Received: 22 October 2019 | Revised: 27 May 2020 | Accepted: 26 June 2020

DOI: 10.1111/mila.12335

SUBMITTED ARTICLE

WILEY

Cumulative culture and complex cultural traditions

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Funding information
Isaac Newton Trust, Grant/Award Number: G101655; Leverhulme Trust, Grant/Award Number: ECF-2018-005

Cumulative cultural evolution is often claimed to be distinctive of human culture. Such claims are typically supported with examples of complex and historically late-appearing technologies. Yet by taking these as paradigm cases, researchers unhelpfully lump together different ways that culture accumulates. This article has two aims: (a) to distinguish four types of cultural accumulation: adaptiveness, complexity, efficiency, and disparity and (b) to highlight the epistemic implications of taking complex hominin technologies as paradigmatic instances of cumulative culture. Addressing these issues both clarifies the cumulative culture concept and demonstrates the importance of further cumulative culture research into non-human animals and ancestral hominins.

KEYWORDS

comparative cognition, cultural evolution, cumulative culture, hominin cognitive evolution

1 | CULTURAL TRADITIONS

Human lifeways range from Australia to the Arctic; from climes with baking sun to freezing cold. In explaining how humans thrive across the varied ecologies of the globe, cultural evolutionary researchers appeal to cumulative cultural traditions.[1] These traditions are

[1]See, for example: Henrich and McElreath (2003), Boyd and Richerson (2005), Henrich (2015), and Laland (2017). For helpful reviews on cultural evolution, see Mesoudi (2011) and Henrich (2015).

taken to distinguish human culture and explain the many adaptive lifeways of the human species.[2]

Only some cultural traditions—genealogies of cultural traits whose existence and form depend upon previously expressed traits[3]—are cumulative, where modifications to their form and/or function are preserved over time. Simplifying for the sake of exposition, traits can be considered as organised (often hierarchical) templates for action. Modifications, then, are additions, alterations to, or replacements of template components.[4] If we consider a trait responsible for producing a particular dish, for example, one can understand the substitution of kale for cabbage represents as a *replacement* of one behaviour with another, while adding another tier to a multi-tiered cake would involve repeating a behaviour at a more encompassing hierarchical level.[5] *Cumulative* cultural traditions, then, are genealogies of traits—organised templates for action—whose modifications are preserved over time.

This rough and ready characterisation provides the conceptual basis for accounts of cumulative culture in the cultural evolutionary literature.[6] However, note that so characterised, a range of human and non-human animal traditions qualify as cumulative. New Caledonian crows (*Corvus moneduloides*), for instance, grub for food using tools. Some of these tools are manufactured, involving the repeated notching and tearing of pandan leaves. Importantly, there is evidence that this manufacturing process is both socially transmitted and cumulative, with spatial variation in notching and tearing behaviour providing a living record of the modifications made to the tradition (Hunt & Gray, 2003). So, on the rough and ready schematic, this tool manufacturing would be a cumulative cultural tradition.[7]

Nonetheless, within the comparative cognition and cultural evolutionary literature, there is an emphasis on exploring and explaining what is distinctive about human cumulative culture.

[2]Precisely what distinguishes culture from other sources of heritable variation is contentious. Ramsey (2013) argues that culture is information flow that leads to the recapitulation of behaviour, a definition very close to Boyd and Richerson's (1985) notion of "cultural transmission." Henrich (2015) (Henrich & Gil-White, 2001) links culture to the activity of high-fidelity learning mechanisms, while Sperber (1996, 2001) identifies it with the persistent expression and acquisition of similar-enough mental representations. These definitions share the idea that culture involves access to the behaviour or behavioural outcomes of conspecifics, that this access provides opportunities for learning, and that the outcomes of such learning are expressible in behaviour. This broad characterisation will suffice for current purposes.

[3]This is a deliberately general and abstract characterisation. Except for a few special instances (Sterelny, 2006), it is likely that individuals learn from and combine information from multiple sources. Theoretical models back the idea that cultural variants are often the result of multiple cultural "parents" and learning episodes (Strimling, Enquist, & Eriksson, 2009). This supports the stability and fidelity of the acquisition process while simultaneously degrading clear parent-offspring lineages (Godfrey-Smith, 2012).

[4]This idealised way of describing cultural traditions in terms of templates or recipes draws on Sterelny's (2012b) notion of "behaviour programs" or "inner templates," though emphasises the substitutionality of component behaviours in a way that his account does not. For similar characterisations of traditions as lineages of organised traits, see Mesoudi and O'Brien (2008), Enquist, Ghirlanda, and Eriksson (2011), Lewis and Laland (2012), and Charbonneau (2015).

[5]The language of hierarchy and replacement has a number of limitations, key among which is that describing changes made to a template often offers little insight into downstream changes in behavioural expression. Charbonneau (2015) has convincingly argued that even small changes to templates may have an outsized effect. This is especially the case when such recipes involve repetitions of behavioural chunks.

[6]See Dean, Vale, Laland, Flynn, and Kendal (2014) and Mesoudi and Thornton (2018) for recent reviews of this literature.

[7]It is worth noting that claims of animal cumulative culture have been hotly contested. Klump, van der Wal, St Clair, and Rutz (2015), for instance, contest the claim that New Caledonian Crow tool manufacturing is an instance of cumulative culture and Tennie and Hedwig (2009) contest that non-human primates have sufficient capacities for cumulative culture, suggesting that purported instances fall within those species' non-social cognitive capacities for reinvention (what they call the *zone of latent solutions*).

Indeed, on one prevalent account, the advent of cumulative culture marks a turning point in evolutionary history; a “Rubicon” whose shores separate organisms dominated by biological evolution (animals) from those dominated by cultural evolution (humans) (Henrich, 2015, p. 317). Humans, but not other animals, have a cultural “ratchet”; a suite of life history traits, cognitive capabilities, and social scaffolds that support the improvement, complexification, and diversification of cultural traditions (Tomasello, 1999). Unsurprisingly then, when further developing the concept of cumulative culture, researchers often do so in ways that delineate the cultural traditions or capabilities of animals from humans and their hominin precursors (Mesoudi & Thornton, 2018).

