TEMPORAL DYNAMICS OF ATTENTION BIAS IN ANXIETY: AN EYE TRACKING STUDY

by

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ABSTRACT

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Behavioral reaction time (RT) measures, like the dot-probe and spatial cueing tasks, have shown that individuals with anxiety tend to bias their attention toward threat as compared to neutral stimuli. However, the literature has revealed mixed findings due to the simplistic calculation of attention bias (AB; i.e., Mean RT Threat – Mean RT Neutral). Research has shown that attention bias fluctuation (i.e., patterns of both vigilance and avoidance), is indicative of attention dyscontrol, which is evident in those with psychopathology. As such, the purpose of this study was to evaluate whether AB fluctuation via behavioral RT measures and eye-tracking, stands as a more viable and consistent measure of AB in predicting overall symptom severity.

Participants were recruited from three different studies: contamination phobia (*n*=52), social phobia (*n*=43), and spider phobia (*n*=72). Behavioral RT measures were evaluated using the trial-level bias score (TL-BS) to calculate AB fluctuation. In terms of eye-tracking, participants were shown four pictures in four quadrants, which included target threat, general threat, pleasant, and neutral photos. Basic individual eye-tracking indices consisted of dwell time, fixation count, and average fixation duration. However, to evaluate the time course of AB fluctuation, we created novel eye-tracking ratio indices, which included (1) dwell time/net dwell time (2) glance count/fixation count, and (3) average fixation duration/fixation time.

The results showed that more than traditional AB indices in behavioral RT measures or basic individual eye-tracking indices, AB fluctuation measures (i.e., TL-BS, temporal eye-tracking ratio indices), significantly predicted overall symptom severity after controlling for general emotional symptoms ($p<.05$). Notably, the temporal eye-tracking ratio indices explained an additional 3-5% of the variance in overall symptom severity, which suggests that temporal eye-tracking fluctuation ratio indices may be a useful predictor of anxiety symptom severity in tandem with other establish AB fluctuation measures.

Overall, the findings suggest that beyond traditional measures of AB to threat, temporal AB fluctuation indices should be given greater consideration when developing future theoretical, assessment, and intervention work related to anxiety disorders. Future research in AB modification may consider incorporating attention control components, which may be a promising treatment to reduce anxiety psychopathology.

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I. Introduction

According to the famous psychologist Edward B. Titchener, "attention is the nerve of psychology" (Titchener, 1908; 1923). However, the definition of attention has become unclear among cognitive psychologists as it is used in a variety of contexts and processes (Hommel, et al., 2019). Broadly, attention is defined as receiving and prioritizing pertinent information amidst conflicting demands (Kirk et al., 2008). The inability to sustain attention over time may result in problems with manipulating information for further use, which is especially important in completing complex tasks or resisting threatening stimuli that maintain psychopathology (Baddeley & Hitch, 1994; Eyesenck et al., 2007). Therefore, it is important for researchers to understand the theoretical frameworks of attention to better delineate its components, discuss higher level aspects of attention (e.g., attention control), evaluate how attention dyscontrol associates with psychopathology (e.g., anxiety), and report current assessment tools used to evaluate attention and psychopathology.

Theoretical Frameworks of Attention

Posner and Peterson (1990) found that attention functions were divided into three different areas of the brain: subcortical (i.e., the alerting network), posterior (i.e., the orienting network), and anterior (i.e., the executive function network). As such, three defined attention networks were established as alerting, orienting, and executive (Posner & Peterson, 1990).

Alerting, also known as the arousal system, is the ability to maintain vigilance while performing a task in order to effortfully process that information (Mezzacappa, 2004). The alerting system is instrumental in knowing *when* a target will occur. Thus, the individual is in a state of sensitivity to a particular stimulus. Orienting is the selection and shifting of information from external sources for further processing (Peterson & Posner, 2012). This includes the ability to disengage, shift, and re-engage focus from one stimulus to the next. The orienting system allows one to identify *where* a target will occur and utilizes a variety of anatomical areas important for eye movements (Reep & Corwin, 2009). The final network is the executive network, which monitors and resolves conflict among various goal-directed behaviors (e.g., planning, initiating, and maintaining) in order to detect target components pertinent for attention (Mezzacappa, 2004; Mahoney, et al., 2010).

Higher-Level Attention Processes

Attention Control. The ability to effectively maintain vigilance to stimuli (alerting), engage and disengage (orienting), and reduce conflict from irrelevant cues (executive) is considered efficient or "good" attention control (Eysenck, et al., 2007; Coombes, et al., 2009; Derakshan & Eysenck, 2009). However, in those with anxiety, attention control becomes dysregulated (Eysenck et al., 2007). Attention control theory is based on the assumption that there is a balance between two attention systems: (1) the goal directed attention system and (2) the stimulus-driven attention system (Corbetta & Shulman, 2002).

The goal-directed (endogenous) attention system relies on *top-down* attention control and involves the individual's knowledge, goals, and expectations (Eysenck et al., 2007). In contrast, the stimulus-driven (exogenous) attention system reflects *bottom-up* attention control and is sensitive to salient stimuli (Eysenck et al., 2007). While top-down processing is internally driven, bottom-up processing is more external (Katsuki & Constantinidis, 2014). Thus, attention control abilities are necessary to maintain task relevant information and keep it in an "active state" when irrelevant stimuli (i.e., internal and external distractors) are present (Unsworth et al., 2014).

Attention control theory (Eysenck et al., 2007) suggests that anxiety causes an imbalance between the goal-directed and stimulus-driven systems giving greater precedence to the stimulus-driven system (Coombes et al., 2009; Reinholdt-Dunne, et al., 2013). In other words, the inability to inhibit irrelevant salient distractors and focus on goal-oriented relevant cues, may result in problems with cognitive task performance (Arnell, et al., 2007; Blair et al., 2007; Bledowski, et al., 2004), and potentially enhance psychopathology (Eysenck et al., 2007). The information processing model argues that the goal of anxiety treatment is to "deactivate the more automatic primal threat mode and to strengthen more constructive reflective modes of thinking" (Beck & Clark, 1997). The inability to orient attention away from threat may cause problems with symptom reduction (Mogoaşe et al., 2014; Price et al., 2016). The quality of one's performance suffers when the utilization of cognitive resources is used up and one's anxiety directs attendance to danger or threat, also known as attention bias (AB; Eysenck & Derakshan, 2011).

AB is the preferential allocation of one's attention to threat-related information rather than non-threat related information (Mogg & Bradley, 2016). Generally, AB is considered one of the key maintenance factors of psychopathology (Mogg & Bradley, 2016). Various valence-specific models of AB hold that heightened threat evaluation occurs even amidst mild or ambiguous stimuli that may appear threatening (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 2002). The literature has consistently shown that, compared to healthy controls, individuals with anxiety tend to show greater AB toward threatening cues (Bar-Haim et al., 2007; Roy et al., 2008; Hakamata et al., 2010). For example, individuals with social anxiety disorder display an AB for threatening cues, which embody angry or disgusted faces (Mogg, et al., 2004), and those with generalized anxiety disorder tend to gravitate toward threatening words (Amir, et al., 2010). Similar findings have also been observed in those with spider phobia (Lipp & Derakshan, 2005; Pflugshaupt et al., 2005; Schechner et al., 2014; Abado et al., 2020;), contamination phobia (Cisler & Olatunji, 2010; Armstrong et al., 2012; Olafsson et al., 2019), and post-traumatic stress disorder (Fani et al., 2012; Badura-Brack et al., 2015; Naim et al., 2015) among others. Typically, results have shown that threat bias is positively correlated with overall anxiety symptoms (Armstrong & Olatunji, 2012; Bar-Haim et al., 2007; MacLeod & Mathews, 2012; Abend et al., 2018). As such, this phenomenon has led to the development of promising computerized training strategies like AB modification to reduce one's AB to threat (Bar-Haim, 2010). Anxiety researchers have found that individuals trained to disengage attention from threatening words produced significant reductions in threat bias and anxiety symptoms (Amir et al., 2009, Hazen et al., 2009). Schmidt and colleagues (2009) conducted a longitudinal study in those with social anxiety, which consisted of eight AB modification sessions in four weeks. The results showed that those who received AB modification training had a greater percentage of participants no longer endorse social anxiety symptoms as compared to those in the control condition (Schmidt, et al., 2009). Unlike cognitive behavior therapy, which draws attention toward anxiety provoking cognitions (e.g., exposure therapy), AB modification implicitly retrains cognitive processes to divert attention away from threat (Wells, et al., 1997). Interventions designed to modify AB seem promising as they may be beneficial for individuals who do not respond well to therapy, for those who cannot afford or access services, and/or for children who are unable to comply with therapeutic protocols (Bar-Haim, 2010).

Assessment of Attention Bias

Dot-Probe Task. AB has typically been measured through behavioral reaction time (RT) tasks. Traditionally, AB is considered a stable or static value, assessed by mean RT, and measured over repeated presentations, as in the dot-probe task (MacLeod, et al., 1986; Zvielli, et al., 2016). The dot-probe task instructs participants to locate the position of dots after specific stimuli are presented at various time lengths. If the dot probe replaces a threatening stimulus, this is considered a congruent trial. If the dot probe replaces a neutral stimulus, this is considered an incongruent trial. Most often, these stimuli are presented side by side and include one threat picture or word, and one neutral picture or word. The speed with which one can identify the probes that replace the salient stimuli indicates the degree to which attention was automatically drawn toward the stimuli (MacLeod et al., 1986). For example, if a threat word or picture was presented on the right side and then a dot probe was presented on the right, anxious individuals would presumably exhibit a shorter RT to detect the dot probe compared to controls. This may suggest the presence of AB toward threat in anxious individuals (MacLeod et al., 1986).

Spatial Cueing Task (Posner, 1980). Another behavioral RT task used to measure AB is the spatial cueing task. The spatial cueing task begins with a fixation cue and two empty boxes. Similar to the dot-probe task, the spatial cueing task instructs participants to immediately locate the target stimulus (e.g., the letter E or F; a shape) after a cue (e.g., a picture of a threatening or neutral face) is briefly presented on the screen. In contrast to the dot-probe task, stimuli are presented one at a time. If the target stimulus replaces the same location of the cue (e.g., right cue and right stimulus), this is considered a congruent trial. If the target stimulus is opposite the location of the cue (e.g., right cue and left stimulus), this is considered an incongruent trial. Research has shown that targets were more quickly detected on congruent trials as compared to incongruent trials (Posner et al., 1987). A slower RT on incongruent trials is because the individual must disengage from the cue and then engage with the target stimulus located opposite the cue location. For those with anxiety, individuals may demonstrate greater difficulty on *incongruent* trials with disengaging attention from threat cues than neutral cues (Amir et al., 2003; Fox et al., 2001; Fox et al., 2002; Koster et al., 2004; Yiend & Mathews, 2001).

Criticisms of Behavioral RT Task Paradigms. Although the literature has revealed preferential attention allocation toward threat cues in anxious individuals, mixed findings exist between those that show threat bias (Pergamin-Hight et al., 2015; Hakamata et al., 2010) and others that show no threat bias (i.e., no difference from controls; Krujit et al., 2018; Badura-Brack et al., 2015; Fox et al., 2015; Heeren et al., 2015). The mixed findings may be due to the poor psychometric properties of these measures and their inability to distinguish between individuals in the population (Hedge et al., 2018). On the dot-probe task, while observed RT for incongruent (i.e., probe replaces the non-target/neutral cue) and congruent (i.e., probe replaces the target/threat cue) trials showed good reliability, the AB index (i.e., the difference in RT between incongruent and congruent trials) showed poor reliability (Brown et al., 2014; Waechter et al., 2015). Further, dot-probe tasks exhibit small to moderate effect sizes (Bar-Haim et al., 2007, Van Bockstaele et al., 2014). Similar flaws were observed on the spatial cueing task such that the emotional cueing paradigm showed poor reliability (Waechter & Stolz, 2015; Enock et al. 2014) and problems with replicability (Cooper et al., 2014). Further, our understanding of attentional engagement and disengagement on the spatial cueing task is ambiguous (Clarke et al., 2013). For example, the difference between the mean RT of incongruent threat cues from the mean RT of incongruent neutral cues on the spatial cueing task may either indicate a slowing effect of threat on RT (e.g., freezing) or difficulty with disengaging attention from threat stimuli (Mogg et al., 2008). These findings suggest that existing analytic approaches of the dot probe and spatial cueing tasks may be overly simplistic, with the assumption that AB is a linear and static measure (Zvielli et al., 2015). Importantly, continuing to use measures with poor psychometric properties may hinder progress within the field of anxiety (Krujit et al., 2016).

The recent literature has shown that AB should be conceptualized more broadly beyond a rather simplistic group-level average value of vigilance or avoidance in response to threat. Specifically, researchers have found an unsteady fluctuation over time between mixed vigilant and avoidant attention allocation as an important sign of attention dyscontrol related to anxiety psychopathologies (Zvielli et al., 2016; Koster, et al., 2006; Mogg et al., 2004; Caudek, et al., 2018; Badura-Brack et al., 2015). Paired with the poor psychometric properties of the dot-probe and spatial cueing tasks, a simply averaged RT value from a few hundred trials can result in a great loss of data, as well as the detailed pattern of fluctuation observed. Thus, traditional AB measurements (for dot probe tasks: Average RT Away from Threat – Average RT Toward Threat) or vigilance measures (for spatial cueing tasks: Average RT Toward Neutral – Average RT Toward Threat), may not adequately account for the fluctuation between vigilance and avoidance of threat over time. It is also quite common to observe the shift between vigilance and avoidance in individuals with anxiety psychopathologies (Bar-Haim et al., 2007). For example, socially anxious individuals display an extreme level of sensitivity toward negative social cues, as well as social contexts to avoid exposure to potential threats (Klumpp & Amir, 2009; Hoffman, 2007). Individuals with spider phobia show significant differences in initial AB depending on whether the individual exhibits high or low fear (Mogg et al., 2006). Similarly, in those with contamination phobia, those with high contamination fear demonstrated disgust related AB at early stages of information processing and more inaccuracies on a behavioral RT task compared to those low in contamination fear (Òlafsson et al., 2019). To address the limitations of the existing analytic approach for behavioral RT tasks, researchers have proposed temporal dynamic measures of attention allocation via the trial-level bias score (TL-BS; Zvielli et al., 2015).

As mentioned, attention fluctuation is indicative of attention dyscontrol (Iacoviello et al., 2014), which is evident in those with psychopathology (Reinholdt-Dunne et al., 2009; Eyesenck et al., 2007; Zvielli et al., 2015; Mogg & Bradley, 2016). The TL-BS evaluates bias toward and away from threat at mean and peak levels (Carlson & Fang, 2020) and better accounts for the fluctuation in AB over traditional AB measures (Davis et al., 2016; Clerkin, et al., 2016; Carlson et al., 2020). While traditional bias measures simply average threat vs. away/neutral trials to determine significant differences, the TL-BS evaluates inter-individual differences between congruent and incongruent pairs over time (Zvielli et al., 2015). Specifically, TL-BS parameters include differences in positive values (toward threat) and negative values (away from threat) and can be utilized to analyze peak "bursts" and the degree of TL-BS variability (i.e., TL-BS covariation = SD divided by the Overall Mean RT of the individual; Zvielli, et al., 2015). The individual with phobia shows greater peaks and lower valleys as compared to the healthy control, although their average values based on the traditional analytic approach would reveal no group differences in the overall pattern of AB. The results suggest greater attention dyscontrol in the individual with phobia, which may be linked to their level of psychopathology. Experimenters using TL-BS have utilized covariation to identify variability, while also controlling for potential confounding components that may affect RT variability (e.g., age or gender; Hultsch et al., 2002; Der et al., 2006; Clarke et al., 2020). Further, Carlson & Fang, 2020 demonstrated that TL-BS scores were more reliable than traditional AB measures but were strongly correlated with RT variability. As such, it is recommended that general response variability should be controlled for

(Carlson & Feng, 2020). Overall, the TL-BS may provide a more valid interpretation of AB, which is not optimally measured by traditional bias measures.

