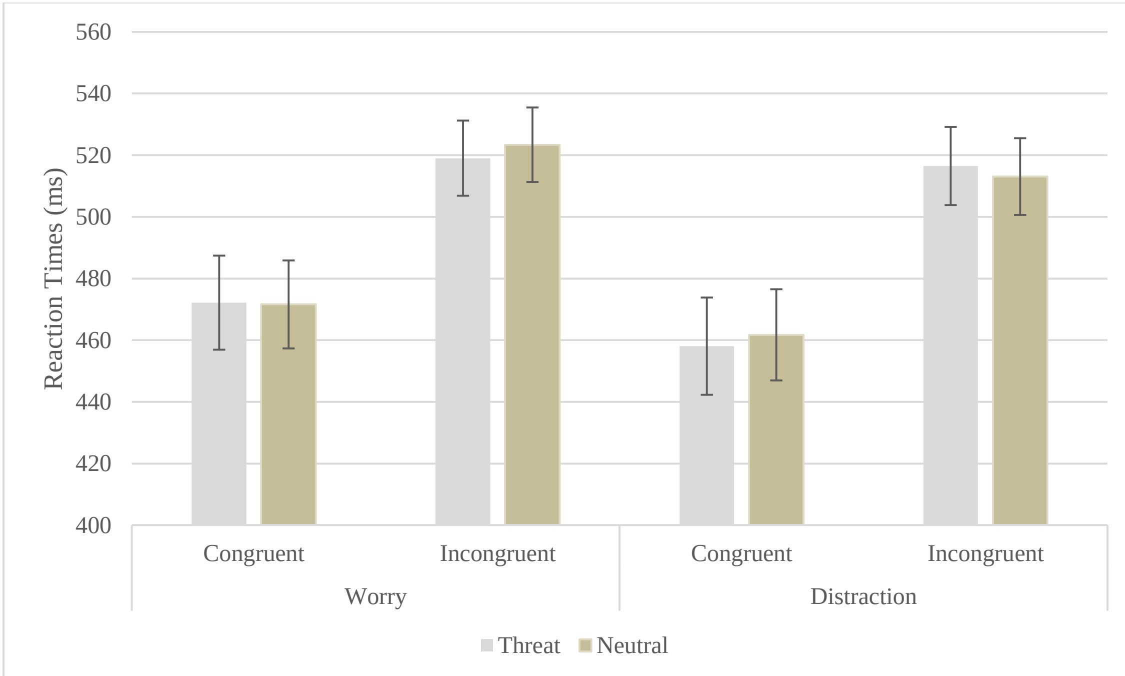


Figure 2. Worry manipulation, Distractor stimuli type, and Task type interaction on Flankers task reaction times. Error bars represent SEs.

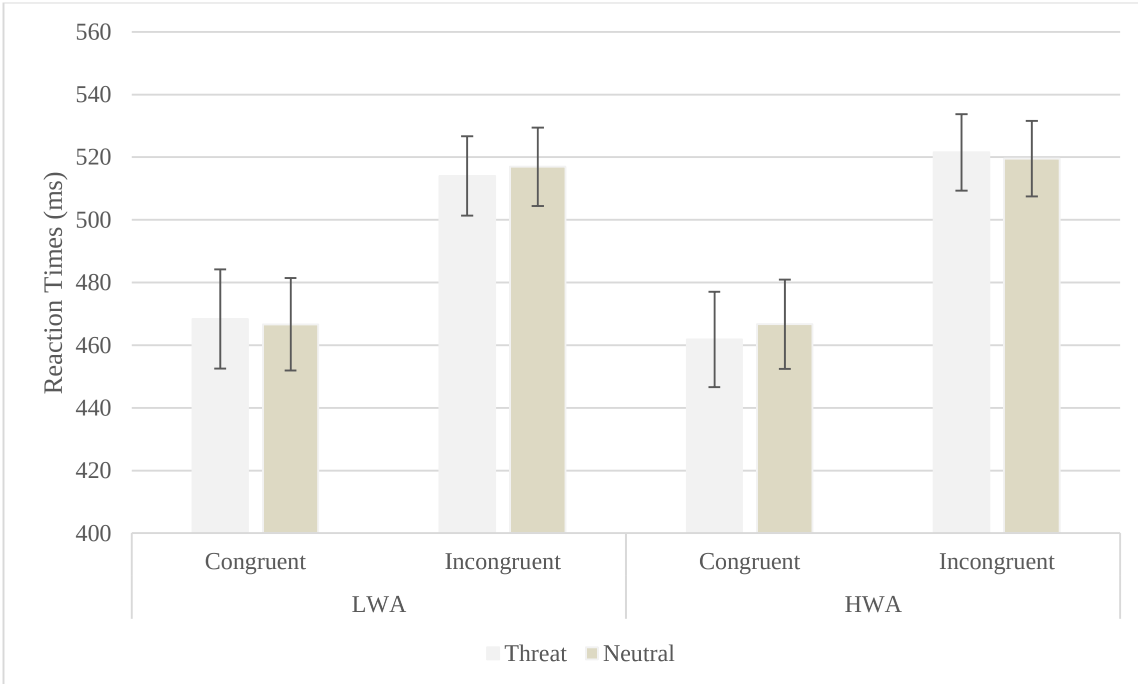


Figure 3. Weather anxiety, Distractor stimuli type, and Task type interaction on Flanker task reaction times. Error bars represent SEs.

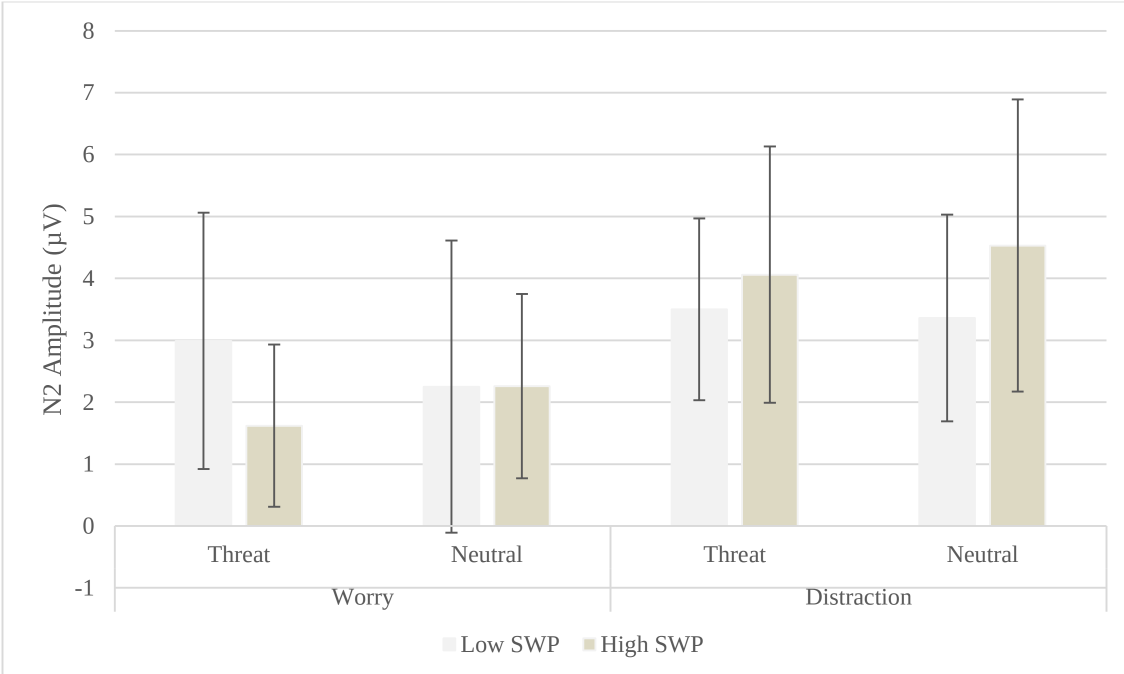
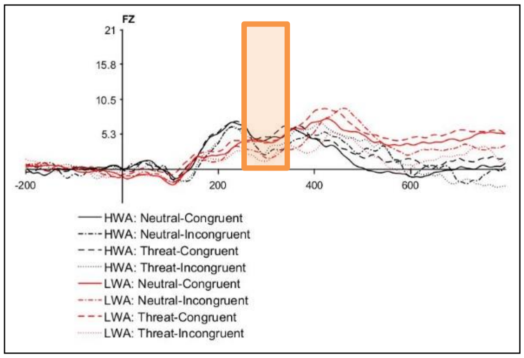


