

The Effects of Anxiety on the Brain and Body.

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ABSTRACT

In this paper, we want to examine the effect of increased levels of anxiety on the brain and body in order to understand its adverse consequences for mental and physical functioning and well-being. Previous research indicated that anxiety causes a left-hemispheric bias of the brain, decreases amygdala activity, increases hippocampal-insula activity, and elevates blood pressure. In our first (correlational) study, we tested the strength of these relationships by examining naturalistic daily changes in their variables longitudinally over a two-week period. We rated the level of anxiety on a scale of 0 to 100, measured left-hemispheric bias by the Global Local task, determined amygdala activity by increases in heart rate after watching scary videos, measured hippocampal-insula activity by the number of memory-induced gut feelings experienced each day, and measured blood pressure by diastolic readings. Data pooled across participants in our correlational study showed a significant correlation of anxiety level with hippocampal-insula activity and blood pressure in half of the participants but not with amygdala activity and hemispheric bias. Based on the strength of correlation found between anxiety level and hippocampal-insula activity in our correlational study, we then conducted a second (experimental) study to test for specifically a causal relationship between these two variables. Over a twelve-day period, we randomly assigned participants each day to either a guided meditation condition or a social media condition and measured the effect this had upon anxiety level each day. The results of our experimental study failed to establish a causal role of anxiety level upon hippocampal-insula activity in most of the participants, with only one participant showing a significant effect. A possible practical application of these findings could be that increased memory-induced gut feelings might indicate higher than usual anxiety in some people.

1. Introduction

1.1 Research Problem

Anxiety is an emotion many people struggle with and can reduce the quality of daily life. We would like to examine the biological mechanisms of anxiety, and how the disorder can impact one physically.

Also, we want to explore how anxiety affects the amygdala and response time under the threat condition. In addition, we will also look at how anxiety affects the connection between emotion and memory. Along with this, the elevation of blood pressure due to changes in levels of anxiety will also be examined. By researching this issue, we can learn how to lessen the physical and mental effects of anxiety and

hopefully improve mental and biological well-being.

1.2 Literature Review

Anxiety has been found to cause different patterns in brain activity, specifically causing hemispheric bias in the brain. Keller et al. (2000) conducted a study to determine which hemisphere of the brain was more highly affected by anxiety. They examined 80 undergraduate students, all of which were right-handed, who completed two questionnaires, the Mood and Anxiety Symptom Questionnaire (MASQ) and Penn State Worry Questionnaire (PSWQ), to self-report different levels of anxiety. Afterward, the participants completed a chimeric face task ($M = -0.540$, $SD = 0.458$), while an electroencephalogram (EEG) reported their brain wave patterns. The chimeric face task to test hemispheric bias used a book of pairs of human faces, with one-half of the face smiling and the other half being neutral. Participants were asked to choose which face they believed appeared to be happier. If a participant “consistently chose faces with smiles on one side of the visual field” (Keller et al., 2000), it demonstrated a level of hemispheric bias. It was found that those with higher levels of self-reported anxiety had a larger left-hemispheric bias. This study demonstrates the effects anxiety has on biological mechanisms and that anxiety has physical implications on the patterns of activity in the brain.

It was also previously found that threat monitoring affects the functioning of the frontal-parietal cortex and amygdala. Forty-one people (22 female and 19 male) participated in the experiment by Choi et al. (2012). Participants needed to perform a response-conflict task after being either under a threat condition of mild electric shock or safe condition for 1.75-5.75

seconds. At the end of the anticipation, period participants were presented with a picture of a house or building overlaid with five letters of string that could appear in one of three variations: congruent, incongruent, or neutral. The participants were asked to respond by using their index finger for building or middle finger for a house regardless of the overlaid letters. The experiment was performed with the use of functional magnetic resonance imaging. The neural processes as well as skin conductance response and reaction time were recorded. The stronger responses to the threat condition were shown across the frontal-parietal cortex, but the amygdala were activated more by the safe condition. Skin conductance response demonstrated that responses were greater after the period of shock monitoring (mean in long-transformed unit .019) than after safe one (.003). Thus, threat monitoring increased response in the frontal-parietal cortex and decreased response in the amygdala.

Trait anxiety also attributes to an aversion of risk-taking behaviors through connections with the hippocampus and right insula. 110 college students, 32 males, and 78 females with an average age of 20.18 were participants in a study by Huo et. al (2020). This study looked at the connection between anxiety and risk-taking, and the connection to the hippocampus and right insula. The participants all took a self-reported trait anxiety report, as well as, Balloon Analogue Risk Task (BART) where participants received a reward as they pumped the balloon. This helped to measure risk-taking because if the participants’ balloon popped they would lose the money. After a certain point, it was risky for participants to continue pumping the balloon. To examine the connection to the hippocampus and Insula, recordings of the participants resting state and structure were taken using an fMRI

for eight minutes. To test the functioning of the connections in the brain a VBM analysis was used to assess the specific regions of the brain. As a result of this study, it was found that anxiety was negatively correlated with risk-taking behaviors. Also, an increased response in the hippocampus and the insula showed that people who have higher trait anxiety use emotion and memory when making decisions and avoid making risky decisions (Huo et. al. 2020). Thus, anxiety increases activity in the hippocampus and insula, which is connected to emotion, decision-making, and memory.

