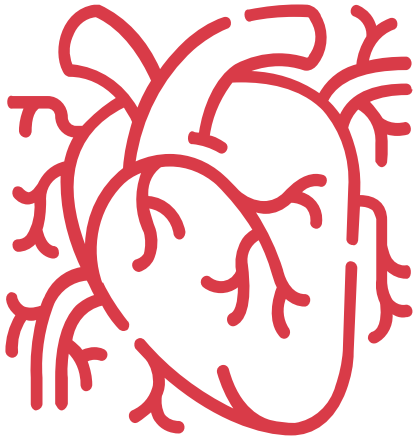
The application of the heart rate variability indicators for studying psychological states

The human heart is not just a pump that circulates blood, but it also serves as a window into our emotional and psychological states.

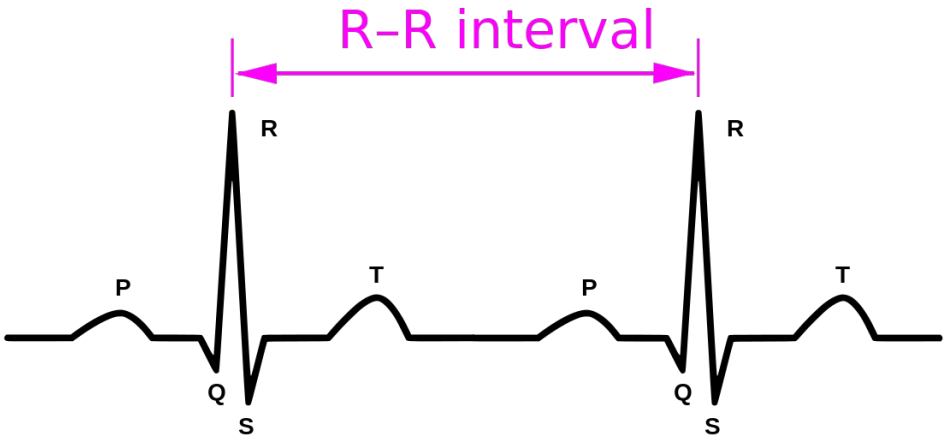


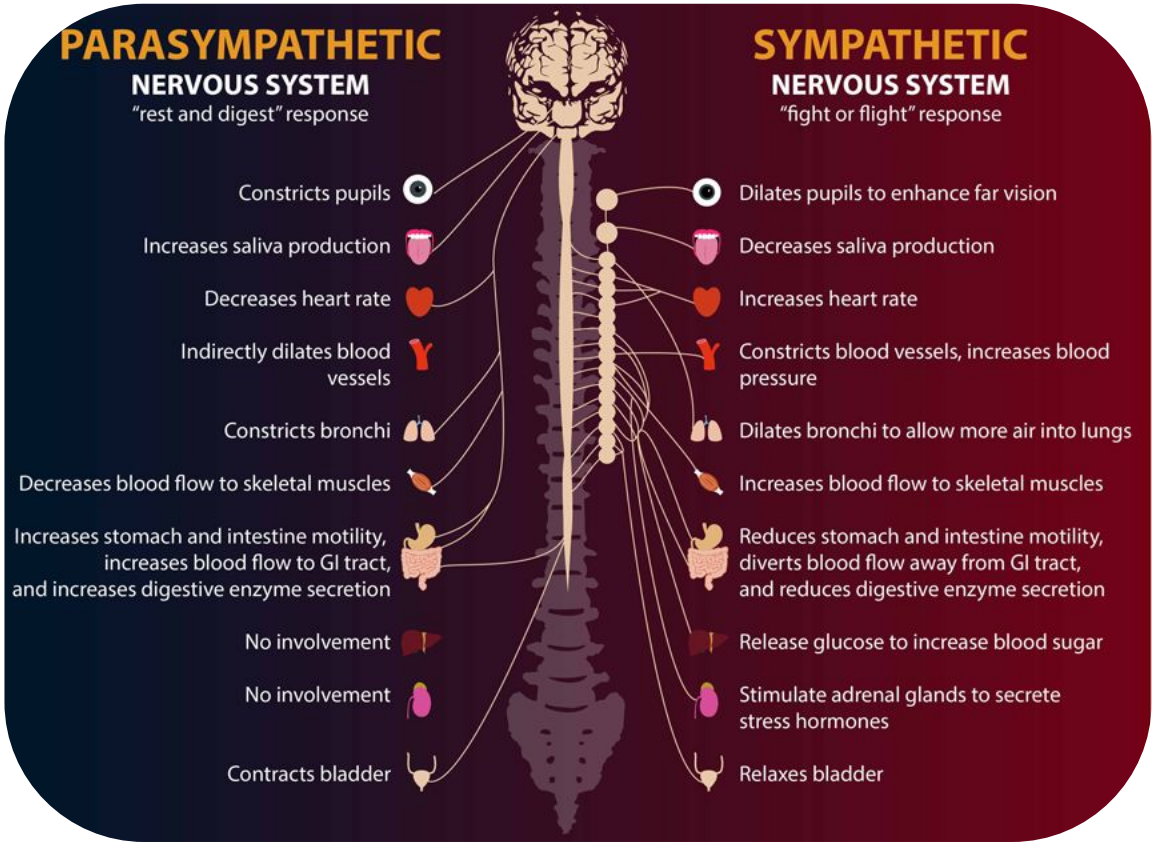
1. P wave: The P wave represents the depolarization of the atria, the upper chambers of the heart.