Figure 4. Weather anxiety, Distractor stimuli type, and Worry Manipulation interaction on Flanker task N2 amplitude. Error bars represent SEs.



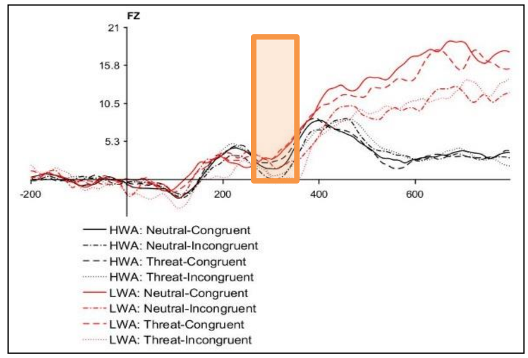


Figure 5. ERP waveforms for the Distraction group (Left) and Worry group (Right).

Highlighted section represents ERP time window.

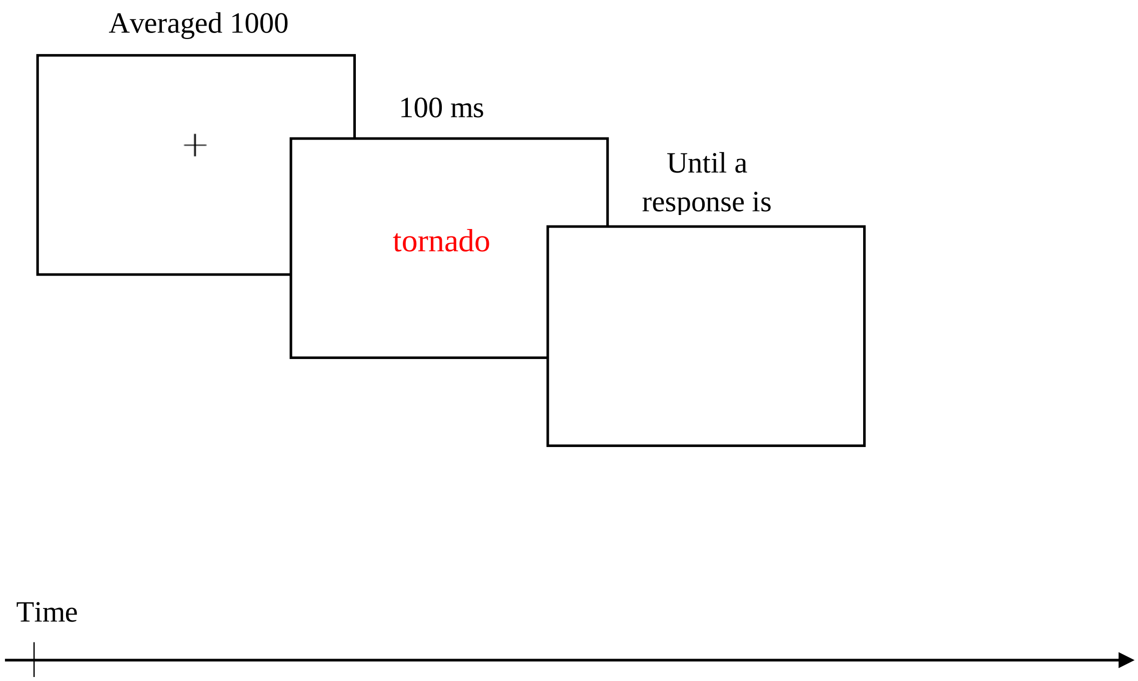


Figure 6. The Emotional Stroop Task

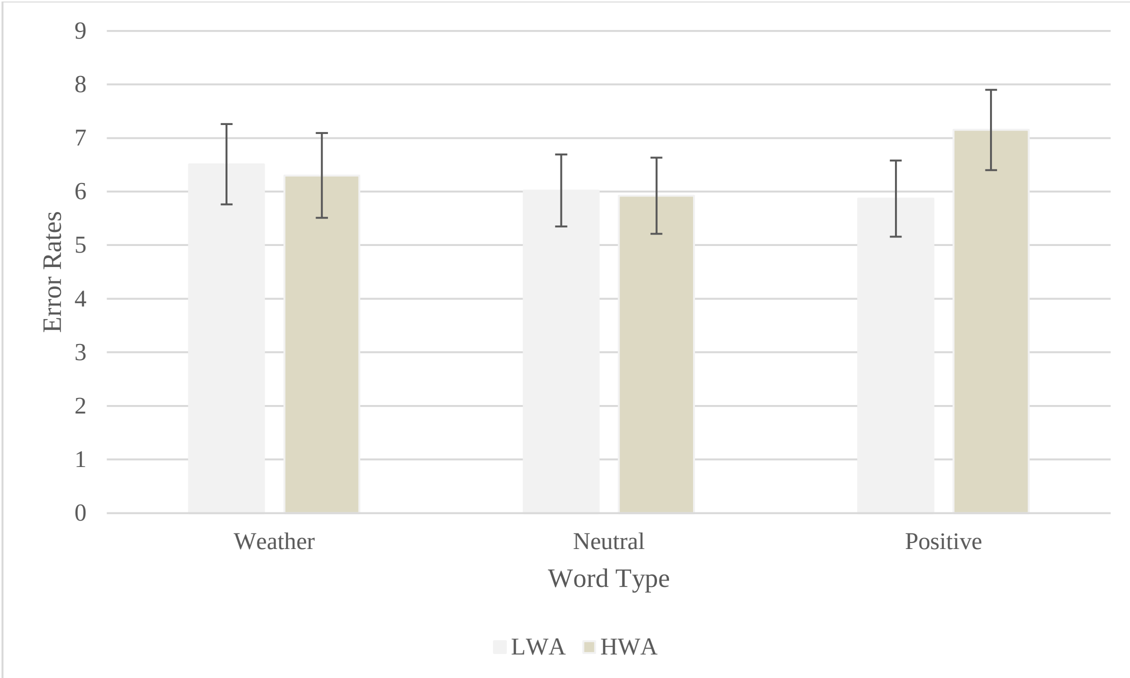


Figure 7. Weather anxiety and Word type interaction on Emotional Stroop task error rates. Error bars represent SEs.

