



**BSc in Psychology**  
**Department of Psychology**

**Heart Rate Variability Among Individuals With Mental Disorders**  
**During Baseline and the Trier Social Stress Test**

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Foreword

Submitted in partial fulfillment of the requirements of the BSc Psychology degree, Reykjavik University, this thesis is presented in the style of an article for submission to a peer-reviewed journal.

### Abstract

Individuals with current and past mental disorders (CPMD) have shown lower heart rate variability (HRV) during baseline compared with healthy controls (HC). However, when it comes to stressful situations, individuals with CPMD do not necessarily show decreased HRV compared with HC. Lower HRV is believed to reflect lower parasympathetic nervous system (PNS) activity. The present study examined if individuals with current and past depressive and anxiety disorders, bipolar disorders, post-traumatic stress disorder, and obsessive-compulsive disorder showed lower PNS activity compared with HC. PNS activity was measured as HRV-RMSSD during baseline and the Trier social stress test (TSST). It was hypothesized that 1) Individuals with CPMD would have lower PNS activity measured as HRV-RMSSD during baseline and that 2) individuals with CPMD do not show more decreased PNS activity measured as HRV-RMSSD during TSST compared with HC. Twenty-two individuals diagnosed with CPMD aged between 19 and 41 were compared with twenty-two HC aged between 20 and 52. The results showed that, although not statistically significant, individuals with CPMD showed reduced PNS activity during baseline compared to HC. Furthermore, individuals with CPMD did not show reduced PNS activity compared with HC during laboratory-induced stress. It was concluded that further research is needed.

*Keywords:* Heart rate variability, depressive and anxiety disorders, post-traumatic stress disorder, obsessive-compulsive disorder, bipolar disorder

### Útdráttur

Einstaklingar með geðraskanir, bæði yfirstandandi sem og í rénun (YRGR) hafa sýnt lægri hjartsláttarbreytileika (HRV) við grunnlínu samanborið við heilbrigðan samanburðarhóp (HS). Aftur á móti er sá munur ekki endilega til staðar þegar kemur að streituvaldandi aðstæðum. Lægri hjartsláttarbreytileiki er talinn endurspeglar lægri virkni sefkerfis. Þessi rannsókn kannaði hvort að einstaklingar með sögu um þunglyndisraskanir, kvíðaraskanir, áfallastreituröskun, geðhvarfasýki og árattu- og þráhyggjuröskun sýndu lægri virkni í sefkerfi samanborið við HS. Virkni í sefkerfi var mæld með hjartsláttarbreytileika (HRV-RMSSD) bæði við grunnlínu og í Trier streituprófi. Eftirfarandi tilgátur voru skoðaðar 1) Einstaklingar með YRGR hafa lægri virkni í sefkerfi mælt með HRV-RMSSD við grunnlínu og 2) einstaklingar með YRGR munu ekki sýna minni virkni í sefkerfi mælt sem HRV-RMSSD í Trier streituprófi samanborið við HS. 22 einstaklingar með YRGR á aldursbilinu 19 – 41 árs voru bornir saman við 22 heilbrigða einstaklinga. Niðurstöðurnar sýndu að einstaklingar í YRGR hópnum sýndu minni virkni í sefkerfi við grunnlínu, þó ekki tölfræðilega marktæk. Enn fremur þá sýndu einstaklingar með YRGR ekki minni virkni í sefkerfi samanborið við heilbrigðan samanburðarhóp við streituvaldandi tilraunaaðstæður. Frekari rannsókna er þörf til að varpa ljósi á sambandið á milli hjartsláttarbreytileika og geðraskanana.

*Lykilorð:* Hjartsláttarbreytileiki, þunglyndisraskanir, kvíðaraskanir, áfallastreituröskun, árattu- og þráhyggjuröskun, geðhvarfasýki

### **Heart Rate Variability Among Individuals With Mental Disorders During Baseline and the Trier Social Stress Test**

Mental disorders are defined as prevalent issues that include difficulties with emotion regulation, behaviour, or cognition, which can lead to severe impairment in everyday life (World Health Organization, 2022). The impairment can sometimes become chronic and mental disorders, such as depression, are among the leading cause of disabilities in the world (World Health Organization, 2022). As described by the Diagnostic and statistical manual of mental disorders, fifth edition (DSM5), depressive disorders are defined as the experience of consistent sadness and lack of enjoyment in formerly fulfilling or joyful activities, among cognitive and somatic changes which impair the individuals' function (American Psychiatric Association, 2013b). Another common group of mental disorders are anxiety disorders, defined as an experience of irrational worries and anxiety related to various situations (American Psychiatric Association, 2013b). Anxiety can be defined as anticipating a future threat, which can make people very uncomfortable, and individuals with anxiety disorders often avoid situations they fear (American Psychiatric Association, 2013a).

