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J Camosun Psyc Res. (2022). Vol. 4(1), pp. 14-47.
Submitted Fall 2021; accepted June 2022.

The Biological Mechanisms of Emotion.

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ABSTRACT

In this paper, we sought to understand the biological mechanisms of emotions, so that we could learn more about how emotions work. Previous research has linked the brain and emotion in structures such as the postcentral gyrus, the posterior parietal cortex, and the orbitofrontal cortex. In our first (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 postcentral gyrus functioning by the Two Point Discrimination Test, posterior parietal cortex functioning by using the PEBL Connections Test, orbitofrontal cortex functioning by using the Go-NoGo task, positive emotions by evaluating external stimuli for emotional response, perfectionism by a Negative Perfectionism questionnaire, and emotional dysregulation with an emotional dysregulation questionnaire. Based on the strength of correlation found between orbitofrontal cortex functioning and emotional dysregulation in our correlational study, we then conducted a second experimental study to test for a causal relationship between these two variables. Over a one-week period, participants alternated each day to either a meditative condition or a non-meditative condition and measured the effect this manipulation had upon emotional dysregulation. Data pooled across participants in our correlational study showed a positive correlation between emotion dysregulation and orbitofrontal cortex functioning, but no significant correlation between postcentral gyrus functioning and positive emotion nor between posterior parietal functioning and negative perfectionism. Data pooled across participants in our experimental study showed no significant difference in emotional dysregulation between days participants meditated and days participants did not meditate. A potential practical application of our correlational study would be the use of the Go-NoGo task to predict emotional dysregulation. While our studies were not successful in finding a way to help control our emotions, they did further our understanding of emotions by showing aspects that were correlated, or not, with the functioning of particular brain areas.

1. Introduction

1.1 Research Problem

Emotions are common occurrences, but the underlying or entwined biological mechanisms behind them are still not fully understood. Our emotions can be a result of external stimuli. By gaining an understanding of the neurochemical communication between the environment and our psychology will further our understanding of emotions. Some emotions have detrimental effects on mental and

physical well being. Students setting high standards for themselves create extra pressure for assignments and exams, making studying more stressful and difficult, leading to decreased grades, thereby increasing and creating a spiral of stress and other negative emotions. By gaining an understanding of the link between how emotions are brought on and impact behaviour we can attempt to better understand emotional responses and outbursts that may otherwise seem irrational. We hope that learning more about the biological factors affecting emotion will help pave the way to helping people manage emotions and improve their mental and physical well-being.

1.2 Literature Review

One neural factor previously found to predict aesthetic experience and emotional responses is activity in the right postcentral gyrus. For example, in a correlational study by Yeh et al. (2018), a sample group of twenty-six college students, with equal numbers of males and females ranging in age from 20-29 years, were presented with a series of ninety images. Participants were instructed to evaluate their aesthetic experience ranging from beautiful, medium and ugly. With fMRI, participants' brains were scanned while images of design were presented and participants rated the images with 1 = negative, 2 = neutral, or 3 = positive in aesthetic experience. They did this again asking participants to rate the emotional arousal of the stimuli ranging from 1= very weak, 2 =weak, 3= strong, and 4 = very strong in emotional response. The researchers then calculated the scores of aesthetic emotion by multiplying the scores of emotional arousal to calculate the correlation of weight of emotion for each stimuli. The results of the correlation between both groups showed that aesthetic judgment and aesthetic emotion have a significant correlation. During the fMRI scanning, both aesthetic judgment and aesthetic emotion stimulated the same regions of the brain depending on the 1-4 rating of beauty/ugly and emotional weighting of strong/weak. The region of the brain showing significant activity for positive emotions was the right postcentral gyrus. Based on these results, the researchers suggested that the postcentral gyrus is significant for positive judgement and emotions.

Another biological factor previously found to predict emotions is an association between larger posterior parietal cortices in individuals with higher negative perfectionism. For example, in a correlational study by Karimizadeh et al, (2015), a group of forty-nine adults each answered a questionnaire about positive and negative perfectionism where they rated how much they agreed or disagreed with twenty questions. Participants then received an MRI scan of their entire brain. Using voxel-based morphometry, a method of dividing the brain into small cubes, it was found that higher grey matter volume of the left precuneus, or left posterior parietal cortex, was related to increased negative perfectionism. While close, the results did not significantly link the precuneus to negative perfectionism, but previous research on aspects of perfectionism, such as self-processing operations and persistence, further supports this link. Based on these results, the researchers suggested that the posterior parietal cortex plays a role in the negative effects of perfectionism.

A third factor previously found to predict the capacity of emotion regulation is the volume of the lateral orbitofrontal cortex. For example, in a correlational study by Petrovic et al. (2016), participants were screened for emotional dysregulation using

the score from the emotion section of the brown attention deficit disorder scale. They then measured these results in correlation with the grey matter volume in the lateral orbitofrontal cortex using MRI imaging. Based on these results, the researchers suggested that reduced grey matter volume in the lateral orbitofrontal cortex was directly correlated with individuals who displayed emotional dysregulation.

1.3 Hypotheses

Based on the above literature review, we predicted the following hypotheses:
Hypothesis #1: If postcentral gyrus functioning increases then positive emotions will increase.
Hypothesis #2: If posterior parietal cortex functioning increases then negative perfectionism will increase.
Hypothesis #3: If orbitofrontal cortex functioning increases then emotional dysregulation will decrease.

2. Methods

2.1 Participants

The three authors of this paper served as the participants in its studies. The participants ranged in age from 19-23 years old, with an average age of 21 years, and included three females. The participants were all undergraduate students at Camosun College who completed the current studies as an assignment for Psychology 215 Biological Psychology and were grouped together due to their mutual interest in the biological mechanisms of emotions. Other external variables included changes in homework, inconsistent amounts slept, and a participant with a mood related disorder.

2.2 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 6 variables: (1) postcentral gyrus functioning, (2) posterior parietal cortex functioning, (3) orbitofrontal cortex functioning, (4) positive emotions, (5) negative perfectionism, and (6) emotional dysregulation.

2.2.1 Postcentral Gyrus Functioning

To measure postcentral gyrus functioning, we conducted the Two Point Discrimination Test on a daily basis in the evening. The premise of the test is to distinguish the two objects touching the skin with as little distance possible. Using two sharp objects (pencil tips or paperclips), participants identified whether they were touched on their skin with two objects at the same time or one object. Participants were asked to conduct the test daily, preferably in the evening, on their shin, eyes closed, and with an assistant to do the poking. Participants then recorded in their journal the measurement of distance in millimeters (mm). The results of the test were used to indicate how refined participants' somatosensory perceptions were and thus how well their postcentral gyrus was functioning.

2.2.2 Posterior Parietal Cortex Functioning

To measure posterior parietal cortex functioning, each participant completed the PEBL Connections Test once a day, typically in the evening before heading to sleep, for 7 days. In the test, participants were presented with several randomly generated 7x7 grids of circles, one grid at a time. Each circle in the grid had one number or letter, where the next number or letter is adjacent to any selected circle. For example, the number 8 would be somewhere adjacent

to the number 7. The participants were given 20 seconds to click on as many of the circles as possible while following an alphabetical or increasing order of numbers, letters, or an alternating pattern of both (for example, A, 1, B, 2, C, 3 or 1, A, 2, B, 3, C). The results included several data points, including the number of total, correct, and incorrect clicks. The greater the average number of correct clicks, the better the posterior parietal cortex functioning. To calculate the average number of correct clicks, the total number of correct clicks is divided by the total number of clicks. To do this, data from file "connections-path-XX#", where XX# is a placeholder for PEBL's participant code, was used, and the following formula was applied in Excel, "=SUM(M1:MX)/COUNT(M1:MX)", where X is a placeholder for the number indicating the last row of column M with data.

2.2.3 Orbitofrontal Cortex Functioning

To measure orbitofrontal cortex functioning, participants were asked to complete the Go-NoGo task, on the Psych lab 101 app, daily, preferably in the evening, and keep a log of their scores for later evaluation. The Go-NoGo task asked the participants to give a motor response to a visual stimulus, hitting the screen when a particular symbol appeared. The results were calculated by the accuracy of the test.

2.2.4 Positive Emotions

To measure positive emotion response, participants were asked to evaluate the emotional response to photos of everyday design elements using a random image generator found online. Participants then evaluated their positive or negative responses on a 3 point scale, evaluating reactions from 1=negative, 2=neutral, and 3=positive. Participants then measured their emotional responses to the stimuli on a 4 point scale, evaluating the emotional response from 1= very weak, 2 =weak, 3= strong, and 4 = very strong in emotional response. Participants were exposed to three pictures daily, preferably in the evening, rated them with the two categories and then recorded their results. The summed scores from these two scales were used to determine the positive emotional experience of the day.