My impression is that researchers typically overestimate the cognitive capacities required for cumulative culture by stressing the role of imitation, mindreading, and other “pre-adaptations” (e.g., Boyd & Richerson, 1985; Dean et al., 2014; Tennie, Premo, Braun, & McPherron, 2017; Tomasello, 1999). Nonetheless, my aim here is not to defend the claim that non-human animals have cumulative cultural traditions.[8] Instead, my efforts are directed toward securing two weaker claims. First, that by crafting, a sharp contrast between animal and human culture, researchers have been led to lump together distinct accumulative trends associated with cumulative culture. Second, that researchers often adopt complex, technical achievements as paradigm instances and central explanatory targets for research on cumulative cultural traditions. In securing these two claims, I demonstrate that researchers often place undue prevalence on late-appearing complex technologies produced through the collective enterprise of large social groups. This leads to an overestimation of the cognitive and cultural differences between contemporary humans, earlier hominins, and animals.

The lumping I diagnose is pervasive but not universal. In discussing the various accumulative trends below, I highlight work within the cultural evolutionary, archaeological, and psychological literature that is sensitive to these differences. Such lumping has also been noticed within the cultural evolutionary literature, and the work I do here extends and expands on efforts to clarify the cumulative culture concept (e.g., Dean et al., 2014; Mesoudi & Thornton, 2018). In the spirit of that work, I here draw attention both to the different kinds of accumulative trends, and the achievements needed to evolve complex technologies. In so doing, I open up a space for further investigations into the early origins of cumulative culture, and the insights that we might gain from comparative cognitive research into the cultural capacities of animals.

2 | WHAT ACCUMULATES?

As mentioned above, the rough and ready schematic of cumulative culture is expansive, encompassing a wide range of socially learned behaviours, including some animal traditions. Yet in attempting to understand the evolutionary success of contemporary human populations, researchers have often been motivated to develop the cumulative culture concept in ways that restrict its domain solely to human culture.

[8]The psychological capacities required for cumulative culture, and their phylogenetic distribution are a pressing concern in the cumulative culture literature which I do not directly engage with here. For an early expression of the idea that relevant cognitive differences between humans and animals have been overhyped, see Avital and Jablonka (2000, pp. 357–364). For more recent reviews surveying the primatological and paleoanthropological literature, see Tennie, Call, and Tomasello (2009), Legare (2019), and Stout, Rogers, Jaeggi, and Semaw (2019).

As I demonstrate in more detail below, these developments often end up pushing and pulling cumulative culture in different directions, identifying it with a mix of distinct trends and features. One recent characterisation has it that cumulative traits, acquired by social learning, involve "an improvement in performance, which is a proxy of genetic and/or cultural fitness" (Mesoudi & Thornton, 2018, p. 2). Along different lines, Henrich (2015) distinguishes the cultural behaviours of animals from "true" cumulative culture, with the latter having a clear signal of a "continuous trend toward greater complexity over time" (p. 289; Enquist & Ghirlanda, 2007, p. 595). Dean et al. (2014) echo and expand on this point, suggesting that cumulative culture involves "ratcheting up its complexity or efficiency" (p. 286). And Caldwell and Millen (2008) suggest that "cumulative cultural evolution … should be distinguished from cultural evolution that does not lead to appreciable improvement in the efficiency of the behaviours" (p. 3529).

As has been noted elsewhere (e.g., Mesoudi & Thornton, 2018), there are varied trends and tendencies associated with the cumulative culture concept. And as the above quotes show, these trends are often aligned and equated with one another. Yet this generates ambiguity as to what features distinguish human cumulative cultural traditions, and thus what underlying features might contribute to the ecological success of the human species. Is it efficiency? Complexity? Something else?

Below I distinguish four trends associated with cumulative culture: *adaptiveness*, *complexity*, *efficiency*, and *disparity*. As I show, these trends are not just conceptually but empirically distinct. Separating them not only adds to conceptual clarity in discussions of cumulative culture, but also aids in the identification and study of causal connections between them. In Section 3, I return to consider why these four accumulative trends might have been lumped together in the literature, and demonstrate the value of keeping them apart.

2.1 | Adaptiveness

The domestication of maize (*Zea mays*) was a turning point in the history of the Americas. Facilitating the expansion of Andean and Mesoamerican civilisation, maize fed a growing population that had increasingly come to rely on seed-based agriculture (Haas et al., 2013). Yet despite being calorie-packed, there are serious problems associated with a reliance on maize: while rich in carbohydrates and amino acids, a diet based on unprocessed maize provides less than half the daily recommended intake of niacin (Katz, Hediger, & Valleroy, 1974). Lack of niacin leads to pellagra, a gruesome disease whose effects are referred to as the "three D's": dermatitis, diarrhoea, and dementia. Often, pellagra leads to a fourth, grim "D," death. Putting these pieces together, one is left with a paleoanthropological conundrum: How could populations come to increasingly rely upon maize if it could not provide nutrients required to sustain them?

The answer comes by recognising that while corn contains enough niacin to satisfy daily requirements, it is chemically bound and not released by normal cooking methods. Simply boiling or roasting corn will not do. Preparing maize with an alkali compound, however—for instance, by soaking corn in lime, or adding alkaline ashes to ground maize—frees up this chemically bound niacin, a process called nixtamalisation. If populations that relied on maize also discovered practices of nixtamalisation, this could explain how carbohydrate rich maize could have come to dominate seed-based agriculture in the Americas without epidemics of pellagra. Surprisingly, this is precisely what seems to have happened (Katz et al., 1974).

The spread of maize in the Americas, and the subsequent success of Mesoamerican populations, cannot solely be explained by pointing to the calories contained in cobs. Instead, the success of maize requires a more complex explanation; one that incorporates special tools and know-how. It is the "package deal" of maize breeding, nixtamalisation, and agricultural know-how that explained the spread of maize and maize-planting populations. This package deal is a cultural adaptation: an agricultural system based around nixtamalised maize that allowed for greater reproductive success by increasing the nutrients and calories that could be extracted from the local environment.

The increasing adaptiveness of cultural traditions helps to explain how humans could persist and thrive in almost all the terrestrial territories of the globe. Food taboos, food-processing techniques, hunting strategies, methods of producing clothing, and botanical knowledge are a few of the hard-won suites of knowledge that played a part in increasing the geographical range and biological fitness of human populations (Boyd & Richerson, 2005; Henrich, 2015; Richerson & Boyd, 2005).