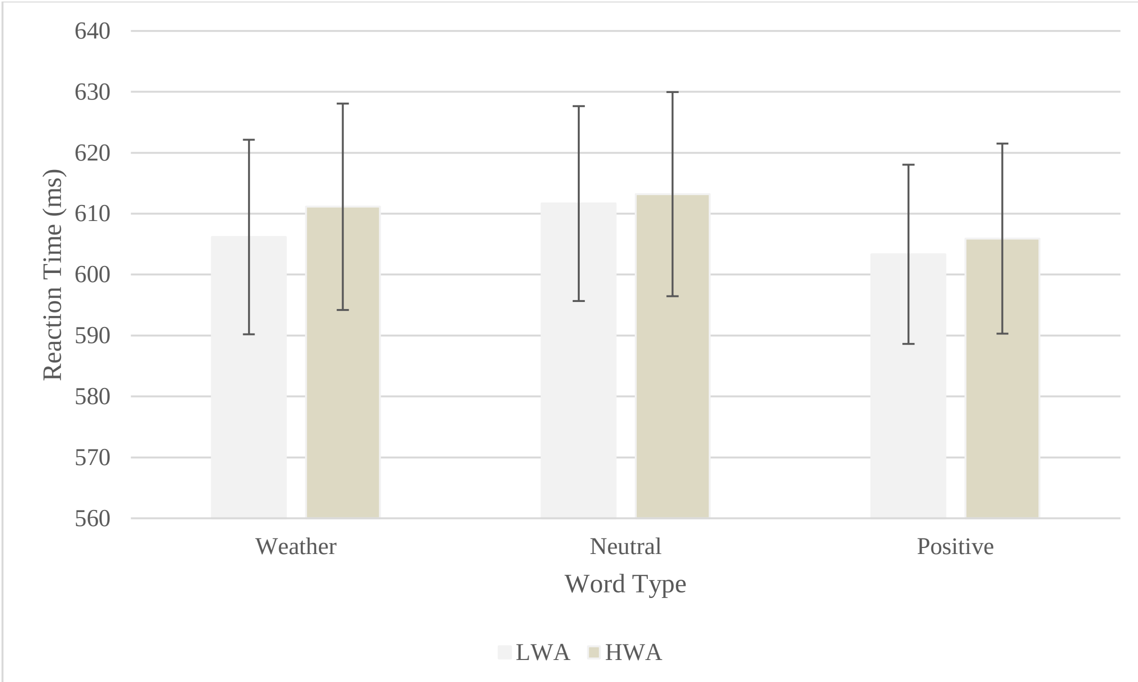


Figure 8. Weather anxiety and Word type interaction on Emotional Stroop task error rates. Error bars represent SEs.

APPENDIX B

STORM FEAR QUESTIONNAIRE

Instructions: Please rate the extent to which each statement is true for you by circling any number from 0 (not at all true) to 4 (almost always true). There are no right or wrong answers.

0 = Not at all
1 = A little
2 = Moderately
3 = Very
4 = Always

1.	I worry about storms more than other people.	0	1	2	3	4
2.	I avoid being in a car during a storm for fear that something bad may happen.	0	1	2	3	4
3.	I tend to monitor the weather on the radio, TV, internet or in the newspapers to ensure that I know when a storm is coming.	0	1	2	3	4
4.	I tend to get anxious when I hear about a storm approaching, even when the storm is a few days away.	0	1	2	3	4
5.	I avoid leaving home during a storm to protect myself from possible harm.	0	1	2	3	4
6.	I tend to get so anxious about a storm system approaching that I have a hard time functioning normally (for example, difficulty concentrating or sleeping at night).	0	1	2	3	4
7.	When there is a storm, my anxiety is so high that I question whether I can cope.	0	1	2	3	4
8.	I feel frightened when I see or hear signs of a storm (for example, dark clouds, heavy rain, wind, thunder, or lightening).	0	1	2	3	4
9.	When there is a storm approaching, my fear prevents me from going to school, work, or social events.	0	1	2	3	4
10.	When there is a storm approaching, I tend to seek safety in a specific room (for example, a basement, bathroom or hallway).	0	1	2	3	4
11.	I worry about being injured or dying as a result of a storm (for example, being struck by lightning).	0	1	2	3	4
12.	I try to distract myself (for example, listening to music, watching television or reading) during a storm to reduce my anxiety.	0	1	2	3	4
13.	I worry that I am going to be harmed or die because of the physical sensations (for example, pounding heart or dizziness) experienced during a storm.	0	1	2	3	4
14.	I avoid being near windows or open doors during a storm to ensure my safety.	0	1	2	3	4
15.	I use medication, alcohol or drugs to help me cope during a storm.	0	1	2	3	4

APPENDIX C

REVIEW OF LITURATURE

Specific Phobia

Anxiety disorders encompass one of the most common forms of psychopathology in the United States, showing point prevalence rates of 15.7 million people and lifetime prevalence rates of 30 million people (Lepine, 2002). A subset of anxiety disorders, Specific Phobia, has a history of being portrayed as an inconsequential psychological phenomenon (Becker et al., 2007); however, more recent accounts suggest that specific phobias impacts nearly 13% of the population over their lifetime. Specific Phobias also are associated with decreased quality of life, impairment, and increased risk for other mental health conditions (Becker et al., 2007; Stinson et al., 2007; Wittchen, Nelson, & Lachner, 1998). Based on prevalence rates and negative outcomes of Specific Phobia, it is imperative to document the pathognomic and transdiagnostic maintenance factors.

Specific Phobia is the presentation of excessive and unreasonable fear or anxiety regarding a specific object or situation (APA, 2013). Presentations are grouped into five categories: Animal, Natural Environment, Blood-Injection-Injury, Situational, and Other. Although these categories fall under the same conceptual class of disorders, their presentation, associated impairment, and hypothesized mechanisms may differ (Becker et al., 2007). Natural Environment Phobia (i.e., phobia of water, heights, and storms) is shown to be the second most common phobia within adult samples, falling behind Animal phobias (APA, 2013; Watt & DeFancescantonio, 2012). In a review of Specific Phobia, LeBeau and colleagues (2010) report that Natural Environment phobias prevalence rates fall between 8.9% and 11.6%.

Ollendick and colleagues (2010) evaluated the presence and characteristics of the two most frequently reported Specific Phobias (Animal or Natural Environment) within 95 children diagnosed with Specific Phobia. Dogs were reported as the most common Animal Phobia, and thunderstorms and severe weather were the most common Natural Environment Phobia. Comparing these two phobias revealed that those with Natural Environment Phobia reported more anxiety, depression, and lower life satisfaction than those with Animal Phobia.

With documented prevalence rates and consequences, the growing concerns for climate change, the American Psychological Association Task Force on the Interface between Psychology and Global Climate Change (2010) is encouraging researchers to investigate the etiology, mechanisms, and treatment of fears related to weather. Although there is a push to document weather-related anxiety, a dearth of research regarding this topic remains.

