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DO ARCTIC HARES PLAY PARRONDO'S GAMES?

KANG HAO CHEONG
Engineering Cluster, Singapore Institute of Technology, 10 Dover Drive, S138683, Singapore
Science and Math Cluster, Singapore University of Technology and Design (SUTD), 8 Somapah Road, S487372, Singapore
kanghao.cheong@singaporetech.edu.sg

JIN MING KOH
Engineering Cluster, Singapore Institute of Technology, 10 Dover Drive, S138683, Singapore

MICHAEL C. JONES
Ashland, MO 65010, USA

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We remark on Nelson and Masel's (2017, 2018) papers, addressing the connection between the published work and the game-theoretic Parrondo's paradox. The Parrondo's paradox refers to the phenomenon of achieving winning outcomes by playing two losing games in a random or deterministic order, and is intimately related to flashing Brownian ratchets with applications in physics, engineering and biology. In this Current Opinion article, we raise important considerations and intricacies pertaining to the paradox, for the benefit of future Parrondo-related research.

Keywords: Parrondo's paradox; Parrondo's games; Brownian ratchets; Game theory, Evolution

In a recently published article by Nelson and Masel (NM) [1], the Parrondo's paradox [2-5] had been misrepresented by the example of an arctic hare that seasonally alters coat color for camouflage. This is misleading, as the hare exemplifies *seasonal adaptation*, not losing strategies exhibiting the Parrondo effect. Environmental context-dependent phenotypes are, in fact, rarely relatable to Parrondo games. The characterizing difference between the two is that Parrondo games yield winning outcomes even with non-periodic or stochastic mixing of the constituent losing games [6, 7]—this robustness is indeed what makes the paradox meaningful—whereas the hare must alternate between coat colours with a rigid seasonal period in order to win.

kanghao.cheong@singaporetech.edu.sg

This misrepresentation extends past reasonable boundaries of definitional creep or generalization. If left uncorrected, such statements can lead to a cascade of erroneous identifications and applications. For instance, driving a vehicle through a corner can similarly be claimed to be Parrondo-paradoxical, since under-steering and over-steering are both losing, but alternating between the two is workable. Even the mundane act of drinking water will become 'paradoxical', for sustained consumption at too large and too little a rate will result in toxemia and dehydration respectively, but alternating between the two will sustain one's health. A further precluding factor is the lack of ratcheting effects, integral in the fundamental driving mechanism of the Parrondo's paradox.

NM states that "exclusive multicellularity tends to be a losing strategy", and rightfully points out the possibility of exceptions. However, it was not claimed in the critiquing letter [8] that "a parent's cellular degradation [is] inherited by offspring"—this is expected to occur only in the germline—and the refutation that "we [NM] do not have a definitive answer" appears inconsistent with the conclusion of their paper that "multicellular aging and death are inevitable" [9]. In fact, NM discusses that "a solution to lineage immortality may come from the alternation of life history stages", suggesting that their findings indeed support an analogy between the biological survival mechanism and the Parrondo's paradox, as pointed out by the critiquing letter [8]. The dismissal by NM is thus confusing.

Lastly, it was also put forth that the "falsity" of "exclusive unicellularity" being a losing strategy is "unambiguous" [1]. The proposition that "exclusive unicellularity is a fantastically successful strategy employed by the majority of life on this planet" is of limited accuracy. For unicellularity to be a truly winning strategy, unicellular lineages must be indestructible. Patently, there has been no such unicellular lineage in the past three billion years. It is more accurately reasoned that unicellularity at a collective level has persisted precisely because all unicells are losers; a persistent winning ensemble is not possible without individual losers—a point that had been discussed [8] but largely neglected thereafter.

The present discussion on the paper [9] and accompanying letters had unveiled numerous fresh perspectives. Overarching the addressed issues [1, 9] is a narrow lens in the single-scale analysis of survival and death. A better understanding of nature may yet be reached by analyzing survival dynamics in a broader sense, across temporal and spatial scales in what had been suggested to be a recurrent hierarchical assembly of losers and winners [8].

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