THE EFFECT OF COGNITIVE BIAS MODIFICATION ON CARDIAC VAGAL TONE

RESPONSE TO A STRESSOR

By

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Abstract

This study examined the effect of Cognitive Bias Modification (CBM) in college students with elevated anxiety. Participants completed a CBM training task, designed to measure and manipulate attentional biases, and were then subjected to an insoluble anagram stressor. Electrocardiogram (EKG) data was recorded first before training and then following the stressor; respiratory sinus arrhythmia (RSA), an indicator of vagal tone, was extracted from the EKG data. With a sample size of 40 participants, no between-groups difference was found in mood state or RSA; however a correlation was found between RSA and the positive component of affect (R=0.336).

Introduction

Although emotion and cognition are often described as separate functions of mind, recent evidence about brain system connectivity and complex task performance suggests that they are integrated at the neural level. In particular, the amygdala, a major emotional center, seems to be involved in the regulation of attention, leading to increased attention toward emotionally significant stimuli (Pessoa, 2008). The amygdala also has outputs to the source nuclei of the vagus nerve, which exerts influence on physiological indexes such as heart rate patterns (Porges, 2011). Taking these observations together, the amygdala appears to be positioned at the center of a cognitive-emotional-physiological loop.

Although much research has focused upon the influences of emotion on attention, there is also evidence that influences go in the other direction as well. In order to measure implicit attentional biases, MacLeod and colleagues developed what is known as the dot probe task. In this task, different affective stimuli pairs are quickly presented and followed by a probe in the spatial locus of one of the stimuli, which the participant is asked to identify as quickly as possible. Usually, this has consisted of a neutral word on one half of a computer screen and a negative word on the other half; a faster response when the dot probe appeared in the locus of the negative word would indicate a bias toward negative information. Using this task, it was discovered that people suffering from anxiety have a greater bias toward threat-related information than healthy controls (MacLeod, Matthews, & Tata, 1986). A training variant of the task was then developed, in which the probes follow a certain class of stimuli most or all of the time, such that overall performance on the task would be improved by biasing attention toward these stimuli. To bias attention toward negative, the probe appears in the locus of the negative stimulus; to bias away from negative and toward neutral, the probe follows the neutral stimulus. This training variant, using neutral and negative words, trained attention toward and away from negative stimuli in healthy college students, leading to greater negative mood in response to an insoluble anagram stressor for those students who had been trained toward negative (MacLeod et al, 2002). The authors referred to this training task as cognitive bias modification (CBM).

After demonstrating that training attentional biases could induce emotional vulnerability, the next logical step was to see if they could alleviate emotion-related attentional biases in stressed persons and those with anxiety or other difficulties. Using the attend-neutral/avoid-negative version of CBM, several researchers measured the effect on emotional responses to stress in non-clinical, subclinical, and clinical populations. Attend-neutral CBM was found to decrease negative affect after a stressor in a non-clinical sample with a stressful life event (See, MacLeod, & Bridle, 2009), a subclinical sample with elevated anxiety (Hirsch, Hayes & Mathews, 2009), samples who met diagnostic criteria for anxiety disorders (Amir, Beard, Burns & Bomyea, 2009; Schmidt, Richey, Buckner & Timpano, 2009), and heavy drinkers (Wiers, Cox, Field, Fadari, Palfai, Schoenmakers, & Stacy, 2006).

All of these studies used subjective (i.e., self-report) measures of affect to assess emotional response. However, because of the amygdala's connections to the vagal source nuclei, an objective measure of modification of emotion response is possible. The vagus nerve has two branches which arise from different source nuclei. The unmyelinated, phylogenetically older 'reptilian' vagus arises from the dorsal medial nucleus of cranial nerve ten (DMNX). It innervates the visceral and thoracic organs, and is associated with digestion and recovery, but also with freezing behaviors and helplessness. The myelinated 'mammalian' vagus emerges from the nucleus ambiguus (NA) and is associated with prosocial behavior, self-soothing, emotional expression, and relaxation. Its effect on heart rate is modulated by the process of respiration, such that heart rate changes based on where the mammal is in the breathing cycle. This phenomenon, known as heart rate variability (HRV) or respiratory sinus arrhythmia (RSA), is a reliable indicator of myelinated vagal tone. Both sections of the vagus nerve slow heart rate, in opposition to the sympathetic nervous system, but only the myelinated portion contributes to heart rate variability. The two portions of the vagus operate independently; for instance, bradycardia, the maladaptive slowing of the heart associated with an excessive activation of the reptilian vagus, involves a large reduction in HRV, indicating less activity by the mammalian vagus (Porges, 2011).

