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Biological Mechanism of Mental Illness.

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ABSTRACT

In this paper, we sought to understand the biological mechanisms of five common mental illnesses so that we could learn about the relationship between the mind and body. Previous research has predicted mental health challenges by variables such as sympathetic/parasympathetic activity in obsessive-compulsive disorder, prefrontal cortex size in borderline personality disorder, amygdala activity in depressive rumination and in generalized anxiety disorder, and cerebellar activity in eating disorders. In our correlational study, we tested the strength of these relationships by examining naturalistic daily changes in their variables longitudinally over a one-week period. We measured sympathetic/parasympathetic activity by measuring heart rate, prefrontal cortex activity by EEG, amygdala activity by increases in heart rate after watching a scary video clip, cerebellar activity by a balance task, and measured by questionnaires levels of obsessive-compulsion, rumination, anxiety, borderline personality, and eating disorder. In contradiction to our predictions, data pooled across our participants showed a significant positive correlation between heart rate and obsessive compulsive disorder symptoms and there were no significant results in support of any of our other predicted relationships. These results could be helpful to understanding the biological mechanisms of obsessive-compulsive disorder. A possible practical application of these findings shows that having increased sympathetic/parasympathetic activity indicates higher obsessive-compulsive disorder symptoms.

1. Introduction

1.1 Research Problem

Mental illness causes suffering and affliction for many individuals worldwide. This study will center on the relationship between body and mind and the effects of those suffering with Obsessive Compulsive Disorder, Borderline Personality Disorder, Major Depressive Disorder, Anxiety, and Eating Disorders. Obsessive Compulsive Disorder (OCD) causes recurring intrusive thoughts, ideas, habits and obsessions that influences and negatively affects different aspects of an individual's lives. These thoughts manifest into actions that prevent those inflicted from leading normal lives, maintaining jobs, creating healthy relationships, and are damaging to their mental health. Borderline Personality Disorder (BPD) influences thoughts and behaviors causing complications in everyday life, such as mood swings, suicidal tendencies, fear of abandonment, and impulsiveness. Major Depressive Disorder (MDD) is a common mood disorder characterized by mental and physical

symptoms, some of which are a depressed mood most of the day, sleep changes, feelings of worthlessness, diminished interest in activities and recurring thoughts of death. MDD can greatly impair one's ability to function in daily life and is associated with high mortality rates. Anxiety involves a constant state of worry and fear. Individuals living with anxiety may avoid places or situations to escape the feeling, which can interfere in many aspects of the individual's life, such as building and maintaining relationships, work and school performance, and social activities. Eating disorders are repeated disturbances in eating patterns, which can cause intense emotions and frustrations as well as bodily harm. Eating disorders can include restricting, bingeing, and purging; they often coincide with other disorders such as mood disorders and substance abuse. Investigation of the underlying biological mechanisms of these particular mental illnesses allows for a deeper understanding of such complex ailments and may identify specific areas of focus for treatment.

1.2 Literature Review

One previously found biological mechanism of mental illness is the relationship between the sympathetic and parasympathetic nervous system's activity in OCD. For example, 70 participants diagnosed with OCD of varying compulsions (57 washing compulsions, 13 with checking compulsions) along with 72 control participants were part of an experimental study by Hinds et al. (2012). In the study participants were hooked up to an ECG machine in order to record respiratory sinus arrhythmia at three different intervals. Respiratory sinus arrhythmia is used as an objective measurement for the parasympathetic nervous system by measuring the variability in heart rate and spontaneous breathing of patients. First, participants were asked to close their eyes for two minutes in order to create a baseline measurement. Secondly, participants were asked to place their hands in either a bin with diapers or Styrofoam beads (this would initiate the sympathetic nervous system by making them believe they were contaminated) for 2 minutes, after which measurements would then be taken. Lastly participants were told they would have 30 seconds in order to wash their hands and that if they continued after the time limit, they would be asked to stop then another 2-minute measurement was taken. The study concluded that participants significantly showed no differences in their increase of sympathetic levels but failed to show a major decrease in their parasympathetic nervous system levels during which they were unable to control the need to stop their obsessive behavior. It also found that OCD participants with washing compulsions did not differ significantly from the control group with the threat of contamination regarding their levels of initial activation. However, the OCD participants had greater challenges reducing their activation through handwashing than to the control group. Based on these results, the researchers concluded that individuals suffering with OCD did not have issues with the part of the brain responsible for flight and fight, but with the section that switches off the compulsion after it has been completed resulting in obsessive behavior.

Another previously found biological mechanism of mental illness is the prefrontal cortex in BPD. For example, in an experimental study by Soloff et al. (2008), participants were randomly selected with the criteria that they were clinically diagnosed with BPD from the DSM-III. MRI scans and voxel-based imaging analysis were

conducted to view brain structures of the participants. Significant findings compared to healthy controls were that the BPD sample had decreased grey matter in the prefrontal cortex (anterior cingulate gyrus), which is the area that controls impulsivity. There was no difference for gender when it came to impulsivity for the BPD sample. Based on these results, the researchers suggested that the reduced grey matter in both the prefrontal cortex and medial temporal cortex influence the impulsiveness contributing to the behaviour in BPD patients for both males and females. The researchers noted that mediation of impulsive-aggression and impulsivity could potentially be explained by reduced connectivity in prefrontal areas of the brain.

A third previously found biological mechanism of mental illness is trait rumination associated with increased sustained amygdala reactivity. For example, 35 participants with a current diagnosis of MDD along with 29 never-depressed control participants were part of an experimental study by Mandell et al. (2014) aimed at examining the relationship between trait rumination and various cortical regions. In this study, participants completed 17 self-report measures of rumination and an alternating emotion-processing and executive-control task during a functional Magnetic Resonance Imaging (fMRI) assessment, as well as a measure of depression severity. Self-report measures were used to sample multiple aspects of persistent negative thought patterns and included the Emotion Control Questionnaire-rehearsal (ECQ-REH), Scott Macintosh Rumination Inventory-motivation (SMRI-EMOT), etc. A task consisting of 60 emotional valence identification (VID) and digit-sorting (DS) was conducted in conjunction with an fMRI screening to measure emotion-processing and cognitive control. Through examination of empirically defined dimensions of trait rumination and sustained neural responses, the fMRI results revealed correlations between depressed participants' rumination scores and left and right amygdala activation. Based on these results, the researchers suggested that multiple types of depressive rumination are associated with increased levels of sustained reactivity in the amygdala.

A fourth previously found biological mechanism of mental illness is the relationship between abnormal emotional and cognitive processing and amygdala dysfunction in individuals with generalized anxiety disorder (GAD). For example, Yang et al. (2021) examined amygdala-based functional connectivity (FC) in an experimental study between 38 GAD patients and 20 healthy individuals to further explore the association between trait anxiety and GAD. The study began by performing a resting-state functional MRI using a 3-Tesla Siemens MRI system to obtain data on the participants. Furthermore, a Clinical Global Impression Severity scale (CGI-S) was used to test the severity of the relationship between FC and trait anxiety. The scale indicated significant differences between the results of GAD patients and healthy individuals. In addition, GAD patients showed more hypoconnectivity in the left amygdala and the left superior temporal gyrus than in healthy individuals. The study found amygdala-rostral anterior cingulate cortex connectivity for GAD patients was negatively correlated with symptom severity and trait anxiety. In contrast, amygdala-inferior frontal gyrus connectivity was positively associated with symptom severity. Based on these results, the researchers suggested focusing on amygdala dysfunction could have important implications in treating anxiety symptoms.