Post Traumatic Stress Disorder (PTSD) is a mental disorder that can occur after exposure to a traumatic event, such as a life-threatening situation, serious injuries, or sexual violence (American Psychiatric Association, 2013b). Common symptoms of PTSD are intrusive and unwelcome memories of the traumatic experience, nightmares, flashbacks, and physiological arousal concerning internal or external cues of the traumatic event.

Finally, Obsessive Compulsive Disorder (OCD) combines two factors: obsessions and compulsions (American Psychiatric Association, 2013b). Obsessions are defined as intrusive and unwelcome thoughts, images or urges which are unsettling for the individuals experiencing them and cause distress and anxiety. The individuals try to correct those obsessions through other thoughts or actions, which are compulsions. The individuals repeat

compulsive behaviours to correct the obsessions. For example, to reduce anxiety or prevent something terrible from happening (American Psychiatric Association, 2013b).

Depression, anxiety, PTSD and OCD have all been associated with dysfunction of the autonomic nervous system (ANS), often manifested as decreased activity of the parasympathetic nervous system (PNS) (Bassett et al., 2016a; Čatipović-Veselica et al., 2007; Chen et al., 2017; Henje Blom et al., 2010; K. Kim et al., 2016; Lin et al., 2019; M et al., 2022; Olbrich et al., 2022a; Schneider & Schwerdtfeger, 2020a). One method to assess the activity of the ANS, including the activity of the PNS and sympathetic nervous system (SNS), is by measuring heart rate variability (HRV). HRV has been widely applied and acknowledged in fields such as clinical psychology, psychiatry, and cardiology as a non-invasive way of measuring the activity of the ANS (Economides et al., 2020; Gehi et al., 2005; McCraty et al., 2001).

HRV can be measured by different variables that can be classified into two groups, time and frequency domain, and there is a strong correlation between some variables across those two groups (Malik, 1996). One of the main time domain HRV variables is the root mean square of successive distances (RMSSD) which is believed to reflect the PNS (Bassett et al., 2016a). Furthermore, RMSSD is correlated to high frequency (HF-HRV) (Shaffer & Ginsberg, 2017). Some studies have argued that when HRV variables correlate, they can be used interchangeably (Massin et al., 1999).

Studies have shown that HRV can be used as a reliable predictor of depression, anxiety, PTSD and OCD (Bassett et al., 2016a; Braeken et al., 2013; Carney et al., 2005; Čatipović-Veselica et al., 2007; Chalmers et al., 2016; Y.-C. Cheng et al., 2022; Hartmann et al., 2019; K. Kim et al., 2016; Koch et al., 2019a; Licht et al., 2008; Pittig et al., 2013; Shinba et al., 2008; Smith et al., 2020; van Bennekom et al., 2021). For example, individuals with depression show decreased PNS activity compared to healthy controls.

Furthermore, studies have also shown reduced activity of the PNS among people with anxiety and anxiety disorders; lower PNS activity indicates that the ANS is moving toward the activity of the SNS (K. Kim et al., 2016; Shinba et al., 2008). In addition, studies have also shown decreased PNS activity among individuals with PTSD (Ge et al., 2020; Schneider & Schwerdtfeger, 2020a; Shah et al., 2013; Wahbeh & Oken, 2013). Finally, OCD is another example of a mental disorder associated with decreased activity of the PNS (Levine et al., 2016; Olbrich et al., 2022b; Pittig et al., 2013).

Although HRV is a prominent way to identify certain mental disorders, not all research studies on HRV and depression, anxiety, PTSD and OCD have been able to show a difference in HRV between those with the disorders and healthy controls either during baseline or in various situations (Gehi et al., 2005; Keary et al., 2009; Levine et al., 2016; Slaap et al., 2004). Nevertheless, many studies have shown that methods used to increase PNS activity can reduce symptoms of depression, anxiety, PTSD and OCD (K. S. Cheng et al., 2019; Chien et al., 2015; Dziembowska et al., 2016; Economides et al., 2020; Lin et al., 2019; Ratanasiripong et al., 2012).