2.2.5 Negative Perfectionism

Negative perfectionism was measured by participants filling out a Negative Perfectionism Scale once a day each day for 7 days, typically near the end of the day before heading to sleep. The questionnaire was modified from a Positive and Negative Perfectionism Scale (PANPS) by removing positive perfectionism questions, rephrasing statements into questions, removing references to lifetime factors such as childhood, and trying to avoid the word "perfect". It measured the amount of negative perfectionism participants experienced that day. Participants answered 20 questions with how much they felt they were affected, with 1 = not at all; 2 = not much, a little; 3 = neutral; 4 = moderate; 5 = lots, very. The results were summed and the greater the number, the more negative perfectionism was present. See Appendix B-2 for the modified questionnaire used and a more detailed explanation of the modifications made to it.

2.2.6 Emotional Dysregulation

To measure emotional dysregulation participants were asked to complete a modified version of the Difficulties in Emotion Regulation Scale (DERS) each day, preferably in the evening. The scale measures nonacceptance, acceptance, goal-directed behaviour, impulse control, emotional awareness, regulation strategies and emotional clarity, through 36 questions that rate the general experience of emotions on a one to five scale based on frequency of

occurrence. Modifications to the DERS were made by changing the format of questions so they applied to daily measurements rather than lifelong, and the amount of questions was also reduced to 23 by removing questions that did not apply to a daily measurement as well as removing those that fell under the regulation strategies category. The score of the test determined the amount of emotion regulation the participants experienced throughout their day, ranging from -25 (low emotional dysregulation) to 67 (high emotional dysregulation).

2.3 Correlational Study Planned Analyses

To assess the strength and statistical significance of associations between variables predicted by our 3 hypotheses, we performed Pearson product moment correlations of their predictor variables (post central gyrus functioning, posterior parietal cortex functioning, and orbitofrontal cortex functioning) with their outcome variables (positive emotions, negative perfectionism, and emotional dysregulation). For testing Hypothesis #1, we correlated Two Point Discrimination Test scores with the positive reception to images. For testing Hypothesis #2, we correlated PEBL Connections Test scores with negative perfectionism scores. For testing Hypothesis #3, we correlated Go-NoGo task scores with emotional scores. 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).

2.4 Experimental Study Methods

Based on the strength of the correlation between orbitofrontal cortex functioning and emotional dysregulation 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, orbitofrontal cortex functioning, over a one-week period by alternating between meditate experimental condition days or non-meditate control condition days. Participants also chose an individual (referred to as "chosen individual"), ideally the same throughout the experiment, who did not know whether the participant meditated or not, to rate the participant's emotional dysregulation for that day using the same questionnaire as the participants.

On the meditate days, participants used a meditation from the app Headspace for five minutes, each time picking the next meditation from the sequence of "Basic" meditations. The basic meditations were a sequence of 10 guided meditations where, for each, the user listened to the meditation guide and followed their guidance, for example to take deep breaths, return to natural breathing, close one's eyes, then mentally scan one's body, then focus on breathing. On the non-meditate days participants did not meditate.

Both days participants measured their emotions three times a day, once at the beginning shortly after waking up, once in the afternoon, and once in the evening, using an app called Daylio. The app asked users to rate their mood out of a list, by default "rad, good, meh, bad, and awful", then asked the user to indicate what they were doing by

selecting as many things as they desired from groups of activities, for example "Social: family, friends, date party", "Hobbies: movies & tv, reading, gaming sport, relax", "Better Me: meditation (for the purposes of this experiment, this was left unticked regardless if the participant meditated or not), kindness, listen, donate, give gift" and more, and the user could write whatever they wished in a note. This information was not used for scoring. Instead, it was used to assist the participant in more accurately recounting their day to their chosen individual by quickly recording down glimpses of what the participant was thinking and doing at various points in the day.

At the end of the day, participants completed the Go-NoGo test (making sure to not look at the score until later), and measured emotional dysregulation via the same questionnaire used in the correlational study for Hypothesis #3 (See Appendix A). As well, each participant told their chosen individual about their day and showed them the entries in Daylio (an emotions journal app), then their chosen individual filled out the same questionnaire to rate the participant's emotional dysregulation.

Since it was impossible for the participant to not know whether they meditated that day or not, other measures were taken to avoid other confounding factors affecting the measurements. One measure taken was to alternate between meditation and non-meditation days to control for order effects. Another measure taken was to do a manipulation check by continuing to complete the Go-NoGo test to test whether there was a tangible change in orbitofrontal cortex functioning, which was significantly correlated with emotional dysregulation in the correlational study in this paper. Also, participants used the same guided meditations from Headspace to ensure they had similar experiences. Another measure taken was to find an individual who did not know if the participant meditated that day to rate the participant's emotional dysregulation. As well, participants regularly recorded their day in an app called Daylio to reduce any bias in the participant's retelling of the day from events that happened later in the day. (For example, if the participant had an enjoyable morning and afternoon, but in the evening received a failing grade for an important test, the participant might give their chosen individual a biased account of the day due to focusing on the negative event.) To avoid participant's expectations when seeing measurements affecting others measurements, participants did not look at the scores until after all measurements were taken.

2.5 Experimental Study Planned Analyses

To assess the statistical significance of differences seen in emotional dysregulation on meditation experimental days vs. non-meditation 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 one-tailed distribution (i.e., to determine if there is a difference between groups in a specific direction), 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, orbitofrontal cortex functioning was significantly correlated with emotional dysregulation. Correlations between postcentral gyrus functioning and positive emotion was found to be statistically insignificant in the pooled raw data (r = -.25, p = 0.28, see Figure 1) and the pooled standardized data (r = -.31, p = 0.17, Figure 2), but was statistically significant for Participant #2 (r = -0.79, p = 0.03).

Posterior parietal functioning was not significantly correlated with negative perfectionism, whether for any single participant (all $r \leq 0.36$, all $p \geq 0.45$), pooled raw data (r = 0.23, p = 0.32, see Figure 3), or pooled standardized data (r = 0.22, p = 0.33, see Figure 4).

Orbitofrontal cortex functioning and emotion dysregulation was significantly correlated using the pooled raw data (r = -.68, p = 0.0003, see Figure 5) and the pooled standardized data (r = -.48, p = 0.0282, see Figure 6), but not for Participant #1 (r = -.03, p = 0.96) and #3 (r = -0.60, p = 0.17). From a comparison of the correlation coefficients from the pooled standardized data, in order to standardize individual differences in how participants used the subjective scales, the strongest correlation was between orbitofrontal cortex functioning and emotional dysregulation.

3.2 Experimental Study Results

As shown in Table 2 and Table 3, no statistically significant difference was found between meditate and non-meditate conditions for levels of emotional dysregulation when either self-measured and other-measured. No single participant's results were significant (all self-measured $p \geq 0.22$; all other-measured $p \geq 0.077$). The pooled raw data was not significant (self-measured p = 0.19, see Figure 7; other-measured p = 0.20, see Figure 9), and the pooled standardized data was not significant (self-measured p = 0.19; see Figure 8; other-measured p = 0.14, see Figure 10).

4. Discussion

4.1 Summary of Results

Based on previous research, we created three separate hypotheses about the functioning of different brain areas for different aspects of emotions: postcentral gyrus functioning with positive emotions (Hypothesis #1), posterior parietal cortex functioning with perfectionism (Hypothesis #2), and orbitofrontal cortex functioning with emotional dysregulation (Hypothesis #3). Data pooled across participants in our correlational study supported the predicted relationship of orbitofrontal cortex functioning and emotional dysregulation (Hypothesis #3), but did not support postcentral gyrus functioning with positive emotions (Hypothesis #1) or posterior parietal cortex functioning with perfectionism (Hypothesis #2). However, based on our experimental study, we could not establish a causal relationship between meditation and emotional dysregulation.

4.2 Relation of Results to Past Research

Our correlational study failed to confirm a relationship between postcentral gyrus functioning and the reception of positive emotion. Unlike our correlational study, Yeh et al. (2018) found positive correlations between the activity expressed in the postcentral gyrus and positive emotion. Yeh et al. (2018) conducted a larger sample of

photo stimuli and MRI scanning proving significant relations, whereas our study did not utilize brain scanning material and instead assessed brain functioning through conducting the Two Point Discrimination Test and had a smaller sample of photo stimuli. While the Two Point Discrimination Test is a good alternative for direct brain scaning, the findings did not hold a significant result. Future study suggestions would recommend utilizing a larger photo stimuli sample size to measure the correlation between positive emotions and postcentral gyrus functioning.