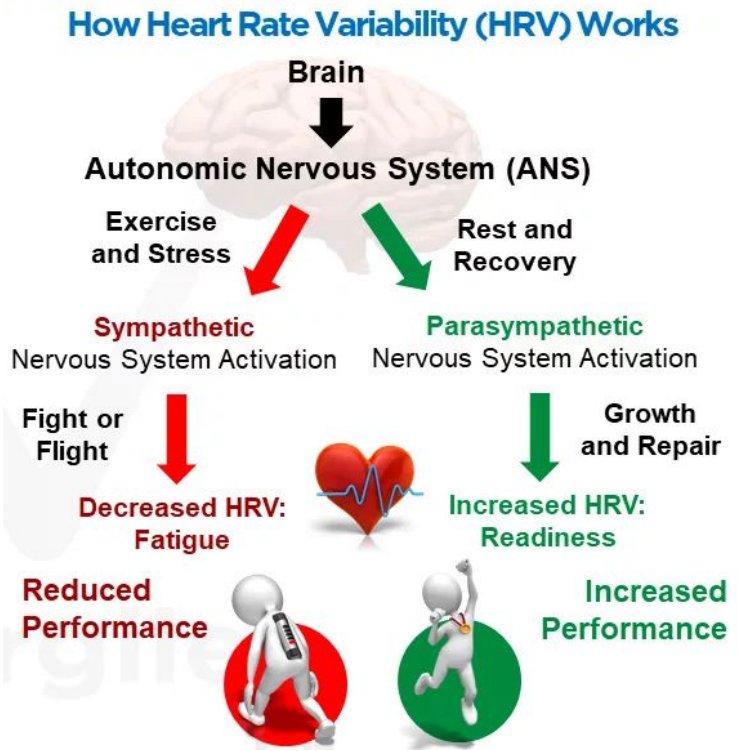
2. QRS complex: The QRS complex represents the depolarization of the ventricles, the lower chambers of the heart.

   The Q wave is the first downward deflection after the P wave, the R wave is the first upward deflection after the Q wave, and the S wave is the downward deflection after the R wave.

