Summer 8-10-2017

A Tale of Two Tasks: Comparing Steady-state Visually Evoked Potentials with the Dot Probe as Measures of the Anxiety-Related Threat Bias

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Submitted in partial fulfillment

of the requirements for the degree of

Master of Arts, General Psychology, Hunter College

The City University of New York

2017

Thesis Sponsor:

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Abstract

Research suggests that individuals with anxiety display a threat bias (TB), or preferential attention towards threatening information. Many prior studies have utilized the dot probe, a response-time (RT) based measure of TB. The dot probe, however, has had poor internal consistency and test-retest reliability. Therefore, it is important to explore additional measures of TB. The present study compared two measures of biased attention to threat: TB measured via the dot probe and steady-state visually evoked potentials (ssVEPs), as a continuous measure of visuocortical engagement. ssVEPs entrain the frequency rate of the stimulus an individual is visually attending to. We explored how the anxiety-related TB measured by the dot probe is associated with ssVEPs, and tested the hypothesis that ssVEPs could account for greater variance in anxiety symptoms than the dot probe. Bivariate correlations were run to examine how TB scores on the dot probe were associated with ssVEP difference scores. Hierarchical regressions were conducted to examine if ssVEP difference scores could account for greater variance in anxiety than dot probe TB scores. Forty-four adults (29 females) with moderate self-reported anxiety completed the traditional dot probe, which included angry and neutral faces as cues, and a modified version of the task featuring angry and neutral faces flickering at different frequencies during which EEG was continuously recorded in order to generate ssVEPs. Results showed that TB measured via the dot probe and ssVEP amplitudes were not significantly correlated, suggesting that the dot probe and ssVEPs may index distinct components of attention to threat. In addition, counter to hypotheses, ssVEPs were not able to better account for variance in anxiety than the dot probe. The implications of these findings and future directions for investigating how attention to threat is dysregulated in individuals with anxiety are discussed.

Keywords: threat bias, ssVEP, dot probe, anxiety

A Tale of Two Tasks: Comparing Steady-state Visually Evoked Potentials with the Dot Probe as Measures of the Anxiety-Related Threat Bias

Anxiety disorders are the most prevalent class of mental disorders in the United States with 28.8% of adults suffering from an anxiety disorder at some point in their life (Kessler et al., 2005). To effectively treat anxiety disorders, the nature of anxiety must first be understood. Thus, it is imperative to identify factors that may contribute to the etiology and sustainment of anxiety.

One of these factors is the threat bias (TB), defined as selective and exaggerated attention toward threatening stimuli in the environment relative to neutral stimuli (Cisler & Koster, 2010; Mathews & MacLeod, 2002). TB has been extensively examined as a core cognitive mechanism involved in the maintenance of anxiety (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007; Mogg & Bradley, 1998). Individuals with anxiety exhibit an attentional preference towards information that is threatening in nature, a pattern that is less prevalent in individuals without anxiety and non-clinical samples (Bar-Haim et al., 2007; Puliafico & Kendall, 2006).

One of the most common paradigms used to measure the anxiety-related TB is the dot probe, a reaction time based task developed by MacLeod, Mathews, and Tata (1986). The dot probe is a computer task in which participants are presented with both neutral and valenced stimuli (e.g. a threatening face) that appear simultaneously on different areas of the screen. The stimuli then disappear from the screen and are directly followed by a visual probe (e.g., a dot or an arrow) which appears in the former location of one of the stimuli. Participants are then required to respond as quickly as possible by pressing a button once they see the visual probe. The main variable of interest is the response latency, or how long the participant takes to detect and respond to the visual probe once it appears on the screen. Participants exhibit a TB when response latencies are quicker for threatening stimuli compared to neutral stimuli (Bar-Haim et al., 2007). A great deal of research has shown that individuals with anxiety exhibit an attentional bias towards threatening stimuli on the dot probe task relative to non-anxious individuals (Bradley, Mogg, Falla, & Hamilton, 1998; Cisler & Koster, 2010).

There is also evidence that certain individuals with anxiety display a bias away from threat. This is referred to as a vigilant-avoidant pattern of TB, and involves an initial facilitation to threat followed by a rapid avoidance (Mogg, Bradley, Miles, & Dixon, 2004). Vassilopoulos (2005) found that individuals with high levels of social anxiety had an initial orienting to threat followed by a quick avoidance of threatening stimuli compared to those with low levels of social anxiety. Similarly, Koster, Crombez, Verschuere, Van Damme, and Wiersema (2006) found that anxious individuals displayed a vigilant-avoidant pattern of TB but this effect was only observed in those with high trait anxiety suggesting that anxiety severity may be an important factor in the vigilant-avoidant pattern of TB. Interestingly, this pattern of attentional processing has also been observed in studies that did not use the dot probe. Garner, Mogg, and Bradley (2006) implemented eye tracking measures and found that those with high levels of social anxiety, when under a socially stressful situation, had a quicker initial orienting to emotional stimuli but then disengaged, compared to those with low levels of social anxiety. One interpretation of the vigilance-avoidant pattern of TB is that some individuals with anxiety may be initially hypervigilant for any potentially threatening stimuli in early stages of information processing, but then engage in more strategic processes to disengage from threat to ameliorate the anxiety caused by the threatening stimuli (Cisler & Koster, 2010; Mogg et al., 2004). One way to examine biases away from threat using the dot probe is by calculating threat disengagement scores. Individuals with higher disengagement scores have greater difficulty in separating their attention from threatening stimuli; conversely, those with low disengagement scores are better able to orient attention away from threat (Koster, Crombez, Verschuere, & De Houwer, 2004). Overall, these findings suggest that bias away from threat could be an important pattern in individuals with anxiety.

Despite the dot probe's status as a widely used measure of the anxiety-related TB, there have been questions over the limitations of the task. One significant methodological weakness is that the dot probe only provides information about attention in the moment that an individual consciously detects and responds to the probe. This is a point of concern as attention is often conceptualized as having multiple stages: an early automatic stage where information is processed outside of conscious awareness, and a later more strategic stage where information is processed with more purposeful intent (Cisler & Koster, 2010). Responses on the dot probe may only capture attention that is reflective of the stage of processing that an individual is in, rather than providing a more complete view of how the individual processes threatening information over time. For example, an individual may have an initial orienting towards a threatening stimulus during the early automatic stages of attention processing, but may then display a bias away from threat in later and more strategic stages of processing akin to the vigilant-avoidant pattern of TB. The dot probe may not be sensitive to detecting more complex patterns of attention to threat.