The final previously found biological influence on mental health is the cerebellar activity found in eating disorders. For example, 17 patients with either Bulimia Nervosa or Anorexia Nervosa were part of a study by Cerasa et al. (2015) looking to see what biomarkers could contribute to eating disorders by using MRI scans. The MRI scans of those with eating disorders were compared to eighty-one healthy participants without eating disorders. The differences were shown mostly in the occipital cortex and the posterior cerebellar lobule. In addition, patients with eating disorder had more damage to the brain regions important for emotional processing, such as precuneus, sensorimotor, premotor cortices, agenesis of corpus callosum, and orbitofrontal cortex. Based on these results, the researchers suggested that the cerebellum could be a contributor to eating disorders because it is involved with other brain regions that play an important role in motor, cognitive and emotional functions.

1.3 Hypotheses

Based on the above literature review, we predicted the following hypotheses:
Hypothesis #1: If activity of the parasympathetic nervous system is increased then the symptoms of OCD will decrease.
Hypothesis #2: If activity in the prefrontal cortex is decreased then BPD symptoms will increase.
Hypothesis #3: If activity in the amygdala is increased then rumination will increase.
Hypothesis #4: If amygdala activity increases then anxiety symptoms will increase.
Hypothesis #5: If cerebellum activity increases then symptoms of eating disorders will increase.

2. Methods

2.1 Participants

The five authors of this paper served as the participants in its studies. The participants ranged in age from 19 to 29 years old college students, with an average age of 24 years, and included gender pronouns of he/him and she/her. 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 biological mechanisms of mental health. The participants (authors) all have a mutual interest or personal experience in the subject of mental health such as BPD, clinical depression, substance use disorder, GAD, OCD, and wished to gain knowledge on the topics.

2.2 Materials and Procedures

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 one-week period in order to record self-observations of the following 9 variables: (1) sympathetic/parasympathetic activity, (2) prefrontal cortex activity, (3) amygdala activity, (4) cerebellum activity, (5), OCD, (6) BPD, (7) rumination, (8) anxiety, and (9) eating disorders.

2.2.1 Sympathetic/Parasympathetic Activity

To measure a differential between symptoms and heart rate, participants measured their heart rates before taking the OCD questionnaire each day. Increasing and decreasing heart rate showed levels of sympathetic and parasympathetic activity, respectively.

2.2.2 Prefrontal Cortex Activity

To measure prefrontal cortex activity participants used the Muse 2.0 headband to indicate prefrontal cortex activity (Muse, 2021). The Muse 2.0 Headband uses an electroencephalography (EEG) system to scan and record brainwaves (Kovacevic et al., 2015). Each group member recorded brain activity for a minute with eyes closed everyday for a total of seven days. The brainwaves were recorded and the data quantified from the Muse using the Mind Monitor App (Mind Monitor, 2021).

2.2.3 Amygdala Activity

To measure amygdala activity, participants monitored heart rate before and after viewing a scary video clip. The video shown to participants was a short one minute YouTube video with a pop-up scare at the end (Jumpscare Zoo, 2019). Participants measured their initial baseline heart rate by counting their pulse rate on their wrist before watching the video and immediately after viewing. Each group member recorded amygdala activity each day for a total of seven days. The measure was completed each day for a total of seven days to track longitudinal changes. Longitudinal scores of heart rate measurements are represented in a chart (see Appendix 3).

2.2.4 Cerebellum Activity

To measure cerebellum activity, specifically motor skills and functioning, participants had their arms out horizontally with palms up and eyes closed. If there was upper body weakness relating to the cerebellum, then the affected side would drift within 30 seconds. To test lower extremities, participants laid in the supine position with knees bent at 30 degrees. The affected leg would have drifted downward within 30 seconds. A scale of 0-10 was given for each participant to use (0 = extremities drifted before 15 seconds, 5 = extremities drifted after 30 seconds, and 10 = extremities did not drift within 1 minute / 60 seconds), and a daily total score for seven days was noted. This method is an examination used by practitioners at the London Health Services Centre in the Critical Care Centre for assessing a conscious patient's motor skills (Morgan, 2019).

2.2.5 Obsessive-Compulsive Disorder

Each day participants filled out an OCD symptoms questionnaire (see Appendix 1). Participants then listed their name, the date, and the time the questionnaire was taken. The questionnaire measured seven different OCD symptoms ranging from excessive cleanliness to repetition of tasks and movement. Levels of these symptoms were rated on a scale from 0-10, with 0 being less severe and 10 being more severe, and with an overall score ranging between 0-70, 70 being the maximum score achieved.

2.2.6 Borderline Personality Disorder

To measure impulsivity (a symptom of BPD), we used a modification of the Zanarini Rating Scale for Borderline Personality Disorder (ZAN-BPD), also known as the McLean Screening for BPD, which was developed by Dr. Mary Zanarini at McLean Hospital Harvard Medical School Affiliate (see Appendix B). The ZAN-BPD questionnaire was developed to determine the severity of and changes in BPD symptoms as well as an indication of BPD diagnosis (Zanarini et al., 2003). The questionnaire had items each scored on a scale of 0 to 10 (0 = not at all and 10 = extremely severe) and which were summed to produce an overall score. Questions on the modified ZAN-BPD were for impulsivity (spending, binging, mood), abandonment, identity and reality questioning.

2.2.7 Rumination

To measure rumination (a popular trait of depressed individuals), we used the Ruminative Response Scale (RRS) each day.

The self-response measure, RRS (PsyToolkit, 2021), consists of 22 questions and a 4-point Likert scale to measure depressive rumination. Rumination scores were interpreted and quantified through the psytoolkit.org website, with a possible range of 22 to 88 points.

2.2.8 Anxiety

To measure anxiety, each participant used the Generalized Anxiety Disorder 7 Item Scale (GAD-7). The GAD-7 scale consisted of seven questions that asked participants daily to read short statements and rate their anxiety levels by indicating whether they felt nervous, anxious, worried, restless, and annoyed (Psychology Tools, n.d.). The following responses were available to the participants: not at all, several days, over half the days, and nearly everyday. A numerical value was derived by the score of the participants, 0-5 = little or no anxiety, 6-10 = mild anxiety levels, 11-15 = moderate anxiety levels, and 16-21 = severe anxiety levels (see Appendix D).

2.2.9 Eating Disorders

To measure eating disorders we used a 20-item questionnaire where each item was measured on a scale from 0 to 10, where 0 = not at all and 10 = extreme (See Appendix E). Participants filled out the questionnaire and summed their scores daily. The questionnaire was derived from The Eating Disorder Foundation (Questionnaire, 2021) and is a tool used for screening eating disorders but is not a true diagnosis.