Our correlational study also failed to confirm the relationship between posterior parietal functioning and negative perfectionism. This matches Karimizadeh et al. (2015) who found, by measuring perfectionism via a questionnaire and grey matter volume of brain areas using an MRI, that, while close, there was no significant correlation between the two ($p = 0.175$ for precuneus). However, Karimizadeh et al. (2015) referred to past research that did confirm a correlation. In contrast, our study did not find it to be close to significant ($p = 0.33$). This may be due to a smaller sample size, subjectivity of or modifications to the perfectionism questionnaire, or from measuring the brain area differently: indirectly measuring functioning of the posterior parietal cortex with the PEBL Connections Test. Future studies could examine if there is a correlation between the PEBL Connections Test and activity of or grey matter volume of the posterior parietal cortex, if the modified questionnaire is a good way of measuring perfectionism, or trying the experiment again with a less subjective measurement of perfectionism.

Just as in the study by Petriovic et al. (2016) a positive correlation between orbitofrontal cortex functioning and emotion regulation was supported in our correlational results. Our correlational study used the Go-NoGo task as a measure for orbitofrontal functioning and a substitute for the MRI scans of gray matter volume in the same area used by Petrovic et al. (2016). A future study could try to determine if the Go-NoGo task would be able to predict emotional dysregulation, perhaps having participants complete the Go-NoGo task earlier in the day, as opposed to then measuring emotional dysregulation in the evening shortly before going to sleep as done in the correlational study.

Our results from the experimental study of the effect of meditation on emotional dysregulation did not find a causal relationship between emotional dysregulation and meditation. The study by Petriovic et al. (2016) was only correlational, therefore they were unable to establish a causal relationship between orbitofrontal cortex activity and emotional dysregulation. However, a study by Wattford and Stafford (2014) supported mindfulness as a potential tool to assist in increased emotional awareness and reduced emotional avoidance. Watford's study used mindfulness training which employs similar skills to those practiced in meditation such as deep breathing and clearing of the mind. Watford and Stafford (2014) concluded that mindfulness training was effective in acknowledging and experiencing emotions which are both assets to emotional regulation. Differences between our studies were duration of mindfulness sessions, (theirs 15 minutes, ours 5), number of participants' data analyzed (theirs 70, ours 3), and they subjected participants to stimuli, such as photos or sounds, that were intended to induce positive or negative emotions, while our study measured our emotions at the end of an uncontrolled day. One factor that may have affected our experimental results was the small amount of data

collected (3 participants for 7 days). While that would likely show a significance for something with a dramatic effect (for example, if one meditation alone was able to counter any emotional dysregulation caused by an otherwise "bad" day), that may not be enough data to show a smaller effect. Another reason for the lack of significance may be other factors and life events overshadowing the effect of meditation. For example, the participants noticed that if they had a "bad" day on a meditate day, their emotional dysregulation was higher than if they had a "good" day on a non-meditate day. One idea for a future study would be running the experiment for longer with more participants to see if meditation has a more subtle effect on emotional dysregulation. As well, perhaps using participants in a more stable and less emotional environment, rather than college students, would be able to reduce random daily events' effects on emotional dysregulation and help detect if meditation has a subtle effect. Another idea for a future study would be to determine if meditation has an effect on orbitofrontal cortex activity measured more directly (e.g., by fMRI).

4.3 Implications of Results

A possible application for our findings would be the use of the Go-NoGo task as a predictor of emotional dysregulation. It could be used similarly to our correlational study, measuring emotional dysregulation at the end of the day over several days to compare the effects of an activity intended to help reduce someone's emotional dysregulation to help them find what works, or does not work, to help reduce emotional dysregulation.

We conducted these experiments in hopes to gain a better understanding of our emotions by controlling emotional dysregulation with meditation to work with our emotions rather than against. Based on the information extracted, disappointingly our experimental study could not signify that meditating alone will improve emotional regulation. Further research and time would need to be conducted to discover what conditions make meditation more effective or testing of other methods of affecting orbitofrontal cortex functioning and emotional dysregulation.

References

Karimizadeh, A., Mahnam, A., Yazdchi, M. R., & Besharat, M. A. (2015). Individual differences in personality traits: Perfectionism and the brain structure. *Journal of Psychophysiology*, *29*(3), 107–111. https://doi-org.libsecure.camosun.bc.ca:2443/10.1027/0269-8803/a000141

Petrovic, P., Ekman, C., Klahr, J., Tigerström, L., Rydén, G., Johansson, A., Sellgren, C., Golkar, A., Olsson, A., Öhman, A., Ingvar, M., Landén, M. (2016) Significant grey matter changes in a region of the orbitofrontal cortex in healthy participants predicts emotional dysregulation. *Social Cognitive and Affective Neuroscience, 11*(7), 1041–1049, https://doi.org/10.1093/scan/nsv072

Watford, T. S., & Stafford, J. (2015). The impact of mindfulness on emotion dysregulation and psychophysiological reactivity under emotional provocation. *Psychology of Consciousness: Theory, Research, and Practice, 2*(1), 90–109. https://doi-org.libsecure.camosun.bc.ca:2443/10.1037/cns0000039

Yeh, Y. C., Hsu, W. C., & Li, P. H. (2018). The modulation of personal traits in neural responses during the aesthetic experience of mundane art. *Trends in*

Neuroscience and Education, *10*, 8–18. https://doi.org/https://www.elsevier.com/locate/tine

Table 1

Correlations for Study Variables

Variables	Participant #1		Participant #2		Participant #3		Pooled raw data		Pooled standardized data	
	r	*n*	*r*	*n*	*r*	*n*	*r*	*n*	*r*	*n*
Postcentral Gyrus Functioning & Positive Emotions	-.22	7	-.79*	7	.09	7	-.25	21	-.31	21
Posterior Parietal Functioning & Negative Perfectionism	-.01	7	.36	7	.32	7	.23	21	.22	21
Orbitofrontal Cortex Functioning & Emotional Dysregulation	-.03	7	-.80*	7	-.60	7	-.68*	21	-.48*	21

* $p < .05$.

Table 2

Descriptive Statistics for Emotional Dysregulation (Self Measured) Across Different Orbitofrontal Cortex Activity Conditions

Condition	Statistic	Participant #1	Participant #2	Participant #3	Pooled raw data	Pooled standardized data
Meditate	*M*	6.75	11.25	-10	5.73	0.18
	SD	4.99	*6.60*	5.57	*8.47*	*0.81*
	n	4	*4*	3	*11*	*11*
Non-Meditate	*M*	4	10.67	-9	1.10	-0.20
	SD	3.61	*15.95*	11.69	*13.92*	*1.09*
	n	3	*3*	*4*	*10*	*10*

Note. *M*, *SD*, and *n*, represent mean, standard deviation, and sample size, respectively. Emotional Dysregulation Questionnaire Score (-25 to 67). (See Appendix A)

* $p < .05$ for comparison of meditate condition with its respective non-meditate condition.

Table 3

Descriptive Statistics for Emotional Dysregulation (Other Measured) Across Different Orbitofrontal Cortex Activity Conditions