Behavioral RT measures have informed our understanding of the nature of AB and vigilance toward threat, but there are inherent limitations of behavioral RT measures despite the use of the TL-BS analysis. First, these measures are static where participants respond to snapshot-like images presented within a fixed and brief time window (e.g., 500 milliseconds [ms]) (Zvielli, et al., 2014; Cristea et al., 2015; Schmukle, 2005). Second, they are arbitrary and quite remote from how we deal with threat in a natural environment. For example, the dot-probe task forces the participant to choose between one of two options. In reality, attention can be biased by a myriad of distractors in one's environment (Peterson & Posner, 2012). Third, while we can understand variability through TL-BS scores, it is uncertain how magnitude or direction are impacted as a result of taking the SD or covariation to evaluate variability (Krujit et al., 2016) so other advanced statistical techniques may be needed to differentiate these components. Therefore, eye tracking may be a promising and ecologically valid method to measure and quantify attention fluctuation among those with anxiety disorders.

Eye Tracking. While the dot-probe task evaluates covert (implicit) attention, eye tracking has shown to be a useful measure for evaluating temporal dynamics of overt (explicit) attention to various areas of interest (AOI; Kulke et al., 2016). During a 30 second display, one's attention can shift multiple times, which may be inadequately reflected by RT measures (Zvielli et al., 2015). Thus, it is considered a continuous measure of attention selection by orienting responses from the onset to offset of threat (Armstrong & Olatunji, 2012; Richards, et al., 2014). Further, eye tracking is a useful tool for evaluating image processing, memory, social cognition, and decision making in an unobtrusive manner (Mele & Federici, 2012; Rahal & Fiedler, 2019). The use of visual target detection allows the researcher to evaluate response time, eye gaze parameters, and maintenance of, as well as vigilance toward/away from target stimuli (Mele & Federici, 2012; Punde et al., 2017). This is measured through a series of fixations (i.e., the state when the eye remains still over a period of time) and saccades (i.e., the rapid motion of the eye from one fixation to another; Figure 1). Thus, this measure can evaluate initial orientation to, as well as the frequency and magnitude of attention to threatening stimuli over a time course. For this study, we used basic individual eye tracking indices as specified by the SensoMotoric Instruments (SMI) RED250 which include dwell time (Figure 2), net dwell time (Figure 3), glance count (Figure 4), fixation count (Figure 5), average fixation time (Figure 6) and total fixation time (Figure 6; Rahal & Fiedler, 2019).

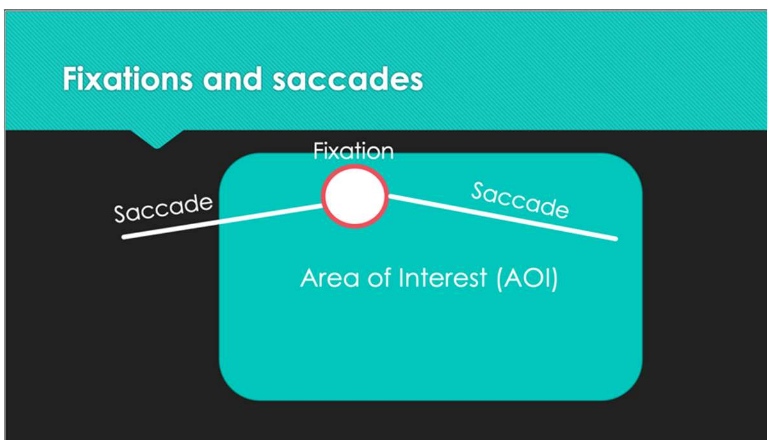


Figure 1. Fixation and Saccade. Fixations are defined as the state when the eye remains still over a period of time. Saccades are the rapid motion of the eye from one fixation to another.

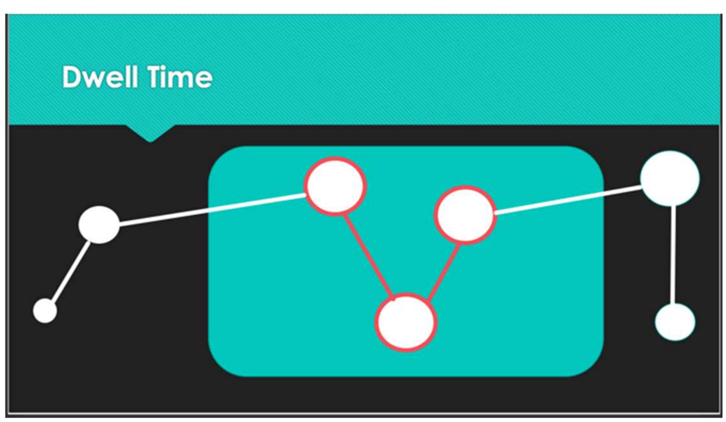


Figure 2. Dwell Time. A dwell is defined as one visit in an AOI from entry to exit. This is measured by the sum of durations from all fixations and saccades that hit the AOI.

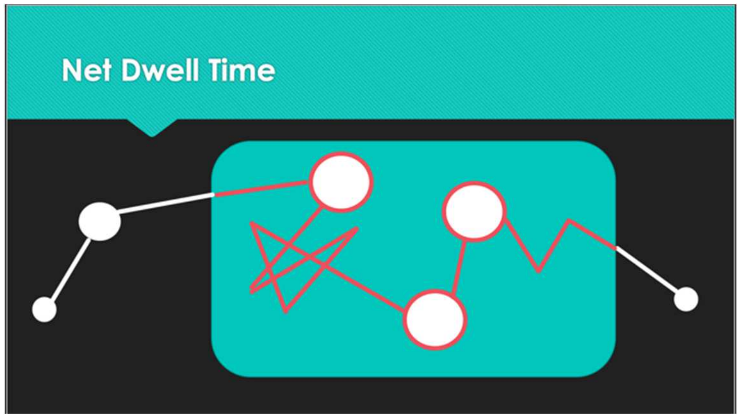


Figure 3. Net Dwell Time. The net dwell time is the duration at which the participant's eye enters the AOI until it leaves the AOI. While dwell time reflects fixation times on the AOI (i.e., fixations + saccades within the AOI), net dwell time includes the entire duration the individual viewed the AOI (i.e., fixations + saccades within the AOI + saccades entering and exiting the AOI). This is measured by the sum of sample durations from all gaze data samples that hit the AOI.

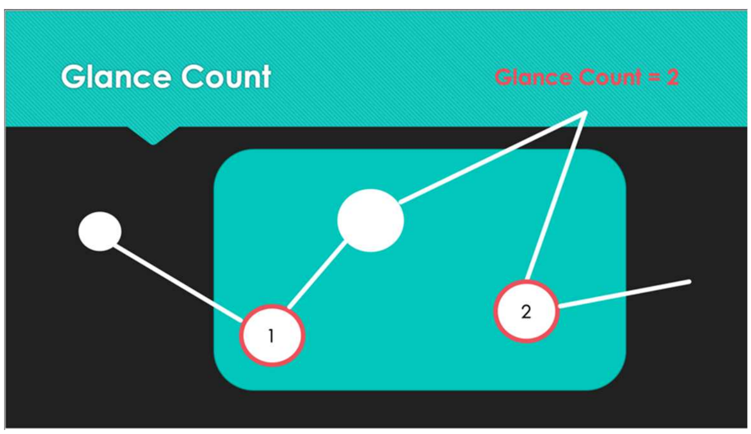


Figure 4. Glance Count. A glance count is the number of visits to a target (saccades coming from the outside) within a certain period (increments the counter each time a fixation hits the AOI, if not hit before). The number of glances in this figure is 2.

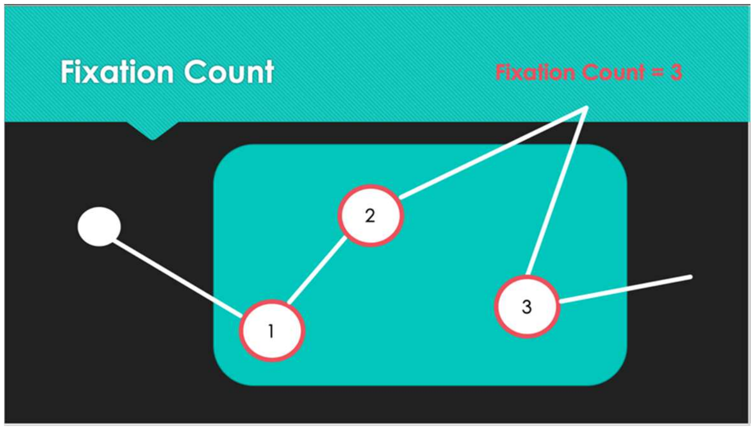


Figure 5. Fixation Count. A fixation count is the number of fixations to the AOI. While glance count is the number of visits to a target from outside the AOI, fixation count is the total number of fixations, including visits and continuous fixations to the AOI. In this figure, the glance count is 2, but the fixation count is 3.

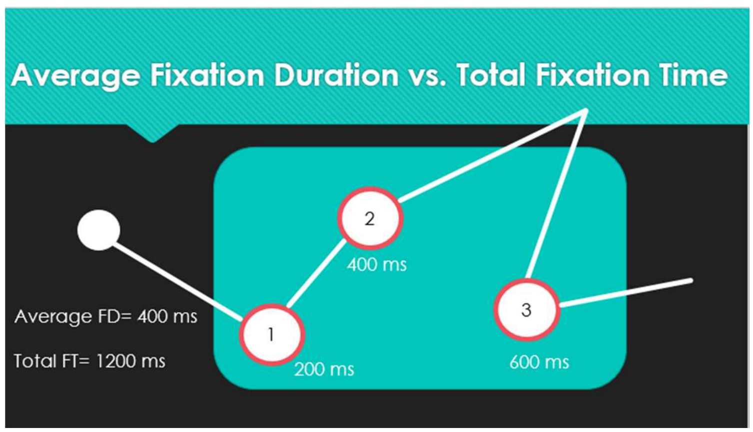
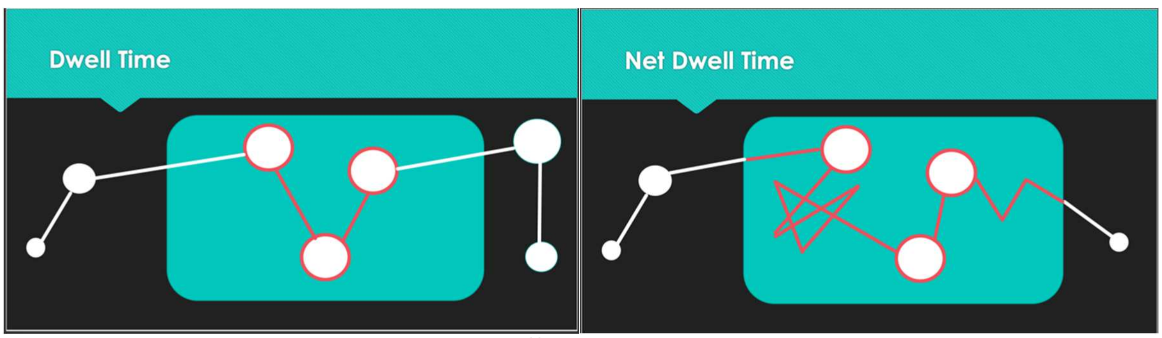


Figure 6. Average Fixation Duration and Total Fixation Time. The total fixation time is the total sum of each fixation duration. Average fixation duration is calculated by taking the average of the length of each fixation. For example, if the three fixations above were 200 ms, 400 ms, and 600 ms, respectively, the total fixation time would be 1200 ms and the average fixation duration would be 400 ms.

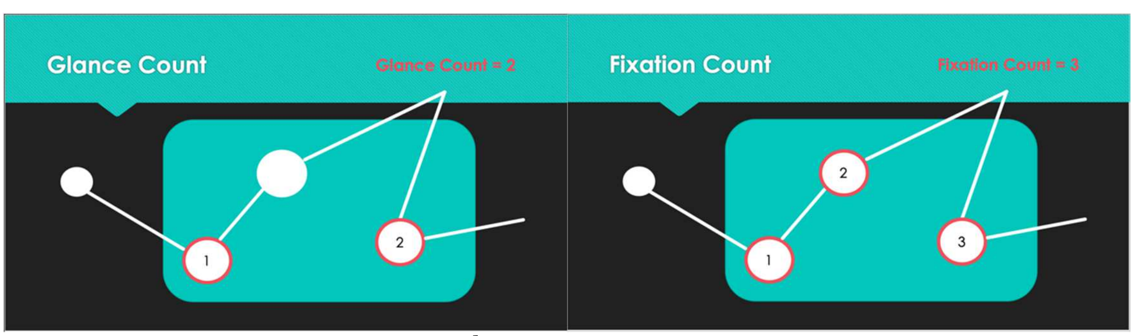
The present study aimed to explore various indices stemming from the eye tracking paradigm to examine how these indices would be associated with (1) attention fluctuation as established by behavioral RT tasks (e.g., TL-BS), and (2) the symptom severity of anxiety problems. Eye tracking is expected to provide enriched data to reflect the pattern of attention fluctuation (Armstrong et al., 2012; Richards et al., 2014). Vigilance is a monitoring system for potential dangers, is one's initial orienting to threat (Armstrong et al., 2012), and involves a state of readiness in order to detect threatening stimuli by broadening one's attention focus (Eysenck, 1992). Thus, anxious individuals may experience increased distraction from task-irrelevant information, as well as excessive sensitivity to threat (Beck & Clark, 1997). Further, anxious individuals tend to avoid threat, which might be related to the compensatory process to down-regulate negative emotions in response to threatening stimuli (Robinson, et al., 2013; Eippert, et al., 2007). Taken together, this may result in a hypervigilant eye gaze pattern, which may manifest as frequent gaze towards threat and difficulty in maintaining stable eye gaze toward the visual target resulting in increased saccades (Richards et al., 2014).

Analogous to the attention fluctuation demonstrated in behavioral RT measures – a mixed pattern of vigilance and avoidance alternating in a haphazard fashion, anxious individuals may display eye gaze patterns that indicate the hypervigilant scanning of the stimuli and unsteady shifting of engagement and disengagement in response to threatening images (Wieser, et al., 2009; Seefeldt, et al., 2014; Wermes, et al., 2018, Pflugshaupt, et al., 2005). As such, eye tracking ratio indices may be a possible solution to measuring AB fluctuation. Eye tracking ratios evaluate the degree (measured as a percentage) to which an individual fluctuates their attention within or outside an AOI. Because we are evaluating anxiety psychopathology, we focused on the threat AOI. Basic eye tracking indices evaluate vigilance towards threat based on the duration of time or number of fixations an individual may attend to the threat AOI. Further, to ensure that other AOIs (e.g., neutral, negative, positive) are accounted for, the percentage of time spent on the target/threat AOI in comparison to other AOIs is calculated. In other words, we can gather the amount of AB fluctuation that occurs toward the target AOI in relation to other AOIs. With ratio indices, we can evaluate how the individual fluctuates their attention toward or away from the target AOI. However, we cannot use the relational percentage of the threat AOI to all other AOIs when calculating the ratio indices because the ratio percentage toward the threat AOI varies from trial to trial. As such, it would be difficult to interpret the meaning of the ratio index, so raw individual basic eye tracking indices were used to create the ratio indices instead. As a new and unexplored area of research, we propose the following eye tracking ratio indices given the literature and inherent understanding of what the basic eye tracking indices measure: Dwell Time/Net Dwell Time (Figure 7), Glance Count/Fixation Count (Figure 8), and Average Fixation Duration/Total Fixation Time (Figure 9).