2.3 Planned Analyses

To assess the strength and statistical significance of associations between variables predicted by our five hypotheses, we performed Pearson product moment correlations of their predictor variables (sympathetic/parasympathetic activity, prefrontal cortex activity, and amygdala activity, cerebellum activity) with their outcome variables (OCD symptoms, BPD symptoms, MDD symptoms, generalized anxiety symptoms, and eating disorder symptoms). For testing Hypothesis #1, we correlated sympathetic/parasympathetic activity with OCD symptoms for each of the participants. For testing Hypothesis #2, we correlated activity of the prefrontal cortex with impulsivity (BPD symptoms) for each of the participants. For testing Hypothesis #3, we correlated amygdala activity with MDD symptoms for each of the participants. For testing Hypothesis #4, we correlated amygdala activity with GAD symptoms for each of the participants. For testing Hypothesis #5, we correlated cerebellum activity with eating disorder symptoms for each of the participants. 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).

3. Results

As shown in Table 1, the parasympathetic/sympathetic activities were significantly correlated with OCD symptoms, although not being statistically significant for any individual participant (all $r \leq 0.63$, all $p \leq 0.81$). Parasympathetic/sympathetic activity was significantly correlated using the pooled raw data ($r = 0.36$, $p = 0.04$, see Figure 1) but

was not significant for the pooled standardized raw data ($r = 0.19$, $p = 0.27$ see Figure 2). In contrast, there was no significant correlation between prefrontal cortex activity and BPD for any individual participant (all $r \leq 0.29$, all $p \leq 0.97$) except for participant #2 ($r = 0.95$, $p < 0.0003$), as well as no statistical significance for the pooled raw data ($r = -0.15$, $p = 0.39$, see Figure 3) and pooled standardized data ($r = 23$, $p = 0.20$, see Figure 4). There was no significant correlation between amygdala activity and rumination for any individual participant (all $r \leq 0.45$, all $p \leq 0.$) as well as no statistical significance for the pooled raw data ($r = 0.23$, $p = 0.19$, see Figure 5) and pooled standardized data ($r = 0.10$, $p = 0.56$, see Figure 6). There was no significant correlation between amygdala activity and anxiety for any individual participant (all $r \leq 0.71$, all $p \leq 0.95$) as well as for the pooled raw data ($r = 0.07$, $p = 0.69$, see Figure 7) and pooled standardized data ($r = 0.31$, $p = 0.07$, see Figure 8). Finally, there was no significant correlation between cerebellum activity and eating disorder activity for any individual participant (all $r \leq 0.75$, all $p \leq 0.93$) as well as for the pooled raw data ($r = 0.10$, $p = 0.56$, see Figure 9) and pooled standardized data ($r = 0.32$, $p = 0.06$, see Figure 10).

4. Discussion

4.1 Summary of Results

Based on previous research, we hypothesized the biological mechanisms of 5 common mental illnesses: if the parasympathetic nervous system increases then obsessive-compulsive disorder decreases (Hypothesis #1), if prefrontal cortex activity decreases then borderline personality symptoms will increase (Hypothesis #2), if amygdala activity is increased then rumination will increase (Hypothesis #3), if amygdala activity increases then anxiety symptoms will increase (Hypothesis #4), and if cerebellum activity increases then eating disorder symptoms will increase (Hypothesis #5). The hypotheses were not supported by significant results.

4.2 Relation of Results to Past Research

The significant relationship found between sympathetic/parasympathetic activity and OCD symptoms in our study differs from previously published work. In Hinds et al. (2012), it was found that participants suffering from OCD did not have any issues with the part of the nervous system responsible for flight or fight (sympathetic nervous system) but instead had a decrease in the division of the nervous system that switches off arousal (parasympathetic nervous system) after compulsions have been completed . In contrast, we found the opposite: that increased (not decreased) heart rate was associated with greater OCD symptoms. The method of our study differed from that of the Hinds et al. (2012) study in two major way that might account for the discrepant results. Firstly, in the Hinds et al. (2012) study they had participants perform a task that would initiate the sympathetic/parasympathetic nervous system by placing their hands into "containments" which produced a significant result using respiratory sinus arrhythmia measurements. Our study differed due to measuring sympathetic/parasympathetic activity by recording naturalistic heart rates each day. Secondly, Hinds et al. (2012) used participants who were diagnosed with two separate obsessive-compulsive disorders (washing compulsion and checking) and a control group. Our study used the five

authors of this paper suffering from a range of different mental health disorders with only one participant who had OCD. These differences could have affected the results due to the small sample size and the range of differences in mental disorders.

Based on previous research (Soloffet al., 2008) about the biological mechanisms of BPD, we predicted that prefrontal cortex activity would be correlated with BPD symptoms. Whereas the research of Soloff et al. (2008) was performed with just diagnosed BPD participants, only one of our five participants had been diagnosed with BPD and that participant's individual results were significant, in contrast to the rest of our participants. The current study shows that the relationship between prefrontal cortex functioning and BPD symptoms only exists for those diagnosed with BPD.

The correlational study failed to confirm the relationship between rumination and amygdala activity. No significant relationship was found between participants' scores on the Ruminative Response Scale (RRS) and their amygdala activity. Previous research by Mandell et al (2014) used multiple questionnaires and an fMRI machine to examine the relationship between trait rumination and increased amygdala activity. Their research was performed with individuals who were diagnosed with MDD and used an fMRI to accurately measure activity levels of the amygdala and other related cortical regions. Our correlational study differed from that of Mandell et al. (2014) in two ways that may explain the different results. First, our study used participants with a range of mental disorders, with only one participant having MDD. Secondly, amygdala activity was measured by heart rate after viewing a scary video instead of using an fMRI technique. The results of Mandell et al. (2014) study revealed that increased levels of sustained reactivity in the amygdala was associated with multiple types of depressive rumination. The methodological differences of measuring clinical levels of depression and amygdala activity regarding the lack of MDD participants and relying upon indirect measures of amygdala activity led to different results. For future research, other methods of evaluating amygdala activity that offer greater internal validity should be applied.

Our correlational study failed to confirm the relationship between amygdala activity and anxiety symptoms reported by previous research. Yang et al. (2021) found that amygdala-inferior frontal gyrus connectivity was associated with anxiety symptom severity after participants were measured with a resting-state functional MRI and the Clinical Global Impression Severity scale (CGI-S). In contrast, our participants did not find that amygdala activity, measured by heart rate activity after viewing a scary video, was associated with their anxiety symptoms, and measured by the Generalized Anxiety 7 Item Scale (GAD-7). The methodology of our correlational study differed from that of the Yang et al. (2021) study in two major ways that might account for the discrepant results. First, differences between the studies in how they measured amygdala activity could have affected the findings. The self-measurement of amygdala activity could have produced different results because it relied on the participants' judgement to measure their heart rate before and after watching a scary video clip each day. Future studies should try to confirm with functional MRI the results of Yang et al. (2021) to see if our insignificant results were due to relying upon indirect measures of amygdala activity. Second, differences between the studies in how they measured anxiety symptoms could have affected their findings. Our study used the five authors of

this paper as participants, which could have affected the results due to the small sample size. Future experimental studies should have a bigger sample size and compare participants with GAD and individuals without GAD, similar to Yang et al. 2021 study while using the GAD-7 scale.