There have also been some doubts over the validity and reliability of the dot probe. Schmukle (2005) examined the validity of the task in a non-clinical sample by having participants perform the task twice across the span of a week and found that not only did the task lack internal consistency based on split-half correlations, but that it featured poor test-retest reliability as well. Price and colleagues (2015) also examined the stability of the dot probe as a measure of TB using both clinically anxious and non-anxious participants and found that the reliability of reaction time as an index of bias was generally moderate to low at best. The researchers recommended utilizing supplementary measures of attention such as eye-tracking, which may potentially improve the validity of the dot probe in measuring TB. Research with eye tracking has been promising with anxious individuals displaying greater attention towards threatening stimuli during visual tasks (Armstrong & Olatunji, 2012), which is consistent with what research with reaction time based measures have shown. However, one weakness of eye tracking measures is that they are overly reliant on the measurement of saccades, or rapid movements of the eyes between two points, and may not be able to capture subtler covert shifts in attention. Thus, a more sophisticated continuous measure of visual attention is necessary.

Steady-state visually-evoked potentials (ssVEPs) are electrophysiological responses in the brain that occur when an individual views a rapidly flickering visual stimulus (e.g. a flashing light). The ssVEP paradigm is remarkable as an individual's cortical response mirrors the frequency rate (how fast the stimulus flickers) of the target stimulus; this neural response can then be measured using electroencephalography (EEG), a non-invasive method of studying the electrical activity of the brain. ssVEPs can be used as powerful tools in attentional research providing a way to continuously measure what an individual is attending to (Norcia, Appelbaum, Ales, Cottereau, & Rossion, 2015). Higher amplitudes in the specific frequency bin of the target stimulus is interpreted as greater visuocortical engagement and sensory activation in response to the stimulus (Andersen & Müller, 2010; McTeague, Shumen, Wieser, Lang, & Keil, 2011).

There is a great deal of evidence for ssVEPs being a strong neural correlate of visual attention. For example, a functional magnetic resonance imaging study by Russo et al. (2007)

found that the two primary sources of the ssVEP response were located in the primary visual cortex (V1) and in the middle temporal area (V5). Vialatte, Maurice, Dauwels, and Cichocki (2010) conducted a review of numerous studies on the source location of ssVEPs and found that different cortical regions were indicated based on the study. While the precise neural basis for the generation of ssVEPs is still unclear, the researchers found that the occipital region was consistently implicated in the generation of ssVEPs regardless of the method of measurement (e.g. functional magnetic resonance imaging, EEG, positron emission tomography). More significantly, V1 was the strongest source of the ssVEP response across the majority of studies examined. As the primary visual cortex is crucial in the conscious perception and processing of visual information, these studies suggest that ssVEPs can be used as a strong electrocortical index of visual attention. Indeed, ssVEPs have been reliably used as indicators of neural activity in the visual cortex in studies of attention (Keil et al., 2008; Vialatte et al., 2010).

ssVEPs have been used to study attentional allocation in individuals with anxiety. McTeague and colleagues (2011) examined visual attention in a socially anxious sample and found increased ssVEP amplitudes for angry faces relative to neutral faces, although this effect was only found in the group that reported high levels of social anxiety. Similarly, Wieser, McTeague, and Keil (2011) investigated fluctuations in electrocortical activity of the visual cortex using ssVEPs as participants viewed simultaneously presented facial expressions (i.e. happy, neutral, angry). They found that individuals with high levels of anxiety had greater ssVEP amplitudes in response to angry faces compared to neutral or happy faces. Taken together, these studies complement the large base of dot probe findings that individuals with anxiety exhibit an attentional bias towards threat (Bar-Haim et al., 2007), while also demonstrating that ssVEPs can be an effective tool to measure anxiety-related processing of threatening stimuli.

ssVEPs may be uniquely advantageous over previous approaches to studying the anxiety-related TB because they do not suffer from some of the methodological limitations of the dot probe. While reaction times on the dot probe are only able to capture attentional allocation in one time point, ssVEPs can be measured continuously providing a way to identify how an individual's visual attention changes over the course of a task; this is particularly beneficial as the specifics of how the anxiety-related TB changes throughout the different stages of attentional processing remains unclear (Wieser et al., 2011). Studying neural activity using ssVEPs is also advantageous because the analysis of the EEG data is limited to specific frequency bins (e.g. 10 and 12 Hz) depending on the flicker rates of the stimuli being used. As EEG recordings typically contain background noise and artifacts which interfere with measuring the specific response of interest, ssVEPs are unique because only the noise in the specific frequency bins of the target stimuli is relevant to the analysis; this results in ssVEPs having a higher signal-to-noise ratio (SNR), meaning that the strength of the response is more distinguishable relative to the background noise (Norcia et al., 2015) even if the number of trials is low (Keil et al., 2008). Another significant advantage of ssVEPs in attentional research is that the nature of the ssVEP response makes it well-suited for studies featuring multiple stimuli. Frequency tagging is a technique often paired with ssVEPs in attentional studies involving the presentation of multiple stimuli simultaneously. It requires assigning unique frequency rates to different stimuli. For example, during a task an individual might be presented with two faces on a screen that are flickering at 10 and 15 Hz, where most of their attention is being allocated to the face flickering at 10 Hz. As ssVEPs reflect where an individual is focusing their attention, there would be a neural trace measurable using EEG that would have a higher amplitude in the frequency bin of 10 Hz compared to 15 Hz (Toffanin, de Jong, Johnson, & Martens).

No prior study has explicitly examined how the anxiety-related TB measured by the dot probe is associated with ssVEPs. We investigated whether the two measures were related by comparing the results of a traditional dot probe task with a modified version of the task which utilized ssVEPs. To explore patterns of attention that may involve a bias away from threat, we also compared threat disengagement scores on the dot probe to ssVEPs. We also examined how ssVEPs compared to the dot probe in predicting anxiety. Our prediction is that ssVEPs will be able to account for greater variance in anxiety; given that ssVEPs are a more direct index of visual attention, we expect that they will be a closer link to the level of an individual's anxiety than the dot probe.

Method

Participants

Participants were 44 adults aged 18-38 (*M* = 26.56, *SD* = 6.24) recruited from both the community and from the psychology participant pool at Hunter College, The City University of New York. Participants were pre-screened for moderate anxiety (scores higher than 5; *M* = 6.93, *SD* = 5.09) using the Depression Anxiety Stress Scales 21 (DASS 21; Lovibond & Lovibond, 1995). There were 15 males (34.1%) and 29 females (65.9%). 22 participants (48.8%) were Caucasian, 9 (20%) were Hispanic or Latino, 7 (15.6%) were Black or African American, 5 (11.1%) were Asian, and 1 (2.2%) participant identified as multiple races. All participants underwent a secondary screening during their visit to the lab using the M.I.N.I. International Neuropsychiatric Interview (Sheehan et al., 2010). Exclusion criteria consisted of high levels of suicidality (scores greater than 16 on Module B), substance dependence or abuse, psychotic disorders, or if a participant had begun a new prescription medication within the past 5 months.