Nonetheless, while the idea of adaptive cultural variants is intuitive, it is important to be clear about the nature of "fitness" and "adaptiveness" at stake, due to the polysemous nature of these terms, especially within the cultural evolutionary literature. Memeticists (e.g., Blackmore, 1999; Dawkins, 1976), for instance, argue that some ideas are more appealing and catchier than others. They suggest it is fruitful to take a "meme's-eye view" and consider the properties that make some cultural variants more attractive than others.

While the meme's-eye view is an important empirical stance, it is one that appeals to a different notion of fitness than the one used here. In the meme's-eye view, what are at stake are the fitness values of particular cultural variants—their relative representation in human populations—and how processes of cultural differentiation generate variants that are more or less catchy. Yet this is not the characterisation of "adaptive" or "fitness" that is predominantly used in the cumulative culture literature. Instead, these researchers identify adaptiveness with an increase in biological fitness of the bearers of cultural variants.[9] For current considerations, fitness refers to expected reproductive output of biological agents.[10]

Thus, the fundamental idea at stake in the accumulation of adaptiveness is as follows: As variants are transmitted over time, they can accumulate modifications, and some of these may bring about a concomitant increase in the biological fitness of the individuals who bear or express those variants. The spread of such adaptive variants may be due to a disparate range of cognitive mechanisms, lumped together into what Enquist and Ghirlanda (2007) helpfully call "adaptive filtering mechanisms." However, the spread of adaptive variants might also be explained by direct appeal to biological fitness: Individuals who strike upon good tricks may be those that leave greater numbers of offspring, who may be more likely to learn such tricks from their parents.

Cultural traditions can have these fitness effects just so long as what is learned makes a difference to reproductive output (Mameli, 2004).[11] Sometimes this may take the form of large and

[9]Birch (2017) has shown how these ideas can be made precise, distinguishing between C_1 and C_2 types of cultural fitness, each of which can be formalised using modifications of the Price equation. The meme's-eye view is what he calls the C_2 type of cultural evolution—formalised elsewhere by el Mouden, André, Morin, and Nettle (2014)—while the more widespread view where cultural variants increase biological fitness is what he calls C_1 (Birch, 2017, pp. 197–208).

[10]Biological fitness may, in some circumstances be indexed to the fitness of groups (Richerson et al., 2014). This can introduce further complexities to the discussion of cultural fitness. For discussion of the intersection of these different distinctions, see Clarke and Heyes (2016).

[11]Though not emphasised here, cultural traits can also be maladaptive. See, for example, Boyd and Richerson (1985) and Mesoudi (2011).

complex suite of variants, like the maize package deal. In other places, the information may be simple. Learning the toxicity of various plants, animals, and fungi may involve recognising only a few highly salient cues. Yet learning to avoiding poisonous or dangerous food resources is directly relevant to fitness. As in the biological realm, cultural traditions vary not only in their adaptiveness, but also in the means and sophistication of the modifications which bring such adaptiveness about.[12]

2.2 | Complexity

Automatic wristwatches are sophisticated artefacts. They contain a number of precision-crafted pieces arranged in an intricate and functional way. The banal function of telling the time belies the complexity of these innards. Often using examples of technological achievements like automatic watches, cultural evolutionary researchers highlight how technical knowledge—typically the manufacturing of tools—demonstrates the way that cumulative culture can lead to the production of complex and functionally integrated innovations. Boyd and Richerson (2005), for instance, note that "what seems unique about human social learning is our ability to accumulate adaptive information over many generations, building complex artefacts and institutions composed of many small innovations" (p. 16). Similarly, Dean and colleagues argue that a central feature of cumulative culture is that it leads to "iterative improvements in technology" (Dean, Kendal, Shapiro, Thierry, & Laland, 2012, p. 114) and quantifiable increases in the "complexity of cultural traits over time" (Dean et al., 2014, p. 285).

Like adaptiveness, the accumulation of complexity is a cultural evolutionary trend that may be associated with particular cultural traditions. As variants are transmitted and modified, changes may occur that increase a variant's complexity. Over time, this simple process can generate paradigmatic examples of complexity: The packed microprocessors of supercomputers, the bundled-tube structure of skyscrapers, and the intricate engineering involved in spaceflight. These examples represent clear instances of cultural outputs where multiple parts are combined in complicated relationships to produce tightly integrated wholes. Yet when one moves away to consider other instances of technological achievement—in bows, weighted nets, and spear-throwers—one is faced with a difficult problem. Are these technologies complex? And just what is cultural complexity?

Surveying the field identifies at least three competing accounts. Each represents a distinct way of measuring the complexity of particular variants—and thus of characterising what complexity consists in.

This is easiest to see with the first of these, where cultural complexity is operationalised by the number of units required to produce a particular behaviour or reach an overall goal. This *unit counting approach* comes in two broad types: process-oriented and product-oriented. Process-oriented unit counting looks at the behavioural steps required to reach an overall goal (Pradhan, Tennie, & van Schaik, 2012). These behavioural steps are individuated in terms of

[12]Precisely how minimal the modifications can be and still be regarded as cumulative hinges on the difference between modifications and the choice between traditions. Suppose one learns from others to defecate downstream rather than upstream from where one bathes, and this leads to increased fitness. Here there is social learning, adaptiveness, and selection. However, whether it is cumulative or not hinges upon whether this change is seen as a modification to a persisting tradition. The difficulty with simple behaviours is that the difference between a modifying a cultural tradition and the adopting of a new trait or tradition might be difficult to discern. However, this is a problem only at the extreme margins of cumulative culture. I thank an anonymous referee for pushing me on this point.

the kinds of actions involved (poking, prodding, knapping, gluing, etc.) as well as by the kinds of tools used (stones, brushes, sticks, sewing needles, etc.). On this approach, cultural traditions increase in complexity both when a greater number of distinct actions kinds are involved in producing a behaviour, as well as when a greater number of tools are used. Thus, cracking nuts with stones is more complex than stick-dipping for ants, since the former involves two tools (a hammer and an anvil) and one behaviour (pounding), while the latter merely involves one tool (a modified branch) and one behaviour (dipping the branch into an ant or termite colony).