The study by Cersasa et al. (2015) regarding the relationship between cerebellum activity and eating disorders found that increased cerebellum activity would lead to a higher likelihood of eating disorders. Cersasa et al. (2015) used MRI scans to look for biomarkers which could lead to eating disorders, but they found that high cerebellum activity corresponded with eating disorders in their participants. Our results were different from the results that Cersasa et al. (2015) found and one of the reasons why we did not get the same results could be because we did not have the same resources for our study. They used MRI scans to see cerebellum activity while we used an arm exercise, and they also had many more participants in their study than we did. We tested cerebellum activity through an exercise which involved keeping our arms straight out for one minute. The exercise was rated out of 10 points and points would be lost if arms waivered or dropped. The eating disorder data was collected through a questionnaire with 20 questions with each question being on a scale of 1-10. Our hypothesis was that high points on the arm exercise positively correlated with high scores on the eating disorder questionnaire, but our study found that there was no significance between cerebellum activity and eating disorders. For future studies, it would be helpful to have a clearer way to measure cerebellum activity that possibly involves brain scans.

4.3 Implications of Results

Based on the current study's findings, increased sympathetic/parasympathetic activity indicates higher obsessive-compulsive disorder. These results have possible practical applications to enhance the knowledge of the relationship between the mind and body regarding the biological mechanisms of individuals diagnosed with obsessive-compulsive disorder. Since sympathetic/parasympathetic activity were found to be significantly correlated with obsessive-compulsive disorder, other studies might use these results to improve research in treatment areas.

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Table 1 - *Correlations for Study Variables*

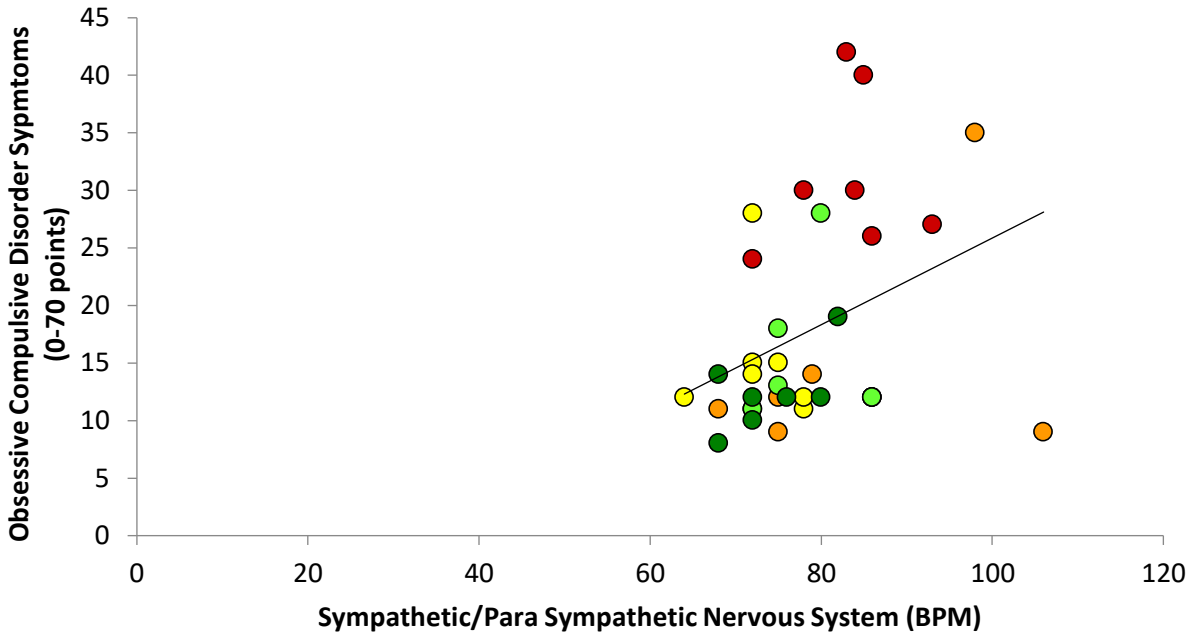
Variables	Participant #1		Participant #2		Participant #3		Participant #4		Participant #5		Pooled raw data		Pooled standard-ized data	
	r	*n*	*r*	*n*	*r*	*n*	*r*	*n*	*r*	*n*	*r*	*n*	*r*	*n*
Sympathetic/ Parasympathetic Activity & obsessive-compulsive disorder	0.16	7	0.42	7	-0.12	7	-0.12	7	0.63	7	*0.36	35	0.19	35
Prefrontal cortex activity & borderline personality disorder	0.17	7	0.95*	9	-0.37	6	0.02	6	0.29	6	-0.15	33	0.23	33
Amygdala activity & major depressive disorder	0.14	7	-0.46	7	0.04	7	0.45	7	0.34	7	0.23	35	0.1	35
Amygdala activity &	0.05	7	0.03	7	0.58	7	0.71	7	0.2	7	0.07	35	0.3	35

generalized anxiety disorder														
Cerebellar activity & eating disorder	0.14	7	0.75	7	0.61	7	0.08	7	0.05	7	0.1	35	0.32	35

* $p < .05$.

Figure 1

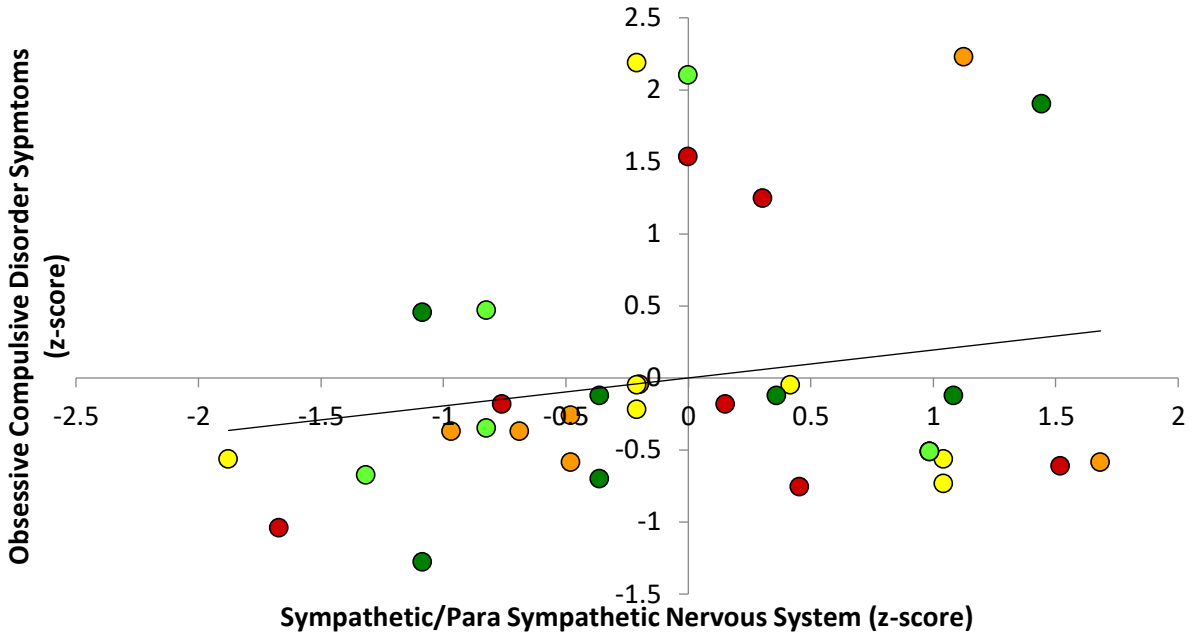
Association Between Sympathetic/Parasympathetic Activity and Obsessive Compulsive Disorder Symptoms Using Pooled Raw Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, light green = participant #4, and dark green = participant #5. Some data might not be visible in the figure due to overlapping markers.