Stress is known to decrease the activity of the PNS (H.-G. Kim et al., 2018). Depression and anxiety have been associated with stress, as well as OCD and PTSD, and stress can, for example, increase the symptoms of those disorders (Fan et al., 2015; Maguen et al., 2009; Park et al., 2009; Raposo-Lima & Morgado, 2020; Steinhardt et al., 2011). Stress and stressful situations are, therefore, factors that need to be considered when individuals with those disorders are being treated. One of the key questions is if individuals with mental disorders show more decreased PNS activity compared with HC while experiencing stressful situations. The answer of which could have value when it comes to psychoeducation which is sometimes combined with the treatment of mental disorders (Huppert, 2009; Parikh et al., 2012). Psychoeducation has also been proven to be a cost-efficient way of treating mental

disorders and sometimes yields the same or better results than more expensive interventions (Al sarairoh et al., 2018; Isasi et al., 2014).

Research has measured the influence of laboratory-induced stress to explore the effects that stress has on people with mental disorders. For example, research studies have investigated the effect of laboratory-induced stress on depression and its effect on the ANS; the results have been mixed (Ahrens et al., 2008; Byun et al., 2019; Sheffield et al., 1998). For example, one study on 41 participants measured HRV among those who scored high on depression and those who scored low on depression while undergoing mental stress tasks. The results showed that participants who scored higher on depression showed decreased activity of the PNS while undergoing the mental stress task compared to those lower on depressive scores (Sheffield et al., 1998).

Byun et al. (2019) got different results in their cross-sectional study when comparing 37 individuals diagnosed with a depressive disorder to 41 healthy controls. The experiment was divided into five phases. Among those were baseline, mental stress task, relaxation task and two recovery periods. Each phase lasted five minutes. In that study, HRV could differentiate between all tasks except the stress task. The results showed that participants in the depressive group had lower HRV in all phases except for the stress task (Byun et al., 2019).

Another example is that although individuals with PTSD often show lower HRV, reflecting the decreased activity of the PNS during baseline, many studies have not been able to show a difference between healthy controls and participants diagnosed with PTSD during various mental stress tasks (Cohen et al., 1998; Hauschildt et al., 2011; Tucker et al., 2012). For example, in a study by Tucker et al. (2012), 38 survivors of Hurricane Katrina diagnosed with PTSD were compared to 38 healthy controls. The participants were asked trauma-related questions, such as if they knew anyone seriously injured or who lost their life. The results

showed that although the HRV of the survivors was lower compared to the healthy controls, there was no significant difference between the groups when it came to trauma reminders.

The literature on the relationship between HRV, anxiety disorders, and OCD lacks studies regarding those disorders and the effect of laboratory-induced stress on HRV. A study by Madison et al. (2021) showed that women with more symptoms of social anxiety showed decreased parasympathetic activity measured by HRV when evaluating information considered socially relevant. However, the difference was not found during baseline (Madison et al., 2021).

In the literature on decreased PNS activity among individuals with depressive and anxiety disorders, PTSD and OCD, various methods have been used in most of the studies to increase the reliability of the studies. For example, using comparison groups with healthy controls, using ECG to measure HRV to increase the precision of the data, controlling for other mental disorders and having trained professionals such as psychologists and psychiatrists perform the diagnosis (Hartmann et al., 2019; Keary et al., 2009; K. Kim et al., 2016; Koch et al., 2019a; Licht et al., 2008; McCraty et al., 2001; Pittig et al., 2013). Furthermore, some studies use 24-hour measurements and ECG to measure HRV, and psychiatrists or psychologists confirmed diagnoses of mental disorders, and some studies also measured both resting HRV and HRV under various tasks (Y.-C. Cheng et al., 2022; Levine et al., 2016; Licht et al., 2008; McCraty et al., 2001; Pittig et al., 2013; Shinba et al., 2008; Tucker et al., 2012).

Nevertheless, the literature on depressive and anxiety disorders, PTSD and OCD and decreased PNS activity among the groups during baseline and mental stress is limited in many ways. For example, some studies only included one gender, which reduces the generalizability of the studies (Braeken et al., 2013; Keary et al., 2009). Furthermore, some studies had a small sample size and did not correct for variables such as sleep, medications,



physical activity, smoking, alcohol, breathing, body mass index (BMI), and caffeine, all known to influence HRV (Bassett et al., 2016a; Chalmers et al., 2016; Cohen et al., 1998; K. Kim et al., 2016; Levine et al., 2016; Lim et al., 2020; Pittig et al., 2013; Smith et al., 2020).