Procedure

The present research was conducted during the first visit of a larger longitudinal study examining how attention bias modification training (ABMT) affects implicit attentional biases in a sample of anxious adults. All procedures were performed prior to any intervention. Once informed consent was collected, participants were taken to a computer booth for EEG setup. They were fitted with nylon headcaps after which water soluble gel was inserted to improve conductivity. Scalp electrodes were then applied. EEG activity was recorded continuously during the tasks. Participants were seated approximately 60 cm away from the monitor (28”) of a Dell computer with 1920 x 1080 screen resolution and refresh rate of 60 Hz. Participants completed the ssVEP task first followed by the dot probe task. After all the tasks were finished, participants filled out multiple self-report questionnaires on anxiety and mood symptoms. Community participants were compensated with $100.00 while Hunter students were given course credit needed to fulfill class requirements.

Measures

The DASS 21 is a shortened version Lovibond & Lovibond’s (1995) 42 item self-report questionnaire. It contains 3 modules assessing for severity of depressive, anxiety, and stress symptoms. Scores range from 0 to 21 for each module, with higher scores indicating greater symptom severity. The DASS 21 has been found to have high reliability as well as concurrent validity in measuring anxiety and mood symptoms (Antony, Bieling, Cox, Enns, & Swinson, 1998).

The Spielberger State-Trait Anxiety Inventory (STAI; Spielberger, 1983) is a commonly used self-report measure of anxiety symptoms. It contains two scales that can be used to measure one’s anxiety at the time of completing the questionnaire (state), as well as how one generally feels (trait). Trait anxiety was specifically examined in the present study. Scores on both scales range from 20 to 80 with higher scores indicating greater severity of anxiety symptoms.

The Hamilton Anxiety Rating Scale (HAM-A; Hamilton, 1959) is a 14 item questionnaire administered to measure the psychological and physical severity of anxiety symptoms. Scores range from 0 to 56 with higher scores indicating greater severity of symptoms. The HAM-A has been found to have concurrent validity and be a reliable measure of anxiety symptoms (Maier, Buller, Philipp, & Heuser, 1988).

Dot Probe Task

The stimuli for the dot probe task consisted of pictures of faces of 20 different individuals (10 male and 10 female) from the NimStim stimulus set (Tottenham et al., 2009) including one female from the Matsumoto and Ekman (1989) set. All images were cropped to a size of 191 pixels in length and 143 pixels in width. The dot probe task was programmed and run using E-Prime version 2.0 (Schneider, Eschman, & Zuccolotto, 2002). At the beginning of the task, instructions appeared on the screen but were also verbally explained to the participants. Participants were told that in each trial, a cross would appear at the center of the screen followed by a pair of faces, and then by a target arrow pointing either to the left or the right. They were instructed to identify which direction the arrow was pointing using a mouse with their dominant hand and to also maintain fixation on the cross at the center of the screen at the beginning of each trial. They were also told to respond as quickly as possible without making mistakes. There were 120 trials in the task with 80 trials featuring threatening (angry) and neutral faces, and 40 trials with only neutral faces. Trials were counterbalanced for probe location (above or below cross), probe type (arrow pointing left or right), and threat location (whether the threatening face appeared above or below the cross). Each trial consisted of 4 steps. First, a fixation cross appeared at the center of the screen for 500 ms. Then a pair of faces appeared above and below the center of the screen for 500 ms before disappearing. As soon as the faces disappeared, an arrow probe appeared in the former location of one of the faces and remained on the screen until participants made a response. Finally, there was an inter-trial interval of 500 ms. Screenshots of the task can be seen in Figure 1.

ssVEP Task

The ssVEP task was a modified version of the dot probe task and used the same stimuli as the dot probe except the images flickered at different frequencies. The task was designed and run using Presentation version 20.0 software (Neurobehavioral Systems, Inc., Albany, CA). All stimuli appeared on a gray background and were cropped to a size of 191 pixels (7 cm) in length and 143 pixels (5.5 cm) in width. A fixation dot was present at the center of the screen throughout the task; the distance between the center of the facial stimuli and the fixation dot was 6 cm. In the beginning of the task, a prompt stating “Ready…” appeared on the screen. Participants were then given the following instructions verbally. They were told that in each trial, a dot would appear on the center of the screen followed by a pair of faces, and then a target arrow; they were instructed to press the “1” key if the target arrow was pointing left and the “2” key if the arrow was pointing right. They were also told to respond as quickly as possible without making mistakes. Each trial consisted of 3 steps. A fixation dot was present throughout the task at the center of the screen. A pair of flickering faces appeared on the left and right side of the dot for 2750 ms. As soon as the faces disappeared, an arrow probe appeared in the former location of one of the faces and remained on the screen until participants made a response. Finally, there was an inter-trial interval that randomly varied between 750-1000 ms. The task consisted of 128 trials which were randomly presented and counter-balanced by emotion (threatening or neutral), frequency (12 or 15 Hz), and location (left or right side) such that there were 32 trials per condition (e.g. 32 trials where the threatening face appeared on the right side and flickered at 15 Hz). Screenshots of the task can be seen in Figure 2.

Calculation of dot probe TB scores

Reaction times on the dot probe were extracted for analysis from E-Prime. Data points greater than 3 standard deviations below or above the mean were identified as outliers and adjusted using mean replacement. The average reaction times for threatening stimuli and neutral stimuli were calculated for all participants. Then threat bias scores were generated by taking the average reaction time for threatening stimuli and subtracting it from the average reaction time for neutral stimuli. This resulted in a TB score such that a positive score indicated a bias towards threatening stimuli, a negative score indicated a bias away from threatening stimuli, and a score near zero indicated no bias. To explore broader group differences, the data was also split into three approximately equal sections to create dot probe TB score groups. The lowest third of the data had a TB away from threat, the highest third had a TB towards threat, and the middle third had no bias. Threat disengagement scores were also calculated to examine whether difficulty in withdrawing attention from threat on the dot probe relates to electrocortical activity of the visual cortex. Disengagement cores were generated by taking the average reaction time for trials in which a pair of only neutral stimuli appeared and subtracting it from the average reaction time for trials in which the probe replaced a neutral stimulus in a threat-neutral pair. This resulted in a disengagement score such that higher scores indicated greater difficulty in separating attention from threatening stimuli.