3. T wave: The T wave represents the repolarization of the ventricles.



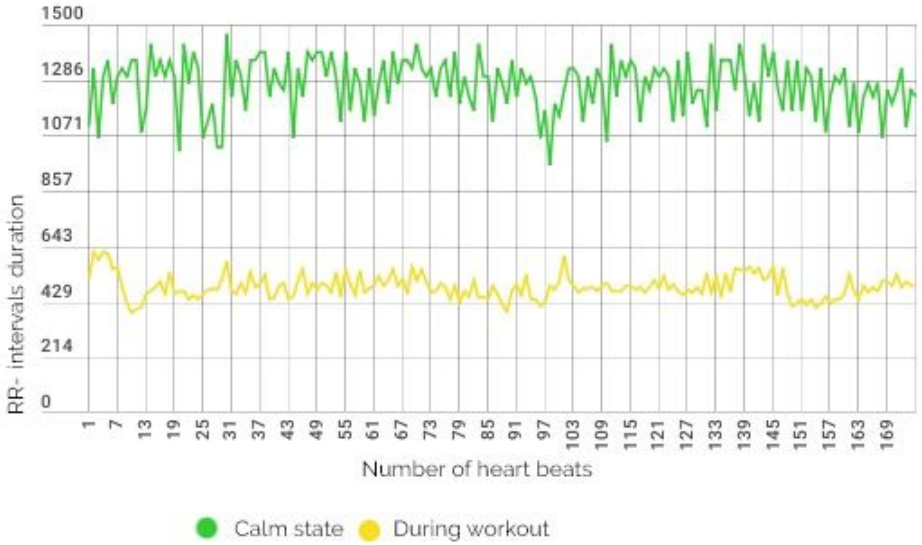

PARASYMPATHETIC
NERVOUS SYSTEM
"rest and digest" response
Constricts pupils
Increases saliva production
Decreases heart rate
Indirectly dilates blood vessels
Constricts bronchi
Decreases blood flow to skeletal muscles
Increases stomach and intestine motility, increases blood flow to GI tract, and increases digestive enzyme secretion
No involvement
No involvement
Contracts bladder
SYMPATHETIC
NERVOUS SYSTEM
"fight or flight" response
Dilates pupils to enhance far vision
Decreases saliva production
Increases heart rate
Constricts blood vessels, increases blood pressure
Dilates bronchi to allow more air into lungs
Increases blood flow to skeletal muscles
Reduces stomach and intestine motility, diverts blood flow away from GI tract, and reduces digestive enzyme secretion
Release glucose to increase blood sugar
Stimulate adrenal glands to secrete stress hormones
Relaxes bladder

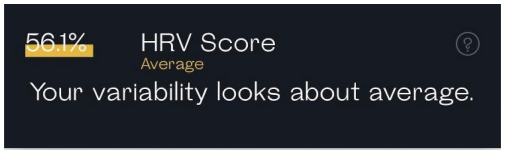

How Heart Rate Variability (HRV) Works
Brain
Autonomic Nervous System (ANS)
Exercise and Stress
Rest and Recovery
Sympathetic Nervous System Activation
Parasympathetic Nervous System Activation
Fight or Flight
Growth and Repair
Decreased HRV: Fatigue
Increased HRV: Readiness
Reduced Performance
Increased Performance

Value	Explanation	Sympathetic/**parasympathetic activation**
HR	A change in the interval between the beginning of two adjacent cardiac cycles.	**Sympathetic system** prevails during increased activity and stressful states, its stimulation leads to **increased HR**. The **parasympathetic system** prevails in calm states and is associated with a **decrease in HR**.
RRNN	Average duration of RR intervals	A **longer mean RR interval** means a lower heart rate and **higher parasympathetic** activation.
min_RR max_RR	Minimum or maximum duration of RR intervals	The **minimum duration of cardiac RR** intervals may reflect the shortest time between heartbeats and can be used to assess the **sympathetic nervous system**, which affects the increase in heart rate.
dRR = max(RR) − min(RR)	The difference between the maximum and minimum duration of RR intervals	A **high dRR value** may indicate the presence of stressful conditions or high **sympathetic activation of the heart**.
RMSSD $\sqrt{\frac{1}{N-1}\sum_{N=1}^{N-1}(RR_{n+1}-RR_n)^2}$	Sequential difference mean squared, the square root of the mean of the squared successive differences between neighboring NNs.	**High RMSSD** values indicate **high parasympathetic** activation.