Product-oriented unit counting, by contrast, tracks the number of "techno-units" required to make a finished product (Oswalt, 1976, pp. 38–44). Techno-units count the number of structural contributions to the form of the artefact. Consider a digging stick. A shaped digging stick, crafted to have either a spatula-like or pointed end, would be a one techno-unit artefact as it requires only the alteration (sharpening, flattening) of a stick's tip. An addition of a stone ring to the digging stick would increase the tool to a two techno-unit artefact; a wooden wedge to keep the ring in place, a three techno-unit artefact (pp. 56–60).

Depending on the evidential base in question, one or another of these approaches may be appropriate. For good taphonomic reasons, evidence about early hominin cumulative culture requires a product-oriented account, as behaviours do not fossilise. The opposite is true in comparative cognition research, where what is of interest are the various behaviours used by organisms to produce (generally simple, single techno-unit) artefacts. Hybrid versions of the process-oriented and product-oriented unit counting approaches are possible, with behaviour indexed to specific contributions to the form of an artefact (Perreault, Brantingham, Kuhn, Wurz, & Gao, 2013); and indeed, such approaches seem to characterise work in experimental studies of cumulative culture (e.g., Caldwell, 2018).

The unit counting approach captures the idea that complexity can be operationalised as an increase in the number of actions and tools involved in producing a behaviour. Yet, however well this account captures the increase in sophistication among early hominin technologies, it is often inappropriate for characterising traditions where a small number of tools and techniques are combined and iterated in context-sensitive ways. Making baskets or clothing may involve nothing more than overlaying and knotting fibres—but the actual act of identifying relevant plants, stripping the leaves or bark, processing the material, and weaving materials together requires knowledge and skill.

Skill too seems more important in the production of early human technologies like Acheulean handaxes—bifacially symmetric stone tools that can be used for a variety of tasks like scraping and cutting. Creating such handaxes requires little more than iterated knapping of a core with a suitable hammerstone, but the identification of suitable cores and knowing how to knap are intricate and hard-won capabilities.[13] These kinds of capabilities are not easily tracked by either unit counting approach, which individuate units in terms of classes of actions

[13]As a reviewer points out, the complexity of such handaxes will differ depending on whether one adopts a product-oriented or process-oriented unit counting approach, and furthermore, how finely grained the behaviours in a process-oriented approach are described. To be sure, there are a wide range of lithic reduction techniques. Yet at least as Shea (2017) organises the lithic record, Acheulian handaxes are a non-hierarchical core reduction strategy employing conchoidal fracture with "opposite sides of a working edge [having] flakes struck from them in more or less the same way and/or interchangeably" (Shea, 2017, p. 29). This suggests that they will be of low complexity on either the process-oriented or product-oriented approach. Of course, to suggest that these handaxes are of "low complexity" and that they are produced with similar kinds of blows is not to deny that lithic reduction is or was easy—it is anything but (Hiscock, 2014).

(e.g., knapping) or structural contributions (e.g., knapping an edge), respectively. In general, technologies and behaviour involving tacit know-how—especially those with iterated behavioural chunks—are poorly captured by the unit counting approach.

Unsurprisingly, these scenarios are better captured by Henrich's (2004) approach that operationalises complexity in terms of *skilfulness*. This operationalisation emerges in the context of models exploring the link between effective population size and the sophistication of tools that can be sustained by a population. One compelling feature of these models is its ability to explain the conditions that both increase and decrease the sophistication of a population's toolkit.

Henrich's case-study looks at the Tasmanian population as it was encountered by European colonists in the eighteenth century. Henrich paints a bleak picture of this population, one that had lost the ability to sew garments and to manufacture fishing-spears, spear-throwers, and boomerangs. Henrich identifies a declining effective population size as the culprit: As skilled members of a population died out, there were fewer sources of knowledge for transmitting technologies and behaviours requiring experience and tacit knowledge. This was compounded by a downward spiral in the effectiveness of extractive foraging. With less effective acquisition of food, the population experienced further declines in population number, which decreased even further the possibilities for maintaining sophisticated kit.[14]

Skilfulness is operationalised in Henrich's model in two distinct ways: first, as the number of individuals needed in a population to sustain cultural variants, and second, as the difficulty in transmitting a variant from one individual to another. The two are related, as Henrich's suggests, yet each operationalisation highlights distinct features involved in the transmission of expertise and know-how.

When operationalised at the population-level, skilfulness serves as a proxy measurement for a range of societal features assumed to support the ability to maintain traditions. These features are broadly socioeconomic in character, involving at least sufficient access to resources, differentiation of societal roles, and opportunities for the acquisition of complex traditions over extended periods of time. As Henrich's telling of the Tasmanian case is supposed to show, the relationship between these variables can lead to vicious cycles of population and skilfulness declines.

Yet, however, well the population-level measure serves as a proxy for the conditions supporting complex cultural traditions; it is not a measure of increasing complexity *as such*. This is captured by Henrich's second operationalisation of skilfulness. Here, skilfulness is identified with the difficulty in the transmission of traits over time—the more skill required, the harder it is to transmit. More specifically, the more skill that is required, the more errors that individuals will make in attempting to learn a skill, and the less likely that individuals will become equal to, or more skilful than, their model. This makes intuitive sense. The knowledge involved in identifying tracks, spoors, and how to kill prey means the difference between a successful hunt and an unsuccessful one—but acquiring this knowledge and putting it to use may require a great deal of learning and on-the-job experience (Sterelny, 2012a).

[14]I note that Henrich's case study is contentious, having received critiques from other cultural evolutionary modellers, and experts in Tasmanian archaeology. Hiscock (2008, pp. 136–139), for instance, notes substantial issues with the empirical data underlying the cultural degeneration hypothesis, which forms the core evidentiary base for Henrich's model. For critiques of the model itself, see Vaesen, Collard, Cosgrove, and Roebroeks (2016a) and the responses from Henrich et al. (2016) and Vaesen, Collard, Cosgrove, and Roebroeks (2016b).