Anxiety is supposed to level up hypertension (HT), which is the persistent elevated blood pressure in the arterial vessels. In total, 412 students who belonged to several, health care profession courses (which indicates high levels of anxiety) participated in the study administered by Mucci et al. (2016). 283 participants were women (68.7%) and 129 were men (31.3%). The average age \pm standard deviation was 23.9 ± 7.5 years. DBP and SBP readings were obtained by using the professional aneroid sphygmomanometer on each student's right arm in a seated position, maintained for at least 5 min at a constant room temperature. The diastolic scores ranged between 70 and 90 mmHg; the systolic scores ranged between 100 and 170 mmHg. Life-style variables were also investigated during the medical consultation. As a result of this study, it was found that hypertension and anxiety are correlated. Anxiety will improve the sympathetic response and more easily activate the sympathetic nervous system. Activation of the sympathetic nervous system not only reduces renal blood flow, increases renal water and sodium retention, but also elevates blood pressure. Thus, anxiety levels up hypertension (blood pressure).

1.3 Hypotheses

Based on the above literature review, we predicted the following hypotheses:

- Hypothesis #1: If anxiety increases then the left-hemispheric bias of the brain will increase.
- Hypothesis #2: If anxiety increases then amygdala activity will decrease.
- Hypothesis #3: If anxiety increases then hippocampal-insula activity will increase.
- Hypothesis #4: If anxiety increases then blood pressure will increase.

2. Methods

2.1 Participants

The four authors of this paper served as the participants in its studies. The participants ranged in age from 20 to 33 years old, with an average age of 23.5 years, and included all female participants. The participants were all undergraduate students at Camosun College who completed the current studies as an assignment for Psyc 215 ("Biological Psychology") and were grouped together due to their mutual interest in the effects of anxiety on the brain and body. All participants had high levels of self-reported anxiety.

2.2 Materials and Procedure

2.2.1 Correlational Study Methods

We first performed a correlational study to test concurrently all of our hypotheses by examining naturalistic daily changes in their variables longitudinally. Each participant kept a study journal with them at all times over this study's two-week period in order to record self-observations of the following four variables: (1) levels of anxiety in correlation with (2) the levels of activity in

the left-hemispheric bias of the brain, (3) the response of the amygdala, (4) the activity in the hippocampal-insula, and (5) the blood pressure.

To measure the amount of hemispheric bias in the brain, participants used the Navon task from the website PsyToolKits.org (see Appendix A) to measure their levels of right or left hemisphere bias in the brain based on Global and Local dominance. The participants followed the link to the website and ran the demo. All participants completed the Navon task once daily by following the instructions provided within the task, between the hours 6 pm and 8 pm. The task used an interference experiment model, in which the participants were shown large letters made up of smaller letters. If the participants saw the letter H or O, as either the large letter or the smaller letters, they clicked the letter B on their keyboards. If they did not see the letter H or O in either form, they clicked the letter N on their keyboards. The results of the Navon task were recorded in each participant's research journal, based on the amount of Global (large letter) errors and Local (small letters) errors they made. Each participant also recorded the level of anxiety they felt overall throughout that day.

To determine the level of activity in the amygdala, participants used the amount of increase in heart rate after the scary video compared to before it as an indirect measure of amygdala activity. Heart rate was measured by using the "Heart Rate Monitor" App by Health & Fitness AI Lab installed on a cell phone of each participant. Every day the participants performed three measurements. The first measurement was taken between 6 pm and 8 pm. Then participants started watching a 30 seconds video assigned for that day (see Appendix B) and did another measurement right away. The third measurement was performed

immediately after the video stopped. The amount of increase in heart rate was calculated by subtracting the second heart rate measurement from the third heart rate measure. All measurements and results were recorded in an individual research journal.

To determine how anxiety affected the connection between the hippocampus and the insula, participants measured memory induced gut feelings. The participants were asked to keep a journal to tally the amount of memory-induced gut feelings they had throughout their day that will measure the connection between the hippocampus, memory, and insula, emotional gut feelings. The results of the procedure were recorded in the participants' journals with their overall rating of daily anxiety.

To determine the correlation between anxiety and blood pressure, participants measured blood pressure, using a cuff machine around their arm and recorded their diastolic readings. If the participants did not have the machine in their homes, they went to the nearest pharmacy and got their blood pressure measured. The participants performed measurements and recorded their results once daily, during the evenings between the hours 6 pm and 8 pm. The results were recorded in the research journal along with their level of anxiety they felt throughout that day.

