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OPINION
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Opinion: "Heart Rate Variability, Health and Well-Being: A Systems Perspective" Research Topic

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The promotion of health and well-being is a long-standing goal of scientific inquiries. The World Health Organization mission incorporates not only the absence of disease but also an integrative perspective on social, physical, and mental well-being (1). The National Institutes of Health goals are intimately focused on protecting and improving health through funding research and facilitating programs that promote public health (2). Healthy People is an example of a broadly focused, long-range strategic initiative that incorporates results from scientific inquiry into health promotion recommendations (3). Therefore, scientific strategies to understand, describe, and predict health-related issues are important steps in the process of promoting health and welfare.

The Frontiers research topic titled "Heart Rate Variability, Health, and Well-being: A Systems Perspective" is focused on the construct of heart rate variability (HRV) in the context of health and well-being. Autonomic control of peripheral functions involves a complex series of interactions, including the sympathetic and parasympathetic nervous systems as well as central processes, neuroendocrine functions, and reflex arcs. Therefore, studies involving HRV have the potential to provide insight into a wide variety of psychological and physiological processes.

Altered HRV, and its value for predicting dysfunction (or lack thereof), has contributed significantly to our understanding of several conditions [for reviews, see Ref. (4, 5)] such as stress reactivity and resilience (6, 7); emotional reactivity and personality factors (e.g., responses to stress, perception of stress, emotional memory, attention and related cognitive functions, and self-regulation processes) (8–12); emotion-related disorders (e.g., depression, anxiety, and sleep disorders) (13, 14); social behaviors (e.g., social engagement and social–emotional processes) (15–17); cardiovascular functions and risk factors (e.g., hypertension, myocardial infarction, sudden cardiac death, renal dysfunction, and diabetes) (4); and cancer (18). The study of HRV also has provided insight into the interactions of psychological and physiological processes [for review, see Ref. (15)], including stress reactivity following cardiac transplants (8); effects of antidepressants on autonomic function in panic disorder (19); association of depression and cardiovascular disease (13, 20–25); interactions of social factors and cardiovascular function (26–28); treatments for comorbid psychological and physiological conditions (29–32); and novel non-pharmacological treatment strategies for psychological and physiological disorders, such as deep brain stimulation, vagal nerve stimulation, exercise, or yoga (31, 33–35). These brief examples highlight the value of HRV research for describing and predicting several conditions that influence public health.

This integrative research topic on HRV which spans two *Frontiers* journals (*Frontiers in Medicine* and *Frontiers in Public Health*), contributes novel perspectives on the scientific and practical value of HRV research. For example, Kirby and colleagues (12) address the utility of HRV in training exercises to facilitate compassion, highlighting the importance of considering physiological processes in the context of psychological interventions. As discussed, a better understanding of behavioral, social, and emotional factors that contribute to HRV will provide evidence for its utility as an outcome measure, a potential method for manipulating behavioral and emotional states, and an index for understanding the integration of autonomic regulation and emotional reactivity (12). Similarly, Lamb et al. (35) and Steffen et al. (36) present novel findings from techniques that capitalize on altering

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autonomic function, including the effects of resonance frequency breathing exercises on HRV and mood in healthy humans (36), and the influence of vagal nerve stimulation on HRV and other physiological parameters in combat veterans with posttraumatic stress disorder (35). These concepts are related to those addressed by Ernst (37), who stresses the importance of considering neural–cardiac communication in the context of HRV.

To comprehensively appreciate the role that HRV measurement and manipulation has in health promotion, translation from basic to clinical research strategies is critical. To this end, the prairie vole is an example of an animal model that is used to investigate the integration of social experiences, behavior, and autonomic function (38, 39). This species is reliant on the surrounding social context for the promotion of health and behavior. Prairie voles exhibit several characteristics that mimic human social systems, including social monogamy, living in family groups, displaying biparental care of offspring, and responding negatively to social environmental disruptions (40–42). Given these characteristics, the prairie vole has been considered a useful translational model of social behavior, and the benefits of social monogamy on the endurance of this species have been discussed in the context of studies on parental behavior, pair bonding, and reproductive processes, among others (39, 42–45).

Although there is a large body of literature on prairie vole social behavior and neuroendocrine processes, research questions focused on autonomic and cardiovascular regulation using this model have only been explored over the past 10 years. This research has provided mounting evidence that the prairie vole is a valuable model for the study of social interactions and the heart (39, 46–48). The prairie vole has interesting physiological characteristics that may promote autonomic nervous system health, including a high degree of parasympathetic regulation, which in turn supports a high level of HRV (relative to other rodents, and more in line with larger mammals such as dogs and human infants) and a low resting heart rate (relative to body size scaling) (49).

Recent studies in the prairie vole model have described several autonomic correlates of behavior and physiological processes, including altered heart rate and HRV under different social conditions (50–52). This line of research has provided insight into neurobiological and behavioral processes associated with negative social experiences and stress-related disorders, including isolation, loneliness, depression, anxiety, and cardiovascular disease. For example, prairie voles exposed to social stressors display elevated heart rate, reduced HRV, impairment of endothelial-dependent vascular relaxation, cardiac arrhythmias, and cardiac gap junction protein dysregulation (38, 53–57). Some of these consequences may be due to altered neural control of peripheral processes (e.g., autonomic function, endocrine reactivity, and behavior), including changes in hypothalamic and brainstem autonomic nuclei (54, 58–61).

The issues discussed in this Frontiers research topic coupled with studies using valid and reliable animal models, will inform strategies for preventing and treating disease and facilitating good health practices. Continued dialog—such as that included in the articles focused on this HRV research topic—is crucial for ensuring that the techniques used in the laboratory are theoretically and evolutionarily grounded (37, 62–64) and are fully vetted both from a basic scientific and an applied perspective (65–68). Incorporating HRV measurement and manipulation into studies that include a translation from animal models to humans (and the reverse from human studies to the development of animal models), as well as parallel multispecies experimental protocols, will enhance our understanding of biopsychosocial factors that promote health and well-being.

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AG, the sole author, was responsible for the design of this work and interpretation of findings, drafting the work, final approval of the version to be published, and is accountable for all aspects of the work to ensure its accuracy and integrity.

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