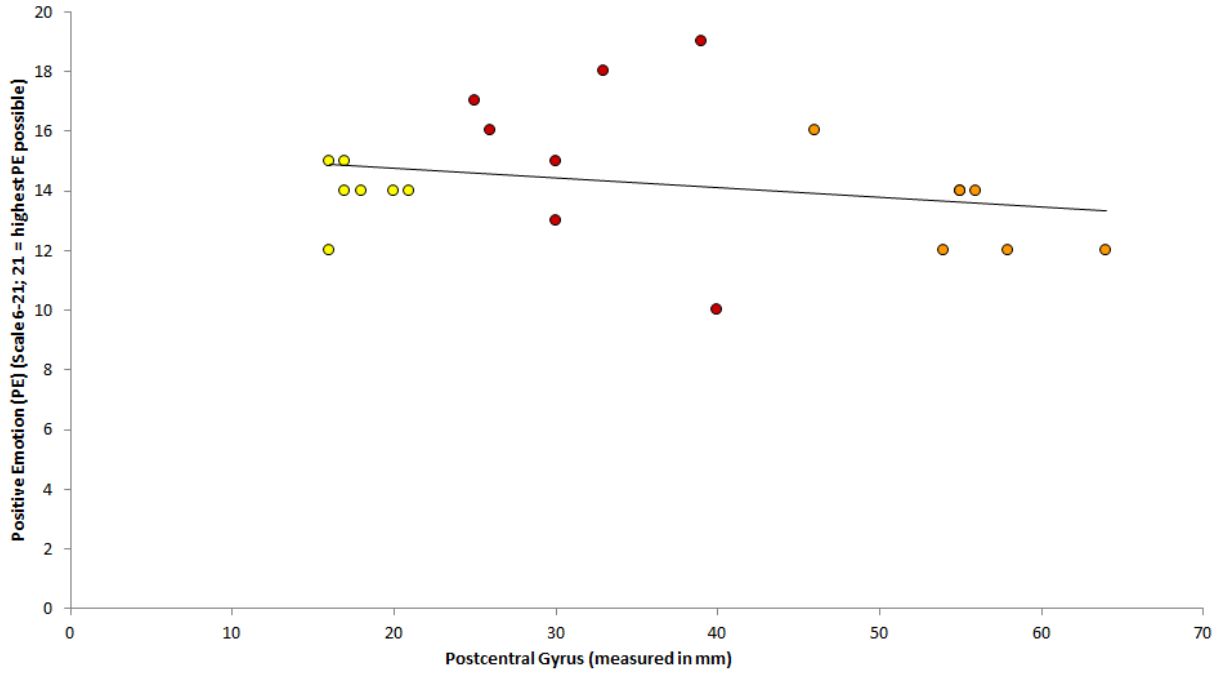
Condition	Statistic	Participant #1	Participant #2	Participant #3	Pooled raw data	Pooled standardized data
Meditate	*M*	-0.75	-5.50	-3	-5.00	-0.22
	SD	3.84	*9.47*	8.89	*7.24*	*0.93*
	n	4	*4*	3	*11*	*11*
Non-Meditate	*M*	-0.33	7.67	-8.25	-1.40	0.24
	SD	1.5	*10.79*	13.67	*11.20*	*0.96*
	n	3	*3*	4	*10*	*10*

Note. *M*, *SD*, and *n*, represent mean, standard deviation, and sample size, respectively. Emotional Dysregulation Questionnaire Score (-25 to 67). (See Appendix A)

* $p < .05$ for comparison of meditate condition with its respective non-meditate condition.

Figure 1:

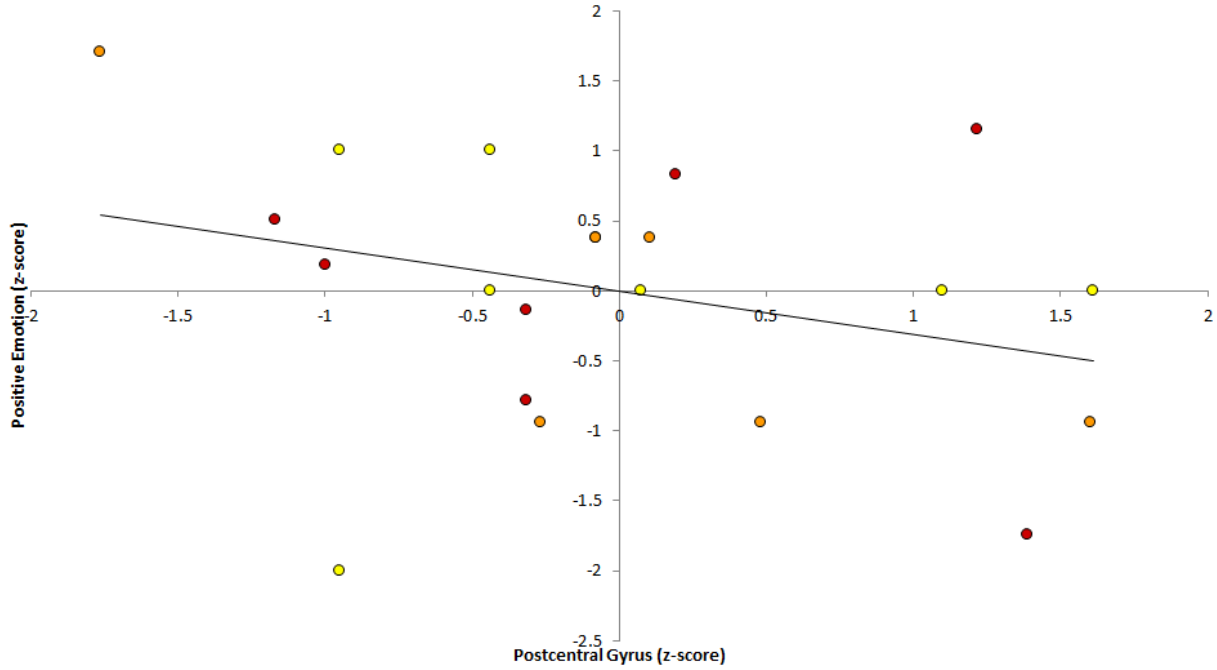
Association Between Postcentral Gyrus and Positive Emotion using Pooled Raw Data.



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3.

Figure 2

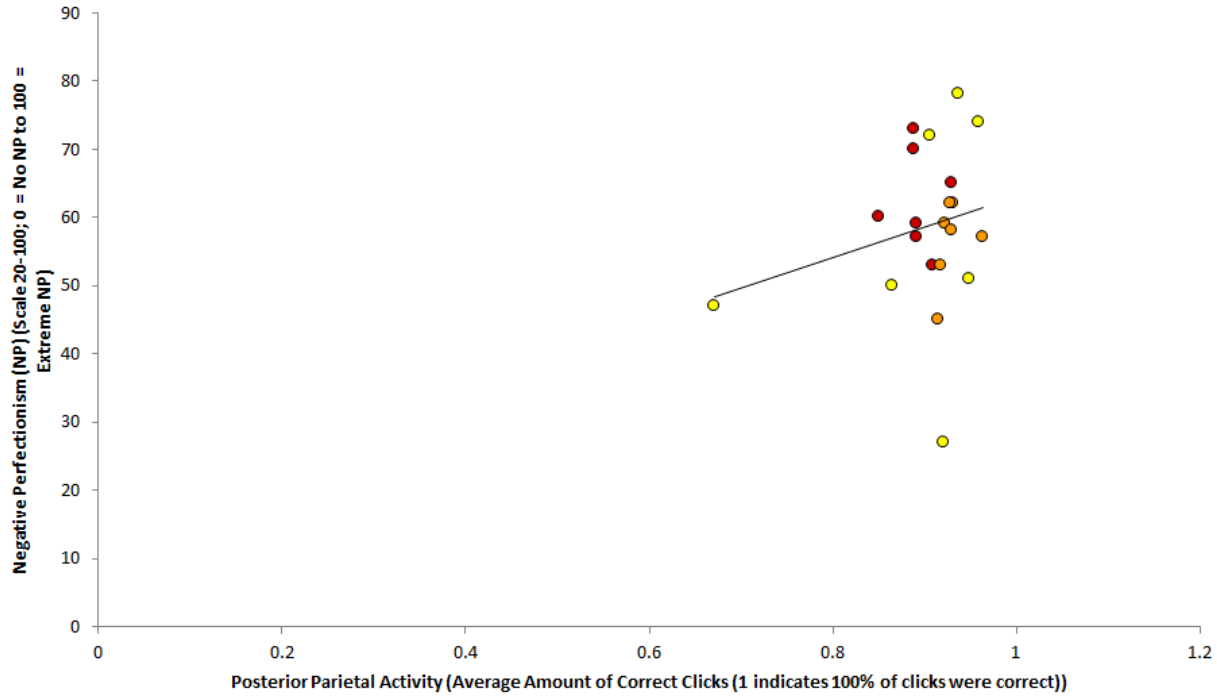
Association Between Postcentral Gyrus and Positive Emotion Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3.