Severe Weather Phobia

Certain phobias, such as spiders, snakes, and heights, receive considerable attention, whereas less research has investigated weather anxiety (i.e., Storm anxiety, storm phobia, Severe Weather Phobia, lilapsophobia, and astraphobia). Although the documentation of severe and traumatic weather events is seen throughout history, Liddell and Lyons (1978) provided some of the first empirical documentation of anxiety and phobia related to thunderstorms. In completing a retrospective analysis of 10 clients who received treatment for thunderstorm phobia, the authors reported that a majority of clients reported onsets in childhood (70%), whereas some (30%) reported adult onset. Only one of the ten clients reported a traumatic weather experience as the etiology, whereas others reported either social learning (e.g., parents, news) or unknown etiology. Liddell and Lyons (1978) described the client's fears as being seasonal, such that late-spring, summer, and fall led to increases in anxiety, avoidance, preoccupation, and anticipatory preparation related to weather. A majority of the subjects reported excessive and uncontrollable anxiety, shaking, screaming, crying, hot/cold flashes, palpitations, sweating, and difficulty breathing during the threat of inclement weather. Liddell and Lyons' (1978) retrospective analysis provided initial documentation of weather anxiety and created a foundation for future research.

It was not until nearly two decades later that Westefeld (1996) first laid claim to the term "Severe Weather Phobia". Westefeld (1996) defined Severe Weather Phobia as the "intense, debilitating, and unreasonable fear of severe weather," with an emphasis on defining severe weather as either severe thunderstorms or tornadoes. Using this novel terminology, Westefeld interviewed 81 individuals that self-reportedly identified with Severe Weather Phobia. Results revealed that 80% of subjects recalled watching or experiencing severe weather as the etiology, whereas 20% reported onsets originating from T.V., media, word of mouth, or parental modeling. Although participants reported seasonal fluctuations in symptoms, 58 subjects report constantly monitoring the potential for bad weather (e.g., watching the weather channel on TV, newspaper, radio) year-round. During months where severe storms are prevalent, participants reported increased anxiety, especially when the potential for storms increases in weather forecasts (5+ days in the future). In anticipation of and during severe weather events, participants reported worrying about safety, engaging in increased checking behaviors (e.g., windows are shut, weather radio), increased physiological symptoms (e.g., rapid breathing, sweating), restlessness, and inability to concentrate. Similar to Liddell and Lyons (1978), Westefeld (1996) documented potential etiological pathways and the prevalence of excessive anxiety; however, Westefeld (1996) provides some of the first objective description of the symptoms, safety behaviors, and behavioral manifestations of Severe Weather Phobia.

Wang (2000) provided further documentation of Severe Weather Phobia using three case studies. Broadly, Wang (2000) concluded that Severe Weather Phobia presented with significant anticipatory anxiety, monitoring of weather-related events, and significant anxiety and functional impairment during severe weather phenomena. These studies provided the initial recognition that Severe Weather Phobia goes above and beyond adaptive anxiety. That is, although it is adaptive to fear and avoid certain weather events, the anxiety, avoidance, and functional impairment related to any weather event (e.g., cloud formation, moderate wind gusts, rain) often seen in Severe Weather Phobia is disproportional to the risk and is dysfunctional (Klainknecht et al., 2002).

In an attempt to understand Severe Weather Phobia outside of a clinical population, Westefeld and colleagues (2006) asked 138 university students to rank how frequently (0 = Never; 5 = Always) they experienced symptoms of anxiety (e.g., dizziness, shortness of breath, heart pounding, panic, helplessness, difficulty sleeping) related to severe thunderstorms and tornadoes. Approximately 20% of the sample indicated at least a moderate degree of anxiety, whereas 76% reported a "bit of fear." Although a majority (79%) of individuals experienced little to mild levels of anxious physiology towards severe weather, a portion (21%) of the sample indicated frequent palpitations, sweating, panic, helplessness, obsessive thoughts, anxiety and avoidance towards Severe Weather. These results suggest that outside of the clinical population, elevations in severe storm phobia and associated physiological and safety behaviors are prevalent.

Coleman (2014) and colleagues assessed the extent and frequency of exposure to severe weather in a more demographically and geographically diverse sample. Specifically, Coleman and colleagues (2014) aimed to determine the generalizability of Westefeld's (1996) definition of Severe Weather Phobia and believed that coastal and northern states may be partially excluded from this definition. Two hundred ninety-eight subjects from 43 states were recruited via Amazon's online Mechanical Turk service and asked survey questions regarding overall fear, exposure, and behavioral and psychological responses to severe weather events. To include the more common weather events along the coasts and north, severe weather was defined as "any meteorological event that poses a significant threat to life and property and/or encompasses the purview of the National Weather Service watch/warning system".

Results revealed that 99% of respondents reported experiencing some form of severe weather, with 90% experiencing a severe thunderstorm and severe wind. Nearly 4% self-reported suffering from Severe Weather Phobia, whereas nearly 12% reported knowing someone who likely meets diagnostic criteria. Approximately 10% reported having an overall fear of severe weather either in the “extreme” or “quite a bit” range. Although the researchers did not compare results across geographical regions due to insufficient power, they suggested that geographical location likely influences the nature and focal point of storm anxiety. Importantly, although a small portion of the demographically diverse sample self-reported suffering from Severe Weather Phobia, 40% indicated moderate levels of anxiety related to storms. Again, it is clear that anxiety related to weather is present at both clinical and sub-clinical levels. Therefore, more investigation is necessary.

Overall, recent research suggests that Severe Weather Phobia occurs in a subset of the population, where general severe weather anxiety lays on a continuum and is more common. Furthermore, these studies document the frequently self-reported etiology and common physiological and behavioral manifestations of this anxiety. Commonalities are shown across these investigations, which implies that common etiological and maintenance factors may be present. Unfortunately, no studies have investigated or documented a comprehensive model or framework to conceptualize Severe Weather Phobia.

Models and Etiology of Specific Phobia

Although little research has formally documented the idiosyncratic etiology and maintenance factors of Severe Weather Phobia, broad models of specific phobia can be applied to understand the condition. Conditioning, non-conditioning, and cognitive models are discussed and applied to Severe Weather Phobia.

Learning and conditioning models of phobias have origins dating back to the 1920’s animal studies pioneered by Watson and other behaviorists (Fyer, 1998; Watson and Rayner 1920). These early classical conditioning models of phobia proposed that feared responses are a learned phenomenon. Specifically, an individual can be conditioned to have a fear response (CR) to a harmless stimulus (CS) by continually pairing the harmless stimulus with a frightening one (US; Fyer, 1998; Merckelbach, de Jong, Muris, van den Hout, 1996). This model has been extensively demonstrated in both animal and human samples (Merckelbach et al., 1996; Fyer, 1998; Coelho & Purkis, 2009; Campbell, Sanderson, & Laverty, 1964; Watson & Rayner, 1920). In the 60's Mowrer (1960) added to the traditional learning model, by arguing that avoidance of the CS often leads to the maintenance of the feared response (Merckelbach et al., 1996). This addition suggests that avoiding the CS is negatively reinforced by not experiencing an aversive emotional reaction (anxiety and fear), which hinders the individual's ability to learn that the CS is truly harmless.

