Should Physicists Analyse Heart Rate?

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Physicists are trained to deal with non-living matter and until recently, it was considered detrimental to physics training and practice to depart from a strictly material philosophy of physical science. This status quo began to change rapidly around the turn of the millennium, when physicists started to embrace elements of physics of complexity, biology, systems, networks and living systems in general. Physicists were looking for new terrains offering new chances for physics methods of science to be applied, but also challenging scientists established in their own disciplines of biological origin to explore rigorous methodologies of physics in their fields.

The particular trend to apply methods of physics to other disciplines of science can perhaps be traced back to the success of physics methodology in offering tractable, simplified models of complex phenomena. One such paradigm was offered by the statistical physics of phase transitions. The 'translational' success of universality observed in phase transition phenomena and, in particular, at criticality was a breakthrough in physics – it offered a unifying view of inaccessible system-level complexity, using tractable, low-dimensional models. Suddenly, physics became capable of approaching and successfully treating a multitude of system scales and degrees of freedom. Indeed, a multiscale view of phenomena, in physics and beyond, flourished following the pioneering, breakthrough work on statistical physics of phase transitions and criticality.

It is perhaps no wonder that physicists deeply involved in the theory of universality approached the challenge of systemic complexity of biological origin, that of heart rate regulation. The dynamic complexity of our own life-perpetuating system – the cardiovascular regulatory system, consisting of intertwined feedback loops involving cardiac and baroregulation – is inherently non-trivial. Elucidation of fundamental molecular, cellular and biological mechanisms involved in this particular complex dynamical system is done by physiologists and put into practice by medical doctors. Yet physicists pursued the challenge from their own perspective – that of identifying possible universal laws governing the dynamics of the cardiac regulatory system [1].

The insights gathered in recent years all point towards the view that the cardiac regulatory system works in the critical regime [2]. A plausible, albeit not proven hypothesis would be that this criticality is of a self-organised nature. Indeed, in terms of Zipfian distribution of the probabilities of states, Kalda [3] contributed to the body of evidence that heart rate follows Zipf statistics. The Zipfian distribution of states has recently been established as a hallmark of self-organised criticality in complex systems, including biological systems [4].

The origin of these laws, however, remains somewhat of a mystery. The inherently multiscale, self-organising and adaptive regulatory feedback scenario still remains the most plausible paradigm of complexity of heart rate [5]. Recently, this evidence has been strengthened by contributions from non-physicists who adopted the phenomenological view mainly purported by physicists [6, 7]. This is an exciting development, which may both signal an emerging trend of the acceptance of physicists' findings, and lead to a whole new way for physiologists and medical doctors to embrace the work and findings of physicists and apply them in their own research and practice. Going back to the question posed in the title, the benefits in fact work both ways. By tackling a real-life problem, physicists have to learn to adapt their methodology and mindset to cope with reasoning with the uncertainties and poor statistics for which life science research is known.

References

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