Figure 2

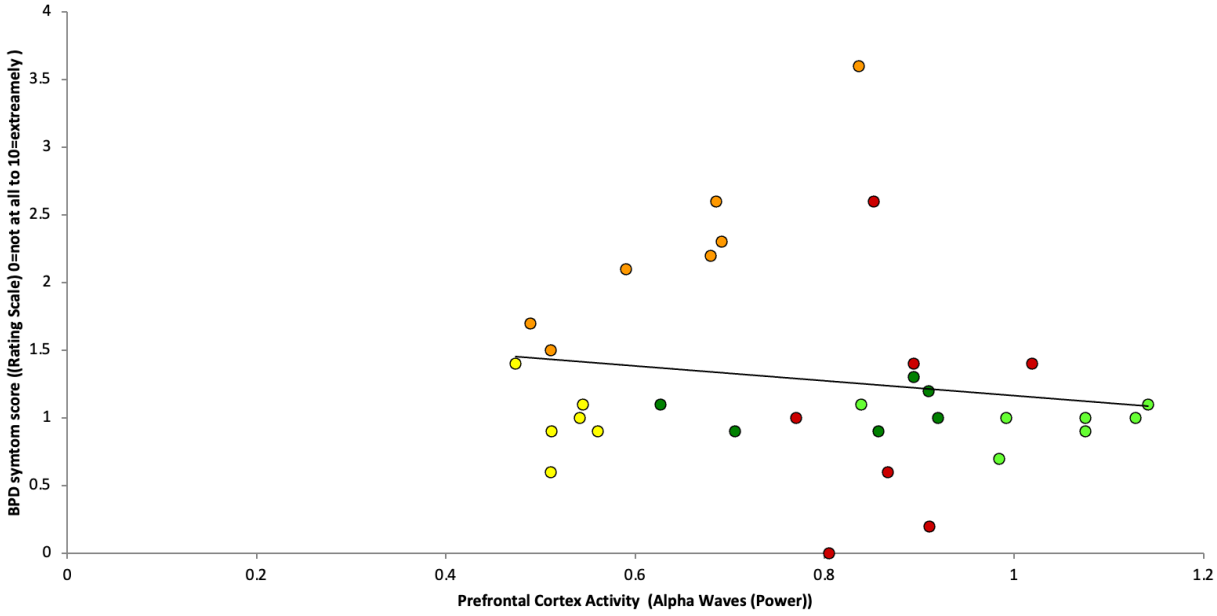
Association Between Sympathetic/Parasympathetic Activity and Obsessive Compulsive Disorder Symptoms Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, light green = participant #4, and dark green = participant #5. Some data might not be visible in the figure due to overlapping markers.

Figure 3

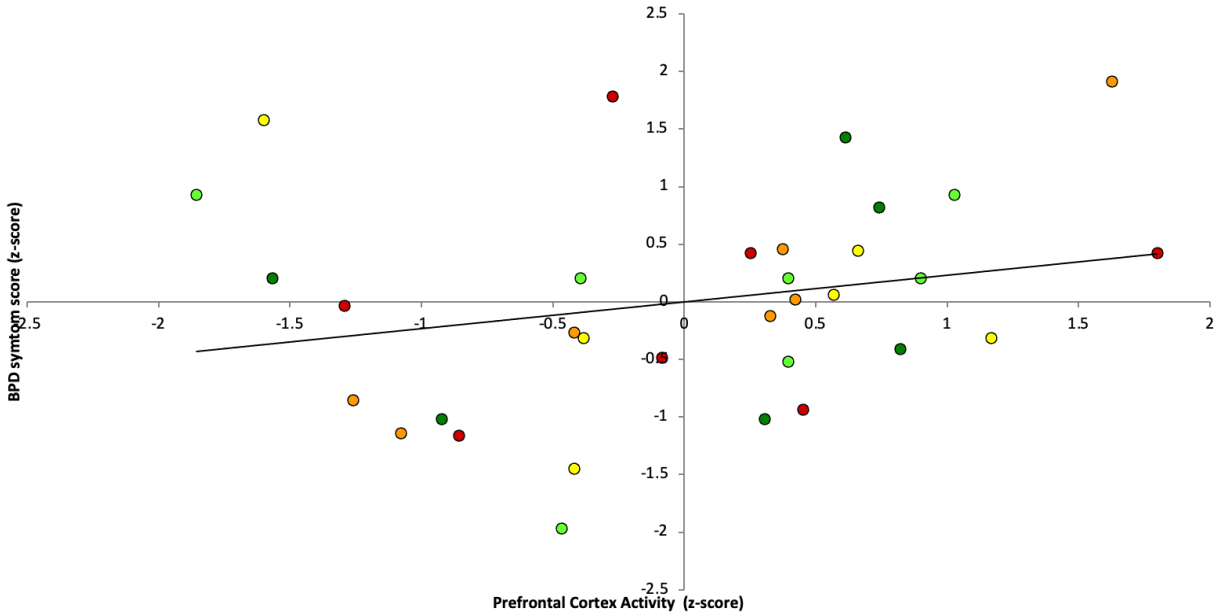
Association Between Prefrontal Cortex Activity and Borderline Personality Disorder Symptoms Using Pooled Raw Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, light green = participant #4, and dark green = participant #5. Some data might not be visible in the figure due to overlapping markers.

