Attention Bias Modification in High Trait Anxious Adults: An ERP Study

Laura O'Toole[1], Jean Quintero[2], Sayma Ahmed[2], Jenna Rieder[1], & Tracy A. Dennis[2, 1]
[1]The Graduate Center, The City University of New York
[2]Hunter College, The City University of New York

- Clinical and non-clinical anxiety are associated with exaggerated attention to threatening stimuli, termed the threat bias (Bar-Haim et al., 2007).
  - The potential of this threat bias as a target for intervention is supported by almost two decades of research showing that reducing threat bias via computerized attention bias modification treatment (ABMT) also reduces anxiety severity at levels comparable to gold-standard treatments (Hakamata et al., 2010). ABMT has been shown to reduce threat bias, stress reactivity (Amir et al., 2008), and symptoms of generalized anxiety disorder (Amir et al., 2009a), social anxiety disorder (Schmidt et al., 2009), social phobia (Amir et al., 2009), and pathological worry (Hazen et al., 2009).

- Despite its promise, little research to date has delineated specific mechanisms underlying ABMT's effects on anxiety (Heeren et al., 2013), nor identified predictors of treatment response. **It remains unclear *how* and *for whom* ABMT is effective, limiting clinical translation.**
  - One potential explanation is that behavioral measures may fail to distinguish between two distinct cognitive processes that may be modified by ABMT: attentional capture, the relatively bottom-up, initial evaluation of stimulus threat value, which is elevated in anxiety (Beck & Clark, 1997; Mogg & Bradley, 2002; Wilson & MacLeod, 2003); and cognitive control, the relatively strategic, top-down control of threat processing and reactivity, which appears to be dampened in anxiety (Bishop, 2009; Derryberry & Reed, 2002).

- Scalp-recorded event-related potentials (ERPs) are sensitive to both types of cognitive processes and can capture changes in bottom-up attentional capture (P1, N1; Hillyard & Anllo-Vento, 1998; Luck et al., 1990; Luck & Hillyard, 1995) and top-down cognitive control (N2; Folstein & Van Petten, 2008; Nieuwenhuis et al., 2003; van Veen & Carter, 2002) on the order of milliseconds. This temporal and functional sensitivity makes them ideal candidate neural correlates to measure the time course of the anxiety-related attentional bias to threat and its remediation through ABMT (Eldar & Bar-Haim, 2010; O'Toole & Dennis, 2012).

- The present study takes an additional innovative approach by including more salient stimuli (i.e., pictures of scenes versus words or emotional faces). It is important to explore whether the use of higher arousal non-verbal stimuli yield comparable ABMT effects.

- **Hypothesis 1:** ABMT versus placebo training (PT) will reduce threat bias, anxiety, stress reactivity, and alter ERP responses indicating reduced early attention capture by threat (i.e., reduced P1 and N1 amplitudes) and increased control of attention to threat (i.e., greater N2 amplitudes).

- **Hypothesis 2:** ERP responses specified in Hypothesis 1 will predict ABMT effects on threat bias, anxiety, and stress reactivity, suggesting these ERPs are viable measures of neurocognitive processes underlying ABMT (*how* ABMT works). Exploratory analyses will test whether ERP responses at baseline predict treatment outcomes, helping to clarify who is most likely to benefit from ABMT (*for whom* ABMT is effective).

METHOD

Participants

- Fifty four adults (45 females), aged 18-38 (M = 20.28, SD = 4.33), participated in this study.
- Participants were recruited for the study based on elevated trait anxiety scores (+1SD from college norm; Spielberger, 1983). Trait anxiety scores ranged from 49-75 (M = 55.52, SD = 5.71).