EEG data recording

EEG was recorded continuously using a BioSemi ActiveTwo system (BioSemi, Amsterdam, NL) with a set of 64 Ag/AgCl scalp electrodes referenced to the mastoids. EEG data for the ssVEP task was recorded using ActiView acquisition software (Version 7.07) at a sampling rate of 1024 Hz.

EEG data reduction and analyses

Brain Vision Analyzer (Version 2.1, GmbH; Munich DE) was used to process and analyze the ssVEP EEG data. All electrodes were re-referenced to the mastoids. Bipolar channels were computed for VEOG (vertical eye movements) and HEOG (horizontal eye movements). All 128 trials for every participant were separated into segments of 0-2750 ms. Ocular correction was performed using the Gratton and Coles (1983) method to remove trials with excessive blinks. The first round of artifact rejection was ocular rejection for horizontal eye movements; trials with saccades that had a difference >100 uV within a 75 ms window (HEOG channel only) were rejected. Trials were then re-segmented from 750 to 2750 ms to ensure that the steady-state had been achieved. Only the final 2 seconds of data were each trial were analyzed. This also ensured that the number of data points (2048) was twice the sampling rate of the data (1024 Hz), a crucial requirement for a fast Fourier transform (FFT). Next, all segments underwent a baseline correction from 0 to 2000 ms. In the second round of artifact rejection, any two data points that exceeded a difference of 150 uV were removed. All segments in each of the 4 conditions counterbalanced by emotion, frequency, and location were then averaged. An FFT was performed at maximum resolution to yield the amplitude of each frequency bin (12 and 15 Hz) which provided the strength of the ssVEP response at those specific frequencies for the 4 conditions across all participants. The specific electrodes used were O1 and PO3 on the left occipital lobe and O2 and PO4 on the right occipital lobe. These specific electrodes were chosen as the strength of the ssVEP response was strong in these electrode sites, consistent with other studies that have found increased ssVEP amplitudes in electrodes located in the parieto-occipital regions (Miskovic & Keil, 2013; Wieser et al., 2011). The average ssVEP amplitude spectrum at the frequencies of 12 and 15 Hz in the O1, O2, PO3, and PO4 electrode sites is displayed in Figure 3. The mean ssVEP amplitudes for threatening stimuli and neutral stimuli flickering at 12 Hz were 2.80 µV and 3.05, respectively. The mean ssVEP amplitudes for threatening stimuli and neutral stimuli flickering at 15 Hz were 2.02 and 2.40, respectively. A summary of the data is presented in Figure 4. There was a significant difference in the ssVEP amplitudes for stimuli flickering at 12 Hz compared to 15 Hz, with a greater response to stimuli flickering at 12 Hz; this is consistent with what other studies utilizing ssVEPs in these specific frequency bins have found (Wieser & Keil, 2014).

Calculation of ssVEP Difference scores

The ssVEP amplitude in each frequency bin for all conditions was then extracted for analysis from Brain Vision Analyzer. Data points greater than 3 standard deviations below or above the mean were identified as outliers and adjusted using mean replacement. As there was a significant difference in the ssVEP amplitude for stimuli flickering at 12 and 15 Hz, the data was averaged across frequencies (12 or 15 Hz) and presentation side (left or right) resulting in an ssVEP threat average score and an ssVEP neutral average score. The threat average score reflected the amplitude of the ssVEP response to threatening stimuli, or how much electrocortical activity occurred in response to threatening faces regardless of which side the face appeared on or how fast it was flickering. Similarly, the neutral average score reflected the amplitude of the ssVEP response to neutral stimuli, or how much electrocortical activity occurred in response to neutral faces regardless of which side the face appeared on or how fast it was flickering. ssVEP difference scores were calculated by subtracting the threat average score from the neutral average score resulting in a ssVEP difference score for each participant. A positive score indicated greater visual attention towards threatening faces, a negative score indicated greater visual attention away from threatening faces, and a score near zero indicated no difference in visual attention. To explore broader group the differences, the data was also split into three approximately equal sections to create ssVEP difference score groups. The lowest third of the data had greater visual attention away from threat, the highest third had greater visual attention towards threat, and the middle third had no difference in visual attention towards or away from threat.

Results

Participant demographic information and mean anxiety and mood symptoms for all participants are presented in Table 1. All statistical analysis was performed using SPSS (Version 21). Additionally, all statistical analysis was performed on both continuous ssVEP and dot probe scores, as well as ssVEP and dot probe groups to explore broader group differences.

Hypothesis 1: Explore the association between ssVEPs and TB measured from the dot probe

Bivariate correlations revealed no significant correlations between ssVEP and the two measures of TB, attention bias and disengagement, r (44) = -.05, p = .73, and r (44) = .22, p = .15, respectively. A summary of these correlations is presented in Table 2.

To examine the relation between the ssVEP difference score groups and the dot probe TB score groups, chi-square tests for independence were conducted. A chi-square test demonstrated no significant difference in ssVEP difference scores based on dot probe TB scores, χ^2 (2, n = 44) = 1.73, p > .05, and also no significant difference in ssVEP difference scores based on dot probe disengagement scores, χ^2 (2, n = 44) = 3.60, $p > .05$. A crosstabulation of scores for all the groups are presented in Tables 3 and 4.

Hypothesis 2: ssVEPs will account for greater variance in anxiety and mood symptoms than the dot probe

A series of two-step hierarchical regressions were conducted with dot probe TB scores entered in step one of the regression, and the ssVEP difference scores entered in step two. For the ssVEP difference scores and the dot probe TB scores, there was no significant association between either measure and anxiety and mood symptoms (*p's* > .05). A summary of the regression results is presented in Table 5 for all questionnaires.

To further investigate, two-stage hierarchical regressions were conducted again except with ssVEP difference scores entered at step one of the regression, and the dot probe TB scores entered at step two. There was no significant association between the two measures and anxiety and mood symptom-s, (*p's* > .05). A summary of the regression results is presented in Table 6 for all questionnaires.

One-way ANOVAs were conducted to compare the effect of ssVEP difference score group on anxiety and mood symptoms in participants with greater visual attention away from threat, greater visual attention towards threat, and no difference in visual attention. One-way ANOVAs were also conducted to compare the effect of dot probe TB score group on anxiety and mood symptoms in participants with a bias away from threat, a bias towards threat, and no difference in bias. There were no significance differences in anxiety and mood symptoms across the levels of both the dot probe TB group and the ssVEP difference score group, (*p*'s > .05). A summary of the ANOVA results for both measures is presented in Tables 7 and 8.