To measure the levels of anxiety throughout the two week period, the participants self-reported the level of their anxiety on a scale of 0 to 100. At the end of each day between 6 pm and 8 pm, the participants gave an overall score of their feelings of anxiety for that day using this anxiety level scale: 0 = no feelings of anxiety, 25 = minimal feelings of anxiety, 50 = moderate feelings of anxiety, 75 = high levels of anxiety, and 100 = extreme levels of anxiety. Then the participants recorded

their results in the individual research journals.

To assess the strength and statistical significance of associations between variables predicted by our four hypotheses, we performed Pearson product-moment correlations of their predictor variables (levels of anxiety) with their outcome variable (hemispheric bias, decrease in the amygdala, increase in the right hippocampus, and increase in diastolic blood pressure). To test hypothesis #1, we correlated the average levels of anxiety with the average Global and Local errors from the Navon task that the participants completed daily. To test hypothesis #2, we correlated the average levels of anxiety with the average response of the amygdala of each participant on each day during the threat monitoring phase. To test hypothesis #3, we correlated the average levels of anxiety with the average level in the hippocampal-insula connection activity of each participant on each day. To test hypothesis #4, we correlated the average levels of anxiety with the average blood pressure results of each participant on each day. We performed all of the above correlations separately for each participant as well as using data pooled across all of the participants. For the correlations using pooled data, in addition to using the raw data, we also performed correlations after we had first transformed the data from each participant into z -scores in order to standardize differences in averages and variability seen between the participants in their data and thus make them more comparable. A correlation coefficient was considered statistically significant if the probability of its random occurrence (p) was $< .05$ (i.e., less than 5% of the time expected by chance alone).

2.2.2 Experimental Study Methods

Based on the strength of the correlation between anxiety levels and levels of hippocampal-insula connection found in our correlational study, we then chose to conduct an experimental study to test for a causal relationship between these two variables from Hypothesis #3.

We manipulated the independent variable, levels of anxiety, over a twelve-day period by randomly assigning participants each day to either a guided meditation experimental condition or a social media control condition. On guided meditation experimental days, participants completed a five-minute mindful breathing meditation YouTube video (See Appendix C). On the control days, participants spent five minutes on social media. All conditions were completed within 30 minutes of the participants waking up each day. Between 6 pm and 8 pm, the participants recorded their overall anxiety levels and the amount of memory induced gut feelings they had throughout the day.

To avoid order effects, participants were randomly assigned to a condition each day by choosing the top card from a pre-shuffled 14-card deck that had equal amounts of each color (black suit = experimental condition and red suit = control condition). To avoid experimenter expectancy effects, the participants tried to be extremely objective about what they considered to be memory induced gut feelings.

To assess the statistical significance of differences seen in hippocampal-insula connection on guided meditation experimental days vs. social media control days, Student's t -tests were performed. We performed t -tests separately for each participant as well as using data pooled across all of the participants. For the t -tests using pooled data, in addition to using the raw data, we also performed t -tests after we had first transformed the data from each

participant into z -scores in order to standardize differences in averages and variability seen between the participants in their data and thus make them more comparable. An average difference between conditions was considered statistically significant if, using a two-tailed distribution (i.e., allowing this difference to be positive or negative), the probability of its random occurrence (p) was $< .05$ (i.e., less than 5% of the time expected by chance alone).

3. Results

3.1 Correlational Study Results

As shown in Table 1, hippocampal-insula activity was significantly correlated with anxiety levels. Although not statistically significant for half the participants, hippocampal-insula activity was significantly correlated with anxiety levels using both pooled raw data ($r = .49$, $p = .00009$) and pooled standardized data ($r = .49$, $p = .00009$; see Figure 3). In addition, although not statistically significant for half the participants, blood pressure was significantly correlated with anxiety levels using both pooled raw data ($r = .42$, $p = .001$) and pooled standardized data ($r = .43$, $p = .0008$; see Figure 4). In contrast, no statistically significant correlations were found between anxiety level and hemispheric bias using any single participant's data (all $r \leq .28$, all $p \geq .33$), pooled raw data ($r = .05$, $p = .70$), or pooled standardized data ($r = .04$, $p = .78$; see Figure 1). Similarly, no statistically significant correlations were found between anxiety level and amygdala activity using any single participant's data (all $r \leq .25$, all $p \geq .39$), pooled raw data ($r = .08$, $p = .58$), or pooled standardized data ($r = .10$, $p = .46$; see Figure 2). Based on a comparison of the correlation coefficients using either the

pooled raw data or the pooled standardized data, both hippocampal-insula activity and blood pressure showed the strongest correlation with anxiety levels.