While the skilfulness account captures the way in which tacit know-how and experience can be important components of some cultural traditions, it is less than clear that complexity is adequately captured in terms of the difficulty involved in transmitting techniques and know-how. Cooking recipes represent complex knowledge that can be easily transmitted from one individual to another. Though tacit knowledge and experience might be needed to whip up a complex patisserie or de-bone a pike, a great deal of cooking knowledge can be simplified and easily transmitted in the form of instructions. On the flipside, some difficult to transmit capacities do not seem to be complex. Many horticultural tasks are simple—sowing, pruning, watering—but knowing when, where, and how to carry these out requires careful attentiveness to seasonal patterns, condition of plants, and prevailing weather conditions. These evaluative and perceptual skills are hard to transmit, even if the actions they occasion are simple. So while skilfulness is a reasonable guide to the length of training needed to become capable at a particular task—in part because of the tacit nature of the skills involved—it too may not capture some central features of complex traditions.

This leads to the final operationalisation, the *interactive complexity* account (Querbes, Vaesen, & Houkes, 2014; Simon, 1962). Here, complexity is operationalised in terms of the number of component parts of a tradition and the degree of interaction among these parts. Interaction is here understood as the extent to which modifying a single part changes the overall functioning of the whole. Wristwatches are good examples of entities with both a large number of parts, and a high degree of interaction: Changing the material out of which a cog is made, or removing one, may change a functioning wristwatch into a fancy paperweight.

Interactive complexity is a useful operationalisation of complexity for variants with easily identifiable parts or steps organised into functional wholes—things like watches, automobiles, or baking recipes. Furthermore, such interactively complex traits exist deep in the hominin lineage. Consider the complexity needed to produce Middle Stone Age (MSA) adhesives. These adhesives were mostly likely used to attach knapped stone to hafts of bone or wood. As Wadley (2010) shows, MSA adhesives required a number of ingredients, combined in precise quantities, processed at multiple heat-levels for different amounts of time. Too much or too little of an ingredient will generate a tacky, brittle, or otherwise ineffective adhesive. Similarly, leaving adhesive to dry too near to a fire can lead to efficiency-reducing charring, bubbling, or cracking. In short, though there may only be a few components and steps involved in the making of MSA adhesives, these ingredients need to be carefully combined and processed to produce a useful glue.

These three operationalisations of complexity—unit counting, skilfulness, and interactive complexity—overlap and conflict with each other in diagnoses of cultural complexity. While paradigm cases of complexity, like wristwatches and space shuttles, likely rank high on all three accounts, there are a number of behavioural and technical innovations that show how the accounts diverge. Adhesives used to haft weapons, for instance, would likely rank high on both skilfulness and interactive complexity measure since they involve hard-won skills for combining a number of ingredients in careful, context-dependent ways. However, adhesives would rank comparatively low on a unit counting approach, since these adhesives involve few behavioural steps and ingredients. On the other hand, a stew combining many processed resources might rank high on the unit counting and skilfulness accounts, but low on interactive complexity. While more work is required to clarify these different notions of complexity, and how they are related to one another, it seems reasonable to hold that each of these accounts captures something important about the kinds of cultural variants produced by cumulative cultural evolution.

Importantly, as the example of wristwatches show, complex traits need not be adaptive. Nonetheless, one might think that in the evolutionary history of humans, complex traditions were adaptive ones. After all, there are learning and resource-acquisition costs involved in maintaining such adaptations, and presumably such costs are only paid if there are adaptive benefits. Henrich (2015), for one, seems to argue as much when he states that the distinctiveness of cumulative cultural evolution is its power "to produce … adaptive complexity" (p. 166). Yet there are good reasons to resist eliding these two trends together.

Consider the existence of food taboos for pregnant women in Fiji. Surprisingly, though women require more calories during pregnancy, they scrupulously avoid many marine foods. As Henrich and Henrich (2010) show, this is plausibly related to toxicity of these resources, as women seem to avoid potentially highly toxic species both during and immediately after pregnancy. Yet the suite of food prohibitions that women learn are relatively simple and seem to be readily available from multiple sources including parents, elders, and in-laws. Food taboos are not readily evaluable as complex on any of the accounts offered above, yet they represent a compelling suite of adaptive knowledge.[15]

Along the same lines, one should be cautious in assuming that complex traits are those with the highest relevance to fitness in human evolutionary history. Ethnic and socioeconomic markers are cultural traditions that can involve simple variations in dress, speech, or character. Yet such markers are critical in determining whether to communicate with an individual, engage in economic exchange, express deference, or gear up for a fight.

2.3 | Efficiency

Related to measures of complexity are notions of efficiency. Often what is remarkable about a cultural tradition is not only its adaptive character, or its complexity, but also its artfulness and economy. Take, for instance, Sterelny's (2012a) characterisation of apprenticeship learning. Apprentices learn the skills of their future trades by becoming integrated into spaces of organised labour. There they are able to contribute to ongoing processes of production by contributing to tasks commensurate with their abilities. At the same time, they are exposed to more difficult tasks produced by nearby skilled individuals and are able to acquire a rich repertoire of experience by observing the successes and failures of these skilled operators. By lowering the costs associated with acquiring or performing behaviours, efficiency is in many ways related to adaptiveness. Nonetheless, there are important reasons for treating it separately, particularly when efficiency is linked with role-based specialisation (more on this below).

Sterelny's example of apprenticeship learning is associated with the idea of an efficient learning environment and draws on the burgeoning literature on *scaffolding* (Clark, 1997; Sterelny, 2010; Sterelny, 2012a, 2012b). Scaffolding consists in the repeated assembly of social and material resources that facilitate an individual's ability to carry out tasks (Caporael, 2013). So, for example, Flynn, Laland, Kendal, and Kendal (2013) use the idea to explain how young children can solve a difficult block-assembly task when assisted by an adult. By highlighting the pieces needed to progress, orienting the child's attention to pertinent parts of pieces, and removing distractors, adults produce a simplified epistemic environment. In this case, the adults serve

[15]Indeed, prohibitions are tricky candidates for complexity, even if traditions of prohibition accurately track a complex phenomenon, for instance, the toxicity of various food resources.

as the social scaffolding, structuring the learning environment so that infants are able to complete the task. Often, without such support, the children were unable to solve the puzzle.