The present study aims to add to the existing literature by replicating previous findings on the association between current and past mental disorders (CPMD) and decreased PNS activity. The relationship will be explored both during baseline and stressful situations. It will be investigated whether individuals with depressive and anxiety disorders, PTSD and OCD, as a group, will show decreased activity of the PNS during baseline and laboratory-induced stress compared with healthy controls (HC). Based on the literature, the current study has two hypotheses. 1) Individuals with CPMD have lower PNS activity than healthy controls during baseline, measured as lower HRV-RMSSD. 2) Individuals with CPMD do not show less decrease in PNS activity compared with HC measured as HRV-RMSSD during three conditions of laboratory-induced stress. In addition, the interaction effect of gender of HRV during baseline and TSST will be examined.

## Method

### Participants

Sixty individuals of two genders, 27 male (45%) and 33 female (55%), aged between 19-50 years old ( $M = 27.73$ ,  $SD = 7.14$ ), participated in the current study. Twenty-two participants diagnosed with depressive or anxiety disorders, PTSD or OCD (38.3%) were compared with twenty-two healthy controls with no known mental disorders (38.3%). The diagnoses used for the current study were past manic episodes ( $n = 4$ , 6.7%), past hypomanic episodes ( $n = 3$ , 5%), panic disorder ( $n = 9$ , 15%), social phobia ( $n = 6$ , 10%), OCD ( $n = 1$ , 1.7%), PTSD ( $n = 2$ , 3.3%). A psychologist performed a screening interview based on the DSM 5 criteria for the mental disorders included in the current study using the mini

international neuropsychiatric interview (MINI) (Sheehan, 1998). Healthy controls with no known mental disorders were randomly drawn from the dataset.

Participants were recruited by sending out emails to Reykjavik University (RU) students, by posters distributed in Reykjavik and through advertisements on social media. To participate in the study, individuals needed to be between 18-45 years of age, speak Icelandic fluently and be willing to be interviewed by a psychologist through online meeting equipment. Participants also had to give their informed consent. Furthermore, participants also needed to attend RU, where their vital signs were measured while undergoing various psychological testing. In addition, participants answered multiple questions concerning their mental health using an online digital platform. After participating in the current study, participants received 4000 ISK gift certificates to a local shopping mall, Kringlan.

## **Design**

The current study was cross-sectional, the independent variable had two levels: Current or past mental disorders and healthy controls. The dependent variable was HRV-RMSSD during the baseline period and the Trier social stress test (TSST).

## **Materials**

### *Physiological measurements*

First, the participant's blood pressure was measured, and then a medical Caretaker, a wireless device put on the participant's wrist, measured the participant's physiological activity during the study. The Food and drug administration has approved the Caretaker, which measures real-time vital signs such as heart rate and the heart's interbeat interval (Caretaker Medical, 2020).

### *The Trier Social Stress Test*

The Trier Social Stress Test (TSST) is used in a laboratory setting to examine stress reactions (Kirschbaum et al., 1993a). Participants are instructed to imagine that they have

received an invitation to a job interview. The interview is for their dream summer job. In the interview, the participants are asked to explain in front of a recording camera why they are the right person for their dream summer job. They are told that the researcher and a special committee trained to evaluate their performance will evaluate their overall performance.

After receiving the instructions, participants are given three minutes to prepare their speech. While participants prepare their speeches, they are allowed to note key points. However, they are not allowed to look at those points while they perform their speeches. After three minutes of preparation, participants are told that they have four minutes to perform their speech after the three minutes. They are told that they must talk the entire time. If the participant becomes silent before the four minutes are over, they are prompted to speak again. After the speech condition, the participants are informed that their skills in mathematics need to be evaluated. They are instructed to subtract 17 from 2023 as many times as they can out loud for three minutes. If they respond incorrectly, they must start again from 2023 (Kirschbaum et al., 1993b).

### ***MINI neuropsychiatric interview***

The mini-international neuropsychiatric interview (MINI) was created to meet the demand for a short and cost-efficient structured diagnostic interview based on DSM IV and ICD criteria (Sheehan, 1998). It can diagnose 24 current and past mental disorders, takes around 15 minutes to administer, and is highly sensitive.