Many researchers argue that theses traditional learning models are not sufficient at conceptualizing specific phobias (see Merckelbach et al., 1996; Fyer, 1998; and Coelho & Purkis, 2009 for details). For example, traditional models do not explain why phobias tend to revolve around evolutionarily salient stimuli. Seligman (1997) and other researchers proposed that evolutionary process interact with the traditional learning process. This model proposes that an evolutionarily recent object (e.g., electricity) will be less likely to produce a phobia compared to an evolutionarily relevant stimulus (e.g., snake, spiders, and weather). To demonstrate this idea, Mineka and colleagues (Mineka, 1987; Cook & Mineka, 1989; Mineka & Cook, 1993) conditioned monkeys to fear evolutionarily salient (i.e., snake) and non-salient (i.e., flower) stimuli. Results revealed a similar level on fear acquisition, but the evolutionarily salient stimuli showed more difficultly experiencing a habituation response. These and similar findings (McNally 1987; Cook, Hodes, & Lang, 1986) suggest that evolutionary salient phobias may be more prevalent due to the increased difficulty to habituate potentially due to their evolutionarily and adaptive values. Although research provides consistent evidence of this effect, many researchers question the underlying mechanisms and the adaptive relevance of evolutionarily relevant stimuli (McNally, 1995), and hesitate to apply this framework to clinical samples.

These models of conditioning propose that fear is learned by having a direct conditioning experience; however, many reports reveal that those with specific phobia either have never experienced the phobic situation, therefore could never have engaged in traditional conditioning, or attribute it to non-associative factors (Merckelbach et al., 1996; Fyer, 1998). Two additional pathways may explain these cases of “non-conditioning” learning: Modeling and negative information transmission. Modelling proposes that phobic fears can be acquired by observing the fearful reactions in others (Merckelbach et al., 1996). Research by Cook and Mineka (1989) found that monkeys can learn to respond fearfully to a stimulus by watching other monkeys respond fearfully. Parental or caregiving modelling also shows a strong influence on child behavior, therefore, if fear responses by parents are modelled by parents, then that response may be learned by the child.

Another pathway is via negative information transmission. This pathway proposes that phobias can develop by hearing about the negative consequences of situations or stimuli (Merckelbach et al., 1996). This information transmission can create a negative expectation towards the feared stimuli, which translates to fear and avoidance of those stimuli and perceived consequences. Hearing about the negative consequences of snake bits, spider bites, hurricanes, tornadoes (via parents, social media, television) can elicit a similar fear reaction as directly experiencing the stimuli. A number of researchers have documented that individuals recall the etiology of phobic reactions after verbally hearing the negative consequences of a stimuli (Fyer et al., 1990; Merckelbach et al., 1996).

Another limitation of traditional learning perspectives is that many individuals hear about and experience the phobic stimuli (e.g., storms, spiders), but do not develop a phobia (See Fyer, 1998 for details). Cognitively focused models of phobia suggest that interpretations, expectations, and beliefs about the stimuli facilitate the development of a phobia (Thorpe & Salkovskis, 1995). Mineka and Cook (1986) found that monkeys who developed a sense of mastery and control over their environment habituated to fearful stimuli quicker than those without mastery of control. Similarly, other studies (Davey & Dixon, 1996; Davey & Craigie, 1997; see Fyer, 1998 for details) suggest that cognitive factors (i.e., expectations, beliefs, and controllability) influence the developmental course of phobias. It is proposed that, whereas exposure to a feared stimulus may increase the chances of developing a fear, the interpretation and beliefs regarding that stimuli may better predict phobia development.

Etiology of Severe Weather Phobia

Evaluation of general Specific Phobia models provides a foundation in which to organize and interpret findings of Severe Weather Phobia. Many studies document the traditional learning etiology, such that subjects report their phobia was a result of experiencing a severe weather event (Blaustein, 1991; Dollinger, 1985; Muris et al., 2002; Liddell et al., 1978; Watt & DiFrancescantonio, 2012; Westefeld, 1996; Westefeld et al., 2006). In accordance with Mowrer's model of avoidance, studies also reveal that avoidance of weather-related events is used to decrease anxiety (Liddell et al., 1978). It is apparent that the traditional learning explanation may account for some of the etiology of Severe Weather Phobia and that an increase in anxiety and psychological distress as a result of exposure to the severe weather phenomena is common (e.g., Blaustein, 1991; Dollinger, 1985).

Researchers also have found that many individuals with Severe Weather Phobia attribute their fear to modeling or negative information transmission. For example, Watt and DiFrancescantonio (2012) investigated the prevalence and etiology of Severe Weather Phobia in 533 college students. In study one, they documented that 42% of the sample had experienced a severe weather event and that those with high levels of weather fear (16%; "often" or "always" responded to storms with anxiety and fear) were more likely to have experienced a severe weather event than those who have "never" experienced anxiety towards storms. Importantly, of those in the high-fear group, roughly 42% indicated origins of their storm anxiety as resulting from a direct experience with the feared stimuli, whereas roughly 40% report origins from observational learning or negative information (e.g., parental modelling, weather events on the news). Interestingly, 61% of the high-fear group reported tornadoes as their most feared weather event, whereas only 16% reported having experienced or witnessed a tornado. It is clear that within Severe Weather Phobia, both conditioning and non-conditioning facilitate the onset and development.

Watt and DiFrancescantonio (2012) also documented that those with higher levels of Severe Weather Phobia reported more cognitive concerns related to weather than the low group. Additional researchers have documented the importance of cognitive factors in Severe Weather Phobia (e.g., Greening & Dollinger, 1992a; Westefeld, 1996). For example, Greening and Dollinger (1992a) had 455 adolescents who grew up in South East Missouri (where Severe Weather is common) estimate the likelihood of personal death from a natural disaster and the national prevalence rate of death from a natural disaster. Results revealed that those who have first-hand experience with a severe weather event estimated a higher probability of themselves or others dying due to future weather-related events compared to those who had not experienced a severe weather event. In a second study using the same sample, they found that most participants (66%) indicated that tornadoes pose a greater risk than lightning strike, although lightning is factually responsible for more deaths (Greening & Dollinger, 1992b). Additionally, cognitive influences can be seen via increased reporting of the probability of severe weather occurrence, probability of devastation, worry, and reassurance seeking (Man & Simpson-Housley, 1987; Liddell et al., 1978; Wang, 2000).

Overall, it appears that traditional conditioning, modeling, information transmission, and cognitive factors may all contribute and interact to lead to the onset of Severe Weather Phobia. Experiencing and learning about the potential consequences of a severe weather event increases the risk of developing Severe Weather Phobia; however, maladaptive beliefs and cognitive distortions also contribute to increased anxiety prior to and during a severe weather event. This brief synthesis supports Ost and Hugdahl's (1981) findings that a majority of those with phobia attribute the etiology to multiple sources. Although not directly discussed in the studies of Severe Weather Phobia, many maintenance factors within broad models of specific phobia likely contribute to the maintenance of the symptomatology after its genesis. Two of those factors include worry and attentional biases.

Maintenance Factors of Severe Weather Phobia

Worry is defined as the perseverative verbal-linguistic thought process aimed at problem solving (Borkovec et al., 1983; Wells, 1995). Models of worry propose that worrying may be used to avoid imagined or real threats, to prepare for the possibility of negative consequences, and/or to regulate emotions (Wells, 1995). Individuals with high levels of worry often report that worry is an adaptive and protective factor because it is perceived to help prepare for potential challenges, even though there is an elevation in state anxiety and reports of uncontrollability (Borkovec & Inz, 1990; Hirsch & Mathews, 2012; Wells, 1995).