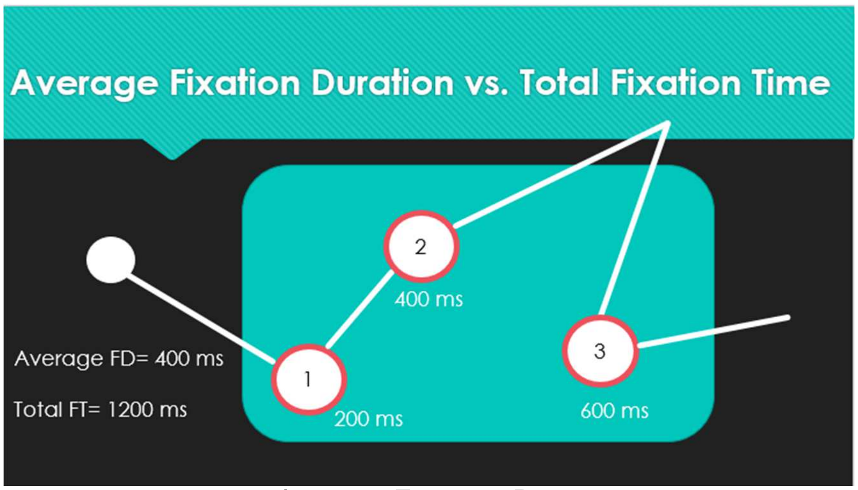
$$\frac{\text{Dwell Time}}{\text{Net Dwell Time}}$$

Figure 7. Dwell Time/Net Dwell Time. This ratio reflects what % of the entire dwell time the individual is able to form fixations on the target image. Hypothetically, if this ratio is approaching 0%, this means the participant was not able to form fixations on the AOI while unstably scanning the area. If a ratio yields 100%, this means the participant fixated on the AOI throughout the entire dwell time. Thus, this ratio indicates the degree to which an individual was able to form fixations within the AOI (the lower the value, the more fluctuation).



$$\frac{\text{Glance Count}}{\text{Fixation Count}}$$

Figure 8. Glance Count/Fixation Count. This ratio compares the number of visits (i.e., incoming eye gaze) from outside of the AOI to the total number of fixations within the AOI. If the ratio approaches 100%, this indicates that the individual was *not* able to form consecutive fixations within the target AOI. In other words, each time a fixation is formed, the person would disengage from the image immediately, which would increase the number of saccades. In contrast, if the ratio approaches 0%, this would indicate that in the given target image, most of the fixations were formed consecutively while the eye gaze stably remained within the AOI (suggesting a more stable pattern of attention allocation). Thus, this ratio indicates the degree to which an individual stably maintained eye gaze within the target image (the higher the value, the more fluctuation).



$$\frac{\text{Average Fixation Duration}}{\text{Total Fixation Time}}$$

Figure 9. Average Fixation Duration/Total Fixation Time. This ratio compares the average fixation duration to the total fixation time within the AOI. If the ratio approaches 100%, this would indicate that the individual formed a small number of long fixations within the target AOI such that the average duration of a fixation approached the total length of fixations. In contrast, if the ratio approached 0%, this would indicate that in the given target image, most of the fixations were shorter or fragmented (the lower the value, the more fluctuation).

Overall, behavioral RT tasks may only portray a snapshot of the rich data and analyses that are available through eye tracking. Eye tracking captures multiple facets of attention in a natural manner. Research has yet to demonstrate how dynamic physiological measures like eye tracking can be used in tandem with behavioral RT measures. It is also unknown whether these dynamic processes, including TL-BS, would demonstrate similar findings. More work must be done to evaluate the role of eye movements to better understand the diverse roles of attention on anxiety.

Aims and Hypotheses

The overarching goal of this project was to evaluate AB fluctuation in various anxiety problems using two modalities: (1) behavioral RT measures and (2) eye tracking. Our lab collected behavioral RT data (dot-probe task and spatial cueing task) and eye tracking data among individuals with three different anxiety-related disorders: spider phobia, contamination phobia, and social phobia. The underlying fear-based mechanism behind these three disorders is similar, yet the presentations are different. Specific phobias (e.g., spider phobia) include marked fear or anxiety about an object or situation that immediately provokes anxiety (American Psychiatric Association, 2013; APA, 2013). Further, this fear leads to active avoidance and is out of proportion of the danger posed by the object or situation (APA, 2013). Contamination phobia may manifest as a need to compulsively clean to reduce the threat posed by the contaminant and can be caused with or without physical contact (Rachman, 2004). Most commonly, the obsessions about contaminants are neutralized by the compulsion of handwashing (APA, 2013). Social anxiety involves a persistent fear of social or performance-based situations where the person is exposed to unfamiliar people or potential scrutiny from others (e.g., humiliation, ridicule; APA, 2013). Evaluating these three disorders will allow us to tap into a wide spectrum of anxiety in order to better understand the pattern of AB findings in those with anxiety psychopathology.

This project has a two specific aims. First, we composed and examined various novel eye tracking ratio indices to evaluate the pattern of attention fluctuation over time. We also evaluated how these eye tracking ratio indices correlated with the traditional bias level threat score (AB-

Avg) and TL-BS (Zvielli et al., 2015). The picture-viewing eye tracking task presents threat and control stimuli and allows us to examine the degree to which individuals were specifically engaging in and disengaging from threatening stimuli. We created three eye tracking index ratios: (1) dwell time/net dwell time (Figure 7), (2) glance count/fixation count (Figure 8) and (3) average fixation duration/total fixation time (Figure 9). Each of these novel eye tracking ratio indices were designed to reflect the pattern of *overt attention fluctuation* in response to threatening images in a manner that has not been evaluated before. Each eye tracking trial was 30 seconds in length. These eye tracking variables were calculated at two different levels: (1) the *overall* attention fluctuation, which includes the entire 30 second time window for each of the three eye tracking indices and (2) the *temporal fluctuation* of attention fluctuation, which were indexed by the standard deviation (i.e., SD; variability) of these ratios across six time bins (i.e., 0-5 sec, 5.01-10 sec, 10.01-15 sec, 15.01-20 sec, 20.01-25 sec, and 25.01-30 sec). To this end, eye gaze data were pre-processed into six, 5-second time-bins to evaluate changes in viewing activity across time, as well as their overall values throughout the entire 30-second trial. We also calculated the percentage of time spent on the threat AOI compared to other AOIs (e.g., neutral, positive, negative) for the basic individual eye tracking indices (i.e., net dwell time, fixation count, average fixation duration) to account for overall AB to threat. As mentioned, the raw basic individual eye tracking indices were used to make up the overall and temporal eye tracking ratio indices.

For the first aim of the study, we hypothesized that TL-BS and the overall and temporal fluctuation eye tracking ratio indices would demonstrate a positive correlation with one another. We also expected that overall symptom severity would positively correlate with TL-BS and overall and temporal fluctuation eye tracking ratio indices.

For the second aim of the study, we evaluated whether the basic individual eye tracking indices, TL-BS, and general emotional threat (i.e., DASS-21 Depression and Anxiety) could predict symptom severity scores. The symptom severity outcome measures (i.e., Fear of Spiders Questionnaire, Obsessive Compulsive Inventory-Revised Washing Subscale, Liebowitz Social Anxiety Scale) were combined as an overall z-scored value to serve as the dependent variable. We combined the three subsamples to examine the association between attention fluctuation indices and the severity of broad-spectrum anxiety problems. We hypothesized that the overall and temporal fluctuation eye tracking ratio indices along with TL-BS and general emotional threat would significantly predict anxiety symptom severity symptoms, with temporal eye tracking ratio indices accounting for the greatest amount of variance.

II. Method

Participants

Participants were recruited from three different studies (i.e., spider phobia, contamination phobia, social phobia) conducted at the University of Wisconsin-Milwaukee (UWM) and surrounding areas.

Participants in the contamination phobia study included 52 students with moderate levels of contamination fear concerns. Inclusion criteria were as follows: Obsessive Compulsive Inventory-Revised (OCI-R) washing subscale was ≥ 1 or the overall mean fear on a pretreatment behavior approach task (BAT) was ≥ 20. For the BAT, the participant was instructed to touch a contaminated area (e.g., a toilet) and evaluate their subjective units of distress or overall fear on a scale of 0 (no fear) to 100 (extreme fear).

Participants in the social phobia study included 43 participants with social anxiety. Participants were included in the sample if the following inclusion criteria were met: (a) between the ages of 18 and 60, (b) demonstrated at least moderate levels of fear of social situations as indicated by the Mini International Neuropsychiatric Interview (MINI 6.0.) Social Phobia module, and (c) eye tracking calibration was correctly captured. Participants were excluded if any of the following exclusion criteria were met: (a) current or past schizophrenia, bipolar disorder, or organic mental disorder, (b) severe attention problems and/or (c) receiving treatment for social anxiety.

Participants in the spider phobia study included 72 participants with high levels of spider fear. Participants were included in the sample if the following inclusion criteria were met: (a) between the ages of 18 and 60 and (b) demonstrated moderate levels of spider fear as indicated by a score of ≥ 15 on the Fear of Spiders Questionnaire (FSQ). Participants were excluded if any of the following exclusion criteria were met: (a) current or past schizophrenia, bipolar disorder, or organic mental disorder, (b) severe attention problems, (c) known or possible allergies to latex, band aids, or Neosporin, and (d) known or possible allergies to spider or insect venom (e.g., bees, spiders).

Measures

Structured Clinical Interview. The MINI (M.I.N.I.; Sheehan et al., 1998) is a brief diagnostic structured interview for the major Axis I psychiatric disorders. The interview assessed whether individuals met exclusion criteria. The specific phobia module was used for the spider phobia and social phobia studies. Other modules including the substance use, psychotic disorders, bipolar disorder, and ADHD categories were also used for exclusion purposes. Interviews were conducted by trained research assistants.

The Depression, Anxiety, and Stress Scale (DASS-21; Lovibond & Lovibond, 1995). The DASS-21 measures responses relating to depression, anxiety, and stress on a scale of 0 (“did not apply to me at all") to 4 ("applied to me very much or most of the time"). The DASS-21 is able to distinguish the emotional subscales, and has good internal consistency, and concurrent validity in both clinical and nonclinical samples (Antony et al., 1998). In terms of our sample, the contamination phobia sample demonstrated adequate internal consistency for depression (α = .87), anxiety (α = .76), and stress (α = .77) subscales. In the social phobia sample, internal consistency ranged from good to excellent for depression (α = .92), anxiety (α = .86), and stress (α = .87) subscales. In the spider phobia sample, internal consistency ranged from good to excellent for depression (α = .92), anxiety (α = .83), and stress (α = .84) subscales. For our study, only the depression and anxiety subscales were utilized for two reasons. First, the literature has reported concerns regarding the low reliability (Anghel, 2020) and weak measurement invariance across cultures for the stress subscale (Oei et al., 2013; Bibi et al., 2020) Second, given our interest in anxiety-related problems and the comorbidity of depression with anxiety (APA, 2013), it appears that the depression and anxiety subscales were the most applicable to our study.

The Obsessive-Compulsive Inventory-Revised (OCI-R; Foa et al., 2002) is an 18-item measure of OCD symptoms. Participants rated the degree to which they have been bothered by OCD symptoms in the past month on a 5-point scale from 0 ("Not at all") to 4 ("Extremely"). The measure assesses for six types of symptoms: (1) Washing, (2) Checking, (3) Obsessing, (4) Mental Neutralizing, (5) Ordering, and (6) Hoarding. The OCI-R has adequate internal consistency, test-retest reliability for both the total and subscale scores, and distinguishable factor structure (Hajcak et al., 2004). For the purposes of this study, we evaluated the 3 items that load onto the Washing subscale. Internal consistency for the OCI-R washing subscale in our contamination phobia sample was .87.

The Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987). The LSAS is a 24-item questionnaire divided into two subscales that address social interactions (11 items) and performance situations (13 items). The questionnaire ranges from 0 to 3 and provides 6 subscale scores (i.e., total fear, fear of social interaction, fear of performance, total avoidance, avoidance of social interaction, and avoidance of performance). The LSAS showed excellent internal consistency and good convergent validity (Heimberg et al., 1999). For the purposes of this study, we used the LSAS total score. The measure showed a Cronbach's alpha of 0.98 in our social phobia sample.

The Fear of Spiders Questionnaire (FSQ; Syzmanski & O'Donohue, 1995) is an 18-item self-report measure of an individual's fear of spiders and is able to discriminate those with spider phobia from those without spider phobia. Participants rate the degree to which they have been bothered by their symptoms on a 7-point scale from 1 ("not at all") to 7 ("very much"). In addition, the FSQ loads onto two factors: fear of harm and avoidance/help seeking. The FSQ showed adequate test-retest reliability and convergent validity (Szymanski & O'Donohue, 1995). The FSQ total score was used in our study. This instrument demonstrated good internal consistency ($\alpha = .95$) within our spider phobia sample.

Procedure

Across all three studies, participants completed an informed consent process, followed by a series of questionnaires (per their respective study), computerized dot-probe (for contamination and social phobia studies) or spatial cueing task (for the spider study), and eye tracking. While these studies conducted post-exposure and follow-up assessments, only the baseline portion of each study was analyzed to consistently evaluate the studies prior to any intervention. A structured clinical interview was conducted only with the spider phobia and social phobia studies.

Dot-Probe Task (Figure 10). The dot-probe task was used for the contamination and social phobia studies. The dot probe task instructed the user to locate the position of dots after specific words (e.g., social-related or contamination-related) were shown. The stimuli were presented for 500 ms. The speed with which one was able to identify the probes (i.e., asterisks for the contamination study or an "X" for the social phobia study) that replaced the salient stimuli indicated where that individual's attention was drawn during stimulus presentation. All data were measured using RT and were further processed using the TL-BS approach.

In the contamination phobia study, contamination-related words (e.g., infection, toilet) and neutral words (e.g., calculator, shrub) were displayed on a white background. In this study, 125 trials were shown which included 6 practice trials, two blocks of 48 contamination-neutral (e.g., blood, rotten), and 23 neutral-neutral (e.g., bloom, radio) pairs presented in a random order. Words pairs were of similar length. Participants were instructed to identify the probes as quickly as possible by pressing the number 1 or 2 keys on the keyboard depending on the number of asterisks observed. For example, if one asterisk was observed the participant would select the number 1 key on the keyboard.

Similar to the contamination phobia study, the social phobia study presented 106 trials of social-phobia related words, which included two blocks of 40 anxious-neutral trials (e.g., worthless, ridiculous), 20 neutral-neutral trials (e.g., candle, headlight), and 6 practice trials. Participants were presented with a stimulus cue, the stimuli, and then told to press "E" if the X was located on the top or “F” if the X was located on the bottom of the screen.

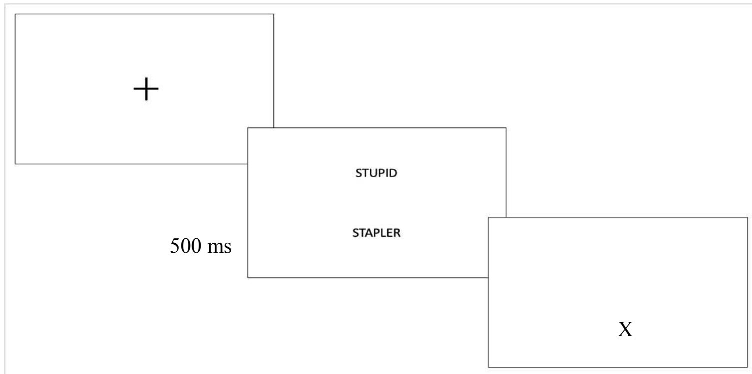


Figure 10. Example Trial from the Social Phobia Dot-Probe Task.

Spatial Cueing Task (Figure 11). In the spider phobia study, the spatial cueing task presented a total of 156 picture trials (i.e., 12 practice trials and 144 valid or invalid trials). The trials presented pictures of household images (e.g., a fan or a couch), general threat images (e.g., a fire or shark), or spider pictures in a random and counterbalanced order. The pictures were presented on a white background. Each trial had a central fixation cross followed by two empty boxes on each side of the computer screen. Next, a cue appeared in the center of one of the boxes of 500 ms. Then, both boxes and the cue disappeared for 50 ms. Finally, a probe (either an E or F) appeared in either the same (=valid trial) or opposite (=invalid trial) box of the cue. The participant was instructed to press the E or F key as accurately and quickly as possible in order to proceed to the next trial. All data were measured using RT and were further processed using the TL-BS approach.