3.2 Experimental Study Results

As shown in Table 2, only one participant (#3) was shown to have a significant effect. No other participants had a significant difference that was found in memory induced gut feeling between the meditation condition and the social media condition. Statistically significant differences between the conditions were seen using participant's #3 data (all $p = .08$). All other participants' data were not statistically significant individually ($p \geq .09$), with pooled raw data ($p = .53$; See Figure 5), or with pooled standardized data ($p = .42$).

4. Discussion

4.1 Summary of Results

Based on previous research, we hypothesized that increases in anxiety levels would result in increases in the four variables: left hemispheric bias (Hypothesis #1), amygdala activity (Hypothesis #2), the activity in the hippocampal-insula (Hypothesis #3), and the diastolic blood pressure (Hypothesis #4). Data pooled across participants in our correlational study supported the prediction relationship of daily level of anxiety and the activity in the hippocampal-insula and blood pressure but only with half of the participants (Hypothesis #3&4) but not with hemispheric bias or amygdala activity (Hypotheses #1&2).

4.2 Relation of Results to Past Research

The lack of correlation between anxiety levels and hemispheric bias is not in line with previous research. Keller et al. (2000) found that those with high levels of self-reported anxiety also had a significant correlation with a left hemispheric bias based on measurements of a chimeric face task electroencephalogram (EEG) to measure brain activity. The methodology of our correlational study differs from that of Keller et al. (2000) that may account for the discrepant results. Our study used a Navon task, which used global and local features within letters to measure hemispheric bias. It was predicted that those with higher levels of anxiety would have fewer local errors compared to global errors, suggesting an increased left-hemisphere bias. One of the major errors of this correlational study could be a result of carryover effects. As the participants completed this task daily, it is possible that they became increasingly better at the Navon task due to learning. Future studies may want to examine this phenomenon of hemispheric bias and anxiety in such a way that carryover effects will not have the ability to confound the study.

A strong relationship between anxiety level during the threat monitoring phase and amygdala activity was not found in our correlational study. These results contradict past research. Choi et al. (2012) found that threat monitoring decreased response in the amygdala. While the Choi et al. (2012) study showed a negative correlation between these two variables, our correlational study demonstrated a weak positive correlation. This difference in findings can be related to the way we conducted our studies. In addition to threat monitoring, Choi et al. (2012) also used a response-conflict task where participants needed to perform cognitive actions and respond by using either index finger or middle finger. Our

study only included the threat monitoring phase. Future studies should test whether the addition of response-conflict tasks influences the relationship between anxiety and amygdala activity.

The moderate correlation between the anxiety levels and the hippocampus-insula connection is partially in line with previous research. The previous research by Huo et al. (2020) found that trait anxiety can accredit to risk-taking behaviors throughout the connection with the hippocampus and the right insula. The research measured connections between anxiety and risk-taking, and the connection to the hippocampus and the right insula. The Huo et al. (2020) participants all took a self-reported trait anxiety report paired with the BART, whereas, our research was a daily self-report tally of memory induced gut feelings. The similarities of both our conclusions despite using different research designs suggest a generalized relationship with the level of anxiety and between risk-taking behaviors and memory induced gut feelings.

The strong correlation between anxiety level and blood pressure is completely in line with previous research. Mucci et al. (2016) found out that anxiety improves the sympathetic response and easily activates the sympathetic nervous system. The activation reduces the renal blood flow along with increasing renal water and sodium retention. This elevates blood pressure. Thus, anxiety levels up blood pressure. The Mucci et al. research participants conducted a survey where the blood pressures were recorded and other factors such as lifestyle variables (smoker, alcoholic, etc.) were also considered, however, we did not consider all these factors in our research. Our research was about self-reported anxiety levels where participants measured their blood pressure

daily. The similarities of both our conclusions despite not considering the lifestyle variables suggest that anxiety elevates blood pressure.

4.3 Implications of Results

Possible practical applications of our current findings are that increased memory induced gut feeling and blood pressure might be the indicators of higher than usual levels of anxiety in some people.

We originally conducted a current study to find out how anxiety affects our body and brain in order to learn how to better manage anxiety and improve our general well-being. Based on our experimental study we cannot recommend using memory-induced gut feeling for monitoring anxiety level. It remains for future studies to find more precise ways of testing the effects of anxiety on the body and brain given our limited access to comprehensive testing equipment.

References

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Table 1

Correlation coefficient (r) values, with the number of daily trials (n) per correlation in brackets.

Variables correlated	Participant #1	Participant #2	Participant #3	Participant #4	Pooled raw data	Pooled standardized data
Anxiety level & hemispheric bias	0.09(14)	0.00(14)	-0.22(14)	0.28(14)	0.05(56)	0.04(56)
Anxiety level & amygdala activity	-0.09(14)	0.03(14)	0.21(14)	0.25(14)	0.08(56)	0.10(56)
Anxiety level & hippocampal-insula connection	0.21(14)	0.36(14)	0.60(14)*	0.80(14)*	0.49(56)*	0.49(56)*

* $p < .05$.