Figure 4

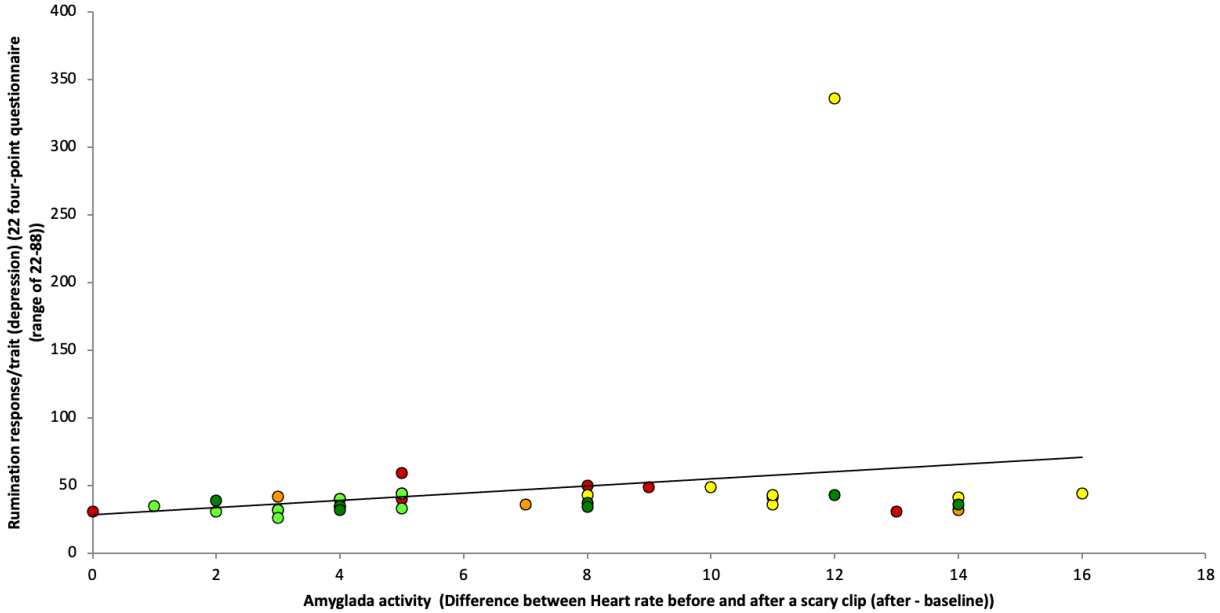
Association Between Prefrontal Cortex Activity and Borderline Personality Disorder Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, light green = participant #4, and dark green = participant #5. Some data might not be visible in the figure due to overlapping markers.

Figure 5

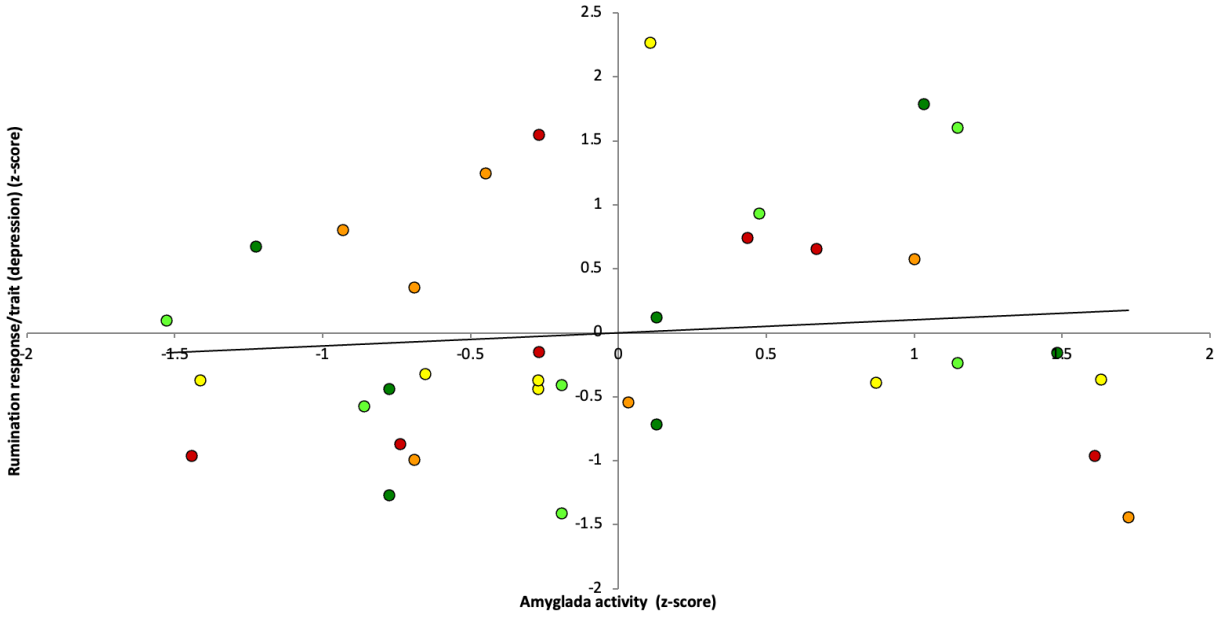
Association Between Amygdala Activity and Rumination Using Pooled Raw Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, light green = participant #4, and dark green = participant #5. Some data might not be visible in the figure due to overlapping markers.

Figure 6

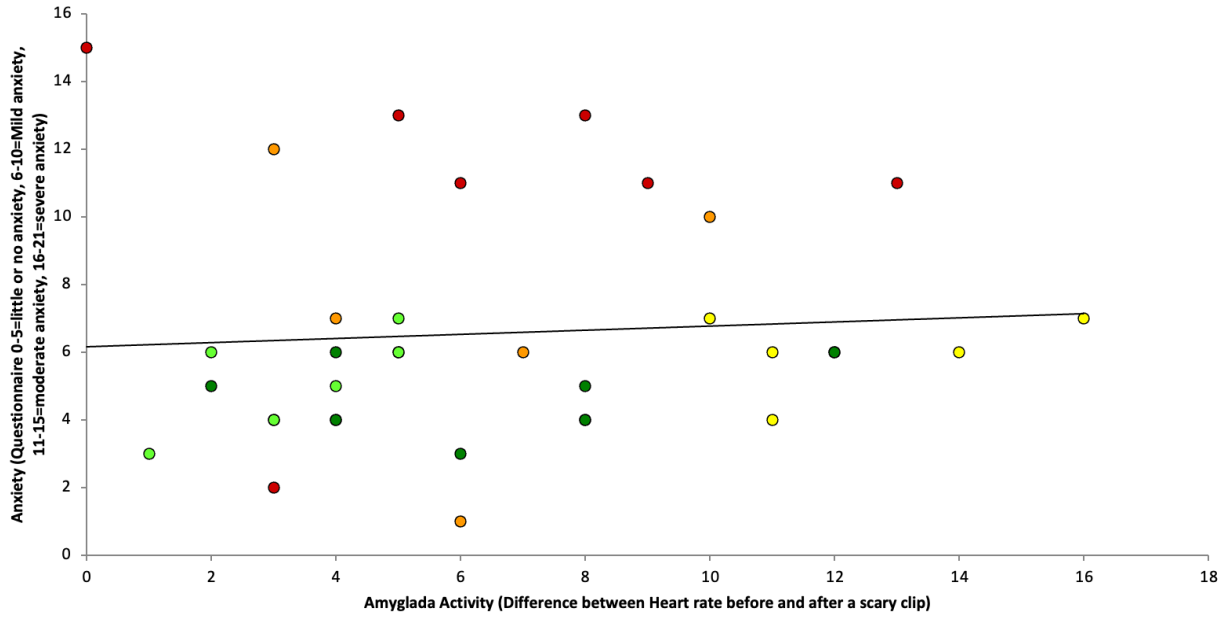
Association Between Amygdala Activity and Rumination Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, light green = participant #4, and dark green = participant #5. Some data might not be visible in the figure due to overlapping markers.