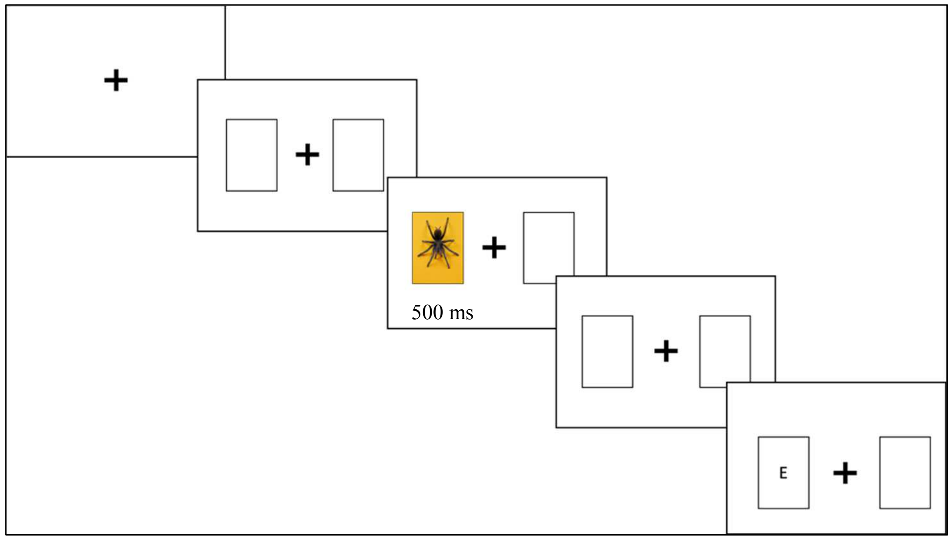


Figure 11. Example Trial from the Spider Phobia Spatial Cueing Task

Eye Tracking (Figure 12). All pictures for the eye tracking tasks were gathered from the International Affective Pictures System (IAPS; Lang, et al., 1999) or the Paul Ekman Group (Ekman et al., 1996). In terms of eye tracking, all participants completed a naturalistic picture-viewing task with slides using the SensoMotoric Instruments (SMI) RED250. Each slide included four pictures in four quadrants in which participants were asked to view each slide for 30 seconds as if they were viewing a photo album without any constraints. From the task, the number of fixations (i.e., defined as the focused gaze within a 1-degree visual angle for 100 ms or longer), and their lengths were computed for each of the four areas of interest (AOIs). During each trial, the subject's line of free gaze was recorded by the eye tracking device, generating several indices that depicted the pattern of attentional processing (i.e., the number and location of fixation points; fixation duration). As mentioned earlier, we evaluated specific eye tracking indices which included dwell time (Figure 2), net dwell time (Figure 3), glance count (Figure 4), fixation count (Figure 5), average fixation duration (Figure 6), and total fixation time (Figure 6).

In the spider phobia study, 10 slides were shown. The four quadrants presented the following four picture types: spider (i.e., target AOI), general threat (e.g., fire), neutral (e.g., chair), and positive (e.g., flowers). The contamination phobia study also included 10 slides. The four quadrants included a contaminated surface (i.e., target AOI; e.g., dirty toilet), general threat (e.g., lion), neutral (e.g., stapler), and positive (e.g., ocean). The social phobia study showed 10 slides of which two of the four faces shown were disgust (i.e., target AOI) and anger. We chose disgust faces as the target threat because the literature has shown that disgust faces are rated as more negative than angry faces (Amir et al., 2010) and capture attention in individuals with high social anxiety (Yuan et al., 2021). Other slides included happy, fearful, surprise, and calm faces.

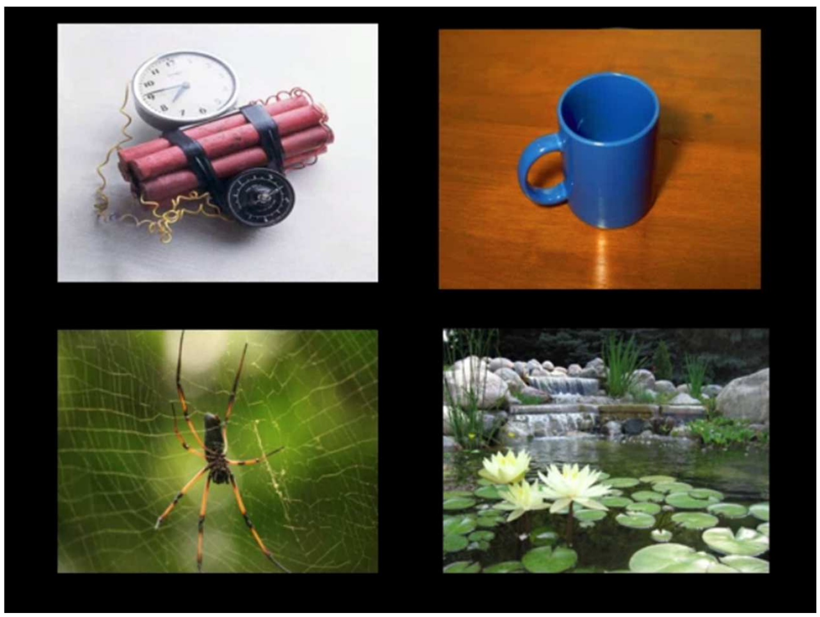


Figure 12. Example slide from the spider phobia eye tracking task.

Data Analysis Plan

Dot-Probe Task. We measured AB variability in two ways. First, the traditional bias level threat score (AB-Avg) was calculated by subtracting the mean RT of congruent threat trials by incongruent threat trials (i.e., Away Threat Mean RT – Toward Threat Mean RT). As mentioned above, incongruent trials are those in which the probe replaces a non-target or neutral cue and congruent trials are those in which the probe replaces a target or threat cue. (2) We employed the TL-BS calculation (Zvielli et al., 2015) for each individual trial such that neutral (incongruent) trials were paired with the next closest threat (congruent) trial, and threat trials were paired with the next closest neutral trial. Pairs of trials were no further than five trials apart either before or after, and redundant pairings were retained. The resulting bias scores ranged from positive (= vigilance at the moment) to negative (= avoidance at the moment) values. Positive scores indicated a bias toward threat and negative scores indicate a bias away from threat. The variability (= SD) of these momentary AB scores, obtained across the dot-probe trials, were used as indicators of attention fluctuation for each sample. We controlled for mean overall RT to control for associations between mean and variance by calculating the coefficient of variation (i.e., SD divided by the participant's mean overall RT; Zvielli et al., 2015; Clarke et al., 2020). Because the social and contamination phobias studies used the dot probe task and not the spatial cueing task, like the spider phobia study, we calculated the z-score value of the AB-Avg to account for paradigm differences across the three studies.

Spatial Cueing Task. The spatial cueing task presented stimuli differently from the dot-probe task (i.e., one picture per trial as compared to two pictures per trial), so the calculation of the AB-Avg was calculated by subtracting the mean RT of congruent threat trials from congruent neutral trials (i.e., Mean RT Toward Neutral – Mean RT Toward Threat). We calculated the z-score value of the AB-Avg to account for paradigm differences across the three studies. While the TL-BS measure has typically been used to calculate AB variability for the dot-probe task, Krujit and colleagues (2015) reported that the TL-BS can also be used in other behavioral RT tasks, like the spatial cueing task, that "evaluate the difference between two types of trials to demonstrate the presence or absence of a processing bias." By conducting the calculations in this manner, we assured that the dot probe task and spatial cueing task scores were evaluated similarly.

Eye Tracking. Using the basic individual eye tracking indices (i.e., dwell time, net dwell time, fixation count, glance count, average fixation duration and fixation time). The threat AOI was also calculated as a percentage to evaluate the duration and number of fixations to the threat AOI compared to other AOIs (i.e., neutral, positive, negative; Threat AOI % = ((Threat AOI)/(Threat AOI + Neutral AOI + Positive AOI + Negative AOI)).

We created three eye tracking index ratios: (a) dwell time/net dwell time (Figure 7), (b) glance count/fixation count (Figure 8) and (c) average fixation duration/total fixation time (Figure 9). The overall fluctuation eye tracking ratio indices were calculated as a percentage and averaged across the entire 30-second trial. Additionally, to quantify the temporal variability of attention fluctuation we divided each 30 second trial into six, 5-second time bins and took the SD. In terms of nomenclature, we differentiate the overall fluctuation eye tracking ratio indices from the temporal fluctuation eye tracking ratio indices, by placing an SD in front of the temporal fluctuation ratio indices (e.g., SD dwell time/net dwell time).

Analyses. For the first aim we examined how the proposed eye tracking indices were associated with the (1) TL-BS and (2) overall symptom severity. We conducted a Pearson's correlation to evaluate whether the basic individual eye tracking indices, as well as the overall and temporal fluctuation eye tracking ratio indices were correlated with TL-BS and overall symptom severity. We chose net dwell time, fixation count, and average fixation duration as the representative basic eye tracking indices because they provide us with information about the duration, frequency, and average length of fixation toward threatening stimuli, respectively.

For the second aim, we evaluated whether the individual basic eye tracking indices (net dwell time, fixation count, and average fixation duration), overall fluctuation eye tracking ratio indices. and temporal fluctuation eye tracking ratio indices could predict symptom severity over and above (1) DASS-21 Depression and Anxiety, and (2) AB-Avg and TL-BS scores. We conducted a series of hierarchical linear regression analyses. We predicted overall symptom severity by controlling for general emotional symptom severity (DASS-21 Depression and Anxiety), and then added AB-Avg, TL-BS, and the basic individual eye tracking indices to the model as covariates. The overall fluctuation eye tracking ratio indices were computed across the 30 second trials (i.e., dwell time/net dwell time, glance count/fixation count, average fixation duration/total fixation time), and included as predictors in the hierarchical regression analysis to predict symptom severity while using DASS-21 Depression and Anxiety subscales, AB-Avg, TL-BS, and basic individual eye tracking indices as covariates. Similarly, the temporal fluctuation eye tracking ratio indices (i.e., SD dwell time/net dwell time; SD glance count/fixation count; SD average fixation duration/total fixation time) were used to examine the time varying fluctuation of the attention fluctuation indices. The temporal fluctuation eye tracking ratio indices were separately added to the model to predict symptom severity after controlling for DASS-21 Depression and Anxiety, basic individual eye tracking indices, AB-Avg and TL-BS. We separately added each of the temporal fluctuation eye tracking ratio indices to the model to account for multicollinearity (VIF≥4) between the three temporal ratio indices, so they would not have to compete against one another to explain the variance (Gordon, 2015). The z-score of the overall sample symptom severity score was the dependent variable to examine the association between attention fluctuation indices and symptom severity across the three study samples. Using the unified outcome scores (z-score), we conducted hierarchical regression analyses mentioned above to examine how the proposed eye tracking attention fluctuation indices would predict more broad-spectrum anxiety severity across symptom categories. To correct for Type 1 error inflation, we utilized False Discovery Rate corrections (Benjamini & Hochberg, 1995).

Power Analysis

Our power analysis was conducted for a linear multiple regression: fixed model, R^2 increase. To detect a medium-sized effect of 0.15 for the entire sample, with an alpha of 0.05, and 8 predictors, the current sample size yielded a power of greater than 0.95. Therefore, with the combined sample we are sufficiently powered to detect a medium-sized effect.

We did not conduct individual analyses for our three subgroups due to the lack of a power. To detect a medium-sized effect for the contamination phobia sample (n=52), social phobia (n=43), and spider phobia (n=72) samples with an alpha of 0.05, effect size of 0.15 and 8 predictors, the current sample size yields a power of 0.78, 0.69, and 0.89, respectively, which indicates that the size of the contamination and social phobia studies are statistically underpowered to detect a medium sized effect. All samples were underpowered to detect a small sized effect yielding a power ranging between .15 ~ .21 across samples. Taken together, the sample-specific analyses were sufficiently powered to detect a large effect across all three studies but were underpowered to detect a medium effect, particularly for the contamination and social phobia studies. Given the total number of predictors and the limited sample size of the individual groups, we plan to focus our analysis on the combined sample, as compared to the individual sub-samples.

III. Results

Demographic and Clinical Characteristics. Basic demographic and clinical characteristics of our sample can be found in Table 1. No significant differences between groups were observed for sex, $X^2(4, N = 169) = 4.95$, $p = .29$, age, $X^2(46, N = 167) = 51.37$, $p = .27$, or ethnicity, $X^2(2, N = 169) = 2.63$, $p = .27$. In terms of race, no significant differences between groups were observed for White, $X^2(2, N = 169) = 4.16$, $p = .13$, African American, $X^2(2, N = 169) = 1.78$, $p = .41$, Asian or Pacific Islander, $X^2(2, N = 169) = 4.08$, $p = .13$, Native American, $X^2(2, N = 169) = 1.19$, $p = .55$, or Multiracial individuals, $X^2(2, N = 169) = 3.13$, $p = .21$. In terms of symptom questionnaires, significant differences were observed for the DASS-21 depression, $F(2,262)=21.81$, $p<.001$, and DASS-21 anxiety, $F(2,262)=27.18$, $p<.001$ subscales. The results showed that the spider phobia group endorsed significantly less depression and anxiety symptoms via the DASS-21 than the contamination and social phobia groups. There were no differences in DASS-21 symptom subscales between the contamination and social phobia groups ($p<.05$).

Correlations. Correlations among the overall symptom severity, DASS-21 depression and anxiety, AB-Avg., TL-BS, individual eye tracking indices, overall fluctuation eye tracking ratio indices, and temporal fluctuation eye tracking ratio indices can be found in Table 2.

The results showed that overall symptom severity was negatively correlated with net dwell time. Overall symptom severity was positively associated with DASS-21 depression and anxiety. Overall symptom severity was also positively correlated with glance count/fixation count, average fixation duration/fixation time, SD dwell time/net dwell time, SD glance count/average fixation count, and SD fixation duration/total fixation time ($p < .05$). The results showed that dynamic measures of attention dyscontrol (i.e., TL-BS, overall and temporal fluctuation eye tracking ratio indices), were stronger correlates with overall symptom severity than averaged measures of AB (e.g., AB-Avg, fixation count, and average fixation duration).

Hierarchical Regression with Basic Individual Eye Tracking Indices (Table 3). In Step 1, DASS-21 depression and anxiety subscales significantly explained 10% of the variance in overall symptom severity, $R^2\Delta = .10$, $F(2,136) = 7.58$, $p = .001$. The DASS-21 anxiety subscale significantly predicted overall symptom severity, $b = .04$, $t(131) = 2.46$, $p = .02$. In Step 2, AB-Avg, TL-BS, and individual eye tracking indices (i.e., net dwell time, fixation count, and average fixation duration) did not explain a significant portion of the variance in overall symptom severity, $R^2\Delta = .06$, $F(5,131) = 1.91$, $p = .10$. $f^2 = .19$.

Hierarchical Regression with Overall Attention-Fluctuation Ratio Indices (Table 3). As mentioned, values VIF ≥4 indicates multicollinearity (Gordon, 2015). The overall attention fluctuation ratio indices did not indicate problems with multicollinearity: DT/NDT (VIF=1.72), GC/FC (VIF=2.40), and AFD/FT (VIF=3.97).

In Step 1, DASS-21 depression and anxiety subscales significantly explained 9.80% of the variance in overall symptom severity, $R^2\Delta = .10$, $F(2,135) = 7.34$, $p = .001$. The DASS-21 anxiety subscale significantly predicted overall symptom severity, $b = .04$, $t(135) = 2.11$, $p = .04$. In Step 2, AB-Avg, TL-BS, basic individual eye tracking indices, and overall fluctuation eye tracking indices (i.e., dwell time/net dwell time; glance count/fixation count; average fixation duration/total fixation time) did not explain a significant portion of the variance in overall symptom severity, $R^2\Delta = .10$, $F(8,127) = 1.91$, $p = .06$. $f^2 = .24$. However, the DASS-21 anxiety subscale was a significant predictor of overall symptom severity, $b = .04$, $t(127) = 2.04$, $p = .04$.