Value	Explanation	Sympathetic/parasympathetic activation
SDNN $\sqrt{\frac{1}{N-1}\sum_{N=1}^{N}(RR_n - \underline{RR})^2}$	The standard deviation of the mean NN intervals calculated for short periods is usually 5 minutes.	This number always **decreases** when the **activity of the parasympathetic nervous system decreases** and may indicate the presence of stress.
Autonomic balance index (ABI) $\frac{AME}{SD}$	Indicates the ratio between the activity of the sympathetic and parasympathetic divisions of the autonomic nervous system.	Scores of **lower ABI** represent a higher ratio of **parasympathetic activation** over sympathetic and is reflective of higher autonomic balance
Vegetative rhythm indicator (VRI) = 1/(ME*SD)	Assess the vegetative balance	**A lower VRI** indicates greater activity in the **parasympathetic** nervous system, which suggests a shift towards a more balanced autonomic nervous system (with normative values from 35 to 145).
Stress index (SI) $\frac{AME*100\%}{2*ME*dRR}$	A geometric measure of HRV that reflects the stress of the cardiovascular system	**High SI values** indicate reduced variability and high **sympathetic** activation.
High Frequency (HF)	Power spectrum of high frequency component of variability in percentage from total power waves	Relative level of activity of **parasympathetic** chain regulation
Low Frequency (LF)	Power spectrum of low frequency component of variability in percentage from total power waves	Relative level of activity of vasomotor centre

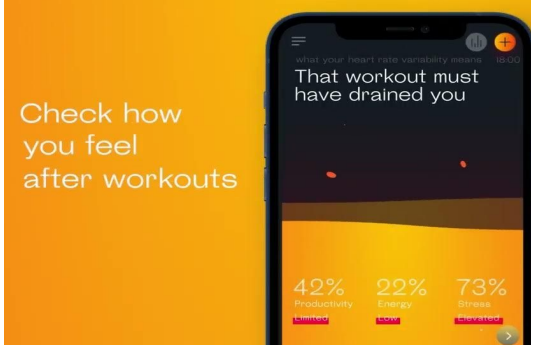
Do you track heart rate variability/other health indicators using apps or devices?





Welltory

- Smartphone camera and a finger pulse sensor
- Blood pressure tracking
- 120+ supported gadgets and apps, you can sync them all with Welltory
- Measure stress and energy
- Recommendations for improving psychological and physical well-being
- Measure heart rate during sleep



Oura

In this 2020 study, which involved 49 healthy adult subjects, researchers sought to validate the accuracy of the Oura Ring in measuring resting heart rate (HR) and heart rate variability (HRV), both of which are essential metrics for measuring recovery and overall health.

How Accurate Is the Oura Ring?

The researchers found “very high agreement” between the Oura Ring and the gold-standard, ECG measurement. The Oura Ring performed **near-perfect for resting heart rate** ($r^2 = 0.996$) and **extremely high for heart rate variability** ($r^2 = 0.980$) when compared to a medical-grade ECG device.

- Reduced heart rate variability associated with poor cardiovascular health outcomes and a range of vascular diseases also with different mental disorders and cognitive impairments. (Pham T, Lau ZJ, Chen SHA, Makowski D. Heart Rate Variability in Psychology: A Review of HRV Indices and an Analysis Tutorial. Sensors. 2021; 21(12):3998. https://doi.org/10.3390/s21123998)

- Chronic stress has been associated with cardiovascular diseases and mental health disorders.

- HRV has been found to be associated with emotion regulation abilities, with higher HRV being related to better emotion regulation skills.