### **Procedure**

At the beginning of the study, participants signed informed consent, which consisted of information about the aim of the study. After reading and signing the informed consent, participants were offered to ask questions about their participation. They were also encouraged to tell the researcher if they experienced any discomfort. The researcher would then discontinue the experiment. After participants had given their approval to participate,

they first met online with a psychologist who performed screening for common mental disorders using the mini-international neuropsychiatric interview (MINI). Later, participants attended a laboratory at RU. At the laboratory, participants were seated in front of a computer screen, and equipment measuring real-time physiological activity was adjusted and placed on the participants' wrists. After being informed about the procedure, baseline measures for physiological activity were conducted. After the baseline measures, the participants underwent various cognitive tasks and the Trier social stress test. The whole session at the laboratory lasted around two hours for each participant. The study received approval from the Icelandic Ethics Review Board (VSN-21-087).

### **Data Analysis**

HRV-RMSSD was calculated from continuous real-time IBI data, and averages for baseline and TSST conditions were made. New variables were made for current or past mental disorders, and healthy controls were randomly drawn from the dataset using Microsoft Excel. A repeated measures analysis of variance (ANOVA) was used to examine if there was a difference between the two groups (CPMD and HC) during baseline and the three conditions of TSST which are speech preparation, speech, and evaluation of mathematics skills. The interaction effect of gender was also investigated. The data was analysed using IBM SPSS statistics (Version 28).

### **Results**

Of the forty-four participants participating in the current study, twenty-two individuals diagnosed with current or past mental disorders (CPMD) and aged between 19 and 41 years old ( $M = 28.30$ ,  $SD = 7.18$ ) were compared with healthy controls (HC) ( $n = 22$ ) aged between 20 and 52 years old ( $M = 28.39$ ,  $SD = 8.94$ ). Independent samples t-test was used to explore whether the two groups (CPMD and HC) differed in terms of age. The test

revealed that the age difference between the two groups was statistically insignificant  $t(44) = -0.036, p = .65$ .

The first hypothesis stated that individuals with CPMD would have reduced PNS activity during baseline compared to HC, measured as lower HRV-RMSSD. The results showed that 22 individuals with CPMD showed lower HRV-RMSSD ( $M = 66.59, SD = 40.22$ ) during baseline compared to the 22 individuals in the HC group ( $M = 76.68, SD = 44.14$ ). However, independent sample t-test showed that the difference between the two groups was not statistically significant  $t(44) = -810, p = 0.42$ .

The second hypothesis stated that individuals with CPMD would not show more decreased PNS activity measured as HRV-RMSSD compared to HC during three different parts of laboratory-induced stress measured with TSST. The interaction effect of gender of HRV during baseline and TSST was also examined. The results showed that during the preparation part of TSST, the CPMD group did have slightly lower HRV-RMSSD ( $M = 57.62, SD = 30$ ) compared to the HC ( $M = 58.19, SD 25.16$ ). Interestingly, regarding the speech condition of TSST, the CPMD group showed higher HRV-RMSSD ( $M = 69.97, SD = 29.12$ ) compared to the HC group ( $M = 63.49, SD = 27.48$ ). However, in the math condition of TSST, the CPMD group showed lower HRV-RMSSD ( $M = 60.63, SD = 28.15$ ) compared to the HC group ( $M = 58.67, SD = 19.34$ ). Table 1 shows that the means and standard deviations for HRV-RMSSD between the four groups varied across different conditions of TSST. Figure 1 shows a graphical representation of the means for HRV-RMSSD.

**Table 1**

*Means and Standard Deviations of HRV-RMSSD for Participants of Two Genders Diagnosed with CPMD and HC During the Three Conditions of the TSST*