Figure 3

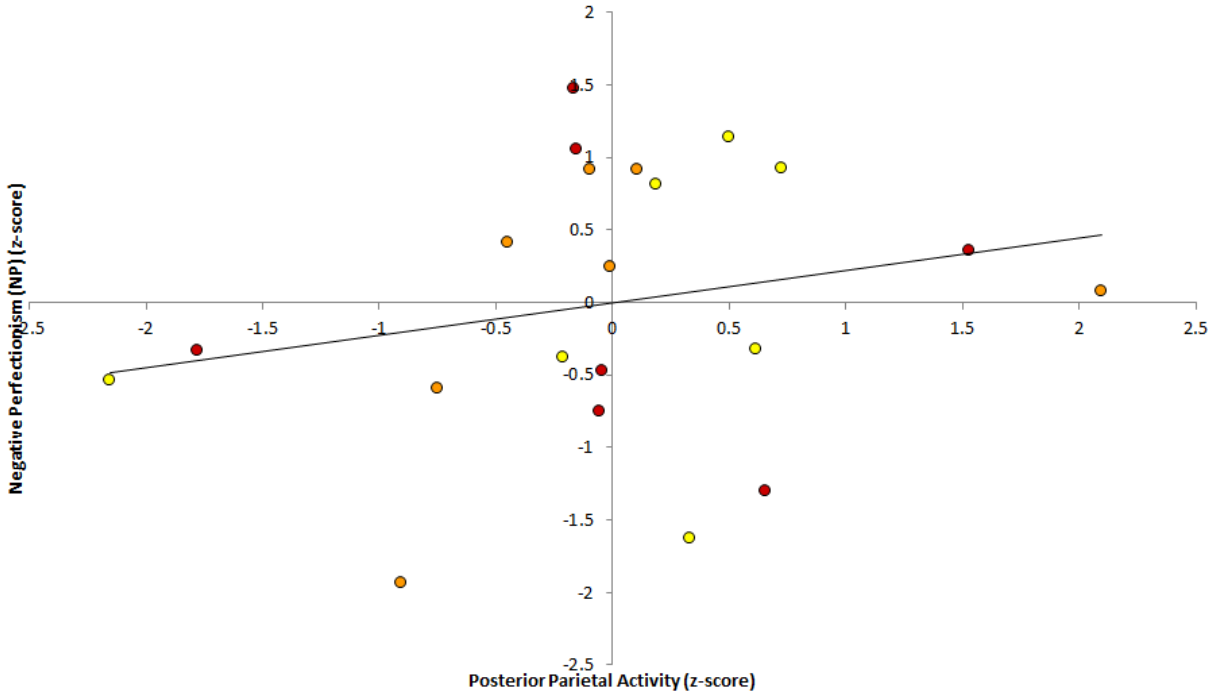
Association Between Posterior Parietal and Negative Perfectionism Using Pooled Raw Data



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

Figure 4

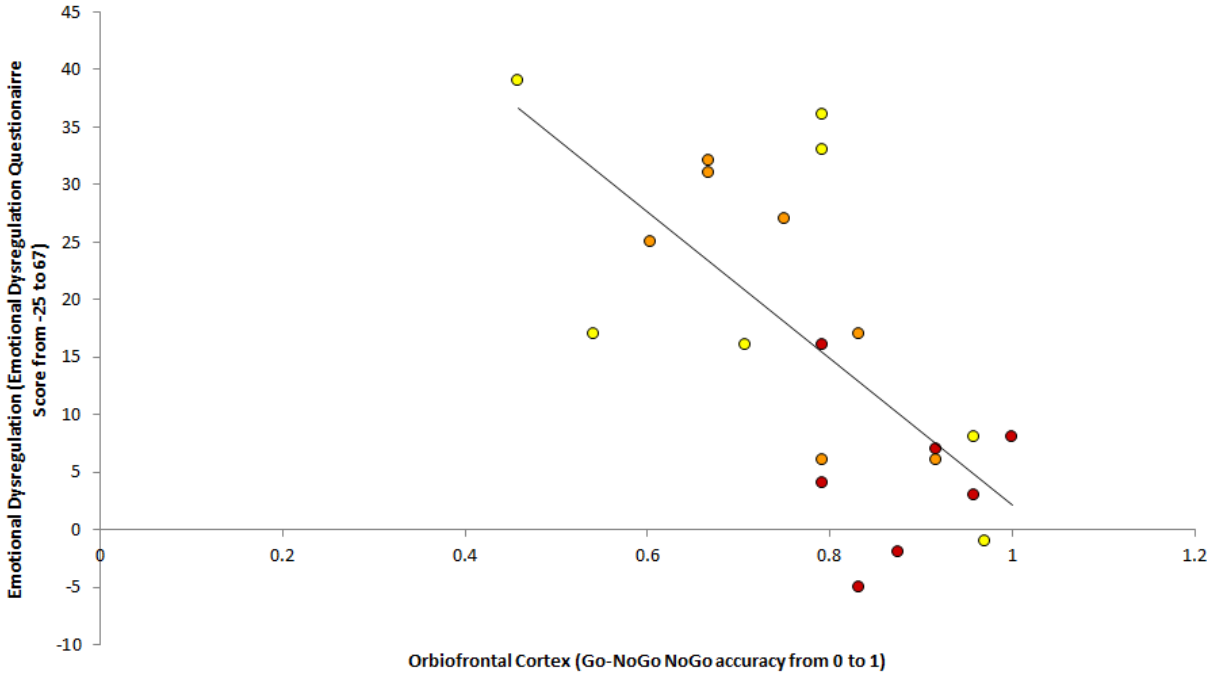
Association Between Posterior Parietal and Negative Perfectionism Using Pooled Standardized Data



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

Figure 5

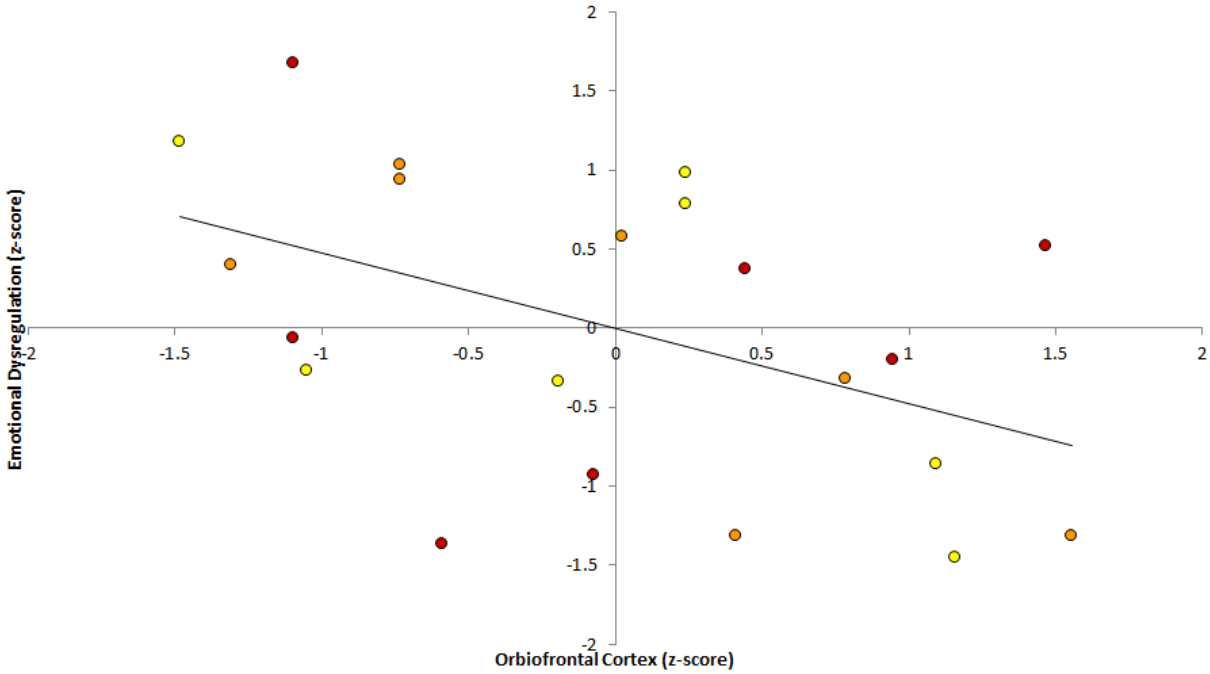
Association Between Orbitofrontal Cortex and Emotion Dysregulation Using Pooled Raw Data