Table 2

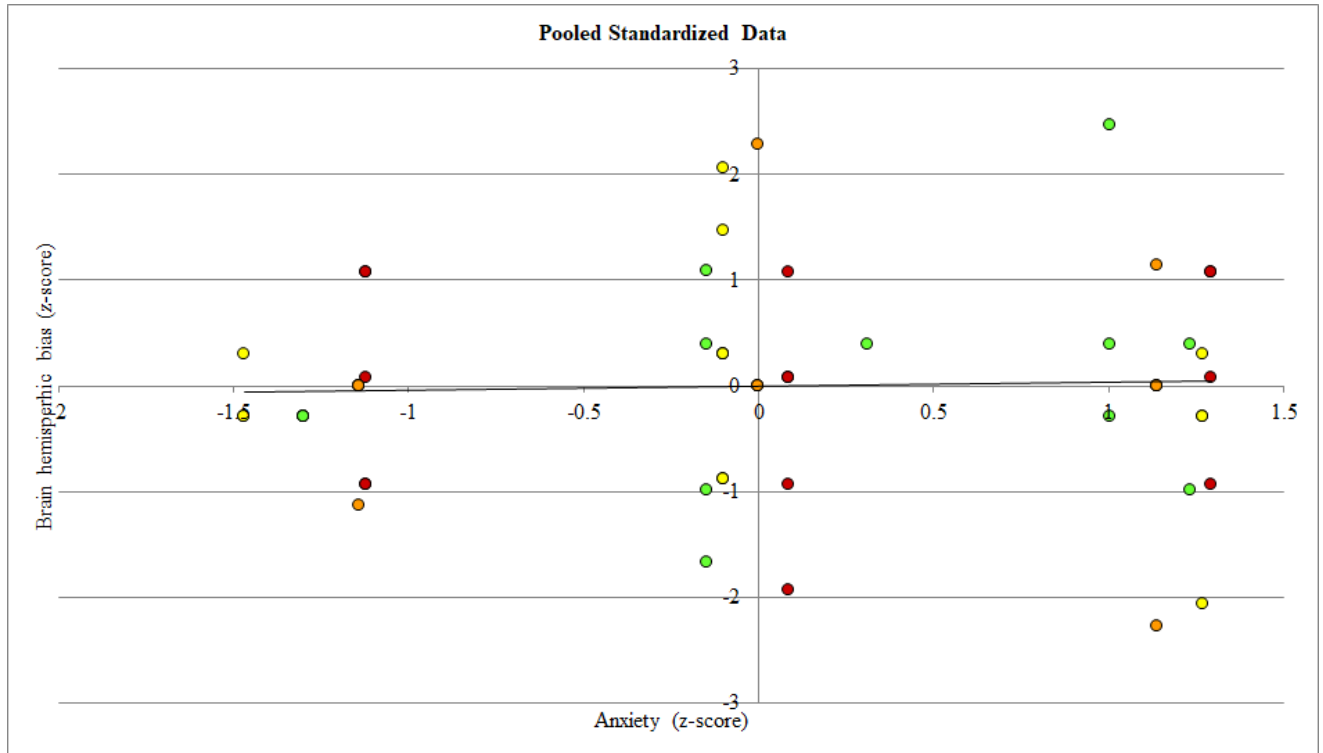
Descriptive statistics on memory induced gut feeling for meditation and social media conditions.

Condition	Statistic	Participant #1	Participant #2	Participant #3	Participant #4	Pooled raw data	Pooled standardized data
5 minutes of guided breathing focused meditation	Mean	1.0	1.20	2.83*	1.57	1.67	-0.11
	S.D.	0.89	0.84	0.75*	0.53	1.01	0.95
	<i>n</i>	6	5	6	7	24	24
5 minutes of social media	Mean	1.33	2.14	1.83*	2.0	1.83	0.82
	S.D.	0.82	0.9	0.75*	0.71	0.11	0.99
	<i>n</i>	6	7	6	5	24	24

* $p < .05$ for comparison of high-congener condition with its respective low-congener condition.