- HRV has also been shown to be influenced by attentional processes, with changes in HRV patterns observed during tasks requiring sustained attention or cognitive load.

Journal of Psychosomatic Research
Volume 48, Issues 4–5, April–May 2000, Pages 493-500

Original articles

Severe depression is associated with markedly reduced heart rate variability in patients with stable coronary heart disease

Phyllis K Stein [a], Robert M Carney [b], Kenneth E Freedland [b], Judith A Skala [b], Allan S Jaffe [c], Robert E Kleiger [a], Jeffrey N Rottman [a]

Journal of Affective Disorders
Volume 40, Issues 1–2, 9 September 1996, Pages 61-71

Research report

Anxiety and autonomic regulation in major depressive disorder: an exploratory study

J.H.M. Tulen [a b], J.A. Bruijn [a], K.J. de Man [a], E. van der Velden [a], L. Pepplinkhuizen [a b], A.J.Manin 't Veld [c]

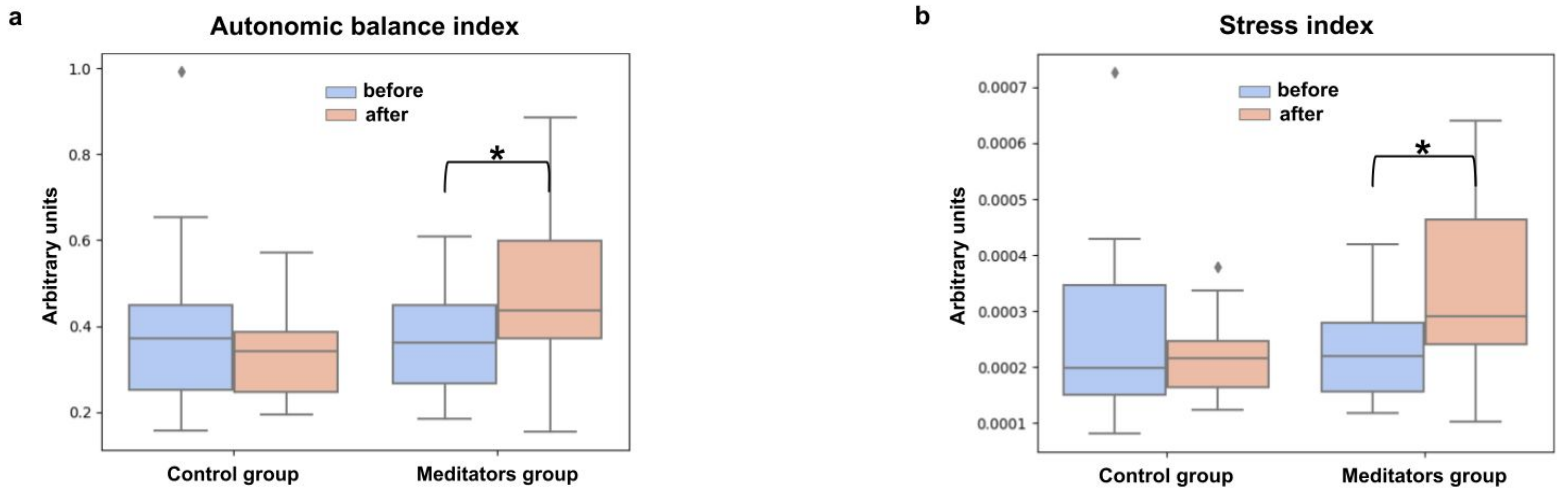
International Journal of Psychophysiology
Volume 66, Issue 3, December 2007, Pages 169-182