As mentioned above, increased efficiency in learning overlaps with adaptiveness—where individuals or variants become increasingly apt at fulfilling particular functions. This kind of increasing efficiency is implicit in a wide range of examples in the cumulative cultural literature. One prominent example is in role-based specialisation, where large collaborative goals are broken down into functionally distinct tasks and distributed among individuals. These subtasks can then serve as the locus for the accumulation of experience, sophistication, and economy. So, for instance, in high-class kitchens, different individuals are assigned to different roles: grilling, frying, preparing sauces and glazes, and plating. This breakdown allows individuals to focus on similar and specific tasks, acquire goal-relevant skills, arrange their workstation with needed tools and ingredients ready to hand, increase the speed of preparation, and minimise the likelihood of errors.

Paleoanthropologically, this kind of role-based specialisation is seen in collaborative hunting, specialisation in tool-manufacturing, and broader divisions of labour to manage food-resources. Consider again the example of hafting weapons using MSA adhesives. Here, one individual might be in charge of the foraging for appropriate stones, another for knapping the blades, a third for the production of hafts, and a fourth for producing adhesive and finishing the final weapon. The specialisation provided by role-based collaboration allows individuals to acquire expertise in distinct tasks, and on this basis, minimise costs and risks associated with such tasks. Like complex behaviours and tools, this role-based specialisation has a deep history in the hominin lineage. Clear evidence of grinding stones, needed for the processing of seeds and nuts, are seen in the Upper Late Paleolithic (Kuhn & Stiner, 2006). The laborious and protracted nature of grinding suggests a task that was likely undertaken by a specific class of individuals, while other individuals foraged or hunted.

Tools and behaviours themselves can also increase in efficiency. Simple grinding stones were eventually replaced by wind-powered or water-powered mills and dressed millstones. Wooden spears were superseded by stone-tipped or metal-tipped projectiles. Here, the function of a behaviour or artefact is rendered more fit-for-purpose. Consider the production of clothing. Piercing hides with awls and then stringing such hides together was rendered much more accurate and speedier with the advent of eyed needles. These needles not only reduced the number of steps involved in sewing garments together, but allowed for more dextrous work, likely facilitating the production of smaller garments (such as gloves) as well as tailored, multi-layered outfits (Gilligan, 2010).

While increased economy or artfulness in carrying out a particular function is prominent in the cultural evolutionary literature (e.g., Basalla, 1988; Boyd & Richerson, 2005; Caporael, 2013; Henrich, 2015), it too tends to be lumped-in with ideas around adaptiveness. As above, this involves sound reasoning: Efficient processes lower costs associated with particular behaviours and may increase the speed, quality, and aptness of the goods produced. Yet like complexity, it is important to distinguish efficiency from adaptiveness, since the two can interact in complex ways.

One possible risk associated with efficiency is that the pursuit of streamlined and artful functioning can come at the cost of exploring other options. Consider, for instance, a group that has access to a reliable food resource, but one that requires specialised tools and training to maintain, extract, and process that resource. Depending on the nature of the tools and training, the costs of innovation, re-tooling, or learning may disincentivise the extraction of other food resources. As Luis Orquera (1984) suggests, such situations can generate a population that "both is and is not efficient. It is in that it permits greater benefit in the adaptive direction chosen; it is not in that it neglects a great many other resources collateral to that direction" (p. 82; see also Sahlins, 1964, p. 138). In other words, demands for specialisation and efficiency can trade-off against those for diversification and flexibility—and these demands can have knock-on consequences for population success.

Sterelny (2012a) brings home the risks of efficiency and specialisation by pointing to a tragic case of specialisation: the extinction of the Neanderthals. According to the scenario put forward by Sterelny, the Neanderthals faced a vicious feedback cycle fed by their reliance on ambush hunting (the use of cover and stealth to track and kill game). Combined with an increasingly cold and hostile climate, and a downward demographic trend exacerbated by the inclusion of women and children in hunting parties, the specialisation in ambush hunting meant that other food resources could not exploited. Increasingly marginalised and in ever smaller groups, and with less time and brainpower to innovate novel solutions, the Neanderthals perished.

2.4 | Disparity

Adaptiveness, efficiency, and complexity are three trends that occur in the history of cultural traditions as modifications to variants are made and retained. Yet according to Morin (2015, p. 226), a focus on trends within traditions draws attention away from another crucial explanandum: that "the human species came to possess an increasingly large stock of traditions." For Morin, a central feature of cumulative culture is how populations are able to accumulate increasing numbers of qualitatively distinct cultural traditions. I call this phenomenon the accumulation of *cultural disparity* (Buskell, 2018). Here, "cultural disparity" identifies variation across cultural traditions.[16]

While other researchers have noted that human cultures support a great deal of cultural traditions (e.g., Boyd & Richerson, 1985; Dean et al., 2014; Henrich, 2015), Morin is right to note that cultural disparity has been underemphasised in recent conceptual and theoretical work. One reason is that recent work has tended to identify cultural disparity with complexity (e.g., Acerbi, Kendal, & Tehrani, 2017; Fogarty, 2018; Fogarty & Creanza, 2017). This is an error: Cultural disparity is an evolutionary pattern at the population-level, not at the tradition-level. Like Henrich's population-level operationalisation of skilfulness described above, however, well cultural disparity correlates with structures or processes that support complexity, it is not itself an operationalisation of complexity (indeed, Dean et al., 2014 object to including accumulation of disparity alongside other accumulative trends partly along these lines).

As I see it, there are good reasons to distinguish cultural disparity, as it interacts with cumulative trends of complexity, adaptiveness, and efficiency in intricate ways. Models by Enquist et al. (2011), for instance, suggest that increases in cultural disparity leads to greater rates of innovation and adaptiveness by means of cultural "recombination," where this captures the

[16]The use of the term is meant to be a direct extension of Maclaurin and Sterelny's (2008) definition of disparity as the manifest variation of phenotypic variation (for similar accounts, see Gould, 1989; Sterelny & Griffiths, 1999). Yet while Maclaurin and Sterelny are interested in biodiversity, and index manifest variation to species, I here highlight the manifest variation of phenotypes as indexed to distinct cultural traditions. While there are issues involved in individuating cultural traditions and identifying the properties that distinguish them—what Maclaurin and Sterelny call the problem of identifying "units and differences"—I do not have the space to substantively engage with these concerns here. For current purposes, it is enough to point out that populations can and do accumulate increasing stocks of qualitatively distinct cultural traditions.

shuffling and fusion of cultural variants as individuals encounter new ideas and experiment with old ones. As Enquist et al. show, this process can lead both to stepwise improvements in technical innovations and an increase in disparity. A similar model by Kolodny, Creanza, and Feldman (2015) links increases in cultural disparity not only to recombination among already existing technical innovations, but to "lucky leaps"; novel tools or pieces of kit that provide platforms for recombination, experimentation and tinkering. And simple models from Buskell, Enquist, and Jansson (2019) suggest that relationships between disparate traits can affect rates of trait turnover, with potential downstream implications for adaptiveness and complexity.