Discussion

The first goal of this study was to investigate how ssVEPs compared to the dot probe as measures of the anxiety-related TB. There was no correlation between the ssVEP scores, and the dot probe TB and disengagement scores. There was also no correlation between the ssVEP and dot probe groups. Additionally, a chi-square test indicated that the two measures were independent of one another. This independence between the dot probe and ssVEPs suggests that the two measures may be capturing distinct components of attention to threat. Reviews of attentional bias research theorize that the stage of information processing is relevant to the nature of the TB observed (Cisler & Koster, 2010). Thus, the time course of attention to threat could be a crucial point of focus. The dot probe is only able to capture a brief instance of an individual's attention to threat whereas ssVEPs offer a more continuous view of electrocortical activity in response to visual stimuli. Given that these two tasks have different timeframes in which data related to attentional processing of threat is collected, it is possible that they had no relation in measuring TB as they could be capturing attentional allocation at different stages of information processing.

There is emerging evidence that it may be more fruitful to view attention bias as a dynamic and rapidly changing process rather than a static process. Zvielli, Bernstein, and Koster (2015) investigated the temporal characteristics of TB in a sample of individuals with spider phobia and found that the TB observed featured multiple phases of attention to threat and subsequent attention away, which changed rapidly multiple times throughout stimulus viewing. The researchers also found that the more dynamic TB scores featured statistically significant levels of split-half reliability compared to very low split-half reliability for the traditional TB scores. In another study, Amir, Zvielli, and Bernstein (2016) examined responses to threatening stimuli using the dot probe, and found that when TB was measured as a dynamic process involving rapid fluctuations in attention to threat and avoidance, the split-half reliability of the measure was moderate to high compared to low reliability when using the traditional static measure. While this study utilized the dot probe instead of ssVEPs, the findings still hold important implications. ssVEPs offer a continuous measure of electrocortical activity of the visual cortex but perhaps studies of TB should be examining the ssVEP response within certain timeframes, as opposed to the full length of a stimulus presentation. This approach could be more effective in understanding how one's attentional processing of threat changes over the course of a stimulus presentation, and may provide a more comprehensive window into how attention to threat is dysregulated in individuals with anxiety. Additionally, this approach could be useful in cases of individuals who exhibit more complex patterns of threat processing which change over time, such as those with a vigilant-avoidant pattern. If the nature of TB is variable and rapidly changing, ssVEPs could potentially be a powerful complement to the dot probe in detecting these changes, given the continuous and temporally-sensitive characteristics of the ssVEPs.

The components that constitute visual attention are also of importance, and may in part explain the lack of association between the dot probe and ssVEP in measuring TB. Visual processing consists of two components: covert and overt attention. Overt attention involves selective orienting towards a specific area by moving one's eyes. Eye tracking measures have been used to study anxiety-related TB as it allows for continuous measurement of what an individual is directly looking at (Schofield, Johnson, Inhoff, & Coles, 2012). There is even research suggesting that tasks utilizing eye-tracking generally had better reliability than reaction time based tasks as a measure of TB (Price et al., 2015). Tasks that use eye tracking primarily focus on overt attention through the measurement of saccades, or rapid movements of the eyes between two points. Covert attention is more subtle, however, and refers to visual orienting towards a specific area without movement of the eyes. In other words, covert visual processing does not necessarily require saccades rendering eye tracking approaches limited in their ability to detect covert shifts in visual attention (Armstrong & Olatunji, 2012). One of the advantages of ssVEPs is that they are not constrained to solely measuring saccades. For example, Kelly, Lalor, Reilly, and Foxe (2005) found that it was possible to parse out overt attention from ssVEPs when participants were instructed to overtly attend to stimuli while maintaining their gaze on a central point. Additionally, Walter, Quigley, Andersen, and Mueller (2012) found that ssVEP amplitudes were increased in tasks involving both overt and covert visual attention indicating that ssVEPs can also be used to capture covert attention. It is unknown how covert attention differs from overt attention in the processing of threatening stimuli in individuals with anxiety. The presence (or absence) of a TB may depend on which component of visual attention is focused on. Tasks requiring individuals to maintain their gaze on a central fixation point as stimuli are presented could only be capturing one component of visual attention. The ssVEP response to the stimuli could be a reflection of only covert visual processing. As there was no instruction for maintaining gaze on a central point in the present study, participants could freely allocate their attention, making it more difficult to parse out differences in covert and overt visual processing. Future studies could address this limitation by incorporating both eye tracking measures along with ssVEPs to examine whether TB changes as a function of covert or overt visual processing.

The second goal of the study was to examine whether ssVEPs accounted for variance in anxiety and mood symptoms above and beyond that predicted by TB metrics derived from the dot probe. We found that none of the hierarchical regressions were significant for the ssVEP difference scores. The ANOVAs for the ssVEP difference score group were also non-significant, suggesting that ssVEPs were not a better predictor of anxiety and mood symptoms than the dot probe. This finding was counter to our hypothesis; as ssVEPs are a more direct index of where an individual is focusing their visual attention compared to the dot probe, we expected that visual attention measured through ssVEPs would be more closely linked to individual differences in anxiety. One way to interpret the lack of significant findings is that the severity of anxiety may be related to the detection of a TB, especially for studies utilizing ssVEPs. Multiple studies have found enhanced visual processing of threatening faces that only occurred in individuals with high levels of anxiety (McTeague et al., 2011; Wieser et al., 2011). The present study did not use a clinical sample, but had individuals with moderate or greater self-reported anxiety. It is possible that enhanced electrocortical activity in response to threat occurs, but only in individuals with high levels of anxiety.

There are important limitations that may have affected the results in the present study. One of the crucial methodological differences between the dot probe task and the ssVEP task is how long the stimuli were present on the screen. For the dot probe, stimuli remained on the screen for 500 ms, consistent with how the task is commonly used. However, for the ssVEP task, stimuli flickered on the screen for a total of 2750 ms. ssVEPs often require using a longer stimulus presentation to ensure that the steady-state has been achieved and that there are sufficient data points to perform a FFT (Norcia et al., 2015). As the nature of TB could vary over time, it is possible that allowing participants to view stimuli for longer durations can lead to differences in attentional processing. Another limitation is that the placement of faces in the two tasks differed. In the dot probe task, the stimuli appeared above and below the fixation cross whereas in the ssVEP task, the stimuli appeared on the left and right side of the fixation dot. It is unclear whether placement of stimuli on the screen can impact attention to threat but future studies should standardize stimuli placement between tasks to account for any potential differences. Another limitation of the present study is the choice of electrodes for extracting the ssVEP amplitudes. The present study examined the strength of the ssVEP response in the O1, O2, PO3, and PO4 electrode sites. However, other studies utilizing ssVEPs in attention research with anxious samples have focused on the Oz electrode site, for its proximity to the primary visual cortex and the strength of the ssVEP response at that location (McTeague et al., 2011; Wieser, Miskovic, Rausch, & Keil; 2014). It is possible that the ssVEP response evoked in the Oz electrode site would have been a more powerful index of an individual's visual attention than the electrodes examined in the present study.