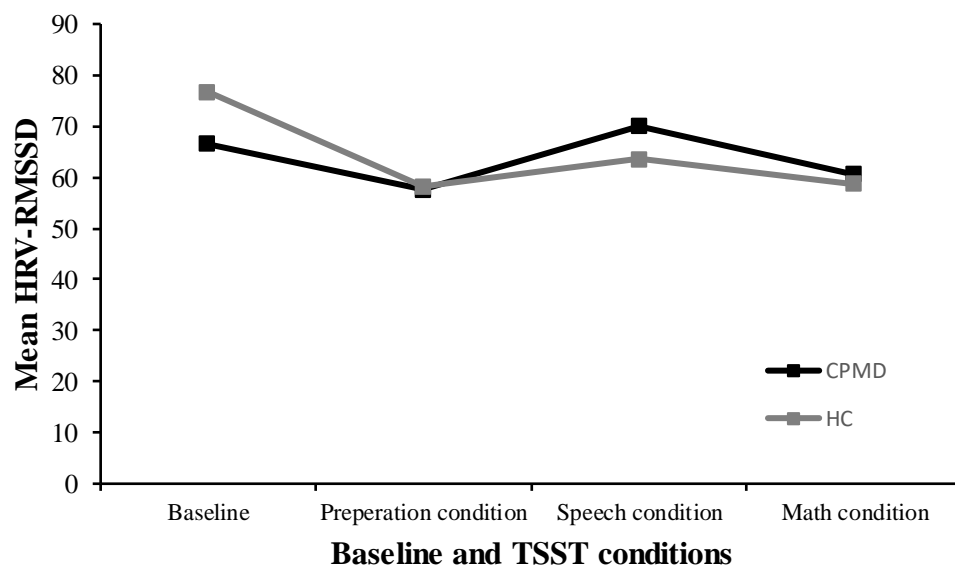
Group	N	Preperation condition		Speech condition		Math condition	
		M	SD	M	SD	M	SD
CPMD	22	57.81	22.08	69.98	29.12	60.63	28.15

Males (CPMD)	10	57.81	22.08	66.76	30.91	60.64	30.07
Females (CPMD)	12	57.47	36.32	72.66	28.62	60.62	27.80
HC	22	58.19	25.16	63.49	27.48	58.67	19.34
Males (HC)	10	56.81	21.85	63.11	18.94	63.13	18.37
Females (HC)	12	59.35	28.55	63.80	33.88	54.95	20.13

*Note.* Baseline and the three conditions of the Trier social stress test for both groups, individuals with current and past mental disorders (CPMD) and healthy controls (HC).

**Figure 1**

*Mean HRV-RMSSD During Baseline and the Three Conditions of the TSST*



*Note.* Mean HRV-RMSSD during baseline and the three conditions of the Trier social stress test for both groups, individuals with current and past mental disorders (CPMD) and healthy controls (HC).

To measure the difference in HRV-RMSSD during TSST for both individuals with CPMD, HC, males and females, a 4x3 mixed design ANOVA was conducted. Mauchly's test of sphericity was significant  $X^2(2) = 9.48$ ,  $p = .001$ , indicating a violation of the assumption of sphericity. Huynh-Feldt correction ( $\epsilon = .826$ ) was therefore used to correct the degrees of freedom and estimate sphericity.

The main effect for HRV-RMSSD during the three different conditions of TSST was not statistically significant  $F(1.80, 73.64) = 2.932, p = .065$ . Indicating that different conditions of the TSST did not significantly affect PNS activity. However, the results could be interpreted as marginally significant. Regarding the effect of CPMD on HRV during baseline and TSST, the difference between CPMD and healthy controls was statistically insignificant  $F(1, 41) = 0.145, p = .706$ . Furthermore, the effect of gender on HRV during baseline and TSST was also statistically insignificant  $F(1, 41) = 0.000, p = .989$ . Those results indicate that gender did not significantly affect PNS activity during TSST.

### Discussion

The current study aimed to explore whether individuals with CPMD would have reduced PNS activity compared with HC. Reduced PNS activity was assessed by measuring HRV-RMSSD. HRV-RMSSD was measured both during baseline and TSST. This is possibly the first research study to group individuals with current or past depressive and anxiety disorders, PTSD and OCD in a group that compares their HRV-RMSSD with HC. The results from the current study could not confirm that individuals with CPMD would have lower HRV-RMSSD during baseline. However, the results support the theory that individuals with CPMD do not show decreased HRV-RMSSD during stressful tasks compared with HC.

The first hypothesis was that individuals with CPMD would have reduced PNS activity during baseline compared to HC, measured as lower HRV-RMSSD. The results showed that the CPMD showed lower PNS activity than the HC group. However, the results were not statistically significant. These results are not in line with accumulated research results, which have indicated that individuals with a variety of mental disorders, such as depression, anxiety, PTSD and OCD, have lower HRV during baseline compared with HC (Borrione et al., 2018; Braeken et al., 2013; Byun et al., 2019; Čatipović-Veselica et al., 2007; Chalmers et al., 2016; Y.-C. Cheng et al., 2022; Cohen et al., 1998; K. Kim et al.,

2016; Koch et al., 2019a; Licht et al., 2008; M et al., 2022; Olbrich et al., 2022a; Pittig et al., 2013; Schneider & Schwerdtfeger, 2020b; Smith et al., 2020). However, these results are consistent with some of the previous literature since not all studies have been able to demonstrate that individuals with CPMD have lower HRV at baseline compared with HC (Ahrens et al., 2008; Gehi et al., 2005; Keary et al., 2009; Levine et al., 2016; Madison et al., 2021). This indicates that although the first hypothesis was not confirmed, it is still in line with some previous literature on the matter.