Hierarchical Regression with Temporal Attention-Fluctuation Ratio Indices (Table 4).

The temporal attention fluctuation ratio indices indicated problems with multicollinearity: SD DT/NDT (VIF=1.59), SD GC/FC (VIF=4.68), and SD AFD/FT (VIF=5.22). Given the nonsignificant contributions of the overall fluctuation eye tracking ratio indices, we removed these variables from Step 2 of the models. Instead, we entered each of the temporal eye tracking fluctuation ratio indices in Step 3 as the main predictor of the models.

SD Dwell Time/Net Dwell Time. In Step 1, DASS-21depression and anxiety subscales explained 10% of the variance in overall symptom severity, $R^2\Delta = .10$, $F(2,136) = 7.58$, $p = .001$. The DASS-21 anxiety subscale significantly predicted overall symptom severity, $b = .04$, $t(136) = 2.46$, $p = .02$. In Step 2, AB-Avg., TL-BS, and individual eye tracking indices, did not explain a significant portion of the variance in overall symptom severity, $R^2\Delta = .06$, $F(5,131) = 1.91$, $p = .10$. In Step 3, we added the SD dwell time/net dwell time as the main predictor of the model.

After accounting for emotional distress measures, behavioral RT measures, individual and overall fluctuation eye tracking indices, SD dwell time/net dwell time significantly explained an additional 4.50% of the variance in overall symptom severity, $R^2\Delta = .05$, $F(1,130) = 7.35$, $p = .008$. $f^2 = .26$. SD dwell time/net dwell time was the only significant predictor among all variables in the model, $b = 1.70$, $t(130) = 2.71$, $p = .008$.

SD Glance Count/Fixation Count. In Step 1, DASS depression and anxiety subscales explained 10.60% of the variance in overall symptom severity, $R^2\Delta = .11$, $F(2,133) = 7.93$, $p = .001$. The DASS-21 anxiety subscale significantly predicted overall symptom severity, $b = .04$, $t(133) = 2.15$, $p = .03$. In Step 2, AB-Avg, TL-BS, and individual eye tracking indices, did not explain a significant portion of the variance in overall symptom severity, $R^2\Delta = .06$, $F(5,128) = 1.98$, $p = .09$. However, the DASS-21 anxiety subscale, $b = .04$, $t(128) = 2.11$, $p = .04$, and TL-BS, $b = .15$, $t(128) = 2.04$, $p = .04$, were significant predictors of overall symptom severity.

In Step 3, SD glance count/fixation count, significantly explained an additional 3.2% of the variance in overall symptom severity, $R^2\Delta = .03$, $F(1,127) = 5.12$, $p = .03$. $f^2 = .25$. SD glance count/fixation count, $b = 2.08$, $t(133) = 2.26$, $p = .03$, TL-BS, $b = .17$, $t(127) = 2.32$, $p =$

.02, and the DASS-21 anxiety subscale, b = .04, t(127) = 2.04, p = .04, were significant predictors in the model.

SD Average Fixation Duration/Total Fixation Time. In Step 1, DASS-21 depression and anxiety subscales explained 10.60% of the variance in overall symptom severity, $R^2\Delta$ = .11, F(2,133) = 7.93, p = .001. The DASS-21 anxiety subscale significantly predicted overall symptom severity, b = .04, t(133) = 2.15, p = .03. In Step 2, AB-Avg., TL-BS, and individual eye tracking indices, did not explain a significant portion of the variance in overall symptom severity, $R^2\Delta$ = .06, F(5,128) = 1.98, p = .09. However, the DASS-21 anxiety subscale, b = .04, t(128) = 2.11, p = .04, and TL-BS, b = .15, t(128) = 2.04, p = .04, were significant predictors of overall symptom severity.

In Step 3, SD average fixation duration/total fixation time, significantly explained an additional 3.5% of the variance in overall symptom severity, $R^2\Delta$ = .04, F(1,127) = 5.62, p = .02. f^2 = .26. SD average fixation duration/total fixation time indices, b = 1.82, t(127) = 2.37, p = .02, TL-BS, b = .16, t(127) = 2.28, p = .02, and the DASS-21 anxiety subscale, b = .04, t(127) = 2.29, p = .02, were significant predictors in the model.

IV. Discussion

The literature has shown that individuals with anxiety tend to bias their attention toward threatening stimuli as compared to neutral stimuli (Pergamin-Hight et al., 2015; Mogg et al., 2016). This has typically been shown through behavioral RT tasks. However, mixed findings have been observed possibly due to the overly simplistic conceptualization of AB, where differences in RT (Mean RT Away from Threat - Mean RT Toward Threat), do not consistently demonstrate the AB pattern in anxious individuals (Salum et al., 2013, Waters et al., 2013, Koster et al. 2015; Bantin et al., 2016; Dennis-Tiwary et al., 2019). The purpose of this study was to examine whether AB fluctuation indices via TL-BS and eye tracking could provide a more accurate picture of attention dyscontrol/fluctuation beyond traditional, linear, AB measures based on threat-oriented biases. First, we aimed to create novel eye tracking ratio indices, averaged across 30 seconds (i.e., overall fluctuation) and divided into time-bins (i.e., temporal fluctuation), to evaluate their correlation with symptom severity and behavioral RT measures (e.g., TL-BS, AB-Avg). Second, we aimed to determine whether overall and temporal fluctuation eye tracking ratio indices could explain a significant portion of the variance in anxiety symptom severity while also considering well-established AB fluctuation indices like TL-BS.

The results showed that AB fluctuation measures (i.e., TL-BS, temporal eye tracking ratio indices) significantly predicted overall symptom severity after controlling for general emotional symptoms, whereas more traditional AB indices such as behavioral threat-bias RT and individual eye tracking indices (e.g., fixation count and length) did not predict overall symptom severity. The temporal eye tracking ratio indices explained a significant portion of additional variance (3 to 5%) after controlling for a number of relevant variables, which suggests that the time course of eye tracking fluctuation measures may be a useful assessment tool and correlate of overall anxiety symptom severity. Our findings are consistent with previous research showing that measures of AB fluctuation, like TL-BS, demonstrate greater reliability and a stronger relationship with anxiety psychopathology than traditional AB measures (Price et al., 2015; Zvielli et al., 2015; Caudek et al., 2017; Cox et al., 2017; Alon et al., 2019; Molloy & Anderson, 2020). Further, the findings indicate that beyond relying on a rather simplistic AB index characterized by vigilance toward or avoidance away from threat, attention dyscontrol is important to evaluate. Heightened anxiety and poor attention control can lead to greater cognitive interference when processing salient emotional stimuli and tends to worsen in the presence of many conflicting cognitive demands (Reinholdt-Dunne et al., 2009; Heeren et al., 2013). Further, the failure to recruit critical areas of the brain involved in attention control (e.g., dorsolateral prefrontal cortex) can lead to increased activation of emotional control centers of the brain like the amygdala, which may increase sensitivity toward threatening stimuli (Bishop et al., 2004; Bishop, 2008, 2009). For example, in individuals with high trait anxiety, research has shown a relationship between poor attention control with greater AB toward threat on behavioral RT tasks (Derryberry & Reed, 2002; Peers & Lawrence, 2009). Notably, the ability to flexibly control one's attention is crucial for emotion regulation (Gross et al., 1998). For example, individuals with greater AB toward threat tend to engage in avoidance and/or suppression of the threat (Bardeen et al., 2017). In other words, their attention toward threat never habituates and instead maintains the anxiety as they continue to monitor and ultimately return to the threatening stimuli (Wezlaff & Wegner, 2000; Bardeen et al., 2017). As such, an important area of work may involve treatments focusing on attention control.

Given our findings including eye tracking ratio indices, TL-BS, and our understanding of AB fluctuation, attention control training (i.e., equal training toward or away from threat) should be considered as an important area of future research. Indeed, attention control training focuses on one's ability to "regulate the allocation of attentional resources" (Heeren et al., 2013). The literature has shown the benefits of attention control training in reducing anxiety-related symptoms to the same or even greater degree than AB modification trainings, which is a treatment focused on avoiding threat stimuli (Badura-Brack et al., 2014; Lazarov et al., 2019; Mathew et al., 2021). Indeed, Badura-Brack and colleagues (2014) showed that compared to AB modification, attention control training showed a greater reduction in PTSD symptoms. Further, they showed that attention control training enhanced attention control (i.e., lower AB variability).

According to attention control theory, improving one's ability to inhibit irrelevant salient distractors would reduce anxiety psychopathology (Eysenck et al., 2007). Attention bias modification training relies upon this assumption, in which individuals are implicitly trained to avoid automatic biases to threat. Yet, we also see reductions in anxiety when individuals are instructed to approach threat (e.g,, exposure therapy; Beck & Clark, 1997). Though causality cannot be determined, our results revealed that greater attention dyscontrol is associated with greater anxiety psychopathology. As such, attention control training may allow for both the bottom-up and top-down attentional systems to interact, restore attention control, and ultimately reduce psychopathology (Connor et al., 2004). To our knowledge, little is known regarding the role of habituation and extinction in AB modification or attention control training. Similarly, research has yet to evaluate whether attention dyscontrol improves after behavior therapy treatment (e.g., exposure). However, there may be some utility in using attention control training, which is designed to offer balanced approach and avoidance of attentional allocation, as an adjunctive treatment to enhance psychotherapeutic effects and reduce treatment time. Future studies may also consider including attention control measures to help disentangle whether attention dyscontrol can function as an endophenotypic marker of anxiety psychopathology. Overall, our results shed light on the narrow understanding of AB toward threat and the need for researchers to focus future work on deficient attention control.

While no research has evaluated attention fluctuation in eye tracking measures using ratio indices, different theories have suggested multiple avenues in visual attention toward threat. The vigilance-avoidance model states that those with anxiety demonstrate initial orienting toward threat but avoidance away from threat during extended viewing, which is considered more "voluntary and strategic" (Mogg et al., 2004; Buckner et al., 2010; Armstrong et al., 2012;

Schofield et al., 2012). Alternatively, Amir et al., 2003, reported that individuals with anxiety demonstrate no differences in initial orienting toward threat but struggle to disengage from detected threat. In a meta-analysis of eye-tracking studies in various anxiety samples, Armstrong et al., 2012 found that individuals with anxiety demonstrate vigilance toward threat with more inconsistent results regarding maintenance of attention on threat (Armstrong et al., 2012). These theoretical differences and inconsistent findings in viewing behavior may be due to the evaluation of only basic individual eye tracking indices, which simply measure the average duration and frequency toward threat stimuli. Our study showed that evaluating basic eye tracking indices did not produce significant correlates or predictors of overall anxiety symptomology. Rather, utilizing temporal fluctuation eye tracking ratio indices (i.e., the fluctuation of AB across a time course), predicted overall symptom severity. The findings suggest that AB fluctuation may provide a more precise representation of AB. Compared to a single snapshot of covert AB like in behavioral RT tasks, eye tracking gathers the time course of AB fluctuation, which can precisely measure initial and subsequent viewing behavior (Weirich et al., 2008; Schofield et al., 2012). In tandem with other AB fluctuation measures like TL-BS, our results demonstrate that temporal eye tracking ratio indices are impactful assessment tools in the prediction of anxiety severity.

We created three novel eye tracking ratio indices that were strongly inter-correlated yet showed unique contributions to our understanding of AB fluctuation. The dwell time/net dwell time ratio index evaluated the *duration* of time the individual was able to stably fixate on the target image. Our results showed that when added to the model, SD dwell time/net dwell time, was the only predictor of overall symptom severity over TL-BS and DASS-21 anxiety. This suggests that an increased number of saccades (representing hypervigilance) and fewer fixations, is indicative of anxiety psychopathology. As a real-world example, consider an individual who has a fear of speaking and recognizes disgusted faces as threatening. In this scenario, the individual may frequently engage and disengage from disgusted as compared to other faces, creating a greater amount of hypervigilant and unstable saccade lengths. The dwell time/net dwell time ratio index gathers the magnitude of AB fluctuation by measuring both saccade and fixation lengths. The ratio also reflects the length of entering and exiting saccades on the target AOI. However, this index does not provide information regarding the number of fixations within the AOI, so we are unable to determine how often one visits the target AOI. Further, due to the minute lengths of saccades, this ratio index may not work well if the stimulus presentation is short, so longer stimulus presentations are likely required.

The glance count/fixation count index identifies *frequency* of visits to the AOI from outside of the AOI compared to the total fixations inside the AOI. When added to the model, SD glance count/fixation count, along with the TL-BS and DASS-21 anxiety subscale were significant predictors of overall symptom severity. This suggests that the diminished ability to form consecutive fixations, when viewing threatening stimuli, is related to anxiety psychopathology. For an individual with a fear of speaking, they may form fewer stable fixations when viewing disgusted faces as compared to other faces. The glance count/fixation count index is based on the number of (consecutive) fixations formed within the AOI. However, the index does not provide information about the quality of the fixation (i.e., how long one spends viewing the AOI or the length of each fixation).

The average fixation duration/total fixation time determines how the average length of the fixation compares to the summed overall fixation time. Similar to the SD glance count/fixation count index, when added to the model, SD average fixation duration/fixation time was a significant predictor of overall symptom severity along with TL-BS, and the DASS-21 anxiety subscale. This suggests that more fragmented and shorter fixations were associated with greater anxiety psychopathology. An individual with a fear of public speaking may demonstrate shorter average fixation lengths when viewing disgusted faces as compared to other faces. The average fixation duration/total fixation time index allows us to gather attention dyscontrol patterns in terms of individual fixation lengths. The limitation of this index is that it does not consider saccades in the AOI so overall duration of time spent in the AOI is unknown.

Overall, these temporal fluctuation eye tracking ratio indices demonstrate the hyperscanning (i.e., vigilance and avoidance) motion of one's viewing patterns on the AOI across time. While the TL-BS and the DASS-21 anxiety subscale were predictive of overall symptom severity when SD glance count/fixation count and SD average fixation duration/total fixation time were added to the model, the SD dwell time/net dwell time was more predictive than TL-BS and DASS-21 symptoms. Future research must replicate these findings to determine whether SD dwell time/net dwell time is truly a superior measure of AB fluctuation or specific to our sample. Regardless, the results point to the importance of using dynamic measures of AB fluctuation measures via temporal fluctuation indices and TL-BS over the individual basic individual eye tracking indices or AB-Avg. The findings suggest that both the TL-BS and eye tracking ratio indices are useful predictors of overall symptom severity. Taken together, dysfunctional attention control in anxiety should include measures of temporal AB fluctuation beyond traditional threat-oriented measures of AB.

The temporal eye tracking ratio indices and TL-BS were correlated with overall symptom severity but were not correlated with each other. There are several reasons this may be. For example, the two measures have various methodological and motivational differences. The TL-

BS is an arbitrary forced choice measure, which involves the brief presentation of one or two stimuli and the detection of irrelevant neutral probes (i.e., "X", or * vs. **) amidst emotional stimuli. It is a repeated, snapshot-like assessment of attention on the main target where the goal is to process a neutral probe as quickly and accurately as possible. As such, participants are aware that the task involves an evaluative component. In contrast, eye tracking is an unstructured and voluntary task, which involves freely viewing pictures on a computer screen for a prolonged period of time (e.g., 30 seconds). The participant is instructed to view the screen with no specific task demands, like they are viewing a magazine, with no evaluative component. Eye tracking is also a continuous measure in the midst of various stimuli (both neutral and threatening).

In addition to the methodological and motivational differences between TL-BS and temporal eye tracking measures, there are differences in the way attention dyscontrol is captured. Using TL-BS, the researcher evaluates one's attention control stability toward a neutral probe, in the presence of emotional stimuli. In contrast, attention dyscontrol in temporal eye tracking indices evaluates the instability of attention control toward emotional pictures themselves. Future research may consider evaluating attention control components when processing more neutral cognitive targets, like in behavioral RT tasks, as compared to processing emotional distractors, like in eye tracking measures. Overall, the results suggest that these two measures may be tapping into different aspects of attention dyscontrol and can be informative in our understanding of AB in a way that simply evaluating preferential AB toward threat cannot (Table 5).