Figure 7

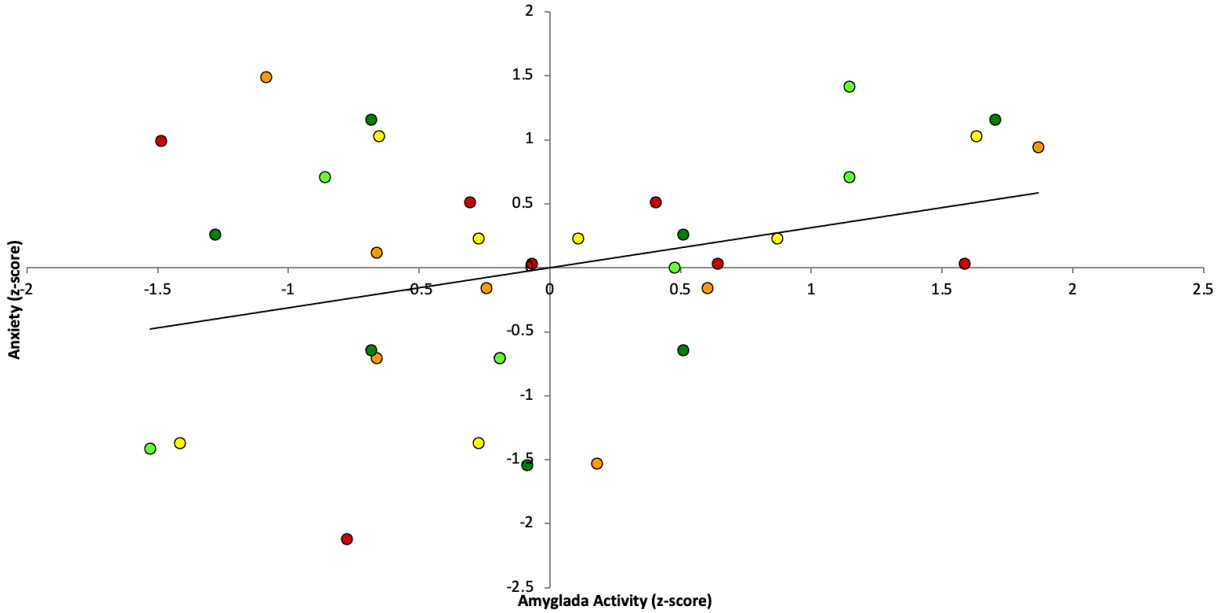
Association Between Amygdala Activity and Anxiety Using Pooled Raw Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, light green = participant #4, and dark green = participant #5. Some data might not be visible in the figure due to overlapping markers.

Figure 8

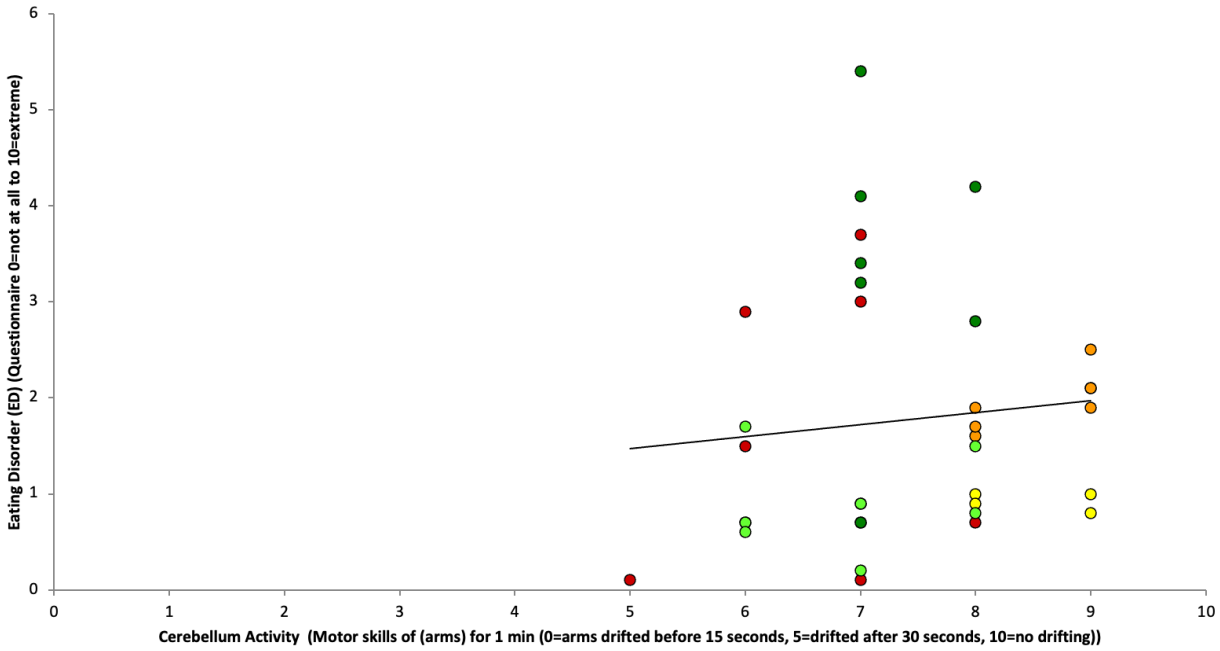
Association Between Amygdala Activity and Rumination Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, light green = participant #4, and dark green = participant #5. Some data might not be visible in the figure due to overlapping markers.