These results indicate that although physiological measures such as HRV can be a powerful tool to indicate CPMD, they are not always dependable. Therefore, results from such measures should be viewed with caution. However, the means for HRV-RMSSD in the CPMD group in the current study were lower for the HC group. Therefore, it could be possible that the small sample size in the current study led to the results not being statistically significant. Another plausible reason for these findings could be that the current study did not control for the severity of the mental disorders' symptoms, which could be an important factor when researching CPMD. For example, Hauschildt et al. (2011) found that the severity of PTSD symptoms was associated with lower HRV.

Nevertheless, research has indicated that it is possible to differentiate between individuals with severe and mild symptoms of individuals with various CPMD and HC during baseline and even when some of the disorders are in remission (Bassett et al., 2016b; Braeken et al., 2013; Carney et al., 2005; Shinba et al., 2008). Finally, publication bias could play a role in why results from studies that have not shown a statistical difference between individuals with CPMD and HC have not been published.

The second hypothesis stated that individuals with CPMD would not show more decreased PNS activity measured as HRV-RMSSD compared to HC during three different parts of laboratory-induced stress measured with TSST. The results showed that the PNS



activity of the two groups did not differ significantly during the TSST. Therefore the results from the present study support the hypothesis. In addition, these results align with previous literature (Ahrens et al., 2008; Byun et al., 2019; Cohen et al., 1998; Hauschildt et al., 2011; Tucker et al., 2012).

These findings support the idea that individuals with CPMD do not necessarily show more decreased PNS activity during stressful situations than HC. Although there is a minimal difference and not statistically significant, the results of the current study even indicate that during both the speech and math condition of the TSST, the CPMD group showed increased PNS activity compared with HC.

Tucker et al. (2012) suggested that floor effect could be one plausible reason individuals with mental disorders do not show decreased PNS activity compared with HC during stressful situations. In their study, although individuals diagnosed with PTSD had lower HRV during baseline, they were not different from HC concerning stressful trauma-related interviews.

A research study by Cohen et al. (1998) was also unable to show reduced HRV among individuals with PTSD compared with HC while they were instructed to remember a significant traumatic event which was the cause of their PTSD. The authors suggested that the reason could be that the ANS of those with PTSD was already hyperactive during baseline and could not show more stress when revisiting the traumatic event. Similar results have been found when individuals with depression undergo stressful tasks (Byun et al., 2019). However, some research studies have shown that individuals with CPMD show lower HRV than HC during stressful tasks (Madison et al., 2021; Sheffield et al., 1998).

The current study's findings might have value when it comes to treating mental disorders and can possibly pave the way for improving psychoeducation often used in rehabilitating individuals with mental disorders. For example, by educating individuals

suffering from the disorders examined in the current study that although it seems overwhelming to participate in stressful events such as job interviews and tests, individuals with those disorders are not physiologically more stressed than those without them. A part of the psychoeducation could be done by educating the individual about physiological arousal and the ANS and emphasizing that the literature suggests that everyone (disorder or not) that goes through a job interview or test is experiencing similar physiological activity. It is normal and uncomfortable but does undoubtedly pass. The aim would be to minimize the effect of the mental disorder on the situation. Monitoring the experienced physiological activity could be encouraged to discuss later with peers the individual trusts afterwards. Therefore, it makes stress a common experience in a group rather than a lonely experience and a symptom of a mental disorder. Psychoeducation, in general, could be an inexpensive intervention for people who suffer from mental disorders and can possibly be done remotely online. Psychoeducation done remotely could be a way of shortening what seems to be infinite waiting lists for treatment among individuals with mental disorders. Possibly be combined with methods that have been proven to increase HRV and reduce symptoms of the disorders (K. S. Cheng et al., 2019; Chien et al., 2015; Dziembowska et al., 2016; Economides et al., 2020; Lin et al., 2019; Ratanasiripong et al., 2012).