Broadly speaking, these models suggest that cultural disparity can interact with other aspects of culture in complex ways. Important for hominin prehistory is the explanatory role of disparity in a positive evolutionary feedback loop where the "increasing ability in some cultural skills would lead to improved demographic conditions (by means of improved reproductive success/resource utility), which would, in turn, further increase skill accumulation" (Powell, Shennan, & Thomas, 2010, p. 145).

This makes sense. When multiple traits are maintained in a population and can be mixed through recombination, this increases the chance that individuals will strike upon solutions to problems or find a means of improving already existing traditions. Yet, as Kolodny et al. (2015) show, this virtuous feedback loop is hostage to the wide diffusion of cultural variants: Sequestering innovations or expertise in distinct classes or sub-sets of a population leads to patchy distributions of traditions in populations. This in turn can hamper the ability to shuffle and experiment with multiple traditions. In short, there are complex trade-offs between the distribution of cultural disparity, the exposure of individuals to that disparity, and concomitant rates of change, improvement, and efficiency.

3 | COMPLEXITY AND DISTINCTIVELY HUMAN CULTURE

Adaptiveness, complexity, efficiency, and disparity are related yet distinct cumulative trends. Three of these (adaptiveness, complexity, efficiency) are generated by processes that modify and retain modifications in cultural variants and which can be observed by tracing the history of particular cultural traditions. The fourth involves the accumulation of qualitatively distinct cultural traditions in a population (disparity).

Above I claimed that researchers often lump these different trends together, and that this in part results from a stark contrast between the psychological capabilities of animals and humans. However, as I hope has become clear in the previous sections, this also results from an emphasis on the role of complexity in cumulative cultural traditions: In each of the above sections, complexity is often taken as interchangeable with other kinds of accumulation. As I hope to show in this section, the reason for this lumping is in part a consequence of what researchers take to be paradigmatic cases of cumulative culture; the (late-appearing) complex technological toolkits of late Pleistocene and Holocene era human beings.

The target is not plucked out of thin air. Paleoanthropologists and cultural evolutionary researchers are rightly impressed by the speed of human cultural achievement. Consider that it only took around 300Kya for humans to have moved from simple lithic toolkits to contemporary technological wizardry. And the speed of cultural innovation processes has noticeably ticked-up in velocity over the last 10kya.

Yet researchers make a misstep when they take contemporary—or even a few millennia-old—technological achievements to represent the sole explanatory target for work on cumulative culture. It is a further misstep to think that such toolkits exhaust the content of the cumulative culture concept: that unless a tradition exemplifies a cumulative increase in complexity, that tradition is not cumulative in the right way. This is not only because there are different kinds of accumulative trends that play an important role in cultural evolution, as I have argued above, but also because a focus on such paradigmatic cases may mislead as to the cognitive and cultural capabilities needed for cumulative cultural traditions to get off the ground.

Consider here some contemporary formulations of the cumulative culture concept. Kempe and Mesoudi (2014) argue, for instance, that "a common criterion for cumulative culture is that cultural traits become too complex for a single individual to invent in their lifetime" (p. 30). Highlighting technology, science, and mathematics, the authors doubt that "string theory, smartphones and space travel" (Ibid.) could have been invented by a single author. In a similar formulation, Muthukrishna and Henrich (2016, p. 2) suggest that cumulative culture is best identified with those "technologies and techniques that no single individual could recreate in their lifetime." Arguing that human populations may function as a "collective brain," Muthukrishna and Henrich argue that the joint effort of individuals can allow for more efficient searches through problem space, leading to the evolution of technologies like wheelbarrows, pulleys, and mills.

In other words, researchers often characterise cumulative culture in a way that links the concept to highly sophisticated technological achievements, produced by multiple agents, that are characterised by an increase in complexity. As Boyd, Richerson, and Henrich (2013) put it:

> The tools essential for life in even the simplest foraging societies are typically beyond the inventive capacities of individuals. Instead they evolve, gradually accumulating complexity through the aggregate efforts of populations of individuals, typically over many generations. People don't invent complex tools, populations do. (Boyd et al., 2013, p. 120)[17]

These distinctively human cultural traits are the result of *collective enterprise*: intra-generational and inter-generational pooling of experience, skills, and knowledge.

Collective enterprise should not be understood as a community explicitly agreeing upon goals to be pursued, nor as population-wide efforts to consolidate and distribute knowledge. Instead, in using the term, I am highlighting how the pursuit of safety, survival, and pleasure requires solving social coordination problems for cohabitation, collective action, and resource allocation (Sterelny, 2016). Under such circumstances, engagement with other community members can provide opportunities for observation and learning, casual conversation, occasional experimentation, and the solicitation of help and collaboration. Through all of these, individuals can learn, produce, and disseminate—whether deliberately or incidentally—improvements on cultural variants.

Yet what is problematic about identifying cumulative cultural traditions with those produced by collective enterprise is that such social collectives are biological and cultural achievements; ones that in part resulted through co-evolutionary feedback loops with capacities for cumulative culture. Our hominin lineage has long been subject to selection pressures for increasing social coordination and cooperation, and these have feed into feedback loops that have radically altered our cognition (Sterelny, 2012a). Yet by identifying cumulative culture with paradigmatic cases seen in recent technological toolkits, one is liable to miss these co-evolutionary feedback relationships. This is further exacerbated by making a stark juxtaposition between human and animal culture. Taken together, these moves risk reading into the concept of

[17]For similar statements, see Kempe and Mesoudi (2014, p. 29) and Muthukrishna et al. (2014, *passim*).

cumulative culture a number of cognitive achievements that were likely outcomes of evolutionary feedback loops that themselves involved cumulative culture. This is especially the case if, as some recent accounts have argued, distinctively human cognitive capacities themselves require ontogenetic exposure to cumulative cultural traditions (Buskell, forthcoming; Heyes, 2018).