Procedure

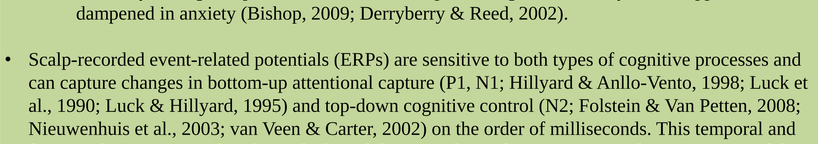
- Participants spent approximately three hours in the laboratory. They completed a pre-training assessment of threat bias, anxiety, and stress reactivity, the training task, then a post-training assessment of threat bias, anxiety, and stress reactivity. EEG was recorded during the pre- and post-training threat bias assessment.

Anxiety Assessment

- State anxiety was measured using the STAI (Spielberger, 1983).

Threat Bias Assessment

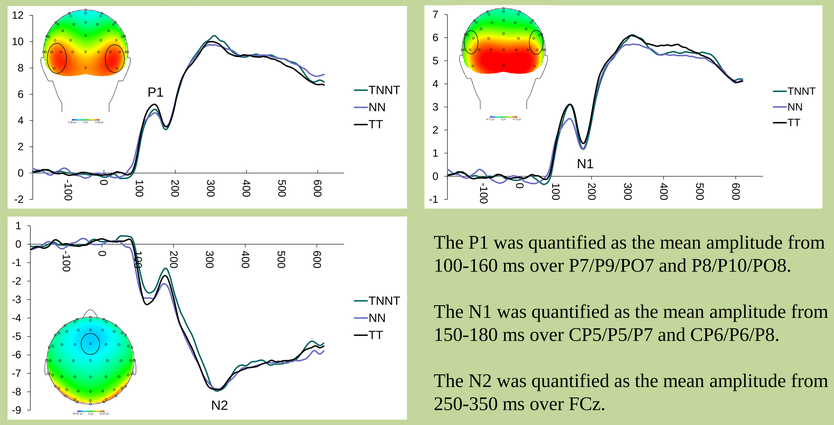
- The present study used a dot probe task (MacLeod, Mathews, & Tata, 1986) with stimuli from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008): 48 threat-neutral (TN), 24 neutral-neutral (NN), 24 threat-threat (TT). Threatening images contain knives, guns, and aggressive animals and non-threatening images contain tools, shoes, and household objects.



- Participants received an equal number of each type of trial (probes replacing the threat or neutral stimulus) during the pre- and post-training assessment (total of 192 trials in each).
- Three threat bias scores are calculated from reaction times (RTs) from correct trials only: attention bias (RT non-threat cue – RT threat cue), vigilance (RT baseline non-threat cue – RT threat cue), disengagement (RT non-threat cue – RT baseline non-threat cue). Higher scores on all scores indicate greater threat bias.

EEG Recording and Analysis

- EEG activity was recorded during the passive viewing and cognitive reappraisal tasks via BioSemi 64 Ag/AgCl scalp electrodes, sampled at 512 Hz and amplified with a band pass of 0.16-100 Hz. Eye movements were monitored by electrooculogram (EOG) signals.
- Using Brain Vision Analyzer, data were referenced offline to the average of the entire scalp and filtered with a low-cutoff frequency of .1 Hz and a high-cutoff frequency of 30 Hz. Stimulus-locked data were segmented into epochs from 200 ms before cue presentation during the dot probe task to 500 ms after stimulus onset, with a 200 ms baseline correction.
- Following ocular correction (Gratton & Coles, 1983), artifacts were identified and removed from analyses: voltage steps greater than 50 µV, changes within a given segment greater than 300 µV, and activity lower than .5 µV per 100 ms. In addition to this semi-automatic identification of artifacts, trials were also visually inspected for any further artifacts and were removed on a trial-by-trial-basis.



The P1 was quantified as the mean amplitude from 100-160 ms over P7/P9/PO7 and P8/P10/PO8.

The N1 was quantified as the mean amplitude from 150-180 ms over CP5/P5/P7 and CP6/P6/P8.

The N2 was quantified as the mean amplitude from 250-350 ms over FCz.