Hirsch and Colleagues (2012) suggest worry is related to a biased processing of emotional information which involves both a habitual (automatic) and an intentional (controlled) component. Specifically, worry cycles may begin as an intentional problem-solving technique and insidiously become a more habitual response to a stressor. As this process becomes more habitual it becomes more uncontrollably focused on threat-related events and habitually increases state anxiety. This biased emotional processing is thought to lead to even further decreased cognitive control, which leads to even further decreased ability to control one's worrisome thoughts (Eysenck et al., 2007; Hayes et al., 2008).

Although no studies of Severe Weather Phobia specifically concentration on worry, many studies allude to it presence. For example, Liddell and colleagues (1978) found multiple instances of perseverative cognitive strategies in those with storm phobia. Westefeld's (1996) interviews documented "worrisome thoughts" and uncontrollable, catastrophizing, and distorted anticipatory thoughts prior to a severe weather event. Participants reported frequently worrying about injury and death due to upcoming weather events. Watt and DiFrancescantonio (2012) were the first to specifically ask about anticipatory behavior in weather anxiety and found that those with higher levels of weather anxiety showed increased worry associated with upcoming weather events.

Nelson and colleagues (2014) found that individuals with higher levels of Severe Weather Phobia often worry more about storms, and that they also engage in increased levels of worry broadly (measured by the PSWQ). Overall, no studies have investigated worry and anticipatory anxiety as a maintenance factor of storms directly, but many studies and models of anxiety recognize its maintaining qualities (e.g., Mogg et al., 2010; Rapee & Hiemberg, 1997).

A second factor often believed to maintain anxiety is attentional bias. These biases represent the preferential attention allocation towards threat-related stimuli as opposed to non-threat-related stimuli (Cisler & Koster, 2010). Models of anxiety suggest that threatening information receives prioritization (e.g., Beck & Clark, 1997) due to its relevance to the individual's fear. Therefore, when threat-related stimuli are present, they will receive preferential allocation of processing for those that have an anxious or emotional association with those stimuli. Attentional biases are posited to maintain anxiety by limiting the content of information that is processed, thereby escalating anxiety symptoms and decreasing focus on non-threatening aspects (Cisler & Koster, 2010). This limited and threat focused processing may lead to decreased habituation and re-learning (Cisler & Koster, 2010), thus, maintaining anxiety.

Attentional biases within Severe Weather Phobia have yet to be documented. Studies often document behavioral correlates of attentional biases (e.g., hyper-focus on weather cues and clouds, continual checking of the news); however, no study specifically targeted and documented its presence. Studies investigating other specific phobias (e.g., spider, snake, social anxiety-formally social phobia) may be used to help conceptualize the existence of attentional biases in Severe Weather Phobia. For example, Mogg and Bradley (2006) found that individuals with a specific phobia towards spiders showed increased attention allocation to images of spiders, suggesting biased attention processing to threat-related stimuli. Pishyar, Harris, and Menzies (2004) found attention to negative faces in those with social anxiety. Lipp and Derakshan (2005) documented that individuals with spider fears showed preferential attention towards images of spiders compared to images of snakes and to those without spider fears. Broadly, these studies document specific attentional biases across multiple specific phobias. Moreover, these biases appear to be specific to the feared stimuli, such that individuals with social anxiety show attention biases to social information, where individuals with spider phobia show biases to spider related information. Whereas the specific fears differ between phobia types, the cognitive, behavioral, and emotional profiles in responses to a feared stimulus show significant overlap. It is posited that, for this reason, attentional biases are likely present in Severe Weather Phobia.

Attentional control theory

Although it is important to document these hypothesized maintenance factors (worry, attentional biases) in Severe Weather Phobia, it is equally as important to document their mechanisms of action. The Attentional control theory proposes that anxiety is partially maintained due to preferential allocation of resources, which occupies valuable and limited cognitive resources (Eysenck et al., 2007). This theory suggests that threat-related information will receive preferential attention and processing as it is emotionally salient. This preferential processing, aimed at evaluating and addressing the threat, consumes mental resources. Therefore, when threat-related information is present, there will be decreased mental resources allocated to the task at hand.

Additionally, this model suggests that anxiety increases bottom-up processing, which in turn decreases top-down processing. This implies that those with anxiety will show a hypervigilance towards and increased attention to threat-related stimuli, due to increased bottom-up processing. This leads to a decrease in top-down processing, which may lead to poorer performance in tasks that involve executive function (Derakshan & Eysenck, 2009; Eysenck et al., 2007). This framework helps explain how those with anxiety display attentional biases to threat and proposes the mechanisms by with they are displayed. Since worry and attentional biases are specific to threat-related information, they are likely targets of this preferential bottom-up processing. This implies that during bouts of worry, individuals will show increased bottom-up processing and decreased top-down processing. Therefore, attentional resources directed towards threat-related information will be prominent, which will lead to observed attentional biases. These two processes decrease top-down processing, thereby leaving fewer resources to complete other activities efficiently.

Testing this hypothesis, Borkovec and colleagues (1983) had participants engage in a worry manipulation and found that, after worrying, participants had decreased cognitive control during an attention-focusing task. These findings were moderated by trait worry, such that those with high levels of trait worry found it increasingly difficult to focus during the cognitive task. Results suggest that worry decreases top-down processing and decreased attentional resources to cognitive tasks, which was exacerbated for those with high levels of trait worry. This implies that trait and state anxiety may interact leading to an exacerbation of cognitive deficits.

In another study, Hayes and colleagues (2008) had participants with high and low trait levels of worry engage in a worry (vs. non-worry) manipulation. Researchers found that during a cognitive task, those with high trait-worry showed lower performance after engaging in worry compared to the non-worry condition, whereas this effect was not shown in the low-trait worry individuals. These and similar findings suggest that those with a propensity to worry and anxiety may be more impacted by worry and anxiety manipulations then those with little trait worry or anxiety (Nelson et al., 2014; Krause et al., 2018). Based on the existing literature on Severe Weather Phobia, individuals who show an increased level of trait worry/anxiety towards storms will display decreased attention and working memory capacity when they worry about storms. Although no study has directly measured this relationship, it is possible that this decreased cognitive control maintains Severe Weather Phobia by focusing attention on negative aspects of the event, decreased habituation, and overall executive function slowing.

Similarly, research has documented the impact of threat-related stimuli and attentional biases on executive function (e.g., Pineles, & Mineka, 2005). Spector and colleagues (2003) had participants with high and low levels of anxiety (i.e., social anxiety) complete a modified Stroop task to measure executive function ability. Results revealed decreased executive function performance in those with anxiety when anxiety specific threats words were used (i.e., blushing), which was not observed for those with low levels of anxiety. Mattia and colleagues (1993) found similar results, in which anxiety specific threat cues (e.g., "stupid" 'failure") led to decreased executive function performance for those with anxiety which was not observed in the non-anxious group. Furthermore, Kindt and Brosschot (1997) investigated threat cues during a modified Stroop task and found that those with spider phobia showed decreased executive performance when spider cues were present, which was not observed for non-threat words and in those without spider phobia. Broadly, researchers interpret these results as representing the immediate attention capture by the threat cues, which decreases executive control to efficiently complete cognitive tasks. Although no studies directly measure attentional biases and their influences on severe weather anxiety, it is likely that similar attentional capture to severe weather cues may occur, which may lead to reductions in executive functioning.