Figure 1

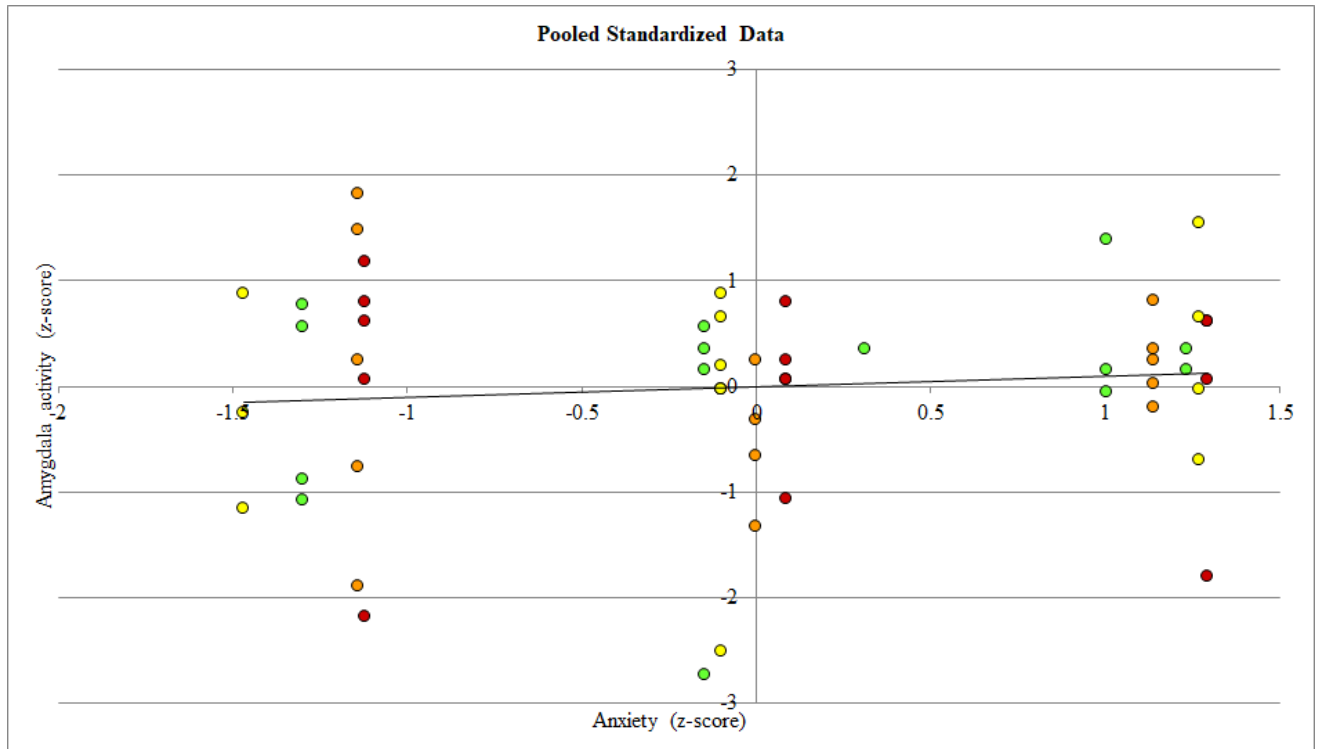
Scatterplot of levels of anxiety and hemispheric bias using pooled standardized data across participants.



Marker color indicates which participant data is from: red = participant #1, orange = participant #2, yellow = participant #3, and light green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 2

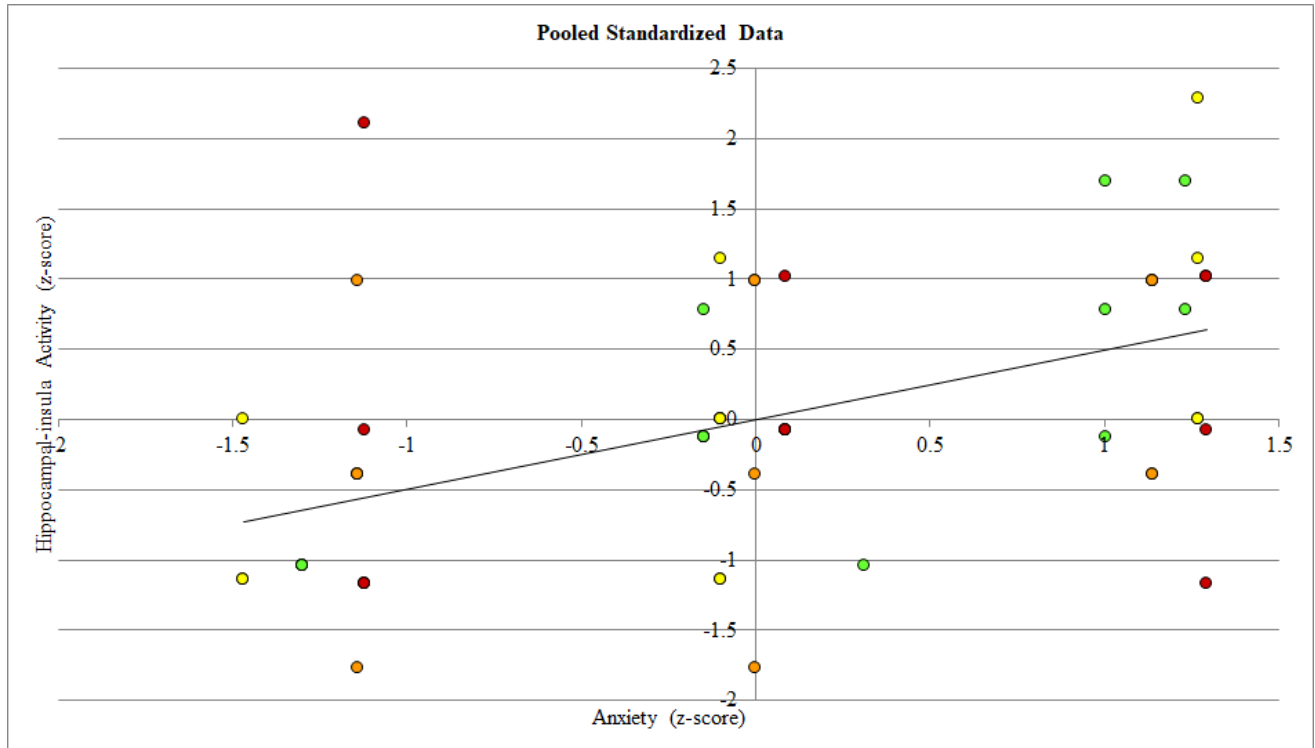
Scatterplot of levels of anxiety and amygdala activity using pooled standardized data across participants.