We conducted these analyses with a combined sample of three different anxiety disorders (i.e., contamination phobia, social phobia, and spider phobia). The reason for this was to allow for a greater understanding of how these various indices play a role in a broad range of anxiety problems. Similarly, studies have conducted meta-analyses to demonstrate how anxiety problems overarchingly respond to threatening stimuli, which has shown the utility of evaluating AB fluctuation in anxiety (Armstrong et al., 2012; Zvielli et al., 2015; Badura-Brack et al., 2016). Moreover, the research domain criteria (RDoC), an interdisciplinary approach to psychopathology (Insel et al., 2010), states that anxiety-related disorders function as a negatively valanced system, which involves processes related to threat or loss (Fernandez et al., 2016). The RDoC allows researchers to trans-diagnostically consider common systems among various anxiety problems (Cuthbert et al., 2015). As such, attention processing, as a continuous variable, and its multiple components via static and temporal fluctuation are important to investigate across various anxiety disorders. For the purposes of this study, the goal was to determine the incremental utility of the TL-BS and eye tracking ratio fluctuation indices across a spectrum of anxiety problems. Given the sample size of each of our individual groups and the number of predictors included in each of our analyses, our power analysis demonstrated that we would not have enough power to sufficiently conduct our analyses. Further, utilizing a small sample size would reduce the chance of detecting a true effect, "reduce the likelihood that a statistically significant result reflects a true effect," and/or reduce measurement precision (Button et al., 2013; Schönbrodt & Perugini, 2013). Therefore, to better understand the nature of AB in both behavioral RT measures and eye tracking measures, the use of the combined sample was the most appropriate. However, the question remains as to how TL-BS and the overall and temporal eye tracking ratio indices would play a role in each of our contamination phobia, social phobia, and spider phobia groups, as well as other anxiety problems that were not addressed in our study (e.g., panic disorder, generalized anxiety disorder, or trauma-related anxiety symptoms). Each of these anxiety problems have unique features, which may lead to inherent differences in the way each of these groups process threat and is thus, a limitation of our study. Future research should consider specific sample characteristics or new approaches to evaluate symptom specific AB in these individual groups using both behavioral RT measures and eye tracking to further elucidate their specific contributions to the assessment of anxiety disorders.

This study is not without limitations. First, we did not include a comparison group of non-anxious controls. While the literature has shown differences in AB on behavioral RT tasks between anxious and non-anxious individuals, it is important to replicate these findings (Cisler et al., 2010; Heeren et al., 2013; Ouimet et al., 2009). Further, evaluating eye tracking differences between anxious and non-anxious controls is important, especially given the novel eye tracking ratio indices we proposed in this study. Second, we included individuals with mild to moderate levels of their respective anxiety disorder. Future research may consider including more clinical samples, which may produce more apparent differences in AB fluctuation in both TL-BS and temporal eye tracking ratio indices. Third, we did not track the onset and course of anxiety problems. Length of symptoms may be important to disentangle the heterogeneity of anxiety problems. Fourth, this study was cross sectional so causal inferences cannot be concluded. Future research may track these samples over time to evaluate changes in AB fluctuation in both behavioral RT and eye tracking tasks. Future study designs may also implement attention control treatments to evaluate how AB fluctuation changes in behavioral RT and eye tracking measures, in various anxiety problems, before and after training. Fifth, we used general words and pictures related to contamination, social, and spider phobia for both the behavioral RT and eye tracking tasks. Given the heterogeneity of each of these disorders, personally tailored stimuli may be more relevant to the individual and produce more robust results. For example, an individual with contamination phobia who is afraid of contaminated bathrooms, may be shown pictures of dirty toilets, sinks, and bathroom stalls. Sixth, we used different methodologies across our three studies (i.e., words with the dot probe task for the social and contamination phobia studies; pictures with the spatial cueing task for the spider phobia study). We systematically accounted for differences by adjusting the AB-Avg between task paradigms and calculating the z-score. Krujit and colleagues (2015) reported that the use of TL-BS would result in no differences in the calculation of AB fluctuation for both the dot probe and spatial cueing task. Further, meta-analytic studies have shown similar findings across anxiety problems despite methodological variation (Armstrong et al., 2012; Pergamin-Hight et al., 2015). However, future studies should consider consistently using one behavioral task paradigm and either words or pictures as stimuli to allow for more consistency in terms of stimulus presentation (i.e., the location of where words/pictures are shown on the screen) and key presses (e.g., E and F or 1 and 2). This will allow for a more direct comparison of anxiety problems. Seventh, our descriptive analyses showed that the mean of the three novel eye tracking ratio indices were in the 90^{th} percentile range. This may suggest a ceiling effect of the vigilance/avoidance pattern or a non-parametric/skewed data set, which is a limitation of our study. Regardless, the key findings are driven by the temporal fluctuation eye tracking ratio indices, which explained an additional amount of the variance in overall symptom severity. In contrast, the overall fluctuation eye tracking ratio indices did not significantly explain an additional amount of the variance. Therefore, more work must be conducted to develop ways to further improve the psychometric properties of these novel eye tracking ratio indices. Finally, we focused our analyses on threatening stimuli given our interests in anxiety psychopathology. However, future studies may consider evaluating AB fluctuation in non-threatening stimuli, which may provide a better understanding of how individuals with anxiety utilize non-threatening stimuli during AB fluctuation.

Conclusion

Overall, attention control is essential to cognitive functioning (Eysenck et al., 2007). The research is beyond a behavioral phenomenon and shows neural underpinnings of attention including the alerting (subcortical), orienting (posterior), and executive (anterior) networks – all of which are important for attention allocation (Posner et al., 2012). Dysfunctional attention control has been associated with psychopathology, like anxiety, especially as it relates to AB to threatening cues (Corbetta & Shulman, 2002; Eysenck et al., 2007). This has been found using behavioral RT tasks like the dot-probe and spatial cueing tasks (MacLeod, et al., 1986). Accordingly, AB modification strategies via behavioral RT measures have been utilized as interventions and have shown an improvement in AB to threat, and in some cases, anxiety-related symptoms (Amir et al, 2009, Hazen et al., 2009; Bar-Haim, 2010). However, traditional AB measurements within AB modification studies are not perfect, and variable findings exist (Zvielli, et al., 2015). As such, innovative behavioral RT measures such as TL-BS have become a crucial area of research in order to evaluate AB fluctuation in a reliable and valid way (Zvielli et al., 2014; Zvielli et al., 2015). Further, psychophysiological measures like eye tracking have become a promising avenue of research, which can be used to more precisely evaluate differences in AB (Armstrong & Olatunji, 2012; Richards et al., 2014). Our results showed that AB fluctuation indices via TL-BS and temporal eye tracking ratio indices significantly predict anxiety symptom severity. Overall, the findings suggest that beyond traditional measures of AB to threat, temporal AB fluctuation indices should be given greater consideration when developing future theoretical, assessment, and intervention work related to anxiety disorders. Further research must be done to replicate these findings to better understand the diverse roles of attention on anxiety.

V. References

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Table 1. Basic Demographic and Clinical Characteristics

	Contamination Phobia (n=52)	Social Phobia (n=43)	Spider Phobia (n=72)	Combined Sample (n=167)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age	23.87 (8.08)	26.23 (12.30)	22.03 (7.16)	23.68 (9.12)
Sex				
Male	29.60% (n=16)	37.20% (n=16)	23.60% (n=17)	29.00% (n=49)
Female	66.70% (n=36)	62.80% (n=27)	76.40% (n=55)	69.80% (n=119)
Race				
Asian or Pacific Islander	9.30% (n=5)	0% (n=0)	8.30% (n=6)	6.50% (n=11)
Black or African Am.	16.70% (n=9)	9.30% (n=4)	9.70% (n=7)	11.80% (n=20)
White	64.80% (n=35)	81.40% (n=35)	77.80% (n=56)	74.60% (n=126)
Native American	1.90% (n=1)	0% (n=0)	2.8% (n=2)	1.80% (n=3)
Multiracial	3.70% (n=2)	4.70% (n=2)	0% (n=0)	2.40% (n=4)
Ethnicity				
Hispanic or Latino	3.70% (n=2)	11.60% (n=5)	11.1% (n=8)	8.90% (n=15)
Not Hispanic or Latino	96.15% (n=50)	88.37% (n=38)	88.90% (n=64)	91.10% (n=154)
Questionnaires				
OCI-R Washing	6.58 (3.23)			6.58 (3.23)
LSAS Total		62.65 (26.96)		62.65 (26.96)
FSQ Total			67.42 (25.65)	67.42 (25.65)
DASS-21 Total	33.45 (8.90)	41.16 (27.17)	11.03 (10.75)	25.75 (20.87)
Depression	9.69 (3.33)	13.11 (11.32)	3.01 (4.37)	7.69 (7.90)
Anxiety	11.04 (3.33)	10.51 (8.86)	3.00 (3.71)	7.44 (6.65)
Stress	13.04 (3.95)	17.53 (9.94)	5.07 (4.30)	10.77 (8.06)

Note. OCI-R Washing = Obsessive Compulsive Inventory-Revised Washing Subscale; LSAS Total = Liebowitz Social Anxiety Scale Total Score; FSQ Total = Fear of Spiders Questionnaire Total Score; DASS-21 = Depression, Anxiety, and Stress Scale

Table 2. Correlation Table and Basic Descriptive Data of Individual Eye Tracking Indices, Overall Fluctuation Ratio Eye Tracking Indices, and Temporal Fluctuation Ratio Eye Tracking Indices

	1	Mean (SD)	2	3	4	5	6	7	8	9	10	11	12	13
1. Overall Sx. Sev.		0 (1.00)												
2. DASS Dep.	.26**	7.69 (7.90)												
3. DASS Anx.	.35**	7.44 (6.65)	.77**											
4. AB Avg.	-.05	-.06 (1.03)	.06	.11										
5. TL-BS	.20*	.08 (1.91)	.10	.04	-.17*									
6. NDT	-.14	.49 (.14)	-.01	-.12	-.10	-.02								
7. FC	-.07	.48 (.13)	-.01	-.05	-.11	.03	.94**							
8. AFD	-.05	.50 (.07)	-.001	-.001	-.09	.07	.64**	.74**						
9. DT/NDT	-.10	.93 (.12)	.01	.07	-.11	.16	.27**	.40**	.47**					
10. GC/FC	.16*	.58 (.13)	-.01	.01	.12	-.02	-.63**	-.65**	-.44**	-.54**				
11. AFD/FT	.22**	.31 (.14)	-.11	.001	.21*	-.03	-.68**	-.67**	-.45**	-.69**	.78**			
12. SD DT/NDT	.16*	.34 (.13)	-.16*	-.06	.09	.07	-.34**	-.29**	-.04	-.06	.35**	.50**		
13. SD GC/FC	.18*	.34 (.10)	-.02	.10	.02	-.07	-.37**	-.33**	-.09	-.23**	.40**	.46**	.47**	
14. SD AFD/FT	.19*	.33 (.12)	.03	.11	.04	-.01	-.51**	-.47**	-.21**	-.26**	.43**	.51**	.52**	.84**

Note: Overall Sx. Sev = Overall Symptom Severity among Contamination, Social, and Spider Phobia Samples; DASS Dep. = DASS Depression Subscale; DASS Anx. = DASS Anxiety Subscale; AB Avg. = Traditional Attention Bias Value; TL-BS = Trial-Level Bias Score Covariation Score; NDT = Net Dwell Time (percentage toward threat compared to other stimuli across entire 30 seconds); FC = Fixation Count (percentage toward threat compared to other stimuli across entire 30 seconds); AFD = Average Fixation Duration (percentage toward threat compared to other stimuli across entire 30 seconds); DT/NDT = Dwell Time divided by Net Dwell Time across entire 30 seconds; GC/FC = Glance Count divided by Fixation Count across entire 30 seconds; AFD/FT = Average Fixation Duration divided by Fixation across entire 30 seconds; SD DT/NDT = the standard deviation of 6, five-second time bins for Dwell Time divided by Net Dwell Time; SD GC/FC = the standard deviation of 6, five-second time bins for Glance Count divided by Fixation Count; SD AFD/FT = the standard deviation of 6, five-second time bins for Average Fixation Duration divided by Fixation Time.
** $p < .01$, * $p < .05$.

Table 3: Hierarchical Regression Predicting Overall Symptom Severity with the Eye Tracking Individual Indices and Overall Fluctuation Ratio Eye Tracking Indices

	Model 1				Model 2				Model 3			
Variable	*B*	*β*	*t*	*p*	*B*	*β*	*t*	*p*	*B*	*β*	*t*	*p*
DASS Dep.	-0.004	-0.03	-0.23	0.82	-0.002	-0.02	-0.13	0.9				
DASS Anx.	0.051	0.37	2.82	0.006**	0.05	0.35	2.48	0.01*				
AB Avg.					-0.07	-0.07	-0.9	0.37				
TL-BS.					0.17	0.18	2.17	0.03*				
NDT					-2.65	-0.39	-1.43	0.15				
FC					2.53	0.34	1.15	0.25				
AFD					-0.9	-0.06	-0.53	0.6				
R^2		0.12		<.001**		0.18		0.1				
F for change in R^2		9.15				1.87						
DASS Dep.	0.001	0.005	0.04	0.97	0.004	0.03	0.23	0.82				
DASS Anx.	0.05	0.34	2.51	0.01*	0.05	0.35	2.46	0.02*				
AB Avg.					-0.11	-0.12	-1.47	0.15				
TL-BS					0.17	0.18	2.1	0.04*				
NDT					-0.33	-0.05	-0.09	0.93				
FC					2.07	0.26	0.52	0.61				
AFD					-1.8	-0.1	-0.68	0.5				
DT/NDT					-0.04	-0.003	-0.03	0.98				
GC/FC					0.17	0.02	0.17	0.86				
AFD/FT					2.3	0.32	1.88	0.06				
R^2		0.12		<.001**		0.22		0.04*				
F for change in R^2		8.84				2.08						

Note: DASS Dep. = DASS Depression Subscale; DASS Anx. = DASS Anxiety Subscale; AB Avg. = Traditional Attention Bias Value; TL-BS = Trial-Level Bias Score Covariation Score; NDT = Net Dwell Time (percentage toward threat compared to other stimuli across entire 30 seconds); FC = Fixation Count (percentage toward threat compared to other stimuli across entire 30 seconds); AFD = Average Fixation Duration (percentage toward threat compared to other stimuli across entire 30 seconds); DT/NDT = Dwell Time divided by Net Dwell Time across entire 30 seconds; GC/FC = Glance Count divided by Fixation Count across entire 30 seconds; AFD/FT = Average Fixation Duration divided by Fixation across entire 30 seconds; SD DT/NDT = the standard deviation of 6, five-second time bins for Dwell Time divided by Net Dwell Time; SD GC/FC = the standard deviation of 6, five-second time bins for Glance Count divided by Fixation Count; SD AFD/FT = the standard deviation of 6, five-second time bins for Average Fixation Duration divided by Fixation Time.