Consider early hominin cultural evolution. During the Middle Paleolithic, hominins employed a range of lithic technologies suited for a number of different tasks: carving up carcasses, scraping skins, and the like. These tools were often used and modified in a way that kept them functioning over multiple tasks opportunities. Yet while diverse, these tools are not well-characterised in terms of the accumulation of complexity. The toolkit of this time is one that required skilled production, but these skills complemented rather than supplanted hard-won ecological know-how. Tools augmented physical capacities—cutting, chiselling, scraping, bludgeoning, and the like—but aside from simple spears and axes, there were few obligate technologies needed for food capture or processing (Shea, 2017; Sterelny, 2016). Instead, knowledge about the local climate, the patchiness of food resources, and strategies for food processing were central to reproductive success.

Whatever the precipitating cause, this situation changed radically when hominins aggregated into larger groups. While larger groups facilitate increases in cultural innovation and transmission—in part by increasing the disparity of the cultural traits individuals were exposed to (Powell, Shennan, & Thomas, 2009)—they require solving social coordination problems that would not have arisen for the mutualistic foragers of the Middle Paleolithic (Sterelny, 2016). I will not go into the details of such accounts here, suffice to say that a great deal of what underlays the radically pro-social and cooperative psychology and cultural organisation of hominins is likely to be a more recent invention than cumulative culture, possibly occurring quite late in the Pleistocene.

The story of early cumulative culture, then, is one where human beings accumulated diverse yet adaptive cultural traditions linked to ecological resources, with simple, sometimes obligate toolkits not well-characterised by complexity. Through aggregation into social groups, cumulative cultural could explode not only through demographic effects—division of labour, increased numbers of specialists, and exposure to different ideas—but also through increasingly collaborative and cooperative societies. This is a condensed story, but the key point is that early cumulative culture likely involved an accumulation of a disparate set of adaptive cultural traditions before accumulating complex ones.

Theoretical models reinforce the idea that early cumulative culture involved adaptive and disparate traditions. Kempe and Mesoudi (2014), for instance, demonstrate that cumulative culture requires a large number of varying cultural traditions in order to facilitate the evolution of complex or efficient traits. Echoing these points are those models that, as I suggested above, conflate disparity with complexity (e.g., Acerbi et al., 2017; Fogarty, 2018; Fogarty & Creanza, 2017). These models demonstrate that an increasing stock of cultural traditions is a necessary precursor to complex cultural traits.

So to the extent that cultural evolutionary researchers identify paradigm cases of cumulative culture with late-appearing cultural traits—seeing these both as paradigm cases of cumulative culture, and as the central explanatory target for work on cumulative culture—they may be overestimating the social and cognitive differences between contemporary humans and earlier hominin precursors, and underestimate the crucial role of cultural disparity in earlier hominin evolutionary history.

Yet this is not the only problem with taking complex technological toolkits to be paradigmatic instances of cumulative culture. Here, I close by suggesting that attention to complexity might also draw attention away from key adaptive innovations in human cultural evolutionary history.

Consider agriculture. As Sterelny (2006) has argued, agriculture is a causally opaque problem domain, characterised by few opportunities for learning: Crops only ripen once or twice a year, and the complexities of weather, soil, sun, and pests make it difficult to isolate, experiment on, and understand the causal features important to growing crops. Nonetheless, despite causal opacity, improvements can be made by way of collective enterprise: Selective retention and commercial exchange of the best seed, opportunities for observing the successes and failures of others, and devising means of food preservation all increase the efficacy and adaptiveness of agriculture. Yet for all the improvements that have been made to agricultural systems, until the rise of industrial agriculture, few are likely to involve significant increases in complexity. The problems involved in cultivation—what crops are good to grow, where to plant them, when to begin the season, how to manage pests, whether to rotate crops, and the like—result from small and local improvements in knowledge about weather patterns, soil, irrigation, and plant varieties. However, this knowledge is better construed as the accumulation of small, adaptive modifications—akin to the widely available information about food taboos discussed above—rather than as the accumulation of increasing complexity.

4 | CONCLUSION

My aim in this paper is not to suggest that contemporary cultural evolutionary research is wrong or misplaced. Explaining how human beings could plausibly have evolved the incredibly complex and bewildering technologies of contemporary societies is an extraordinary achievement of the last 30 years of work in cultural evolutionary research. This work has increased our knowledge of the various social, cognitive, and ecological difference-makers that explain the distinctive cultural capacities of human beings.

Yet as I have shown, this achievement has led to some notable lumping in the literature that should be split up. Grouping together a range of different accumulative trends can hamper understanding of the cumulative cultural concept and its implications for human (and possibly non-human animal) evolutionary history. This is especially so if we take seriously the idea that cumulative cultural traditions are crucial to understanding contemporary human cognition.

As the literature on cumulative culture developed, it took the technological toolkits of the last 10kya as paradigmatic cases of cumulative cultural traditions. The epistemic consequences of such a move is an overestimation of the cognitive and cultural capacities of humans as compared to earlier hominins and animals, and an underestimation of the importance of different kinds of accumulation early in hominin cultural evolutionary history. By distinguishing the different accumulative trends and highlighting the importance of cognitive and cultural adaptations for collective enterprise, I hope to have opened up space for interrogating the early role of cumulative culture in cultural evolutionary research—and the possibility that capacities for cumulative culture may be found elsewhere in the animal kingdom.

ACKNOWLEDGEMENTS

The author is grateful to Mathieu Charbonneau, Tim Lewens, Johan Lind, and Claudio Tennie for their discussions on, and insights into, early drafts of this paper. Research in this article was supported by grants from the Leverhulme Trust (ECF-2018-005), and the Isaac Newton Trust.

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How to cite this article: Buskell A. Cumulative culture and complex cultural traditions. *Mind & Language*. 2022;37:284–303. https://doi.org/10.1111/mila.12335