Review

Cardiac defense: From attention to action ☆

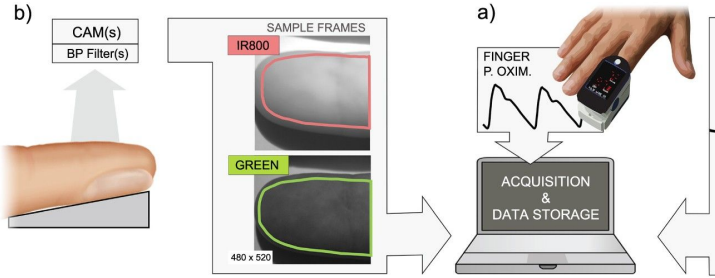
Jaime Vila, Pedro Guerra, Miguel Ángel Muñoz, Cynthia Vico, Maria Isabel Viedma-del Jesús, Luís Carlos Delgado, Pandelis Perakakis, Elisabeth Kley, José Luís Mata, Sonia Rodríguez

Meditation research



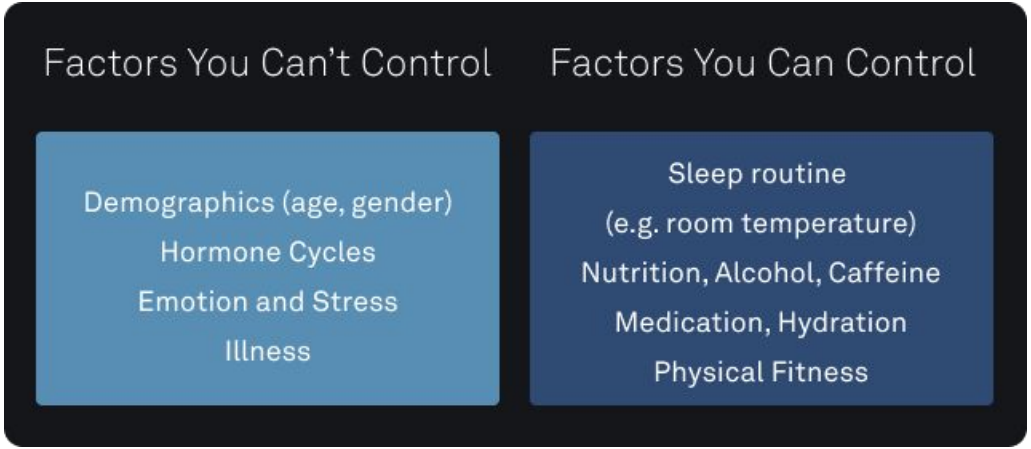
Analysis of differences between groups in PPG data during resting state with open eyes (a - Autonomic balance index, b - Stress index). Data presented as median ± interquartile range. * - indicate significant ($p<0.01$) differences between the meditators group and the control group according to the Wilcoxon signed-rank tests followed by FDR correction.

- **Data collection:** electrocardiography (ECG), photoplethysmography (PPG). The experimenter placed the PPG sensor in the appropriate place on the subject's index finger. The data is usually collected over a specific period of time, ranging from a few minutes to several hours.
- **Pre-processing:** remove noise and artifacts.
- **Analysis:** HRV data is analyzed using different time and frequency domain methods to obtain various HRV indices. Time domain measures (SDNN, RMSSD). Frequency domain measures (LF, HF).
- **Statistical analysis:** significance of the obtained HRV indices in relation to the research question. This may include hypothesis testing, correlation analysis, regression analysis, or other methods.
- **Interpretation and conclusions:** Based on the results of the statistical analysis, conclusions are drawn regarding the significance of the HRV indices in the studied population or health condition.



Limitations to measuring HRV indices

- **Measurement variability**
- **Limitive normative data**
- **Lack of long-term monitoring**



Even though PPG provides accurate interpulse intervals to measure heart rate variability under ideal conditions, it is less reliable due to its vulnerability to motion artifacts.

Limitations of Oximetry to Measure Heart Rate Variability Measures

October 2009 · Cardiovascular Engineering 9(3): 119-25
DOI: 10.1007/s10558-009-9082-3
Source · PubMed

Guohua Lu · Fang Yang

Thank you for your attention!