This was one of the first studies to explore how ssVEPs compared to the dot probe as measures of the anxiety-related TB. Although there were no significant findings, there are multiple directions in which the current research can be extended. Individuals with anxiety may have a TB, but it might only be identifiable if examined in time-specific stages of attentional processing. The time course of the anxiety-related TB is complex and necessitates further research (Mogg, Bradley, De Bono, & Painter, 1997), although recent studies suggest that examining the TB as a dynamic and changing process may provide a more accurate perspective on how attention to threat is dysregulated. For ssVEPs, it is still unclear how the type of visual attention, overt or covert, affects anxiety-related processing of threat. Although this study did not have enough trials for a test of split-half reliability, future studies should also investigate how stable ssVEPs are as measures of anxiety-related threat processing over multiple time points. Despite the longstanding use of the dot probe to study the anxiety-related TB, newer and more sophisticated approaches such as ssVEPs and eye-tracking should be explored to complement the dot probe and expand our understanding of how attention to threat is dysregulated in individuals with anxiety.

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Table 1

Participant Demographics and Anxiety and Mood Symptoms

	Males (*n* = 15)	Females (*n* = 29)
	M (SD)	M (SD)
Age (years)	27.13 (6.19)	26.38 (6.44)
Ethnicity (frequency)		
Hispanic/Latino	1	8
Asian	4	1
Black or African American	1	6
Caucasian	9	13
More than one race	0	1
STAI Trait	51.40 (13.60)	49.59 (12.58)
DASS – Depression	9.73 (5.91)	5.66 (5.34)
DASS – Anxiety	8.13 (6.10)	6.31 (4.47)
DASS – Stress	9.73 (5.36)	9.07 (4.28)
HAM-A	18.21 (11.03)	18.53 (8.57)

Table 2

Correlations for ssVEP Difference Scores and Dot Probe TB and Disengagement Scores

	ssVEP Difference Score	Dot Probe TB Score	Dot Probe Disengagement Score
ssVEP Difference Score	-		
Dot Probe TB Score	-.05	-	
Dot Probe Disengagement Score	.22	.38*	-

Note. *N* = 44 for all correlations; *$p < .05$, 2-tailed.

Table 3

Crosstabulation of ssVEP Difference Score and Dot Probe TB Score Groups

ssVEP Difference Score Group	Dot Probe TB Score Group			
	Bias Away from Threat	No Bias	Bias Towards Threat	Total
Visual Attention Away from Threat	4	6	5	15
No Difference in Visual Attention	5	3	6	14
Visual Attention Towards Threat	5	6	4	15
Total	14	15	15	44

Note. A chi-square test for independence demonstrated no significant difference in ssVEP difference scores based on dot probe TB scores, χ^2 (2, n = 44) = 1.73, p = .785.

Table 4

Crosstabulation of ssVEP Difference Score and Dot Probe Disengagement Score Groups

ssVEP Difference Score Group	Dot Probe Disengagement Score Group			
	Low Disengagement	No Difference in Disengagement	High Disengagement	Total
Visual Attention Away from Threat	6	6	3	15
No Difference in Visual Attention	5	3	6	14
Visual Attention Towards Threat	3	7	5	15
Total	14	16	14	44

Note. A chi-square test for independence demonstrated no significant difference in ssVEP difference score groups based on Dot probe TB score groups, χ^2 (2, n = 44) = 3.60, p = .463.

Table 5

Summary of Hierarchical Regression Analysis for Dot Probe TB Scores and ssVEP Difference Scores Predicting Anxiety and Mood Symptoms

	Measures									
	STAI Trait		DASS Depression		DASS Anxiety		DASS Stress		HAM-A	
Variable	ΔR^2	β	ΔR^2	B	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1	.007		.013		.010		.009		.001	
Dot Probe Scores		-.084		-.115		-.101		-.095		.028
Step 2	.003		.035		.000		.001		.001	
Dot Probe Scores		-.080		-.105		-.102		-.094		.030
ssVEP Scores		.059		.187		-.016		.034		.026
Total R^2	.010		.048		.010		.010		.002	

Note. N = 44 for all regressions except for HAM-A (N = 43); none of the regression results were statistically significant, (p's > .05).

Table 6

Summary of Hierarchical Regression Analysis for Variables Predicting Anxiety and Mood Symptoms with ssVEP Difference Scores Entered First

	Measures									
	STAI Trait		DASS Depression		DASS Anxiety		DASS Stress		HAM-A	
Variable	ΔR^2	β	ΔR^2	B	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1	.004		.037		.000		.003		.001	
ssVEP Scores		.063		.193		-.010		.039		.024
Step 2	.006		.011		.010		.008		.001	
ssVEP Scores		.059		.187		-.016		.034		.026
Dot Probe Scores		-.080		-.105		-.102		-.094		.030
Total R^2	.010		.048		.010		.010		.002	

Note. N = 44 for all regressions except for HAM-A (N = 43); none of the regression results were statistically significant, (p's > .05).

Table 7

One-Way Analysis of Variance of Anxiety and Mood Symptoms by Dot Probe TB Group

	Source	*df*	*SS*	*MS*	*F*	*P*
STAI Trait	Between groups	2	566.57	283.28	1.79	.18
	Within groups	41	6486.59	158.21		
	Total	43	7053.16			
HAM-A	Between groups	2	92.77	46.38	.52	.60
	Within groups	40	3545.53	88.64		
	Total	42	3638.29			
DASS	Between groups	2	150.06	75.03	2.36	.11
Depression	Within groups	41	1301.85	31.75		
	Total	43	1451.91			
DASS	Between groups	2	91.63	45.82	1.84	.17
Anxiety	Within groups	41	1023.16	24.96		
	Total	43	1114.80			
DASS	Between groups	2	80.90	40.45	1.97	.15
Stress	Within groups	41	840.26	20.49		
	Total	43	921.16			

Note. None of the ANOVA results were statistically significant, (p's $> .05$).

Table 8

One-Way Analysis of Variance of Anxiety and Mood Symptoms by ssVEP Difference Score Group

	Source	*df*	*SS*	*MS*	*F*	*P*
STAI Trait	Between groups	2	109.06	54.53	.32	.73
	Within groups	41	6944.10	169.37		
	Total	43	7053.16			
HAM-A	Between groups	2	74.33	37.16	.42	.66
	Within groups	40	3563.97	89.10		
	Total	42	3638.29			
DASS Depression	Between groups	2	72.79	36.39	1.08	.35
	Within groups	41	1379.12	33.64		
	Total	43	1451.91			
DASS Anxiety	Between groups	2	14.42	7.21	.27	.77
	Within groups	41	1100.38	26.84		
	Total	43	1114.80			
DASS Stress	Between groups	2	6.11	3.06	.14	.87
	Within groups	41	915.05	22.32		
	Total	43	921.16			

Note. None of the ANOVA results were statistically significant, (*p's* > .05).