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

Figure 6

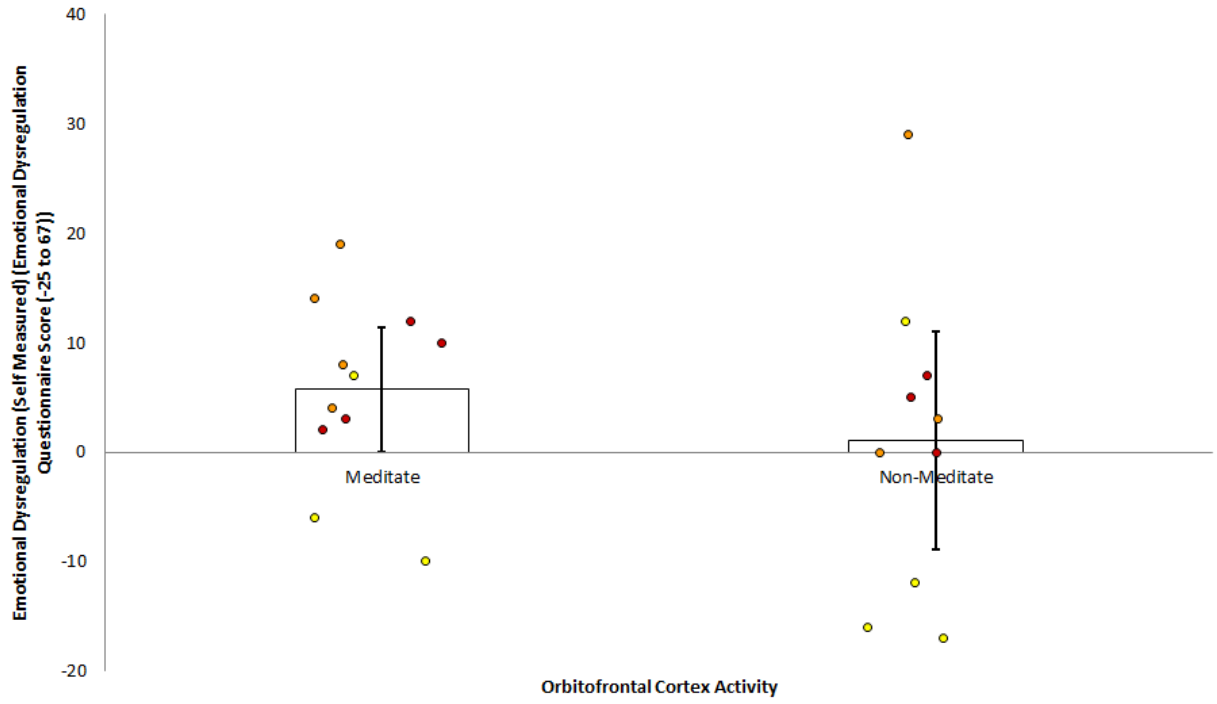
Association Between Orbitofrontal Cortex and Emotion Dysregulation Using Pooled Standardized Data



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

Figure 7

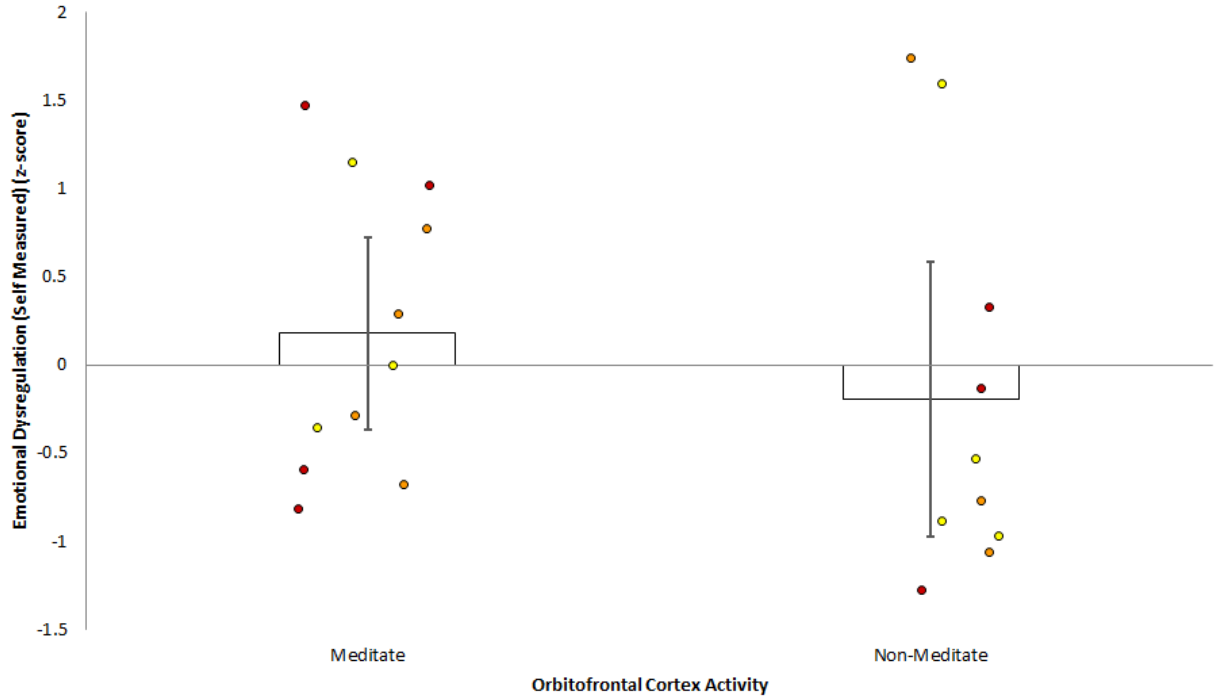
Average Emotional Dysregulation (Self Measured) Across Different Orbitofrontal Cortex Activity Conditions Using Pooled Raw Data



Notes. Emotional Dysregulation (Self Measured) scores are shown for meditate and non-meditate conditions using pooled raw data from all participants. Errors bars show ± 95% confidence levels. Overlapping scatterplot shows data from each participant. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3.

Figure 8

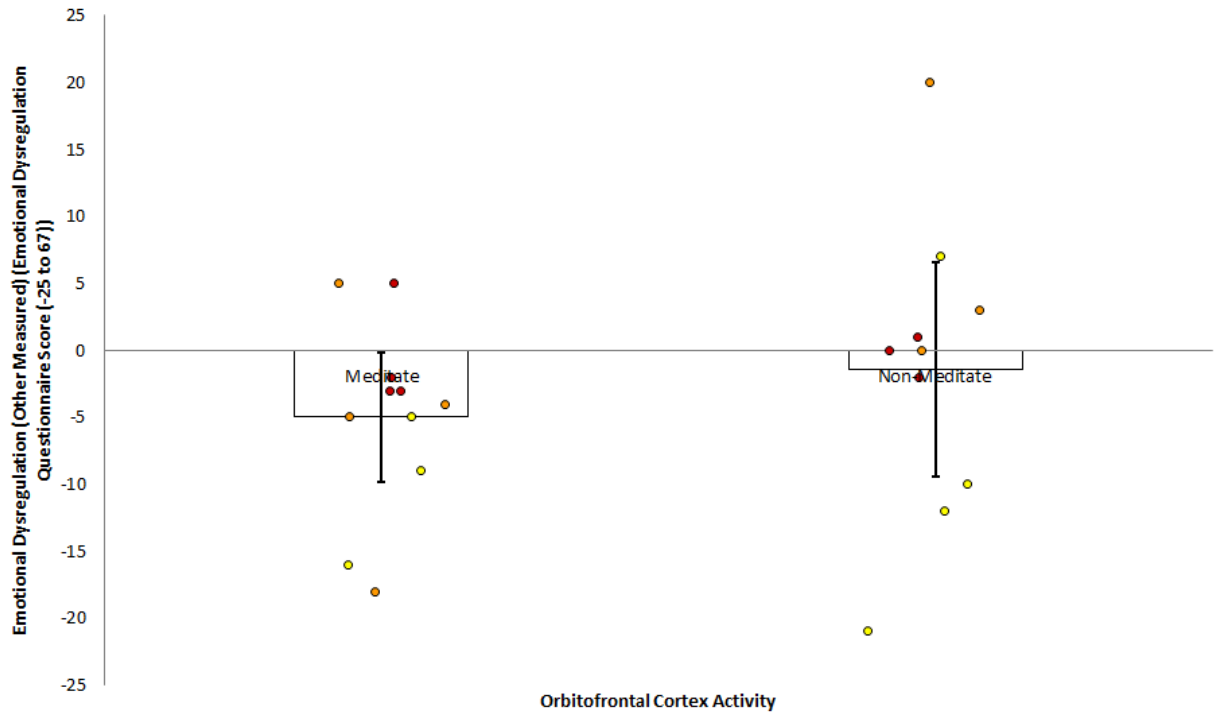
Average Emotional Dysregulation (Self Measured) Across Different Orbitofrontal Cortex Activity Conditions Using Pooled Standardized Data



Notes. Emotional Dysregulation (Self Measured) scores are shown for meditate and non-meditate conditions using pooled raw data from all participants. Errors bars show ± 95% confidence levels. Overlapping scatter plot shows data from each participant. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3.