Table 4: Hierarchical Regression Predicting Overall Symptom Severity with the Temporal Fluctuation Ratio Eye Tracking Indices

	Model 1				Model 2				Model 3			
DASS Dep.	-0.004	-0.03	-0.23	0.82	-0.002	-0.02	-0.13	0.9	0.001	0.01	0.08	0.94
DASS Anx.	0.05	0.37	2.82	0.01*	0.049	0.35	2.48	0.01*	0.05	0.37	2.62	0.01*
AB Avg.					-0.07	-0.07	-0.9	0.37	-0.08	-0.09	-1.12	0.27
TL-BS					0.17	0.18	2.17	0.03*	0.16	0.17	2.05	0.04*
NDT					-2.65	-0.39	-1.43	0.15	-1.5	-0.22	-0.8	0.42
FC					2.53	0.34	1.15	0.25	2.16	0.29	0.99	0.32
AFD					-0.9	-0.06	-0.53	0.6	-1.7	-0.12	-1	0.32
SD DT/NDT									1.65	0.23	2.58	0.01*
R^2		0.12		<.001**		0.18		0.1		0.22		0.01*
F for change in R^2		9.15				1.87				6.67		
DASS Dep.	0.002	0.02	0.12	0.91	-0.003	-0.03	-0.2	0.84	<.001	<.001	-0.001	1
DASS Anx.	0.05	0.34	2.56	0.01*	0.05	0.4	2.77	0.01*	0.05	0.39	2.76	0.007**
AB Avg.					-0.13	-0.14	-1.67	0.1	-0.12	-0.13	-1.57	0.12
TL-BS					0.2	0.21	2.5	0.001**	0.22	0.23	2.82	0.006**
NDT					-4.62	-0.65	-1.06	0.29	-1.4	-0.2	-0.32	0.75
FC					4.62	0.56	1.04	0.3	2.42	0.29	0.55	0.59
AFD					1.54	0.07	0.47	0.64	-0.56	-0.03	-0.17	0.87
SD GC/FC									2.36	0.24	2.53	0.01*
R^2		0.13		<.001**		0.2		0.06		0.24	0.01	
F for change in R^2		9.57				2.23				6.4	-0.32	
DASS Dep.	0.002	0.02	0.12	0.91	-0.003	-0.03	-0.2	0.84	-0.005	-0.04	-0.32	0.75
DASS Anx.	0.05	0.34	2.56	0.01*	0.05	0.4	2.77	0.007**	0.06	0.42	2.99	0.003**
AB Avg.					-0.13	-0.14	-1.67	0.1	-0.13	-0.13	-1.63	0.11
TL-BS					0.2	0.21	2.5	0.01*	0.21	0.22	2.76	0.007**
NDT					-4.62	-0.65	-1.06	0.29	-1.34	-0.18	-0.3	0.77
FC					4.62	0.56	1.04	0.3	2.45	0.3	0.55	0.59
AFD					1.54	0.07	0.47	0.64	-0.36	-0.02	-0.11	0.92
SD AFD/FT						0.2			1.75	0.22	2.22	0.03
R^2		0.13		<.001**		0.2		0.06		0.23		0.03*
F for change in R^2		9.57				2.23				4.96		

Note: Overall Sx. = DASS Dep. = DASS Depression Subscale; DASS Anx. = DASS Anxiety Subscale; AB Avg. = Traditional Attention Bias Value; TL-BS = Trial-Level Bias Score Covariation Score; NDT = Net Dwell Time (percentage toward threat compared to other stimuli across entire 30 seconds); FC = Fixation Count (percentage toward threat compared to other stimuli across entire 30 seconds); AFD = Average Fixation Duration (percentage toward threat compared to other stimuli across entire 30 seconds); DT/NDT = Dwell Time divided by Net Dwell Time across entire 30 seconds; GC/FC = Glance Count divided by Fixation Count across entire 30 seconds; AFD/FT = Average Fixation Duration divided by Fixation across entire 30 seconds; SD DT/NDT = the standard deviation of 6, five-second time bins for Dwell Time divided by Net Dwell Time; SD GC/FC = the standard deviation of 6, five-second time bins for Glance Count divided by Fixation Count; SD AFD/FT = the standard deviation of 6, five-second time bins for Average Fixation Duration divided by Fixation Time.

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

Table 5. Differences in the assessment of attention dyscontrol in TL-BS and temporal eye tracking indices.

	Attention dyscontrol in TL-BS	Attention dyscontrol in (temporal) eye tracking indices
Participant's task goal/motivation	Process a neutral probe as quickly and accurately as possible	No goal; look at the screen like you're viewing a magazine
	Performance evaluation	No evaluative component
Task structure	Detecting and identifying irrelevant meaningless cues	Previewing AOI's with no specific task demands or no correct/wrong responses
	Actual emotional or neutral pictures only provide a context	Unstructured and voluntary
	Arbitrary forced choice measure	Free viewing measure
Key index for attention control	Do you maintain stable attention control towards a neutral probe when emotional stimuli are present?	Do you maintain stable attention control towards emotional pictures themselves?
Continuity of attention processing	Repeated, snapshot-like assessment of attention on the main target	Continuous assessment of attention to emotional distractors/surroundings
Key questions	How do you control your attention in processing the main neutral cognitive target?	How do you control your attention in processing emotional distractors?

Abel S. Mathew

Curriculum Vitae

EDUCATION

Alpert Medical School of Brown University, Providence, RI 2021 – Present
Clinical Resident/Intern in Neuropsychology

University of Wisconsin – Milwaukee, Milwaukee, WI 2022 (expected)
Doctoral Candidate in Clinical Psychology
Minor: Quantitative Research Methods
Advisor: Han-Joo Lee, Ph.D.
Dissertation: *Temporal dynamics of attention bias in anxiety: An eye-tracking study (defense passed June 2021)*

M.S. Psychology 2019
Advisor: Han-Joo Lee, Ph.D.
Thesis: *Evaluating the effect of approach-avoidance training on action tendencies for individuals with skin picking disorder*

Texas A&M University, College Station, TX 2016
B.S. Psychology
Minor: Neuroscience
Honors Thesis: *Anxiety sensitivity in adults with body-focused repetitive behaviors*

FELLOWSHIPS

Graduate Student Excellence Fellowship ($2,000) 2020
UWM Summer Graduate Research Fellowship ($3,300) 2020
Advanced Opportunity Program (AOP) Fellowship ($49,000) 2017 – 2020
UWM Summer Graduate Research Fellowship ($4,266) 2018

HONORS/AWARDS/GRANTS

TLC for BFRBs Poster Presentation Award ($1,000) 2020
UWM Three Minute Thesis (3MT) Winner – 1st place ($1,500) 2019
Sigma Xi Grants in Aid of Research (GIAR) ($1,000) 2019
ABCT Elsie Ramos Memorial Research Award 2019
Association of Clinical and Cognitive Neuroscience Travel Grant ($4,642) 2016 – 2020
UWM Graduate Student Travel Award ($2,000) 2016 – 2019
Association of Graduate Students in Psychology Travel Grant ($1,048) 2016 – 2017
Chancellor's Graduate Student Award – UWM ($7,000) 2016 – 2018
Magna Cum Laude – Texas A&M University 2016
Psi Chi National Honor Society in Psychology 2014 – 2016

PUBLISHED PEER-REVIEWED JOURNAL ARTICLES

Mathew, A.S., Larsen, S.E., Lotfi, S., Bennett, K.P., Larson, C.L., Dean, C., & Lee, H.-J. (2021). Association between spatial working memory and re-experiencing symptoms in PTSD. *Journal of Behavior Therapy and Experimental Psychiatry.*

Webb, E.K., Ward, R.T., **Mathew, A.S.,** Weis, C.N., Price, M., TA deRoon-Cassini, & Larson, C.L. (2021). Role of Pain and Socioenvironmental Factors on PTSD Symptoms in Traumatically Injured Adults: A One-Year Prospective Study. *Journal of Trauma and Acute Care Surgery.*

Mathew, A.S., & Lee, H.-J. (2021). Evaluating the role of the approach-avoidance task on action tendencies in individuals with skin picking disorder. *Journal of Behavioral Addictions.*

Mathew, A.S., Harvey, A.M., & Lee, H.-J. (2021). Development of the social concerns measure in individuals with body-focused repetitive behaviors (SCIB) scale. *Journal of Psychiatric Research. 135,* 218-229.

Mathew, A.S., Davine, T.P., Snorrasson, I., Houghton, D.C., Woods, D.W., & Lee, H.-J. (2020). Body-focused repetitive behaviors and non-suicidal self-injury: A comparison of clinical characteristics and symptom features. *Journal of Psychiatric Research. 124,* 115-122.

Ricketts, E. J., Snorrason, I., **Mathew, A. S.,** Sigurvinsdottir, E., Ólafsson, R. P., Woods, D. W., & Lee, H.-J. (2020). Heightened sense of incompleteness in excoriation (skin-picking) disorder. *Cognitive Therapy and Research.*

Berlin, G.S., **Mathew, A.S.,** Lotfi, S., Harvey, A.M., Lee, H.J. (2020). Evaluating the cognitive effects of online transcranial direct current stimulation (tDCS) and emotional n-back training. *Neuroregulation. 7,* 129-140.

Lotfi, S., Rostami, R. Shokoohi-Yekta, M., Ward, R.T., Motamed-Yeganeh, N., **Mathew, A.S.,** Lee, H.-J. (2020). Effects of computerized cognitive training for children with dyslexia: An ERP study. *Journal of Neurolinguistics, 55,* 100904.

Acca, G.M., **Mathew, A.S.**, Jin J., Maren S., & Nagaya N. (2017). Allopregnanolone induces state-dependent fear via the bed nucleus of the stria terminalis. *Hormones and Behavior, 89,* 137-144.

Houghton, D.C., **Mathew, A.S**., Twohig, M.P., Saunders, S., Cahill, S.P., Franklin, M.E., Compton, S.N., Neal-Barnett, A., & Woods, D.W. (2016). Trauma and trichotillomania: A tenuous relationship. *Journal of Obsessive Compulsive and Related Disorders, 11,* 91-95.

MANUSCRIPTS IN PREPARATION

Mathew, A.S., & Lee, H.-J. (in preparation). Implicit attitudes towards skin related stimuli in individuals with excoriation disorder: An investigation using the implicit association task.

Turkel, J.E., **Mathew, A.S.,** Harvey, A.M., & Lee, H.J. (in preparation). Combining attention bias pre-training with exposure therapy for individuals with a fear of spiders.

Lotfi, S., Ward, R.T., **Mathew, A.S.,** Shokoohi-Yekta, M., Rostami, R. Motamed-Yeganeh, N., Lee, H.-J. (under review). Limited visual working memory capacity in children with dyslexia: An ERP study.

PUBLISHED BOOK CHAPTERS AND REVIEWS

Mathew, A.S., Snorrason, I., Falkenstein, M.J., & Lee, H.-J. (in print). Advances in treating non-OCD OCRDs. In E. Storch, D. McKay, & J. Abramowitz (Eds). *Complexities in obsessive compulsive and related disorders: Advances in conceptualization & treatment.* Oxford University Press.

SYMPOSIUM PRESENTATIONS AT (INTER)/NATIONAL CONFERENCES

Mathew, A.S., Snorrason, I., Harvey, A.M., Alexander, J.R., Woods, D.W., & Lee, H.J. (2020, November). Skin Picking and the Approach Avoidance Task. In **A.S. Mathew** & H.J. Lee (Chairs), *Addictive and Repetitive? Evaluating the Behavior Addiction Model in Body-Focused Repetitive Behaviors.* Symposium conducted at the Association for Behavior and Cognitive Therapies, Philadelphia, PA.

POSTER PRESENTATIONS AT (INTER)/NATIONAL CONFERENCES

Mathew, A.S., Jimenez, T., Oleson, S., Gracian, E.I., Kaufman, D., Ghahremani, D.G., & Bilder, R.M. (2020, October). How important is sustained attention in reversal learning and visual task shifting abilities: A canonical correlation analysis in adults. National Academy of Neuropsychology. Chicago, IL.

Arzuyan, A., **Mathew, A.S.,** Rosenblatt, A., Gracian, E.I., & Osmon, D. (2020, October). HVLT-R and BVMT-R embedded performance validity analyses in a healthy non-clinical sample. National Academy of Neuropsychology. Chicago, IL.

Mathew, A.S., Larsen, S.E., Lotfi, S., Bennett, K.P., Larson, C.L., Dean, C., & Lee, H.-J. (2020, February). Deficits in spatial working memory and re-experiencing symptoms in veterans with PTSD. International Neuropsychological Society. Denver, CO.

Mathew, A.S., Gracian, E.I., Torres, J.R., Jimenez, T., Kaufman D., Ghahremani, D.G., & Bilder, R.M. (2020, February). Memory and executive functioning contributions to deterministic reversal learning in adults. International Neuropsychological Society. Denver, CO.

Mathew, A.S., & Lee, H.-J. (2019, November). Prediction of urges to skin pick using gaze approach indices. Association for Behavioral and Cognitive Therapies. Atlanta, GA.

Mathew, A.S., Harvey, A.M., Davine, T.P., & Lee, H.-J. (2019, November). Evaluating the utility of the social concerns scale for body focused repetitive behaviors. Association for Behavioral and Cognitive Therapies. Atlanta, GA.

***Mathew, A.S.,** Rech, M.A. & Lee, H.-J. (2019, November). Evaluating the role of approach avoidance training on action tendencies in individuals with skin picking disorder. Association for Behavioral and Cognitive Therapies. Atlanta, GA.

**Elsie Ramos Poster Award*

*Rech, M.A., **Mathew, A.S.,** Harvey, A.M., & Lee, H.-J. (2019, November). Social anxiety: Predicting symptoms of pathological skin picking. Association for Behavioral and Cognitive Therapies. Atlanta, GA.

**Mentored undergraduate research assistant*

Mathew, A.S., & Lee, H.-J. (2018, November). Social concerns in individuals with body-focused repetitive behaviors. Association for Behavioral and Cognitive Therapies, Washington, D.C.

Berlin, G.S., **Mathew, A.S.**, Davine, T.P., & Lee, H.-J. (2018, November). Unpacking inhibitory differences in OCD and trichotillomania. Association for Behavioral and Cognitive Therapies, Washington, D.C.

Lotfi, S., Ayazi, M., Bennett, K.P, Dommer, L., **Mathew, A.S.**, Larson, C.L., & Lee, H.-J. (2018, March). The prefrontal theta activity during thought suppression compared with thought free predicts lower working memory and higher worry symptoms and rumination in high trait anxiety. Cognitive Neuroscience Society, Boston, MA.

Mathew, A.S., Davine, T.P., Harvey, A.M., Snorrasson, I, & Lee, H.-J. (2017, November). The role of incompleteness in body-focused repetitive behaviors and non-suicidal self-injury. Association for Behavioral and Cognitive Therapies, San Diego, CA.

Berlin, G.S., Davine, T.P., **Mathew, A.S.**, & Lee, H.-J. (2017, November). Error monitoring and stop-signal performance in the context of OCD. Association for Behavioral and Cognitive Therapies, San Diego, CA.

Mathew, A.S., Houghton, D.C., Balsis, S., & Woods, D.W. (2016, November). Anxiety sensitivity in adults with body-focused repetitive behaviors. Association for Behavioral and Cognitive Therapies, New York City, NY.

Mathew, A.S., Houghton, D.C., Twohig, M.P., Saunders, S., Cahill, S.P., Franklin, M.E., Compton, S.N., Neal-Barnett, A., & Woods, D.W. (2015, November). The meditational role of depressive symptoms in the relationship between trauma and trichotillomania. Association for Behavioral and Cognitive Therapies, Chicago, IL.

Franklin, M.R., **Mathew, A.S.**, Houghton, D.C., Bauer, C.C., Woods, D.W., Twohig, M.P., Compton, S.N., Saunders, S.M., Neal-Barnett, A.M., & Franklin, M.E. (2014, November). Examining the psychometric properties of photographic measures of trichotillomania. Association for Behavioral and Cognitive Therapies, Philadelphia, PA.

MENTORED POSTER PRESENTATIONS AT STATE/LOCAL CONFERENCES

*Conrad R., **Mathew, A.S.,** Lotfi, S., & Lee, H.-J. (2020, May). The effect of rumination on PTSD in veterans exposed to war zones. Undergraduate Research Symposium-UWM. Milwaukee, WI.

*Pandya, A., **Mathew, A.S.,** Lotfi, S., & Lee, H.-J. (2020, May). The relationship between attention focus and hyperarousal symptoms in PTSD. Undergraduate Research Symposium-UWM. Milwaukee, WI.

*Abud, A., **Mathew, A.S.,** Harvey, A.M., Lotfi, S. & Lee, H.-J. (2020, May). The relationship between factors of impulsivity and obsessive-compulsive symptoms in an analogue sample. Undergraduate Research Symposium-UWM. Milwaukee, WI.

