hammerstone, a modified hook tool, an Oldowan flake tool, and a wooden spear—all single-component tools—differ significantly in their processes of acquisition, manufacture, use, and resulting options and thus in the complexity expressed by the problem-solution distance (Haidle 2010, 2012; Lombard, Haidle, and Högberg 2019). To "improve the representativeness of the current evidential base" as Vaesen and Houkes demand, a less restricted view of cultural traits and technology than that of Vaesen and Houkes is required.

Second, we consider cultural traits multifactorial. A tool and the associated behavior, for example, represent an understanding of the combination of material, form, function, technology of production, technology of use, and general problem-solution concept (Haidle and Bräuer 2011). Thus, and contrary to premise 2, the evolution of a cultural trait should be assessed as a multifactorial process. An invention can affect one or several of these factors simultaneously; an evolutionary sequence of inventions can first affect factor a, then c, then e, then b, then a again, and so on. These changes can have different effects on the requirements and outcomes.

Third, consequently, we see a fundamental problem in the connotation of a change as unambiguously "beneficial" as it relates to an increase in complexity, efficiency, or effectiveness (Haidle 2019). While a modification can be beneficial on one axis, for example, the higher availability of raw material, it can prove problematic on another axis, for example, less durability in use, and neutral on a third axis, for example, length of the cutting edge. What can be perceived by some, focusing on factor a, as an increase in efficiency, can be valued by others, regarding factor b, as less efficient. And a cultural trait can become more efficient by introducing a shortcut that reduces complexity. Consequently, CE must not be considered as taking place in one-dimensional space, that is, along a line (of increasing complexity and growing usefulness). CE unfolds in a multidimensional space. It thus might be compared to mountaineering rather than to climbing up a ladder or ratcheting in a single direction (Haidle et al. 2015:51; Lombard 2012). In this scenario, cultural traits anchor populations within their respective evolutionary trajectories and fitness landscapes, and while it is always possible to increase cultural complexity, it is equally possible to revert to seemingly simpler options (Lombard 2016). Thus, in the mountaineering analogue, different paths, each with multiple perspectives, can be explored, and sometimes moving backward proves helpful (e.g., simplification of tools).

The expectation should be that modifications of cultural traits result in diverse effects depending on perspective, if we take into account the plurality of the relevant dimensions. What is more, such variation need not come along with an increase in one of the variables; that is, CCE need not be cumulative in the additive sense described above. A case in point is the repurposing or exaptation of cultural traits (Gould and Vrba 1982), the importance of which has become more and more clear in recent research (e.g., de Beaune 2004; d'Errico et al. 2018; Schlaudt 2020). Cases of exaptation fall in the category of CCE because exaptation (1) draws on preexisting cultural resources and (2) brings about something new. Thus, although exaptations are cumulative innovations, they do not necessarily come along with an increase of complexity, effectiveness, or efficiency.

In this sense, speaking of CCE might be misleading. It tends to identify CCE with or reduce it to the ratchet effect. Instead, we see as crucial to CCE that each invention draws on preexisting cultural resources and therefore can be explained by them (de Beaune 2004). The concept of "path dependence" would lend itself to this if it did not connote the individualistic approach of economics, which we consider at odds with our ecological approach. Not only do inventions have to be approved by the community to become innovations, but also they are produced by individuals who (1) are inherently social and (2) draw on cultural and thus socially inherited resources. All inventions thus go beyond the capacity of individual humans to invent alone, and in this sense, they are cumulative, but they are not additive, linear, and beneficial in the sense of Vaesen and Houkes. This suggests simply refraining from speaking of CCE and accepting that all CE is inherently cumulative in the way described above.

Alex Mesoudi
Human Behaviour and Cultural Evolution Group, Department of Biosciences, University of Exeter, Penryn, Cornwall TR10 9FE, United Kingdom (a.mesoudi@exeter.ac.uk). 16 VIII 20

What Is Cumulative Culture, and How Should It Be Tested?

I agree with the general point made by Vaesen and Houkes: we need more fine-grained, quantitative, cross-cultural data regarding human cumulative cultural evolution (CCE), which tracks the effectiveness or efficiency of a socially learned trait over successive generations within cultural lineages. However, I take issue with some of their specific points. Vaesen and Houkes seem to set the evidential bar so high for CCE that it is unreachable and define CCE in ways that do not always match the literature.

First, Vaesen and Houkes argue that "if cumulativeness is to qualify as a general characteristic of human culture (see the quotes in 1n), it is not enough to show that some human cultural behaviors result from CCE; rather, one must show that a large fraction of such behaviors result from CCE." I do not fully understand what is meant by "a general characteristic," but I do not know of any such claim in the literature. None of the quotes in their footnote make any claims about how much of human culture must be cumulative. They simply assert that human culture exhibits the property of being cumulative in at least some instances. As Vaesen and Houkes point out, technology is the best and most often cited example of a domain that is cumulative. Yet much of human culture is clearly noncumulative. Cultural traits such as pottery decorations, choices of pet breeds, and first names exhibit dynamics consistent with neutral drift (Bentley, Hahn, and Shennan 2004; although see

Kandler and Crema 2019), which by definition is noncumulative. Convergence on intuitive, cognitively attractive representations such as bloodletting (Miton, Claidière, and Mercier 2015) is also a common form of non-CCE. In this, cultural evolution is really no different from genetic evolution, which may sometimes be cumulative, producing complex adaptations such as eyes, but is often characterized by drift. We should not expect more from cultural evolution than we do from genetic evolution.

