Does diffusion of horse-related military technologies explain spatiotemporal patterns of social complexity 1500 BCE–AD 1500?

Turchin et al. (1) use an agent-based model (ABM) to evaluate the hypothesis "...that the diffusion of horse-related military technologies from the steppe-sown interface to the rest of Afroeurasia results in a characteristic spatiotemporal pattern of spread of intense forms of warfare, leading to macrostate forms of political organization." Because of design and simulation choices, it appears that their ABM provides less support for this hypothesis than the authors claim.

First, the core features are underspecified—too simple and too abstract—and therefore do not adequately model the labeled phenomena. "Ultrasocial traits" could just as well be interpreted as any assets, resources, knowledge, or capabilities that endow a region with power or influence, and not just ultrasocial traits. Military technology or "MilTech traits" could just as well be interpreted as any factors that promote socio-cultural hegemony, not just military traits, much less horse-related military traits. The process labeled "warfare" could just as well be labeled as "accretion" (i.e., any combination of expansion, annexation, colonization, migration or warfare). In the *Supporting Information* of ref. 1 the authors do acknowledge the simplicity and abstraction, and propose various ways to make the ABM more specific.

Second, other than parsimony, there seems little justification for the design choice to model MilTech as a single innovation diffusion process lasting 3,000 y. A more

realistic choice (not complicated) would be to model waves of innovation originating from the steppe interface, each with shorter duration.

Third, elevation appears to be a poor surrogate for defensibility. Using the same sources, it should be possible to code each region on a scale of ruggedness: for example, (*max-min*). Substituting ruggedness for elevation might significantly change the results, especially in high plateaus.

Fourth, random seeding of MilTech across the entire space is not a good alternative treatment. A better alternative treatment would be to seed MilTech (as "socio-cultural hegemony traits") in the lowland civilizations that had already achieved a high level of social complexity in 1500 BCE: Egypt, Mesopotamia, Indus Valley, and Northern China. I suspect that the simulation results would be identical. If so, this result would considerably weaken support for the horse-related MilTech hypothesis.

Fifth, running the simulation over several shorter periods and smaller geographic regions would be more fruitful than the author's choice of 3,000 y because sharper comparisons could be made between empirical data and simulations. Initial conditions would be more accurate, dark ages could be excluded, and so forth. It would be very compelling if the same model and parameters accurately reproduced empirical data from different periods and regions.

Finally, the results would be much more compelling if an alternate causal pathway was tested. The authors propose: "spread of military technologies→intensification of warfare→evolution of ultrasocial traits→rise of large-scale societies" (1). However, at least for the war chariot in the Late Bronze Age Near East, there is strong evidence that innovation and diffusion was driven by prestige and elite emulation (2) and only later took on major significance in warfare. Therefore, a good alternative causal pathway to test would be: evolution of ultrasocial traits (including prestige objects)→rise of large-scale societies→spread of military technologies→intensification of warfare.

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1 Turchin P, Currie TE, Turner EAL, Gavrillets S (2013) War, space, and the evolution of Old World complex societies. *Proc Natl Acad Sci USA* 110(41):16384–16389.

2 Feldman MH, Sauvage C (2011) Objects of prestige? Chariots in the Late Bronze Age Eastern Mediterranean and Near East. *Ägypten und Levante* 20:67–182.

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