Methods

Participants

The Penn State Worry Questionnaire (PSWQ) and Beck Depression Inventory (BDI) were administered to the pool of college undergraduates enrolled in Psychology 101 with a paper-and-pencil mass survey. Students whose PSWQ scores were above 52 and BDI scores less than 21 were invited to take an online survey via Surveymonkey that administered the BDI and PSWQ again, as well as the Self-Compassion Scale (SCS). Students who still met the above BDI and PSWQ criteria were invited to the lab; 107 students chose to participate in the experiment. After sessions in which the participant's condition had been revealed to the researcher directly interacting with them, sessions where a technological error occurred, and sessions where some or all of the EKG data was unusable (e.g., participant moved too often, heart rate irregular, or participant was taking medication with cardiac side effects) had been removed, 38 participants remained for analysis.

Materials

Images for the dot probe task were selected from the International Affective Picture System (IAPS; Lang, Bradley & Cuthbert, 2008). Similar to the work of Koster and colleagues (2010), the 484 images in the system were sorted by valence and the 32 most positive images with unique content (e.g., only one picture of puppies, only one of flowers) were selected; nude, erotic, and ambiguous images were omitted. The same process was used with negative and neutral images. The arousal levels of the three image sets were then compared using a t-test, and images from the sets were replaced with similarly valenced images until the positive and negative sets did not differ significantly in arousal rating. These images were then split into two 96-image (48-image pair) sets, Set A and Set B.

All tasks were administered using a Dell STUDIO 1558 Laptop computer and programmed in the DMASTR (DMDX) software system. EKG data were recorded using adhesive electrodes attached just below the medial clavicle, with a third ground electrode placed on the forehead. Electrodes were wired to a Biopac amplification and digitization system, and the signals were processed using Acqknowledge 3.9 software.

Tasks

Bias Assessment

Participants were asked to discriminate whether a flashed probe was composed of one dot or two, and to indicate their choice by pressing a the G key for one dot or the H key for two dots; the keys were labeled with ‘1’ and ‘2’ stickers to alleviate confusion. Following the task structure first described by MacLeod et al (1986), each trial began with a fixation cross, followed after 500 ms by two images, one on the right and one on the left. Image size and distance from the center of the screen were kept consistent for all images. These images remained onscreen for 500 ms; when they disappeared, the probe (one or two dots) appeared in the space formerly occupied by one of the images. The dot probe remained until the participant responded; if they did not respond, it timed out after 1000 ms. In each trial, the two images were either a negative/neutral pair, a positive/neutral pair, or a neutral/neutral pair. The images presented and the response time were recorded for each trial. Probe position relative to the images was random. The inter-trial interval was 500 ms.

For the initial assessment, 9 practice trials and 96 assessment trials were run using image pairs from Set A; the set of images was split evenly between pair types. The post-training assessment consisted of 96 assessment trials using the images from Set B.

CBM

The CBM phase was structured almost identically to the assessment phases, except that probe position relative to the images was manipulated. In group D, the probe was programmed to always follow the positive image of a positive/negative pair. In group E, neutral/negative pairs were used and the probe followed neutral images. For group F, the probe position was kept random and negative/neutral, positive/neutral, and positive/negative pairs were used. All images in this phase came from Set A.

Stressor

Following the stratagem of MacLeod and colleagues (2002), participants were given a set of anagrams to solve. A researcher pretended to focus a video camera on them, telling them that recordings of participants who did particularly well or poorly would be shown to other students for training purposes. Unknown to participants, in reality no video recording was conducted. Participants had a three minute time limit, and all of the anagrams were either extremely difficult or insoluble (no possible English word answer). Participants were allowed to skip any anagrams they could not solve. At the end of the time limit, the computer provided feedback that the participants had performed poorly, scoring in the bottom 10% for their class level, and that their video footage would be used.

Procedure

Participants were randomly assigned to one of three conditions: attend-positive (*n=12)*, attend-neutral *(n=12)*, and no training *(n=14)*. Their assigned condition was indicated by a letter (D, E, or F); they viewed this letter in a Microsoft Word Document labeled with their participant ID number and entered it into the DMDX program when prompted. The researcher directing them did not see this document and was thus blind to condition.

Participants were seated in a comfortable armchair and asked to complete the Positive and Negative Affectivity Schedule (PANAS), a brief self-report questionnaire that provides separate measures of positive and negative mood state. The electrodes were then attached to the participant and a baseline EKG recording was taken. After the recording was complete, the study laptop was given to the participant, who was instructed to open the DMDX program, input the condition letter from their ID-labeled file, and begin the computer tasks. The practice trials and baseline assessment occurred first, followed by the CBM training period, and finally the post-training assessment. The participant was then instructed to rest for a few minutes between tasks.

After the rest period, a researcher entered the testing room to set up the camera and remove the 1 and 2 stickers from the laptop keyboard so that the anagram stressor task could begin. After the task, the researcher reentered and turned off the camera light. The camera was not actually on at any point in the study and no footage of the participant was recorded. The PANAS was re-administered and a second EKG recording was taken. Participants were asked to rate a subset of the study images for perceived valence, after which the equipment was removed and the participant was debriefed. Participants were given experimental credit toward a Psychology 101 course requirement, thanked for their time, and escorted out of the lab area.