Figure 9

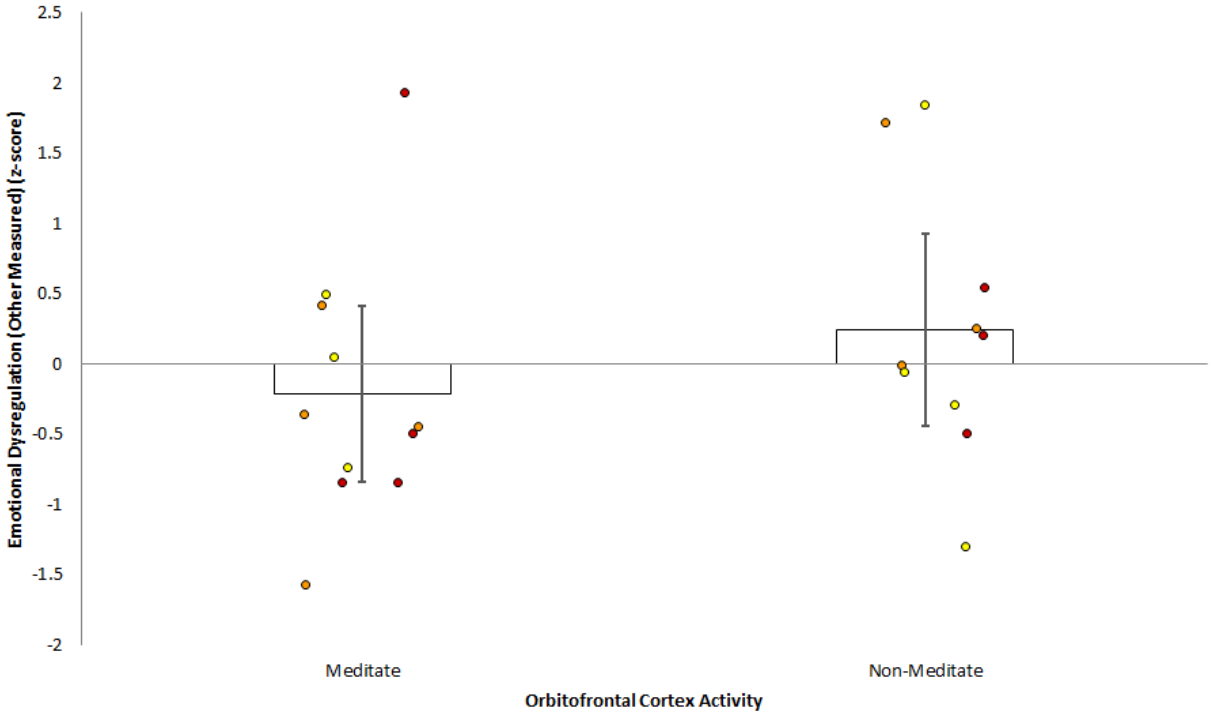
Average Emotional Dysregulation (Other Measured) Across Different Orbitofrontal Cortex Activity Conditions Using Pooled Raw Data



Notes. Emotional Dysregulation (Other Measured) scores are shown for meditate and non-meditate conditions using pooled raw data from all participants. Errors bars show ± 95% confidence levels. Overlapping scatterplot shows data from each participant. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3.

Figure 10

Average Emotional Dysregulation (Other Measured) Across Different Orbitofrontal Cortex Activity Conditions Using Pooled Standardized Data



Notes. Emotional Dysregulation (Other Measured) scores are shown for meditate and non-meditate conditions using pooled raw data from all participants. Error bars show ± 95% confidence levels. Overlapping scatter plot shows data from each participant. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3.

Appendix A: Modified DERS

Please indicate how often the following statements applied to you by writing the appropriate number from the scale below on the line beside each item.

1----------2----------3----------4----------5

almost not at all (0-10%) | some parts of the day (11-35%) | about half the day (36-65%) | most of the day (66-90%) | almost all day (91-100%)

_____ 1) I was clear about my feelings.

_____ 2) I paid attention to how I feel.

_____ 3) I experienced my emotions as overwhelming and out of control.

_____ 4) I had no idea how I was feeling.

_____ 5) I had difficulty making sense out of my feelings.

_____ 6) I was attentive to my feelings.

_____ 7) I knew exactly how I was feeling.

_____ 8) I care about what I felt.

_____ 9) I am confused about how I felt.

_____ 10) I acknowledged my emotions.

_____ 11) I became angry with myself for feeling emotional.

_____ 12) I became embarrassed for feeling emotional.

_____ 13) I had difficulty getting work done due to my emotions.

_____ 14) I believed that my feelings are valid and important.

_____ 15) I had difficulty focusing due to my emotion.

_____ 16) I felt out of control due to my emotions.

_____ 17) I felt ashamed at myself for being emotional.

_____ 18) When I'm upset, I feel guilty for feeling that way.

_____ 19) I had difficulty concentrating due to my emotions.

_____ 20) I had difficulty controlling my behaviors.

_____ 21) I became irritated at myself for feeling emotional.

_____ 22) My emotions caused me to have difficulty thinking about anything else.

_____ 23) I took time to figure out what I was feeling.

Appendix A-2: Original DERS

Difficulties in Emotion Regulation Scale (DERS)

Please indicate how often the following statements apply to you by writing the appropriate number from the scale below on the line beside each item.

1----------2----------3----------4----------5

almost never	sometimes	about half the time	most of the time	almost always
(0-10%)	(11-35%)	(36-65%)	(66-90%)	(91-100%)

_____ 1) I am clear about my feelings.
_____ 2) I pay attention to how I feel.
_____ 3) I experience my emotions as overwhelming and out of control.
_____ 4) I have no idea how I am feeling.
_____ 5) I have difficulty making sense out of my feelings.
_____ 6) I am attentive to my feelings.
_____ 7) I know exactly how I am feeling.
_____ 8) I care about what I am feeling.
_____ 9) I am confused about how I feel.
_____ 10) When I'm upset, I acknowledge my emotions.
_____ 11) When I'm upset, I become angry with myself for feeling that way.
_____ 12) When I'm upset, I become embarrassed for feeling that way.
_____ 13) When I'm upset, I have difficulty getting work done.
_____ 14) When I'm upset, I become out of control.
_____ 15) When I'm upset, I believe that I will remain that way for a long time.
_____ 16) When I'm upset, I believe that I will end up feeling very depressed.
_____ 17) When I'm upset, I believe that my feelings are valid and important.
_____ 18) When I'm upset, I have difficulty focusing on other things.
_____ 19) When I'm upset, I feel out of control.
_____ 20) When I'm upset, I can still get things done.
_____ 21) When I'm upset, I feel ashamed at myself for feeling that way.
_____ 22) When I'm upset, I know that I can find a way to eventually feel better.
_____ 23) When I'm upset, I feel like I am weak.
_____ 24) When I'm upset, I feel like I can remain in control of my behaviors.
_____ 25) When I'm upset, I feel guilty for feeling that way.
_____ 26) When I'm upset, I have difficulty concentrating.
_____ 27) When I'm upset, I have difficulty controlling my behaviors.
_____ 28) When I'm upset, I believe there is nothing I can do to make myself feel better.
_____ 29) When I'm upset, I become irritated at myself for feeling that way.
_____ 30) When I'm upset, I start to feel very bad about myself.
_____ 31) When I'm upset, I believe that wallowing in it is all I can do.
_____ 32) When I'm upset, I lose control over my behavior.
_____ 33) When I'm upset, I have difficulty thinking about anything else.
_____ 34) When I'm upset I take time to figure out what I'm really feeling.
_____ 35) When I'm upset, it takes me a long time to feel better.
_____ 36) When I'm upset, my emotions feel overwhelming.

Reverse-scored items (place a subtraction sign in front of them) are numbered 1, 2, 6, 7, 8, 10, 17, 20, 22, 24 and 34.

Calculate total score by adding everything up. Higher scores suggest greater problems with emotion regulation.

SUBSCALE SCORING:** The measure yields a total score (SUM) as well as scores on six sub-scales:

1. Nonacceptance of emotional responses (NONACCEPT): 11, 12, 21, 23, 25, 29
2. Difficulty engaging in Goal-directed behavior (GOALS): 13, 18, 20R, 26, 33
3. Impulse control difficulties (IMPULSE): 3, 14, 19, 24R, 27, 32
4. Lack of emotional awareness (AWARENESS): 2R, 6R, 8R, 10R, 17R, 34R
5. Limited access to emotion regulation strategies (STRATEGIES): 15, 16, 22R, 28, 30, 31, 35, 36
6. Lack of emotional clarity (CLARITY): 1R, 4, 5, 7R, 9

Total score: sum of all subscales

**"R" indicates reverse scored item

REFERENCE:

Gratz, K. L. & Roemer, L. (2004). Multidimensional assessment of emotion regulation and dysregulation: Development, factor structure, and initial validation of the Difficulties in Emotion Regulation Scale. *Journal of Psychopathology and Behavioral Assessment, 26,* 41-54.