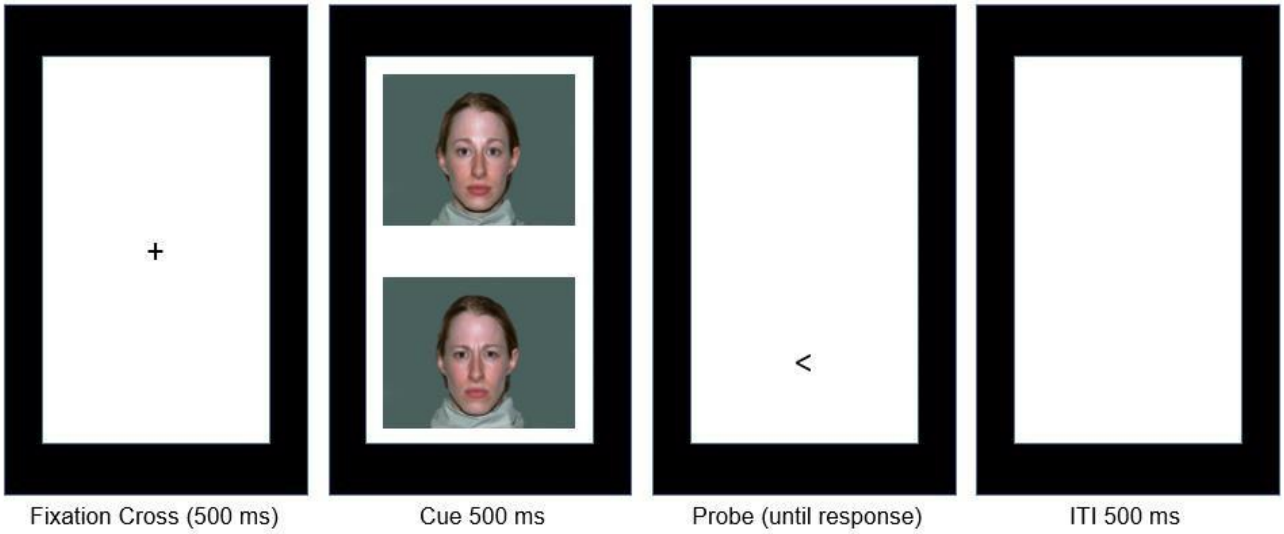

Figure 1. Screenshots of dot probe task.

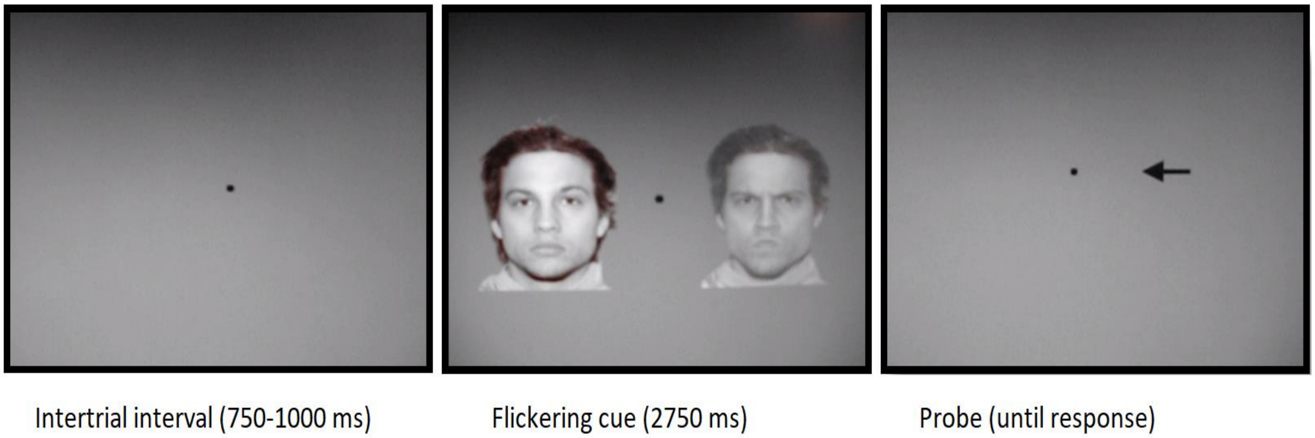

Figure 2. Screenshots of ssVEP task. One cue flickered at a rate of 12 Hz while the other flickered at a rate of 15 Hz.

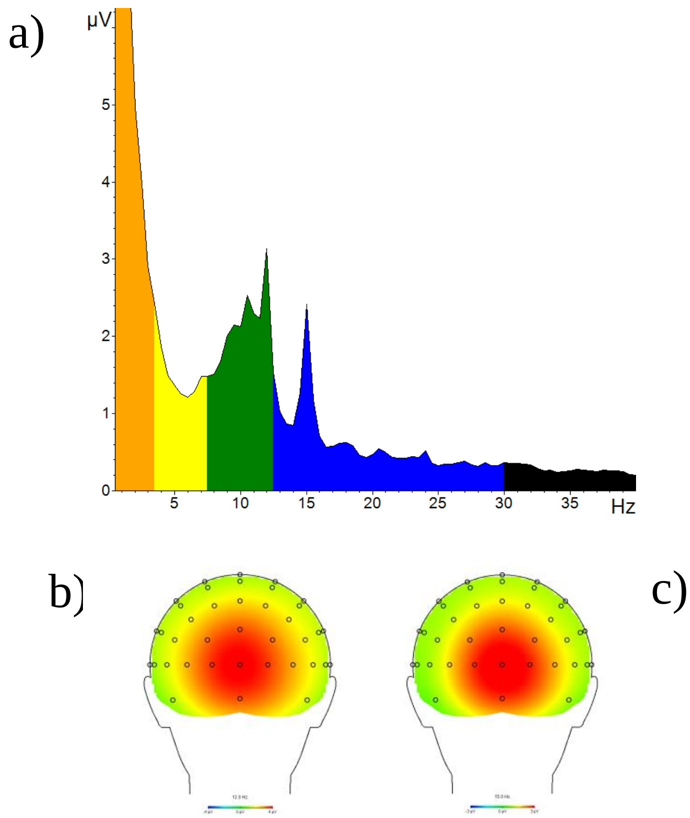

Figure 3. a) The average amplitude spectrum from the O1, O2, PO3, and PO4 electrode sites; b) The mean scalp topography for 12 Hz; c) The mean scalp topography for 15 Hz.