Figure 9

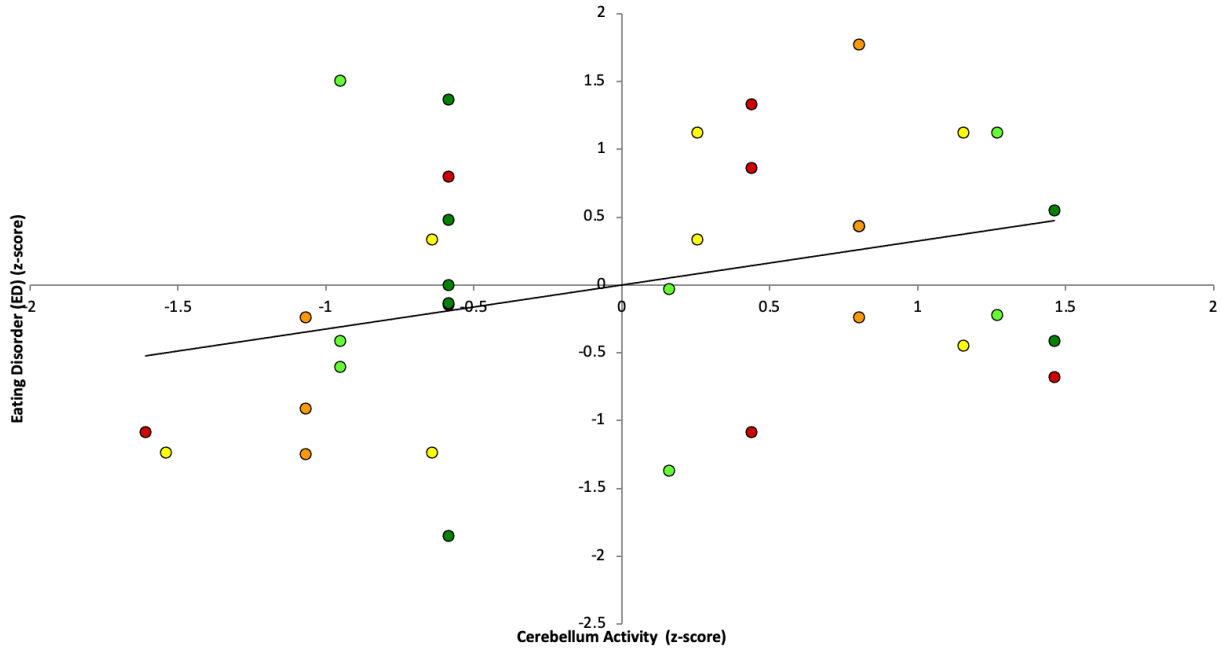
Association Between Cerebellum Activity and Eating Disorder Symptoms Using Pooled Raw Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, light green = participant #4, and dark green = participant #5. Some data might not be visible in the figure due to overlapping markers.

Figure 10

Association Between Cerebellum Activity and Eating Disorder Symptoms Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, light green = participant #4, and dark green = participant #5. Some data might not be visible in the figure due to overlapping markers.

Appendix A

OCD Symptom Scale

Obsessive Compulsive Disorder (OCD) Levels **Symptom Scale**	
Name: **Date:** **Time:**	
Below record data regarding emotions and feelings pertaining to OCD symptoms.	
How affected are you by these behaviours?	**Levels**
Excessive Cleanliness/Hygiene	**0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 - 10**
Constant Checking and Worrying	**0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 - 10**
Hoarding Behaviour	**0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 - 10**

Repetition of Tasks and Movements	**0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 - 10**
Excessive Cleaning	**0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 - 10**
Hard to Control Thoughts or Worry	**0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 - 10**
Depression	**0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 - 10**

Appendix B

Mclean Screening for BPD

Modified McLean Screening Instrument for BPD
Scale from 0-10, (0=not at all 10=extremely severe)

1. Have you had any arguments today?	1. _____
2. Have you deliberately hurt yourself physically? (eg punched yourself, cut yourself, burned yourself) or had ideology or attempt at suicide?	2. _____
3. Have you had at least two problems with impulsivity? (eg binge eating, spending spree, drinking too much, verbal outbursts)?	3. _____
4. Have you had mood changes today?	4. _____
5. have you felt very angry or had a sarcastic manner?	5. _____
6. Have you had distrust of other people?	6. _____
7. Have you felt your reality has been unreal or abnormal today?	7. _____
8. Have you felt chronically empty today?	8. _____
9. Have you had an identity crisis? (Midlife, semi-life, etc.) or questioned your identity?	9. _____
10. have you had thoughts of abandonment (constantly needing reassurance that someone still cares about you)?	10. _____
	Total score: _____

Appendix C

Rumination Response Scale (RRS)

Item	almost never	sometimes	often	almost always
think about how angry you are with yourself	◯	◯	◯	◯
think about how you don't feel up to doing anything	◯	◯	◯	◯
think about how you don't seem to feel anything anymore	◯	◯	◯	◯
think about a recent situation, wishing it had gone better	◯	◯	◯	◯
think about how hard it is to concentrate	◯	◯	◯	◯
think about your feelings of fatigue and achiness	◯	◯	◯	◯
think "Why can't I get going?"	◯	◯	◯	◯
think about how sad you feel.	◯	◯	◯	◯
think "Why do I have problems other people don't have?"	◯	◯	◯	◯
think about how alone you feel	◯	◯	◯	◯
think "Why do I always react this way?"	◯	◯	◯	◯
think about all your shortcomings, failings, faults, mistakes	◯	◯	◯	◯
go someplace alone to think about your feelings	◯	◯	◯	◯
think "Why can't I handle things better?"	◯	◯	◯	◯
think "I won't be able to concentrate if I keep feeling this way."	◯	◯	◯	◯
think "I won't be able to do my job if I don't snap out of this"	◯	◯	◯	◯
analyze your personality to try to understand why you are depressed	◯	◯	◯	◯
go away by yourself and think about why you feel this way	◯	◯	◯	◯
think "What am I doing to deserve this?"	◯	◯	◯	◯
think about how passive and unmotivated you feel.	◯	◯	◯	◯
write down what you are thinking about and analyze it	◯	◯	◯	◯
analyze recent events to try to understand why you are depressed	◯	◯	◯	◯

Appendix D

Generalized Anxiety Disorder 7 Item Scale (GAD-7)

	Not At All	Several Days	Over Half The Days	Nearly Everyday
1. Feeling nervous, anxious, or on edge	○	○	○	○
2. Not being able to stop or control worrying	○	○	○	○
3. Worrying too much about different things	○	○	○	○
4. Trouble relaxing	○	○	○	○
5. Being so restless that it's hard to sit still	○	○	○	○
6. Becoming easily annoyed or irritable	○	○	○	○
7. Feeling afraid as if something awful might happen	○	○	○	○

Appendix E

Eating Disorder (ED) screening questionnaire

Daily Eating Disorder Screening. Scale of 0-10 (0=not at all, 10=extreme yes)

1. Did you feel guilt and remorse when you eat?	1. _____
2. Were you terrified of being overweight?	2. _____
3. Did you isolate so that you can eat?	3. _____
4. Did you avoid eating when you're hungry?	4. _____
5. Did you continue to eat even after you feel full?	5. _____
6. Did you take medication or exercise instead of eating a meal?	6. _____
7. Did you weigh yourself at least once a day?	7. _____
8. Did you evaluate yourself based on your body size and shape?	8. _____
9. Did you eat large amounts of food in a brief amount of time?	9. _____
10. Did you feel out of control when you eat?	10. _____
11. Did you make yourself vomit to avoid gaining weight?	11. _____
12. Did you regularly take laxatives or diuretics to lose weight?	12. _____
13. Did you exercise no matter how tired or sick you may feel?	13. _____
14. Did you skip any meals in order to lose weight or to avoid gaining weight?	14. _____
15. Did you exercise more than once today?	15. _____
16. Did you hide food?	16. _____
17. Did your emotions affect your eating habits?	17. _____
18. Are you preoccupied with food or your body size?	18. _____
19. Did you avoid close relationships or social activities?	19. _____
20. Did you feel as if food controls your life?	20. _____
	Total: _____