Appendix B-1: Original Positive and Negative Perfectionism Scale (link)

PhenX Toolkit

Data Collection Worksheet

Please Note: The Data Collection Worksheet (DCW) is a tool to aid integration of a PhenX protocol into a study. The PhenX DCW is not designed to be a data collection instrument. Investigators will need to decide the best way to collect data for the PhenX protocol in their study. Variables captured in the DCW, along with variable names and unique PhenX variable identifiers, are included in the PhenX Data Dictionary (DD) files.

Positive and Negative Perfectionism Scale

Please choose the appropriate statement and corresponding number under the column which applies best to each of the following statements. Please answer each statement.

All replies are strictly confidential.

	"5" Strongly Agree	"4" Agree	"3" Don't Know	"2" Disagree	"1" Strongly Disagree
1. When I start something I feel anxious that I might fail.	○	○	○	○	○
2. My family and friends are proud of me when I do really well.	○	○	○	○	○
3. I take pride in being meticulous when doing things.	○	○	○	○	○
4. I set impossibly high standards for myself.	○	○	○	○	○
5. I try to avoid the	○	○	○	○	○

disapproval of others at all costs.					
6. I like the acclaim I get for an outstanding performance.	○	○	○	○	○
7. When I am doing something I cannot relax until it's perfect.	○	○	○	○	○
8. It feels as though my best is never good enough for other people.	○	○	○	○	○
9. Producing a perfect performance is a reward in its own right.	○	○	○	○	○
10. The problem of success is that I must work even harder.	○	○	○	○	○
11. If I make a mistake I feel that the whole thing is ruined.	○	○	○	○	○
12. I feel dissatisfied with myself unless I am working towards a higher standard all the time.	○	○	○	○	○
13. I know the kind of person I ought or want to be, but feel I always fall short of this.	○	○	○	○	○

14. Other people respect me for my achievements.	○	○	○	○	○
15. As a child however well I did, it never seemed good enough to please my parents.	○	○	○	○	○
16. I think everyone loves a winner.	○	○	○	○	○
17. Other people expect nothing less than perfection of me.	○	○	○	○	○
18. When I'm competing against others, I'm motivated by wanting to be the best.	○	○	○	○	○
19. I feel good when pushing out the limits.	○	○	○	○	○
20. When I achieve my goals I feel dissatisfied.	○	○	○	○	○
21. My high standards are admired by others.	○	○	○	○	○
22. If I fail people, I fear they will cease to respect or care for me.	○	○	○	○	○
23. I like to please other people by being successful.	○	○	○	○	○

24. I gain great approval from others by the quality of my accomplishments.	○	○	○	○	○
25. My successes spur me on to greater achievements.	○	○	○	○	○
26. I feel guilty or ashamed if I do less than perfectly.	○	○	○	○	○
27. No matter how well I do I never feel satisfied with my performance.	○	○	○	○	○
28. I believe that rigorous practice makes for perfection.	○	○	○	○	○
29. I enjoy the glory gained by successes.	○	○	○	○	○
30. I gain deep satisfaction when I have perfected something.	○	○	○	○	○
31. I feel I have to be perfect to gain people's approval.	○	○	○	○	○
32. My parents encouraged me to excel.	○	○	○	○	○
33. I worry what others think if I make mistakes.	○	○	○	○	○

34. I get fulfillment from totally dedicating myself to a task.	○	○	○	○	○
35. I like it when others recognize that what I do requires great skill and effort to perfect.	○	○	○	○	○
36. The better I do, the better I am expected to do by others.	○	○	○	○	○
37. I enjoy working towards greater levels of precision and accuracy.	○	○	○	○	○
38. I would rather not start something than risk doing it less than perfectly.	○	○	○	○	○
39. When I do things I feel others will judge critically the standard of my work.	○	○	○	○	○
40. I like the challenge of setting very high standards for myself.	○	○	○	○	○

Scoring:

The Positive and Negative Perfectionism Scale includes two subscales:

- Positive perfectionism - items 2, 3, 6, 9, 14, 16, 18, 19, 21, 23, 24, 25, 28, 29, 30, 32, 34, 35, 37, 40.
- Negative perfectionism - items 1, 4, 5, 7, 8, 10, 11, 12, 13, 15, 17, 20, 22, 26, 27, 31, 33, 36, 38, 39.

Item responses are summed to give individual subscale scores that can range from 20 to 100. Higher values indicate greater positive and negative perfectionism.

Protocol source: https://www.phenxtoolkit.org/protocols/view/650601

Appendix B-2: Modified Negative Perfectionism Scale

Negative Perfectionism Scale (NPS)

Modified Positive and Negative Perfectionism Scale by Isabel Ma

For each question, choose the one response that best matches how you have generally felt today. If it is not near the end of the day, think of how you felt within the last 24 hours.

	1 Not at all	2 Not much, a little	3 Neutral, don't Know	4 Moderate	5 Lots, very
1. When starting something, such a new assignment or studying for the day, how anxious have you felt that you might fail?	☐	☐	☐	☐	☐
2. How high have your standards for yourself been today?	☐	☐	☐	☐	☐
3. How much have you tried to avoid the disapproval of others?	☐	☐	☐	☐	☐
4. How much effort have you spent on ensuring something was as good as you could make it?	☐	☐	☐	☐	☐
5. How much have you felt your best was just not good enough for others?	☐	☐	☐	☐	☐
6. How much have you felt that you have to work harder to keep up or exceed your successes?	☐	☐	☐	☐	☐
7. How much have you felt something was ruined if a mistake was made?	☐	☐	☐	☐	☐
8. How dissatisfied with yourself have you been when not working towards a higher standard?	☐	☐	☐	☐	☐
9. How much do you feel you have fallen short of the person you should or want to be today?	☐	☐	☐	☐	☐
10. How much have you felt whatever you have done was not good enough?	☐	☐	☐	☐	☐
11. How much do you feel others expect nothing less than your best?	☐	☐	☐	☐	☐
12. How much do you fear people will cease to respect or care for you if you fail them?	☐	☐	☐	☐	☐

1

	1 Not at all	2 Not much, a little	3 Neutral, don't Know	4 Moderate	5 Lots, very
13. How guilty or ashamed do you feel when you've done less than your usual standard?	☐	☐	☐	☐	☐
14. How much have you felt the need to be your best to gain people's approval?	☐	☐	☐	☐	☐
15. How much have you worried about what others will think if you make mistakes?	☐	☐	☐	☐	☐
16. How much have you felt expected to better because you did well?	☐	☐	☐	☐	☐
17. How much has the risk of making mistakes dissuaded you from starting in the first place?	☐	☐	☐	☐	☐
18. How much do you feel others have critically judged your standard of work?	☐	☐	☐	☐	☐
	1 Satisfied	2 Ok	3 Neutral	4 Meh	5 Dissatisfied
19. How have you felt when achieving your goals?	☐	☐	☐	☐	☐
20. Regardless of the outcome, how have you felt with your performance?	☐	☐	☐	☐	☐

Scoring:

The Negative Perfectionism Scale (NPS) is scored by summing the numbers of the responses to give a range of 20 to 100. Higher values indicate higher levels of negative perfectionism experienced that day.

Modified from the PhenX Toolkit Positive and Negative Perfectionism Scale (PANPS). The following modifications were generally applied:

- Statements relating to Positive Perfectionism were removed.
- Statements were rephrased as questions.
- Participants were told to answer questions thinking about the past 24 hours.
- References to lifetime events that likely will not change on a day-to-day basis, such as childhood, were removed.
- Questions were modified to try to remove the word "perfect" to alter the tone of the questionnaire to help participants relate to the questions more.
- 20 and 27's (originally; in this version they are 19 and 20) responses were rephrased for clarity.

2

Appendix C-1:Random photo generator: https://randomwordgenerator.com/picture.php

Appendix C-2: Aesthetic Experience Evaluation and Emotional Response Evaluation

Aesthetic Experience:

	(1) Negative	(2) Neutral	(3) Positive
Image 1			
Image 2			
Image 3			

Emotional Response:

	(1) Very Weak	(2) Weak	(3) Strong	(4) Very strong
Image 1				
Image 2				
Image 3				