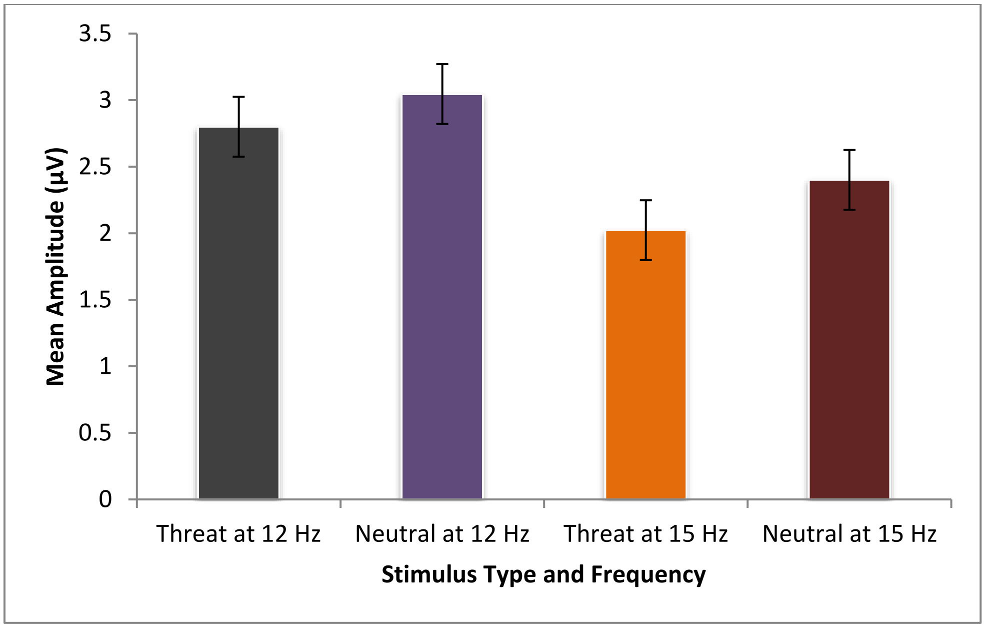

Figure 4. Mean ssVEP amplitude in each frequency bin evoked by threatening and neutral stimuli. Error bars represent one standard error of mean above and below the mean.

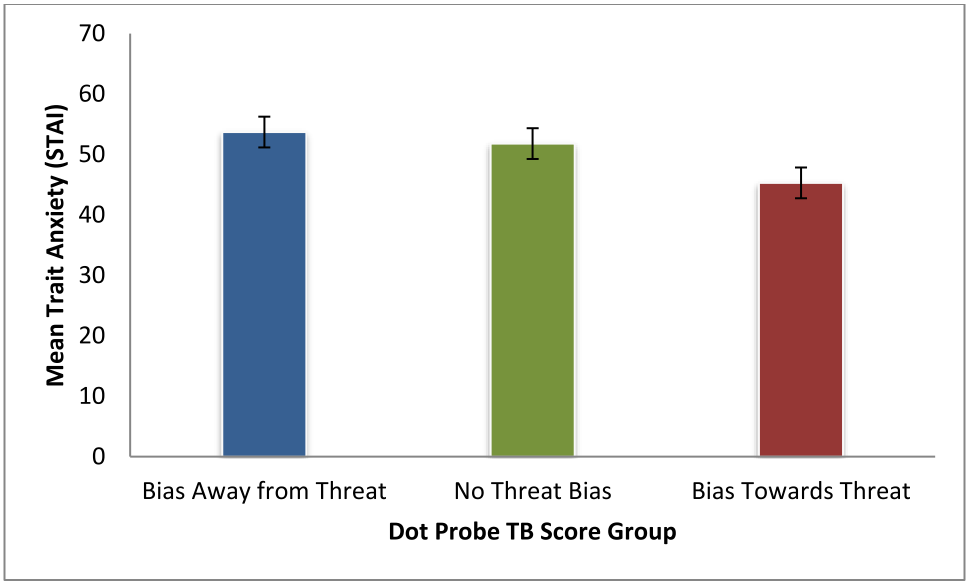

Figure 5. Mean trait anxiety scores on the STAI for each dot probe TB score group. Error bars represent one standard error of mean above and below the mean.

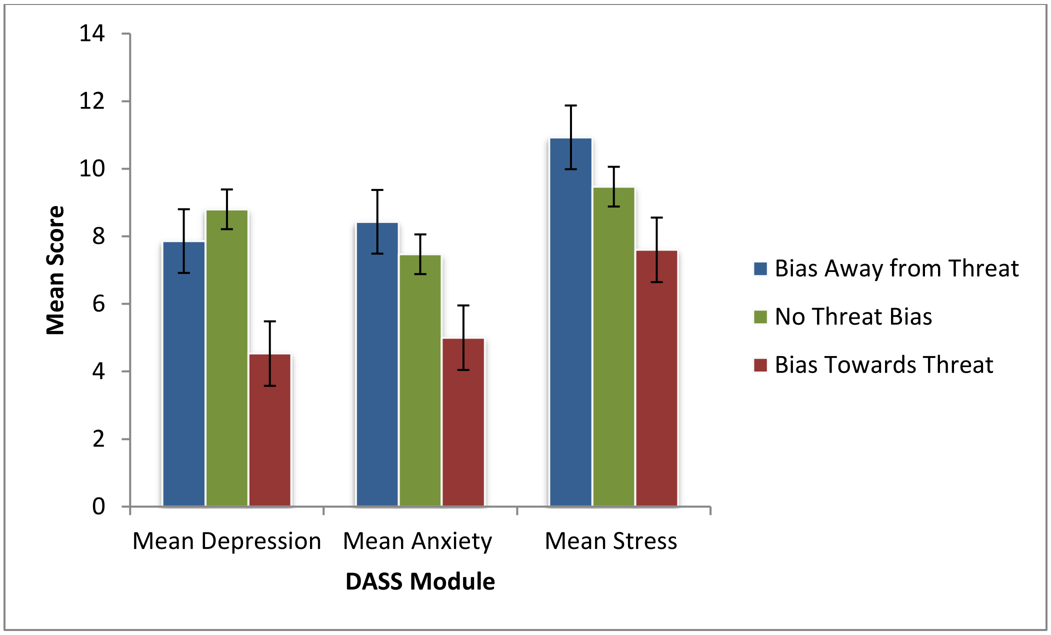

Figure 6. Mean anxiety, depression, and stress scores on the DASS for each dot probe TB score group. Error bars represent one standard error of mean above and below the mean.