### **Strengths and limitations of the current study**

The current study has several strengths. For example, some studies on the association between HRV and mental disorders have very strict inclusion criteria, which may reduce the generalizability of the results (Koch et al., 2019b). The current study did not have rigorous inclusion criteria and, therefore, in a way, has possibly more generalizability compared with some other studies. For example, many studies have excluded individuals while controlling for variables which can be thought of as a part of being with a mental disorder, e.g. medications (Bassett et al., 2016a; Čatipović-Veselica et al., 2007; Cohen et al., 1998; K.

Kim et al., 2016; Koch et al., 2019b; Lim et al., 2020). However, at least two studies have controlled for medications after first calculating the data without them and still had the same results (Y.-C. Cheng et al., 2022; Hauschildt et al., 2011). Additionally, the current study had participants of two genders and investigated the effect of gender on PNS activity during the TSST, which was insignificant. This is an addition since some studies have excluded male participants, affecting the generalizability of the results (Ahrens et al., 2008; Braeken et al., 2013; Madison et al., 2021). Therefore, when all those factors are considered, the current study has a more diverse sample than many other studies. Another strength of the current study is that mental disorders were assessed with a screening interview performed by a trained psychologist, and those results correlated with physiological data. Finally, the current study measured HRV-RMSSD both during baseline and the TSST. Many studies have only used baseline or resting data to assess HRV-RMSSD among individuals with CPMD (Borrione et al., 2018; Chalmers et al., 2016; Y.-C. Cheng et al., 2022; Koch et al., 2019b; M et al., 2022; Olbrich et al., 2022a).

Although the current study has many strengths, some limitations must be considered. First, the sample was a small convenience sample that was self-selected for the study; a small sample size can affect the results because of less statistical power. Another limitation is that it is also possible that individuals with severe symptoms of the mental disorders investigated in the current study wanted to participate but could not due to the severity of their symptoms, which could affect the results.

In addition, the current study only used one time domain HRV variable, RMSSD. However, it is not uncommon that studies on HRV and mental disorders use a variety of both frequency and time-domain HRV variables (Bassett et al., 2016a; Borrione et al., 2018; Čatipović-Veselica et al., 2007; Hartmann et al., 2019; McCraty et al., 2001; Smith et al., 2020). Furthermore, the current study did not control for variables known to interfere with

HRV, e.g. caffeine, medications, alcohol, physical activity, BMI or breathing (Chalmers et al., 2016; K. Kim et al., 2016; Koch et al., 2019b; Lim et al., 2020). Finally, the current study is also cross-sectional, so it is impossible to draw any conclusions about cause and effect.

### **Future directions**

Although the results from the current study support the hypothesis that individuals with CPMD do not show more reduced PNS activity during laboratory-induced stress compared with HC, the relationship should be further explored. It could be of interest to investigate further individuals with CPMD known to have shown autonomic dysfunction, such as lower PNS activity together as a group rather than categorize them according to their disorder, both during baseline and laboratory-induced stress. The hypothesis regarding baseline and HRV could not be confirmed, possibly due to a small sample size and the absence of individuals with severe symptoms of mental disorders. Therefore, recruiting a larger sample of participants from outpatient facilities with more severe symptoms would be useful to understand better the relationship between CPMD and PNS activity during baseline. Many previous studies have controlled very extensively for various variables believed to affect PNS activity and, therefore, inevitably excluded possible participants, affecting generalizability. However, many of those variables can be thought of as being a part of everyday life. Therefore, future studies could lower the inclusion barrier to increase the findings' generalizability.

### **Conclusion**

The results from the current study indicated that although statistically insignificant, individuals with CPMD show decreased PNS activity compared with HC. However, when it comes to stressful situations, such as when strangers evaluated the participants' speech and math performance, there is almost no difference in HRV. The results of the current study should be viewed with caution due to its many limitations. However, these results could be a

small piece of a bigger puzzle by adding information to the existing literature about physiological arousal during stressful situations among individuals with CPMD, possibly later applied in psychoeducation. Similar results from more extensive research studies on the subject could be used as a discussion point when individuals anxiously anticipate physiological arousal during stressful situations. Furthermore, online psychoeducation could possibly be one factor in reducing waiting lists in the health care system. Future studies should further investigate PNS activity during baseline and stressful situations with larger samples with more severe symptoms of CPMD and include more HRV variables.

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