Flanker task

A common way to measure these executive function deficits is by using cognitive tasks. A frequently utilized cognitive paradigm to measure these deficits is the Flanker task. During a traditional Flanker task (Eriksen & Eriksen, 1974), participants are shown an array of letters or symbols (e.g., <<<<<, or HHHHH) and are told to pay attention to and identify the middle stimulus while ignoring the stimuli to the left and right flanks. Participants may see congruent trials (e.g., <<<<< or >>>>>), where the stimuli are the same, or incongruent trials (e.g., <<><< or >><>>), where the middle stimulus differs from the surrounding stimuli. This task is often used to measure executive function by how well participants can ignore distracting information (Eriksen & Eriksen, 1974; Paquet & Craig, 1997). It is frequently found that participants are slower and display more errors during incomparable trials, suggesting that increase executive function and cognitive effort is required to effectively complete these trials.

Modulations within Flanker task performance have been documented within anxiety disorders and often finds that increases in both state and trait anxiety lead to decreased task performance (e.g., Pacheco-Unguetti et al., 2010). It is posited that both state and trait anxiety load working memory and decrease top-down processing, which results in decreased performance. Researchers have modified these Flanker tasks to incorporate threatening information to test how task-irrelevant threatening information impacts performance. For example, Dennis and Chen (2009) presented a Flanker task where, prior to each Flanker trial, either a threatening or non-threatening face was presented. Results found that the trials with the threatening information modulated attention and decreased performance for those with higher levels of trait social anxiety, which was not observed in those with low social anxiety. Another study by Chen and Colleagues (2016) documented that those with high levels of social anxiety demonstrated slower reaction times to the target stimuli when it is flanked by negative faces.

These findings suggest that attentional biases and decreases in task performance are dependent on whether the threatening information is relevant to the subject and to the task. For example, an individual with Severe Weather Phobia may show increased attention to tasks that focus on threat-related information whereas tasks that only show threats as distractors may show decreased attention to the task due to the attentional bias. Together, these studies demonstrate that threat-related distractors can hinder task performance. It is believed that those threat-related distractor stimuli capture attentional resources for those with anxiety regarding that threat, which decreases resource allocation, leading to ineffective task completion. Multiple studies show that threat-related distractors influence performance on a Flanker task (Alguacil et al., 2013; Kanske & Kotz, 2010; Li et al., 2014; Zhang et al., 2019) and that anxiety levels can moderate these effects (Dennis & Chen, 2009; O'Toole, DeCicco, Hong, & Dennis, 2011).

Emotional Stroop task

Another common cognitive tasked used to assess executive function is the Emotional Stroop task. The Emotional Stroop is a variation of the traditional Stroop color-word test (Stroop, 1935), in which participants are shown a series of words (i.e., “red”, “green”, “blue”) and instructed to name the ink color (i.e., red, green, blue) that the word is printed in. It is theorized that the time required to correctly name the color of the ink increases when the word spells a conflicting color name (e.g., Duncan-Johnson & Kopell, 1981). These slower responses are theorized to represent a level of interference within the perceptual processing (Hock & Egeth, 1970) and response production (Keele, 1972). The Emotional Stroop is an extension of this procedure to incorporate emotionally salient words that are disorder specific. A variety of words, including those with emotional relevance, are presented in various colors (i.e., red, green, blue) and participants are asked to name the color that the words are printed, while ignoring the meaning of the word. Researcher reported finding increased interference during trials that present emotionally salient words compared to neutral words (e.g., Amir et al., 1996; Bar-Haim et al., 2007). These results suggest that disorder-specific emotionally salient words reveal a level of attentional bias, which compromises effective and efficient responses.

Variations of the Emotional Stroop task are frequently used to assess the presence of attentional or perceptual biases within anxiety disorders (e.g., Amir et al., 1996; Bar-Haim et al., 2007; Cisler et al., 2011; Dresler et al., 2009; Ruiter & Brosschot, 1994; Williams et al., 1996). Researchers frequently document slower reaction times in those with anxiety disorders in trials with anxiety related printed words (e.g., Bar-Haim et al., 2007) and that there appears to be anxiety specific word effects (Cisler et al., 2011). Specifically, those with generalized anxiety show interference with generalized emotionally salient words, whereas those with social anxiety only show biases with socially relevant words, and those with PTSD only show biases to trauma relevant words (e.g., Cisler et al., 2011). These results suggest that the presence of attentional biases and interference of word stimuli requires the words to be emotionally salient to the participant's idiographic anxiety. It is believed that these attentional biases and interferences are present as a result of the disorder specific stimuli receiving processing priority, which results in inefficient processing and completion of the Stroop task (Williams et al., 1996).

Psychophysiology

An advantageous measure that is frequently utilized in Flanker and other cognitive tasks is Electroencephalography (EEG). EEG allows for the collection of millisecond by millisecond changes in neural activity, which researchers have used to address attention deployment at the neural level. Researchers often use Event Related Potentials (ERPs) to determine attentional resource allocation during cognitive tasks. ERPs are segments of electrocortical activity that are time locked to a specific stimulus or a response (Luck, 2014). Similar trials in these cognitive tasks are averaged and used as to determine the time-course of attention during those trials. A rudimentary understanding of ERP's proposes that a larger amplitude ERP represents increased processing or attention. A common ERP used in Flanker tasks is the N2.

The N2 is a negative going potential that occurs around 200 ms. after a stimulus is presented (Luck, 2014). This potential is often maximal in the anterior area of the scalp and thought to represent attentional resource allocation during Flanker tasks (e.g., Dennis & Chen, 2009; Folstein & Van Petten, 2008; Luck, 2014). The N2 is a measure of recruitment of cognitive control and processing of the matched and mismatched cues during the Flanker task (Folstein & Van Petten, 2008; Luck, 2014). Importantly, modulations of the N2 have been observed across anxiety levels and manipulations that incorporate threat within the Flanker task (e.g., Dennis & Chen, 2009). For example, researchers have substituted the traditional Flanker stimuli (i.e., "H" "I" or arrows) with threat-related words and found modulations in the N2 (Alguacil et al., 2013; Kanske & Kotz, 2010; Li et al., 2014; Zhang et al., 2019), such increased amplitudes in the N2 are observed during trials that contain threat/emotional information within the Flanker Stimuli. Taken together, these studies suggest that trials with threat-related information within the Flanker stimuli led to increased recruitment of attentional resources as indicated by N2 amplitude and that this relationship may be enhanced by trait anxiety (Chen et al., 2016; Owens et al., 2015); however, if threat-related distracting information is presented before or during the Flanker task, decreased neural recruitment is expected due to the attention bias towards the threat. Specifically, those with anxiety may recruit attentional resources to threat-related distractors, thus leaving less resources to effectively complete the task. It is believed that using threat-related distractors prior to the Flanker task will lead to a similar attentional bias, which will potentially result in a decrease in available resources to the upcoming Flanker stimuli. Therefore, presenting both threat and non-threat-related images prior to the Flanker stimuli would allow researchers to determine how task-irrelevant threat leads to subsequent executive function engagement (i.e., N2) during the Flanker stimuli.

