Effects of Relaxed and Stressful Mental States on the Heart Rate Variability Parameters

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Abstract

Background: Heart rate variability (HRV) is a reliable metric for gauging the balance between relaxation and stress within the human body, offering insights into autonomic nervous system regulation. A significant component of HRV is modulated by the vagus nerve, the principal nerve of the parasympathetic system. Its fluctuations provide a valuable way to assess an individual's physiological and emotional well-being. While considerable evidence demonstrates that HRV parameters improve during mental relaxation and decrease during cognitive workload tasks, there is limited research that provides a comprehensive comparison between these states, specifically with regard to vagal activity. This study aims to bridge this gap, offering a detailed comparison of HRV metrics, including those reflective of vagal (parasympathetic) tone, during distinct mental states, thereby contributing valuable data to this critical aspect of autonomic physiology research.

Methodology: A within-group counterbalanced randomized controlled trial with N=44 participants was carried out for two interventions: Relaxation and Stress. In the relaxation group, participants underwent a 5 min of paced breathing task by following a visual cue to maintain their breathing pace at 10 breaths per minute, a practice known to enhance vagal activity. In the stress group, participants underwent a 5 min of time-bound mental arithmetic task, where they had to answer a series of progressively difficult arithmetic questions quickly, a condition expected to reduce vagal activity. Heart rate (HR) and RR beats were recorded and pre-processed before the extraction of HRV parameters.

Results: Out of various HRV parameters, ten were found to differ significantly between the two interventions. Compared to the literature, all the significant parameters exhibit the improving and degrading tendency of HRV parameters in the relaxed and stressed states, respectively. During stress, a reduction in the SDNN, Standard deviation in HR, RMSSD, RR triangular index, TINN, Deceleration capacity (reflective of vagal modulation), and increase in the SNS Index, Stress index, Minimum HR, and respiration rate were seen. All these parameters show a rebound during the relaxation intervention. Large effect sizes were obtained for all the significant parameters, except for a moderate effect for Deceleration capacity and a small effect for RMSSD.

Conclusion: HRV parameters significantly vary in mentally relaxed and stressful states. The computed parameters degrade (become lower or higher) during the stressful state, which indicates the sympathetic dominance and reduced vagal (parasympathetic) tone as mediated by the vagus nerve, and rebounds to significantly different values during relaxation, indicating a resurgence of parasympathetic (vagal) activity and a relaxation response. The large obtained effect sizes assure the use of HRV, and by extension vagal tone, as a reliable indicator to assess a person's relaxed and stressed mental state. This research highlights the nuanced and

significant changes in HRV parameters between distinct mental states, thereby bolstering the case for using HRV as a precise tool in mental health assessment and intervention planning, with a special emphasis on the role of the vagus nerve. Furthermore, the relaxed and stress interventions in the study can be used as baseline measurement interventions for comparative studies in similar areas, paving the way for more targeted and effective mental health strategies.

Keywords

Heart Rate Variability, Autonomic Nervous System, Mental Relaxation, Mental Stress, Paced Breathing, Cognitive workload