Stress Reactivity Assessment

- The Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993) includes both a social-evaluative threat, where participants must give a speech in front of two judges, and a lack of control task, where participants must complete an arithmetic task.
  - **Self-Reported Mood:** Self-reported mood was recorded before and after the social stressors using the 65-item Profile of Mood States (POMS; McNair, Lorr, Heuchert, & Droppleman, 2003). The POMS measures six different mood states (Tension/Anxiety, Depression/Dejection, Anger/Hostility, Vigor/Activity (reverse scored), Fatigue/Inertia, Confusion/Bewilderment) which are combined to generate a Total Negative Mood score. Difference scores of post-TSST versus pre-TSST were generated for the pre- and post-training stressors to index changes in negative mood.

Attention Bias Modification Training

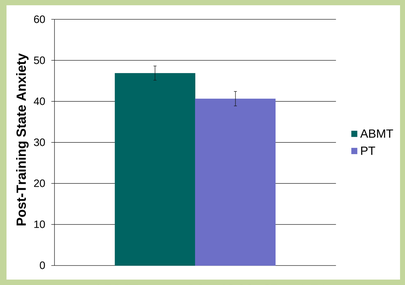
- Participants were exposed to a training condition of the dot probe task intended to induce an attentional bias away from threatening stimuli (non-threat cues only; n = 27) or a placebo training condition (equal numbers of threat and non-threat cues; n = 27). There were 576 training trials in both training conditions.

RESULTS

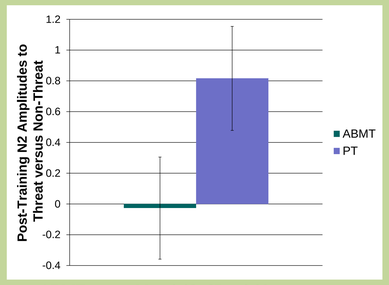
Hypothesis 1: ABMT versus PT will reduce threat bias, anxiety, stress reactivity, and alter ERP responses indicating reduced early attention capture by threat and increased control of attention to threat.

- This hypothesis was tested with a series of ANCOVAs with post-training as the dependent variable, the corresponding pre-training measure as the covariate, and Training as the between-subjects factor.

Figure 1. Counter to predictions, there was a significant effect of Training on state anxiety such that participants in the ABMT group versus PT group showed greater state anxiety. Additionally, there was a trend-level effect of Training on N2 amplitudes such that, as predicted, participants in the ABMT group versus PT group showed greater N2 amplitudes to threat.



ABMT group: M = 46.90, SD = 1.74
PT group: M = 40.66, SD = 1.77
$F(1, 52) = 6.31$, $p = .02$

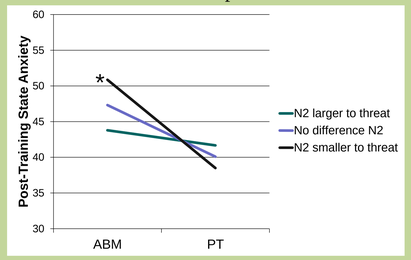


ABMT group: M = -0.03, SD = 0.33
PT group: M = 0.82, SD = 0.34
$F(1, 48) = 3.16$, $p = .08$

Hypothesis 2: ERP responses will predict ABMT effects on threat bias anxiety, and stress reactivity.

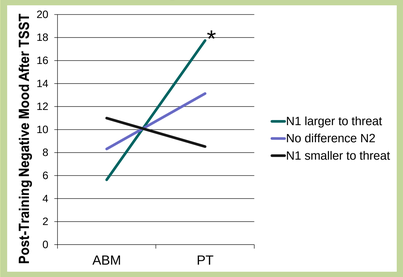
- Each of the post-training measures were entered separately as the dependent variable with the following variables entered in separate steps: 1) the corresponding pre-training measure; 2) Training; 3) ERP (P1, N1, or N2); 4) interaction between Training and ERP (e.g., ABMT x N2).

Figure 3. State anxiety was greater following ABMT versus PT, but only for participants who showed smaller N2 amplitudes to threat versus non-threat at baseline.