Measures of Severe Weather Phobia

Weather Experiences Questionnaire. Nelson and colleagues (2014) state that the lack of research in Severe Weather Phobia and associated cognitive deficits is likely due to the dearth of empirically validated measures of Severe Weather Phobia. Recently, researchers have developed questionnaires to more reliably measure anxiety and the associated behaviors for weather anxiety. The earliest questionnaire focusing on weather-related experiences is the Weather Experiences Questionnaire (WEQ; Watt & MacDonald, 2010). The WEQ is a 26-item questionnaire to evaluate the fear of severe weather, origins of those fears, and the anxiety and related behaviors during severe weather events. The initial 7 questions prompt participants to rate their fear towards severe weather events (e.g., thunder, lightning, tornadoes, floods) on a scale from 1-7. Items 8-16 assess the origins of the fear by asking yes/no questions (e.g., “Can you trace your fears back to a specific instance in your childhood or adolescence?”). Question 18 aims to evaluation anticipatory anxiety whereas question 19 measures anxiety severity during the severe weather event. Although no questionnaire development or psychometric properties papers exists for the WEQ, the WEQ and a shortened “screening version” were used to document and evaluate group differences in Severe Weather Phobia (Watt & DiFrancescantonio, 2012).

Storm Fear Questionnaire. More recently, the Storm Fear Questionnaire (SFQ; Nelson & Antony, 2013; Nelson et al., 2014) was developed. The SFQ is a 15-item questionnaire aimed to measure cognitive, affective, and behavioral components of storm phobia in adults. On a Likert scale (0 = “not at all true” to 4 = “almost always true”) participants rate how much statements (e.g., “I worry about storms more than other people”) relate to them. The 15 items are summed to create an overall storm fear score. The SFQ shows adequate convergent and discriminant validity as well as test-retest reliability and internal consistency (Cronbach’s α = .95; Krause et al., 2018).

Nelson and colleagues (2014) further investigated how the SFQ related to anxiety ratings during a virtual thunderstorm. Based on a pre-screener question, which asked participants to report their level of anxiety level towards storms on a scale from 0 (no fear) to 4 (extreme fear), participants we split into a high (*N* = 11) and low fear of storms groups (*N* = 19). Participants who reported at least a moderate fear of storms (score of 2 or greater) or no fear of storms (score of 0) during the screener were recruited to the high or low fear of storms groups, respectively. Of note, 55% of the participants in the high group met diagnostic criteria for Specific Phobia related to storms using the SCID-IV-TR; First et al. 1996), whereas an additional 36% met all DSM criteria except for the distress or impairment criteria.

Participants then completed the SFQ and a behavioral approach task, where they approached a virtual thunderstorm using visual, auditory, and kinesthetic (vibration) cues of clouds, rain, lightning, and thunder. Participants rated their anxiety (0 – 100) after the thunderstorm. Results found the high fear group reported significantly higher SFQ scores (*Mdn* = 24) then the low fear group (*Mdn* = 4). All participants experienced increased anxiety after the virtual thunderstorm, but the high-fear participants reported significantly more fear following the thunderstorm then the low group. Taken together, these results suggest that 1) the SFQ is a psychometrically sound measure of Severe Weather Phobia, 2) it predicts of anxiety levels during realistic simulations of storms, and 3) predicts whether an individual will meet diagnostic criteria.

Storm-Related Safety Behavior Scale. Krause and colleagues (2018) recognized the shortage of validated measures of Severe Weather Phobia and wanted to develop a measure to document associated safety behaviors. The Storm-Related Safety Behavior Scale (SRSBS; Krause et al., 2018; Vorstenbosch & Antony, 2017) is a 24-item questionnaire aimed to measure the use of safety behaviors to manage anxiety during storms. Participants rate how much they use strategies to manage anxiety (e.g., frequently and repeatedly check weather reports to see if bad weather is expected) on a scale from 0 ("I never do this to manage a fear of storms") to 4 ("I always do this to manage a fear of storms"). The SRSBS shows adequate convergent and discriminant validity as well as test-retest reliability and internal consistency (Cronbach's α = .96). The SRDBS also was correlated with the SFQ (r = .397).

Similar to Nelson and colleagues (2014), Krause and colleagues (2018) had participants complete the SRSBS and a virtual thunderstorm simulation. Using Nelson and colleagues' (2014) recruitment and inclusion criteria, 20 participants were recruited for the high-fear group and 20 for the low. Twenty percent from the high-fear group met DSM criteria for Specific Phobia, whereas 30% met all criteria except for distress or impairment. Results revealed that SRSBS was positively correlated with self-reported anxiety during the virtual thunderstorm. Additionally, the high-fear group showed higher levels of SRSBS (M = 52.30) compared to the low-fear group (M = 14.69). Similar to the SFQ, the SRSBS showed 1) sound psychometric properties, 2) predicted subjective anxiety during a simulated storm, and 3) related to DSM-5 criteria. Together, it appears that the SFQ may more accurately measure Severe Weather Anxiety, since it has documented psychometric properties as opposed to the WEQ, and directly addresses anxiety towards weather as opposed to only safety behaviors in the SRSBS.

Current Study and Hypotheses

Although multiple case studies have documented the prevalence and behavioral features of severe weather phobia, no research has evaluated potential maintenance factors. Furthermore, no study has attempted to evaluate the mechanisms behind those maintenance factors. Based on the dearth of research on Severe Weather Phobia, the current two studies aimed to 1) identify psychological and physiological responses to the threat of severe weather and 2) determine how worry may maintain that response, and 3) document attentional biases, their underlying neurological mechanisms, and executive function deficits within Severe Weather Phobia. By documenting cognitive and neurological processes within Severe Weather Phobia, researchers may better understand how attentional biases are influenced by worry within Severe Weather Phobia. Furthermore, this may help explain how individuals with severe weather anxiety show functional impairment and are unable to experience habituation.

Study 1 utilized a threat induction and worry manipulation to induce weather-related anxiety. EEG data were collected for those with high and low trait level storm anxiety during Flanker task to document cognitive and attentional impairment. It was believed that using threat-related distractors prior to the Flanker task would lead to an attentional bias, which would result in a decrease in available cognitive resources to the upcoming Flanker stimuli. Therefore, presenting both threat and non-threat-related images prior to the Flanker stimuli would allow researchers to determine how task-irrelevant threat leads to subsequent deficits in executive function engagement (i.e., N2) during the Flanker stimuli.

Due to predictions from the Attentional Control Theory, the Study 1 had two hypotheses. 1) Individuals with higher storm anxiety would show increased anxiety related to the storm threat, which would be exacerbated by the worry condition. 2) Individuals with higher storm anxiety would show a decreased N2 response to trials proceeded by threat-related distractors (suggesting increased resources allocation to threat), which would be exacerbated in the worry condition.

Study 1 utilized an Emotional Stroop task to assess the presence of storm related attentional biases in those with elevations in severe weather anxiety. Storm-threat related words were presented along with non-storm-threat related words to determine the whether these threat related words capture attention, thus impeding efficient responding in the task. Within the same Attentional Control Theory framework, Study 2's hypothesis was that individuals with higher storm anxiety would show increased interference, such as longer reaction times and increased error rates, to trials with threat-related words (suggesting increased resources allocation to threatening meaning of the word).

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