EKG data was extracted from the Acqknowledge files recorded during the study and converted to text files. These files were loaded into Dr. John Allen's QRSTool software for processing. For each data file, the R spikes or S spikes of individual EKG waveforms were identified so that the program could track the Inter-Beat Intervals (IBI) as the base measure for RSA. In cases of ectopic beats or movements that only obscured a single beat, the surrounding two beats were averaged. If this did not fix the error or the disrupted period was longer than one beat, the dataset was cropped; a minimum stretch of two minutes was required for reliable RSA data to be determined. Each data file was examined twice by independent researchers for reliability purposes.

Results

The collected data were statistically analyzed using IBM SPSS. Log-transformed RSA data were used in order to normalize distributions, since individual variations can be large. No significant between-groups differences were found at baseline. ANOVA with $p<0.05$ showed a significant difference between the attend-positive and control groups in post-training RSA (Table 1), with the mean RSA values in the attend-positive group being higher (Table 2). However, when the baseline RSA values were subtracted from the post-training values, there was no longer a significant difference (Table 3). No other changes from baseline were significantly different between groups (Table 3) A correlation between positive affectivity and RSA was found, but only in the post-stressor data (Table 4).

Table 1 – RSA by CBM condition

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Post-Stressor RSA	Between Groups	8.621	2	4.310	4.198	.023
	Within Groups	35.937	35	1.027		
	Total	44.558	37			

Table 2 – Condition Pairwise Comparisons (*=significant at p<.05)

Multiple Comparisons						
Tukey HSD						
Dependent Variable	(I) CBM	(J) CBM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval
						Lower Bound
logRSA_post	Positive	Neutral	.18667	.41368	.894	-.8257
		Control	1.06869*	.39863	.029	.0931
	Neutral	Positive	-.18667	.41368	.894	-1.1990
		Control	.88202	.39863	.083	-.0935
	Control	Positive	-1.06869*	.39863	.029	-2.0442
		Neutral	-.88202	.39863	.083	-1.8576

Table 3 – Changes from Baseline ANOVA Results

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Change in Bias toward Positive	Between Groups	12863.492	2	6431.746	1.993	.152
	Within Groups	112975.612	35	3227.875		
	Total	125839.105	37			
Change in Bias toward negative	Between Groups	6319.068	2	3159.534	1.674	.202
	Within Groups	66078.820	35	1887.966		
	Total	72397.887	37			
Change in Positive Affectivity	Between Groups	23.054	2	11.527	.411	.666
	Within Groups	982.762	35	28.079		
	Total	1005.816	37			
Change in Negative Affectivity	Between Groups	74.096	2	37.048	2.587	.090
	Within Groups	501.167	35	14.319		
	Total	575.263	37			
Change in RSA	Between Groups	1.594	2	.797	1.787	.182
	Within Groups	15.607	35	.446		
	Total	17.201	37			

Table 4 – RSA and Positive Affectivity, post-stressor (*=Correlation is significant at the 0.05 level (2-tailed))

		Positive Affectivity (post)	RSA (post)
Positive Affectivity (post)	Pearson Correlation	1	.336*
	Sig. (2-tailed)		.039
	N	38	38
RSA (post)	Pearson Correlation	.336*	1
	Sig. (2-tailed)	.039	
	N	38	38

Discussion

The hypothesis of this study was that the different CBM conditions would a) differentially alter participants' bias toward positive and negative information, b) differentially impact their positive and negative affect in response to a stressor, and c) affect their vagal response, as measured by RSA. Although the outcomes of the three training regimens initially appeared to differ, none of them were statistically significant once the pre-post difference scores were analyzed. However, since the body of research mentioned in the introduction does suggest a real effect from CBM training, the authors are hesitant to conclude that it is ineffective. Due to the format of the statistical analysis (i.e., subtracting baseline from initial scores to compute change), the results may differ from the results found with a repeated-measures ANOVA, which will be examined in the future.

There are several factors that may have impacted the results of this study. First, EKG HRV has not been used as a dependent variable with CBM procedures before; it is possible that, at least for populations high in anxiety, having the electrodes on their skin is in itself stressful. This creates a problem in the particular format used here: the baseline PANAS was recorded before electrodes were attached, whereas the second measurement took place with the electrodes on. Additionally, it may be that the stress of having EKG electrodes on their skin impairs participants' attentiveness to the computer stimuli or their ability to shift attention away from negative stimuli, as the training subtly requires. This is a potential confound that could be explored in future studies. For instance, participants low in anxiety and participants high in anxiety could be compared on their induced attentional biases when wearing EKG recording electrodes; participants high in anxiety could also be compared on their responsiveness to training with and without the electrodes.

The second issue is that so much of the EKG data was unusable. Participants moving and medications with cardiac side effects were the most common causes, although irregular heartbeats and equipment malfunctions also played their role. In future studies using RSA as a variable, it might be necessary to plan a larger sample size to increase the number of usable files.

One interesting correlation emerged from this dataset, however. There was a significant positive association between RSA and positive affectivity – but only following a stressor. This correlation is consistent with earlier findings that the mammalian vagus is active during self-soothing behaviors (Porges, 2011).

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