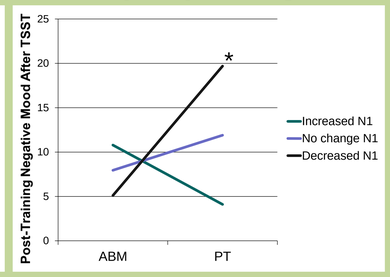


Full model: F(4, 46) = 6.14, p < .001, R2 = .35
Interaction: F(1, 46) = 4.06, p = .05, R2 = .06
Interaction slope: t = 3.48, p = .001

Figure 4. Negative mood after the TSST was reduced following ABMT versus PT, but only for participants who showed larger N1 amplitudes to threat versus non-threat at baseline and decreases in N1 amplitudes to threat versus non-threat from pre- to post-training.



Full model: $F(4, 46) = 6.14$, $p < .001$, $R^2 = .35$
Interaction: $F(1, 46) = 4.06$, $p = .05$, $R^2 = .06$
Interaction slope: $t = 3.48$, $p = .001$



Full model: $F(4, 46) = 3.77$, $p = .01$, $R^2 = .25$
Interaction: $F(1, 46) = 3.56$, $p = .07$, $R^2 = .06$
Interaction slope: $t = -2.22$, $p = .03$

SUMMARY AND DISCUSSION

- The present findings suggest a role for attentional control in ABMT: ABMT led to increases in attentional control (i.e. greater N2 amplitudes to threat) and increases in state anxiety for participants showing poor attentional control at baseline (i.e. reduced N2 amplitudes to threat).

- Results also suggest a prominent role for attentional capture in ABMT. Participants showing greater N1 amplitudes to threat at baseline and reductions in N1 amplitudes following ABMT reported reduced negative mood following a social stressor. These findings implicate plasticity of the N1 response to threat as a candidate marker of individual responsiveness to ABMT training.

- **Taken together, findings suggest a role for both attentional capture and attentional control in ABMT (Hereen et al., 2013), with reductions in early attentional capture being most relevant to the question of how ABMT reduces anxious stress reactivity.**

- The present study also suggests that ABMT with complex emotional scenes as stimuli is effective, but perhaps not as strongly as the traditional word pairs or emotional faces. The use of these more complex stimuli may be detrimental as evidenced by greater state anxiety for ABMT versus control for participants with poor attentional control at baseline.

- ABMT holds promise as a powerful adjunct to current gold-standard treatments for anxiety and by better understanding how attentional mechanisms are changed by training we can move towards more personalized treatments for anxiety.
  - ERPs may be a useful tool for identifying those individuals for whom ABMT is best suited and for identifying neurocognitive processes underlying effective ABMT.