Rech, M.A., **Mathew, A.S., & Lee, H.-J. (2020, May). Nail biting and nail picking: A comparison of related behaviors. Undergraduate Research Symposium-UWM. Milwaukee, WI.

*Rech, M.A., **Mathew A.S.,** *Michalski, C, & Lee, H.-J. (2019, May). Fixation of irregular skin stimuli in individuals with pathological skin picking. Undergraduate Research Symposium-UWM. Milwaukee, WI

**Mentored undergraduate research assistants*

***Outstanding poster award*

AD HOC JOURNAL REVIEWER

Cognitive Behavior Therapy (under supervision of Han-Joo Lee, PhD)

Journal of Cognitive Psychology (under supervision of Han-Joo Lee, PhD)

RESEARCH EXPERIENCE

Neurocircuitry of Neuropsychiatric Disorders 2021 - 2022

Butler Hospital

Internship Research Placement

Supervisor: Nicole McLaughlin, Ph.D.

- Obsessive Compulsive Disorder: Evaluate response inhibition performance in participants (1) of the OCD Collaborative Genetic Association Study (OCGAS) and (2) who engaged in aerobic exercise as an adjunct intervention for OCD.
- Measure the association between childhood trauma and OCD symptomology.
- Neuromodulation: Evaluate response inhibition differences among OCD patients who engaged in transcranial direct current stimulation (tDCS) and transcranial magnetic stimulation (TMS).

Anxiety Disorders Lab 2016 - 2022

Department of Psychology, University of Wisconsin-Milwaukee

Graduate Researcher

Supervisor: Han-Joo Lee, Ph.D.

- Evaluating neuropsychological underpinnings of adult psychopathology (e.g., OCRDs, PTSD, anxiety-related disorders) via technological assessments and interventions (e.g., working memory, attention bias, response inhibition)
- Obsessive-compulsive related disorders (OCRDs): (1) determined whether response inhibition training can reduce symptoms of OCD and trichotillomania, (2) developed a psychometric measure that reflects social concerns in those with body-focused repetitive behaviors, (3) conducted a randomized, placebo-control clinical trial to determine whether the approach-avoidance task (AAT) can reduce action tendencies and urges to pick in those with skin picking disorder *(Master's Thesis)* (4) evaluated differential activation of the dorsolateral prefrontal cortex using functional near infrared spectroscopy among individuals with skin picking before and after completion of the AAT
- Posttraumatic stress disorder (PTSD): (1) determined whether working memory (WM) training can reduce PTSD symptoms (2) evaluated specific WM components as it relates to PTSD symptoms (3) analyzed data to disentangle the relationship between attention control and PTSD symptom clusters

- Anxiety-related disorders: (1) evaluated whether transcranial direct current stimulation (tDCS) could improve WM capacity in those with heightened anxiety (2) to evaluate attention bias fluctuation in those with social phobia, contamination phobia, and spider phobia via the dot-probe task and novel eye-tracking fluctuation indices *(Dissertation Project)*

Memory Disorders Clinical Translation Science Team 2020 - Present
Medical College of Wisconsin
Graduate Research Assistant
Supervisor: Laura Umfleet, Psy.D.

- Translation research that evaluates patients with mild cognitive impairment (MCI) and dementia who underwent neuroimaging (i.e., volumetric measures and DTI) within 1 year of a comprehensive neuropsychological evaluation.
- Assisted in pre-processing images for data analysis using Computational Anatomy Toolbox (CAT12) for SPM.
- Skills include aligning images, voxel-based morphometry (VBM) and surface-based morphometry (SBM) analysis, and quality checks.

CLINICAL NEUROPSYCHOLOGY/ASSESSMENT EXPERIENCE

Neuropsychological Assessment Rotation 2021 – Present
Clinical Resident/Intern in Neuropsychology
Providence VA Medical Center
Supervisors: Megan Spencer, Ph.D., ABPP-CN, Donald Labbe, Ph.D., ABPP-CN, & Ryan Van Patten, Ph.D.

- Conducted neuropsychological assessments for individuals with neurodegenerative disorders, neurologic conditions, decision making capacity, psychiatric disorders, attention disorders, and learning disabilities.
- Conducted military deployment-related traumatic brain injury assessments in the Polytrauma/TBI clinic.
- Provided empirically validated psychoeducational cognitive training protocols for patients with traumatic brain injury.
- Ages 22 – 93
- Presented and participated in weekly "Cranium Club" meetings, and weekly neuropsychology didactics

Advanced Practicum in Neuropsychology 2020 – 2021
Milwaukee VA Medical Center (Zablocki), Milwaukee, WI
Supervisors: Kathleen Patterson, Ph.D., ABPP-CN, Eric Larson, Ph.D., ABPP-CN, Angela Gleason, Ph.D., ABPP-CN, & Leia Vos, Ph.D.

- Conducted clinical neuropsychological assessments and wrote reports for Veterans with several comorbidities and psychiatric conditions in the outpatient neuropsychology clinic.
- Conditions included major and mild cognitive impairment, multiple sclerosis, Parkinson's disease, personality disorders, ADHD, learning disabilities, and bipolar disorder
- Ages: 29 – 92 years
- Participated in weekly didactics and case conference

Advanced Practicum in Neuropsychology 2019 – 2020
Medical College of Wisconsin (MCW)/Froedtert, Milwaukee, WI
Supervisors: Sara Swanson, Ph.D., ABPP-CN, Julie Bobholz, Ph.D., ABPP-CN, Michael McCrea, Ph.D., ABPP-CN, Laura Umfleet, Psy.D., ABPP-CN, Sara Pillay, Ph.D., Julie Janecek, Ph.D., ABPP-CN, Lindsay Nelson, Ph.D., ABPP-CN, & Alissa Butts, Ph.D., ABPP-CN

- Conducted clinical neuropsychological assessments via paper-pencil testing and technological assessments via iPads/Q-interactive, engaged in telehealth intakes and feedbacks, and wrote reports for patients in the following neuropsychology clinics: Neuro-oncology, Memory Disorders, Traumatic Brain Injury, Epilepsy, and General Clinical Service
- Ages: 18 – 91 years
- Participated in weekly didactics, neurology grand rounds, tumor-board conference, and case conference

Learning Disability Specialty Clinic 2018 –2020
Program Assistant/Psychometrist
UWM Psychology Clinic, Milwaukee, WI
Supervisor: David Osmon, Ph.D.

- Conducted clinical neuropsychological assessments for UWM students and individuals in the community
- Involved in the development of assessment telehealth practices within the UWM Psychology Clinic
- Ages: 16 – 65 years
- ***NFL Baseline Assessment Program (BAP):*** Conducted neuropsychological examinations with retired NFL players to evaluate cognitive functioning and memory impairment.
- ***Independent Medical Evaluations (IME):*** Conducted neuropsychological assessment examinations for individuals seeking answers to legal or administrative questions.

Practicum in Assessment/Child Neuropsychology Clinic 2016 – 2018
UWM Psychology Clinic, Milwaukee, WI
Supervisors: Bonita Klein-Tasman, Ph.D. and Kristin Smith, Ph.D.

- Conducted clinical neuropsychological assessments, interviews, and feedback for clients across the lifespan.
- Ages: 10 – 56 years
- Diagnoses: Attention Deficit/Hyperactivity Disorder, Mild Cognitive Impairment, Oppositional Defiant Disorder, and various anxiety and mood disorders

CLINICAL INTERVENTION/THERAPY EXPERIENCE

Post-Deployment and Readjustment Program (PDRP) 2021 – Present
Clinical Resident/Intern Therapy Experience
Providence VA Medical Center
Supervisor: Amy Cameron, Ph.D., ABPP

- Conducted intake assessments and individual therapy to Veterans who have recently returned from active-duty military deployment(s) in Iraq and/or Afghanistan
- Provided time-delimited focused intervention to Veterans with trauma- and stress-related disorders within the Trauma Recovery Service
- Ages 49 – 55
- Diagnoses include comorbid depression, PTSD, ADHD, and/or substance abuse
- Empirically supported treatments: Cognitive Processing Therapy (CPT), Prolonged Exposure (PE), and Acceptance and Commitment Therapy (ACT)

Traumatic Stress and Anxiety Disorders Clinic 2018 – 2021
Student Therapist
UWM Psychology Clinic, Milwaukee, WI
Supervisor: Shawn Cahill, Ph.D.

- Provided individual psychotherapy with university and community clients with social anxiety, depression, adjustment disorder, trichotillomania, and grief

- Ages: 21 – 54 years
- Empirically supported treatments: Cognitive Behavior Therapy (CBT), Exposure and Hierarchy Development, and Habit Reversal Training (HRT)

Cognitive Behavioral Psychotherapy Clinic 2018 – 2021
Student Therapist
UWM Psychology Clinic, Milwaukee, WI
Supervisor: Robyn Ridley, Ph.D.

- Provided individual psychotherapy with university and community clients with social anxiety, chronic pain, and mood disorders.
- Ages: 15 – 27 years
- Empirically supported treatments: CBT, Behavioral Activation, Dialectical Behavior Therapy (DBT), and Acceptance and Commitment Therapy (ACT)

Vertical Teams 2016 – 2019
UWM Psychology Clinic, Milwaukee, WI
Supervisors: Shawn Cahill, Ph.D., Robyn Ridley, Ph.D., and Stacey Nye, Ph.D.
Vertical teams are the method by which students experience "hands on" therapy training.

- Each vertical team consists of 1-2 first year students, 1-2 second year students, 2-3 third year students, and a supervising Psychologist.
- Each student has a defined role on the team. Third year students serve as therapists, second year students conduct psychological assessments, and first year students are asked to observe therapy sessions and learn the empirical basis for intervention with the different cases seen on the team.
- Each team meets weekly to discuss cases with the supervisor.

Practicum in Empirically Supported Interventions Spring 2018
UWM Psychology Clinic, Milwaukee, WI
Supervisor: Shawn Cahill, Ph.D.

- Attended a weekly experiential learning course to receive training in empirically supported treatments (e.g., CBT, exposure therapy, behavioral activation, chain analysis) for DSM-V diagnoses.

Rock Prairie Behavioral Health 2015 – 2016
Mental Health Technician
College Station, TX

- Collaborated with physicians, nurses, and therapists in assessing, guiding, and encouraging patients towards measurable therapeutic outcomes.
- Conducted both formal and informal psycho-educational group therapies.
- Documented clinical observations in electronic medical records, shift reports, and treatment planning meetings.

Student Counseling Helpline 2014 – 2016
Volunteer
Texas A&M University, College Station, TX
Supervisor: Susan Vavra

- Crisis intervention, education, and counseling to callers
- Quickly assessed the nature/intensity of an individual's crisis through active listening skills.
- Developed a therapeutic relationship in a confidential phone call.

CLINICAL SUPERVISION EXPERIENCE

Supervision (Assessment II) 2020 - 2021
UWM Psychology Clinic, Milwaukee, WI
Supervisor: Bonita Klein-Tasman, Ph.D., & Kristin Smith, Ph.D.

- Supervised second- and third-year doctoral students in their assessment practicum as they conducted intakes, testing, and feedback to UWM students and individuals in the community.

Supervision (Cognitive Behavioral Psychotherapy Clinic) Fall 2019
UWM Psychology Clinic, Milwaukee, WI
Supervisor: Robyn Ridley, Ph.D.

- Provided vertical team and individual peer-to-peer therapy supervision for third-year clinical psychology doctoral students.

PROFESSIONAL SERVICE

Association of Neuropsychological Students & Trainees (ANST) 2019 – 2021
Society of Clinical Neuropsychology, Division 40
Graduate Student Representative

- Graduate student representative for the ANST Interest Group at UWM.
- Gathered neuropsychology resources, didactics, and seminars for UWM students.
- Coordinated an 8-week summer neuropsychology seminar in 2019 and 2020 at UWM.

Inter Organizational Practice Committee (IOPC) 2020
Student Volunteer

- Assisted in gathering insurance information, CPT codes, and government mandates surrounding telehealth practices in the Midwest region for neuropsychology providers.

Tic & Obsessive-Compulsive Related Disorders SIG 2017 - 2019
Association of Behavioral and Cognitive Therapies
Vice-Chair

- Assisted in planning the Tic and OCRD SIG's annual meeting.
- Assisted in selecting abstracts for SIG sponsorship and presentations at the SIG poster exhibition at ABCT.
- Collected SIG dues.

Clinical Training Committee (CTC) 2017 – 2019
University of Wisconsin-Milwaukee, Department of Psychology
Graduate Student Representative

- Served as a graduate student representative during bi-weekly meetings with clinical faculty.
- Conveyed feedback from UWM doctoral students regarding admissions, coursework, didactics, and clinic practices.

Association of Clinical and Cognitive Neuroscience (ACCN) 2017 - 2020
University of Wisconsin-Milwaukee, Department of Psychology
Secretary

- Coordinated discussions and trainings with UWM's Student Appropriations Committee.
- Assisted with travel grant applications and grant hearings for academic conferences.

Student SIG 2018
52nd Annual Association of Behavior and Cognitive Therapies
Poster Judge

Getting Into Clinical Psychology Doctoral Programs 2017
51st Annual Association of Behavior and Cognitive Therapies
- Served as a graduate student panelist for individuals interested in applying to clinical psychology graduate programs.

TEACHING EXPERIENCE

Associate Lecturer
University of Wisconsin-Milwaukee, Department of Psychology
- PSYC 407 – Personality Theory (online) Spring 2021
- PSYC 205 – Personality (online) Fall 2020

Guest Lecturer
University of Wisconsin-Milwaukee, Department of Psychology
- PSYC 815 – Clinical Cases in Neuropsychology Fall 2020
- PSYC 842 – Practicum in Assessment I Fall 2018
- PSYC 205 – Personality Spring 2017

Teaching Assistant
University of Wisconsin-Milwaukee, Department of Psychology
- PSYC 205 – Personality Spring 2017
- PSYC 101 - Introduction to Psychology (online) Fall 2016

MENTORSHIP EXPERIENCE

Undergraduate Mentees
University of Wisconsin-Milwaukee
Ryan Conrad (UG-RA) Fall 2019 – Spring 2021
Adriana Abud (UG-RA) Spring 2019 – Spring 2021
Madeline Rech (Post-baccalaureate, SURF) Fall 2018 – Spring 2021
Ashna Pandya (UG-RA) Fall 2019 – Spring 2020
Caitlin Michalski (UG-RA) Fall 2018 – Spring 2019

PROFESSIONAL DEVELOPMENT

Clinical Cases in Neuropsychology Seminar 2017 – 2021
University of Wisconsin-Milwaukee (1-hour, bi-weekly)
Krista Lisdahl, Ph.D.

Professional Development in Psychology 2016 – 2021
University of Wisconsin-Milwaukee *(1-hour weekly)*
Stacey Nye, Ph.D.

APA Telepsychology Practices 101 Webinar Series 2020
American Psychological Association (8-hours)
Marlene Maheu, Ph.D.

Tending to Racial Trauma During Crisis 2020
Inclusive Therapists Online Training (10-hours)
Sam Lee, LPC and Melody Li, LMFT

Neuroimaging Workshop using AFNI 2019
University of Wisconsin-Milwaukee (12-hours)
Andrew Jahn, Ph.D., University of Michigan, Ann Arbor

Eating Disorders Seminar 2017
University of Wisconsin-Milwaukee (8-hours)
Stacey Nye, Ph.D.

PROFESSIONAL MEMBERSHIPS

International Neuropsychological Society (INS) 2019 – Present
Student Member

Society of Clinical Neuropsychology, Division 40 2019 – Present
Student Member, ANST - UWM Representative

Association for Behavioral Cognitive Therapies (ABCT) 2015 - Present
Student Member

Association of Graduate Students in Psychology (AGSIP) 2016 – 2021
University of Wisconsin – Milwaukee
Student Member

REFERENCES

Han-Joo Lee, Ph.D.
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Shawn P. Cahill, Ph.D.
Associate Professor
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University of Wisconsin-Milwaukee
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Alissa Butts, Ph.D., ABPP-CN
Assistant Professor of Neurology
Medical College of Wisconsin
Email: abutts@mcw.edu