Marker color indicates which participant data is from: red = participant #1, orange = participant #2, yellow = participant #3, and light green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 3

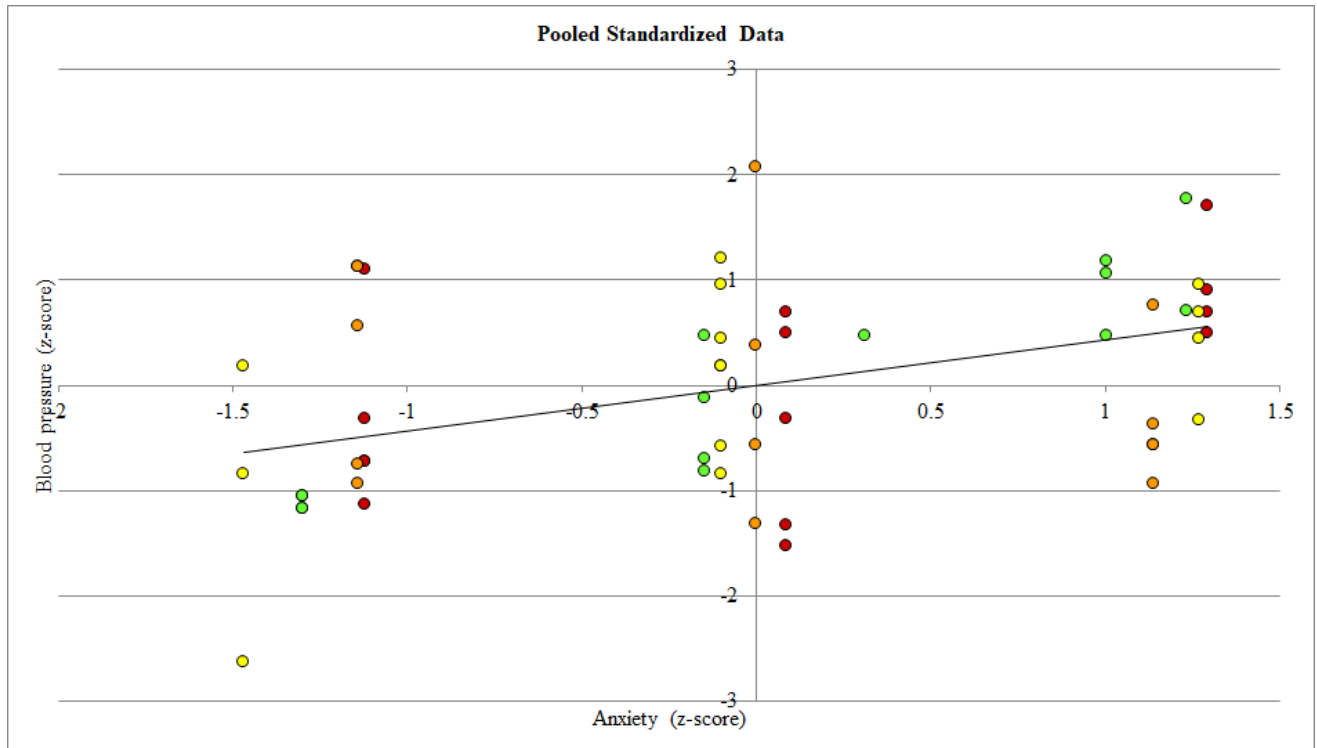
Scatterplot of anxiety and Hippocampal-insula activity using pooled standardized data across participants.