REFERENCES

Amir, N., Beard, C., Burns, M., & Bomyea, J. (2009a). Attention modification program in individuals with generalized anxiety disorder. *Journal of Abnormal Psychology, 118*(1), 28-33.
Amir, N., Beard, C., Taylor, C. T., Klumpp, H., Elias, J., Burns, M., & Xi, C. (2009b). Attention training in individuals with generalized social phobia: A randomized controlled trial. *Journal of Consulting and Clinical Psychology, 77*(5), 961-973.
Amir, N., Weber, G., Beard, C., Bomyea, J., & Taylor, C. T. (2008). The effect of a single-session attention modification program on response to a public-speaking challenge in socially anxious individuals. *Journal of Abnormal Psychology, 117*(4), 860-868
Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van Ijzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin, 133*(1), 1-24.
Beck, A. T., & Clark, D. A. (1997). An information processing model of anxiety: Automatic and strategic processes. *Behavior Research and Therapy, 35*, 49-58. Bishop, S. (2009). Trait anxiety and impoverished prefrontal control of attention. Nature Neuroscience, 12(1), 92-98.
Derryberry, D., & Reed, M. A. (2002). Anxiety-related attentional biases and their regulation by attentional control. *Journal of Abnormal Psychology, 111*(2), 225-236.
Eldar, S., & Bar-Haim, Y. (2010). Neural plasticity in response to attention training in anxiety. *Psychological Medicine, 40*, 667-677.
Folstein, J. R., & Van Petten, C. (2008). Influence of cognitive control and mismatch on the N2 component of the ERP: A review. *Psychophysiology, 45*(152-170).
Hakamata, Y., Lissek, S., Bar-Haim, Y., Britton, J. C., Fox, N. A., Lieberluhr, E., . . . Pine, D. S. (2010). Attention bias modification treatment: A meta-analysis toward the establishment of novel treatment for anxiety. *Biological Psychiatry, 68*, 982-990.
Hazen, R. A., Vasey, M. W., & Schmidt, N. B. (2009). Attentional retraining: A randomized clinical trial for pathological worry. *Journal of Psychiatric Research, 43*(6), 627-633.
Heeren, A., De Raedt, R., Koster, E. H. W., & Philippot, P. (2013). The (neuro)cognitive mechanisms behind attention bias modification in anxiety: Proposals based on theoretical accounts of attentional bias. *Frontiers in Human Neuroscience, 7*, 1-6.
Hillyard, S. A., & Anllo-Vento, L. (1998). Event-related brain potentials in the study of visual selective attention. Proceedings of the National Academy of Sciences, 95, 781-787.
Kirschbaum, C., Pirke, K., & Hellhammer, D. H. (1993). The 'Trier Social Stress Test': A tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology, 28*, 76-81.
Koster, E. H. W., Baert, S., Bockstaele, M., & De Raedt, R. (2008). Attentional retraining procedures: Manipulating early or late components of attentional bias? *Emotion, 10*(2), 230-236.
Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). International affective picture system (IAPS): Affective ratings of pictures and instruction manual. Gainesville, FL: University of Florida.
Luck, S. J., Heinze, H. J., Mangun, G. R., & Hillyard, S. A. (1990). Visual event-related potentials index focused attention within bilateral stimulus arrays: II. Functional dissociation of P1 and N1 components. *Electroencephalography & Clinical Neurophysiology, 75*(6), 528-542.
Luck, S. J., & Hillyard, S. A. (1995). The role of attention in feature detection and conjunction discrimination: An electrophysiological analysis. *International Journal of Neuroscience, 80*, 281-297.
MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology, 95*, 15-20.
Mogg, K., & Bradley, B. P. (2002). Selective orienting of attention to masked threat faces in social anxiety. *Behavior Research and Therapy, 40*, 1403-1414.
Nieuwenhuis, S., Yeung, N., van den Wildenberg, W., & Ridderinkhof, K. R. (2003). Electrophysiological correlates of anterior cingulate function in a go/no-go task: Effects of response conflict and trial type frequency. *Cognitive, Affective, & Behavioral Neuroscience, 3*(1), 17-26.
O'Toole, L., & Dennis, T. A. (2012). Attention training and the threat bias: An ERP study. *Brain and Cognition, 78*, 63-73.
Schmidt, N. B., Richey, J. A., Buckner, J. D., & Timpano, K. R. (2009). Attention training for generalized social anxiety disorder. *Journal of Abnormal Psychology, 118*(1), 5-14.
Spielberger, C. D. (1983). State-trait anxiety inventory manual. Redwood City, CA: Mind Garden, Inc.
van Veen, V., & Carter, C. S. (2002). The anterior cingulate as a conflict monitor: fMRI and ERP studies. *Physiology & Behavior, 77*, 477-482.
Wilson, E., & MacLeod, C. (2003). Contrasting two accounts of anxiety-linked attentional bias: Selective attention to varying levels of stimulus threat intensity. *Journal of Abnormal Psychology, 112*(2), 212-218.
Acknowledgement. This research was supported by National Institutes of Health (NIH) Grants 5T34GM007823, 5K01 MH075704, R03DA027 from the National Center for Research Resources (NCRR), and the Doctoral Student's Research Grant #7 from The Graduate Center, CUNY.

Contact information: Tracy Dennis, tracy.dennis@hunter.cuny.edu

Society for Psychophysiological Research (SPR) Annual Conference, October 2013, Florence, Italy