Consequently, to demand that "a proper test" of CCE requires data that are "representative of all of the cultural-evolutionary processes that have taken place in our species" surely sets the bar unnecessarily high. There is no reason to expect that all cultural-evolutionary processes in our species should be cumulative, only those in which selection pressures favor increasing effectiveness or efficiency.

Second, Vaesen and Houkes discount evidence because it comes from Western, educated, industrialized, rich, and democratic (WEIRD) samples (e.g., dismissing experiments because "all were performed on WEIRD subjects"). I am all for diversifying samples beyond WEIRD countries (Mesoudi et al. 2015, 2016). But that does not mean that we can discount evidence because it comes from WEIRD samples. WEIRD people are people too. Vaesen and Houkes seem to imply that CCE must be demonstrated in every society worldwide before we can accept it as a valid concept—surely far too high a bar for an idea that emerged in the late 1990s. Most examples of CCE in the literature do indeed involve historical trajectories or samples from WEIRD countries, probably because written historical records are more readily available and experiments more feasible in such societies. However, Henrich (2015) and Boyd (2018) provide examples of complex technologies and customs found in hunter-gatherer and other small-scale societies that seem to exceed individual learning and are therefore suggestive of CCE. No doubt, future empirical research will provide better evidence across more diverse contexts, but dismissing research on WEIRD people altogether seems unreasonable.

Third, Vaesen and Houkes ignore recent evidence regarding nonhuman CCE. While many authors have indeed claimed that CCE is unique to humans, others have claimed to have shown CCE in nonhuman species. Sasaki and Biro (2017) showed how homing pigeons improve the efficiency of their route over successive generations as a result of repeated social learning. This exactly fits Vaesen and Houkes's definition of CCE, requiring "individuals, across generations, [to] gradually improve their behavior through social transmission of beneficial modifications." By their own definition, then, it has already been demonstrated that CCE is not unique to humans. Mesoudi and Thornton (2018) argued that the concept of CCE should be unpacked: we described the repeated improvement of a socially learned trait as the "core criterion" for CCE and identified several "extended criteria" that may be what distinguish human CCE from that of other species.

Fourth, Vaesen and Houkes do not present any alternatives to CCE for the technological and sociopolitical complexity that our species has produced. Are such complex traits instead the product of individual learning (e.g., the "improvisational intelligence" of Pinker [2010])? Or genetically encoded responses "evoked" by different environments (Tooby and Cosmides 1992)? Scientific progress requires testing between alternative explanations.

Fifth, Vaesen and Houkes criticize experiments for finding that "CCE occurs in some conditions but not in others." Yet this is not a problem. Models demonstrate how cultural complexity can be lost under various conditions (e.g., small population sizes; Henrich 2004) or plateau because of learning costs (Mesoudi 2011). Contrary to nineteenth-century unilinear social evolutionism, the modern concept of CCE does not predict inevitable and unidirectional cultural change. The accumulation of cultural modifications, just like the accumulation of genetic modifications, is reversible and subject to demographic and other constraints.

Finally, the examples that Vaesen and Houkes provide from the literature are somewhat limited. Vaesen and Houkes are correct that Morris (2013) conflates multiple cultural lineages and uses coarse-grained data subject to substantial error. But several other studies that track increases in effectiveness or efficiency within specific cultural lineages also exist: Nia et al. (2015) showed that violins gradually improved in acoustic conductance over several centuries, Miu et al. (2018) showed how solutions to math problems improved within a programming community via successive bouts of copying and innovating, and several studies have traced the evolution of increasingly energy-efficient bicycle designs (Lake and Venti 2009; Minetti, Pinkerton, and Zamparo 2001; Van Nierop, Blankendaal, and Overbeeke 1997). To return to my initial point: more such evidence is definitely needed and from more diverse sources and samples. But let us not ignore or dismiss the evidence that does exist or make requirements (e.g., that all human culture is cumulative or that CCE should be unidirectional) that are not warranted by theory.

Antoine Muller
Computational Archaeology Laboratory, Institute of Archaeology, Hebrew University of Jerusalem, 91905 Jerusalem, Israel (antoine.muller@uqconnect.edu.au). 4 IX 20

The Ongoing Search for the Origins of Cumulative Culture

I first wish to thank Vaesen and Houkes for their concise and thought-provoking article. They seek to question the perceived orthodoxy that cumulative cultural evolution is inherent to humans and that cultural evolution in humans is inherently cumulative. In doing so, they argue that this topic requires more and different lines of evidence to test it properly. This is a welcome challenge to archaeologists and one that will no doubt engender a robust and valuable debate.