Marker color indicates which participant data is from: red = participant #1, orange = participant #2, yellow = participant #3, and light green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 4

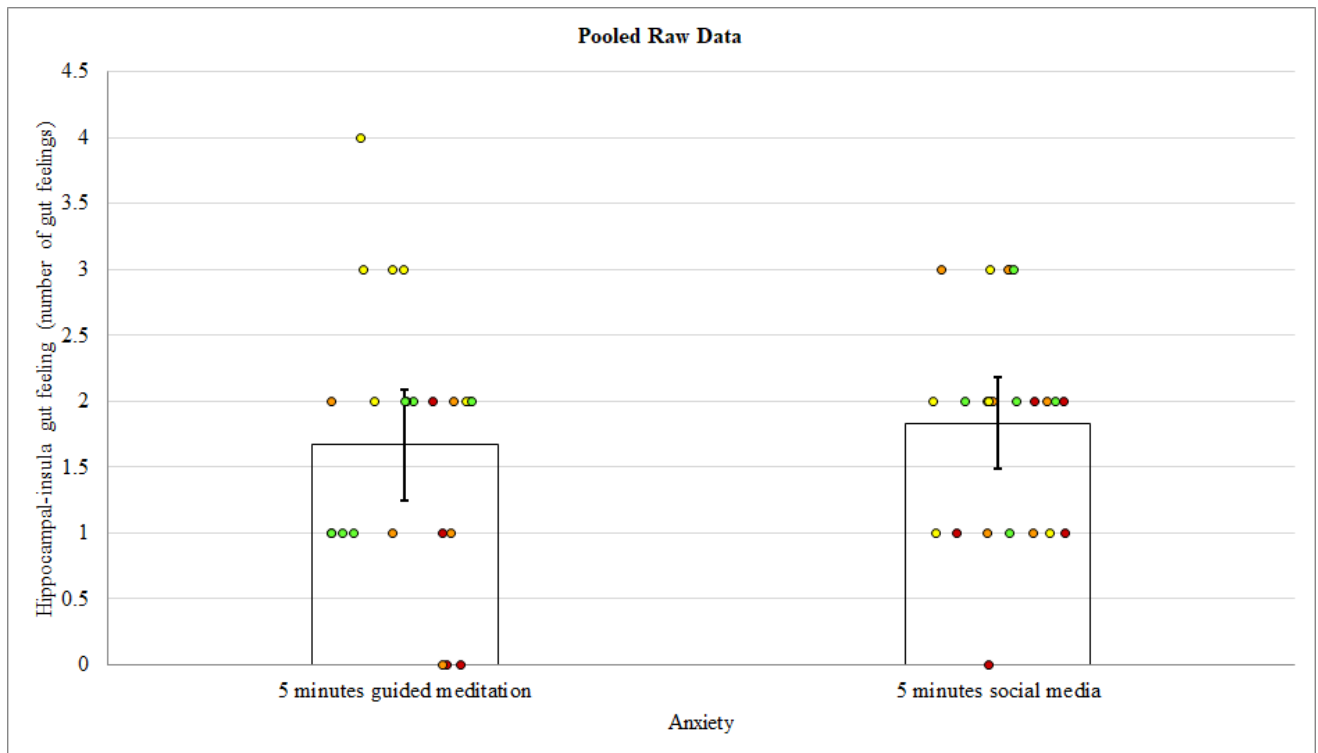
Scatterplot of anxiety level and blood pressure using pooled standardized data across participants.



Marker color indicates which participant data is from: red = participant #1, orange = participant #2, yellow = participant #3, and light green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 5

Bar graph of average memory induced gut feelings across guided meditation condition and social media condition using pooled raw data from participants, with error bars showing $\pm 95\%$ confidence levels, and with an overlapping scatterplot of data from each participant.



Marker color indicates which participant data is from: red = participant #1, orange = participant #2, and yellow = participant #3, light green = participant #4.

Appendix A

Link to Navon Task: <https://www.psychtoolkit.org/experiment-library/navon.html>

Appendix B

The list of videos used for measuring heart rate during the threat monitoring.

1. <https://www.youtube.com/watch?v=104f8of0eh4>
2. <https://www.youtube.com/watch?v=HrbR8Y6XpuY>
3. <https://www.youtube.com/watch?v=XPeBqO4yyGk>
4. <https://www.youtube.com/watch?v=Rv1YvQbkPBY>
5. <https://www.youtube.com/watch?v=zQYcc5cDywY>
6. <https://www.youtube.com/watch?v=xEbNulX-xds>
7. <https://www.youtube.com/watch?v=U49r1MmyuIw>
8. https://www.youtube.com/watch?v=zV_XnEMjA74
9. <https://www.youtube.com/watch?v=pp9iU5RAp20>
10. <https://www.youtube.com/watch?v=104f8of0eh4>
11. <https://www.youtube.com/watch?v=HrbR8Y6XpuY>
12. <https://www.youtube.com/watch?v=XPeBqO4yyGk>
13. <https://www.youtube.com/watch?v=Rv1YvQbkPBY>
14. <https://www.youtube.com/watch?v=zQYcc5cDywY>

Appendix C

Link to guided breathing meditation:

http://youtube.com/watch?v=nmFUDkj1Aq0&feature=youtu.be&ab_channel=MyLife