MIT Press • Open Encyclopedia of Cognitive Science

Cumulative Culture

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MIT Press

Published on: Mar 16, 2026

URL: https://oecs.mit.edu/pub/6bvu7f8m

Cumulative culture refers to the process by which cultural traits improve over time through the gradual accumulation of innovations across individuals and generations. This process gives rise to cultural traits that no single individual could invent alone, highlighting the importance of cultural transmission. Cumulative culture underpins the emergence of complex technologies that have enabled humans to thrive in environments for which we are not genetically well adapted. Although most visible in material technologies, cumulative culture operates across diverse domains, including social technologies (e.g., norms and institutions), symbolic communication (e.g., language), and knowledge systems (e.g., physics and medicine). Often considered a key feature that sets humans apart from other animals, the sociocognitive requirements for cumulative culture and the question of whether it is uniquely human remain subjects of ongoing debate.

History

As early as 1714, philosophers stressed the cumulative nature of human achievements, noting that innovation is often the result of time and collective effort rather than individual genius (Mandeville, 1714). In the 20th century, scholars began to study the expansion of cultural knowledge more systematically, drawing on data from diverse domains such as material technologies, science, and literature (e.g., Basalla, 1988). These efforts were not unified under a single framework but collectively contributed to a growing empirical foundation for understanding cultural change as a cumulative process.

It was only in the 1980s that cultural evolution theory began to offer a formal mathematical framework for understanding how cultural traits evolve and diversify over time and space (Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981) [see Cultural Evolution]. Observing that nonhuman animals do not appear to develop cultural traits that increase in complexity across generations, Michael Tomasello and colleagues introduced the term *cumulative culture* to explain the stark disparity between human and nonhuman cultural repertoires (Tomasello et al., 1993). Cumulative culture quickly came to be seen as a key factor in the ecological success of our species and its remarkable adaptive flexibility. This development spurred growing interest in the sociocognitive prerequisites for cumulative culture across disciplines such as psychology, primatology, and evolutionary anthropology.

Around the 2010s, laboratory experiments began to complement mathematical modeling in testing hypotheses about the factors that support cumulative culture (Caldwell & Millen, 2008; Marshall-Pescini & Whiten, 2008). Transmission chain experiments (in which participants iteratively build on the solutions of their predecessors) were increasingly used to investigate the effects of selective social learning, group size and connectivity, and constraints on learning and memory on the cumulative process [see Iterated Learning]. In parallel, comparative research across a growing range of species—from birds to cetaceans—began to reveal increasingly rich repertoires of socially transmitted behaviors, raising new questions about the evolutionary origins and distribution of cumulative cultural processes beyond humans (Whiten et al., 2022).

Core concepts

Ratchet effect

A central concept in cumulative culture is the *ratchet effect*, a metaphor describing how beneficial modifications to cultural traits are preserved and built upon over generations (Tennie et al., 2009). Once a useful innovation is introduced and socially transmitted, it tends to be retained rather than lost, like a mechanical ratchet that prevents backward movement. This mechanism allows cultural traits to become more complex or efficient over time.

Collective brain

A defining feature of cumulative culture is that it produces outcomes far beyond the capabilities of any single individual. No one person could invent a smartphone, develop a GPS navigation system, or formulate the standard model of particle physics. These achievements result from many minds building on each other's work across time (Muthukrishna & Henrich, 2016). In this sense, cumulative culture is "smarter than us"; it stores, refines, and extends collective knowledge in ways that exceed the limits of individual cognition.

Population structure

Cumulative culture is a population-level phenomenon shaped by the features of the population in which it unfolds. Population size plays a key role: larger populations generate more cultural variation, provide more models to learn from, and are less prone to cultural loss (Henrich, 2004). Patterns of connectedness also matter, influencing the quantity and diversity of information available to individuals and, in turn, their capacity to develop new ideas (Derex & Mesoudi, 2020).

Cultural loss

Cumulative culture is not a guaranteed upward march; cultural traits can also be lost. *Cultural loss* refers to the disappearance of adaptive cultural knowledge, skills, or technologies. Such loss can occur when populations become too small or isolated or when opportunities for learning from knowledgable individuals are disrupted. A well-known example is the loss of complex tools in Tasmania, where demographic changes are thought to have impeded the preservation of certain technologies (Henrich, 2004).

Selective social learning

High-fidelity social learning supports cumulative culture by mitigating cultural loss. However, cumulative culture depends not just on preserving cultural information but also on preferentially retaining beneficial modifications [see Social Learning]. This is made possible by social learning strategies such as payoff-biased learning, in which individuals tend to copy those who appear most successful (Henrich, 2004).

Questions, controversies, and new developments

A long-standing view in cultural evolution is that high-fidelity transmission, through mechanisms such as imitation or teaching, is essential for cumulative culture (Lewis & Laland, 2012) [see Imitation]. Yet, experimental research suggests that high-fidelity transmission may not always be necessary for cumulative improvement, particularly in the case of relatively simple and causally transparent tools, in which the production process can be inferred directly from the tool's design (e.g., a specific pottery form) [see Cultural Attractors]. In such contexts, even low-fidelity social learning mechanisms (such as *emulation*, in which learners attempt to reproduce the tool without copying the specific manufacturing steps) have been shown to support cultural accumulation (Lucas et al., 2020).

Another active area of debate concerns the role of individual reasoning abilities in cumulative culture. Some researchers argue that cognitive capacities such as causal reasoning are essential, allowing learners to build internal causal models, simulate imagined tools, and predict how changes in their features affect performance [see Causal Reasoning]. However, others emphasize that cumulative culture often solves problems whose complexity far exceeds individuals' cognitive limitations (Boyd et al., 2011). This is possible because mechanisms like *payoff-biased social learning* can drive the retention and refinement of cultural traits across generations, even when individuals do not understand why those traits are effective (Derex et al., 2019). At the same time, empirical findings do not rule out the influence of causal reasoning (Derex et al., 2019). The extent to which cumulative culture depends on, or is merely enhanced by, causal reasoning thus remains an open question.

A related debate concerns whether nonhuman animals possess cumulative culture [see Animal Culture]. Behaviors such as tool use in chimpanzees and navigational strategies in birds have been proposed as potential examples (Whiten et al., 2022). However, these cases typically lack key features of human cumulative culture (such as sustained increases in complexity) and remain the subject of ongoing controversy.

These debates may stem, in part, from a deeper issue: the lack of a clear and consistent definition of cumulative culture. Because human culture is so obviously cumulative—especially compared to that of other animals—relatively little attention has been paid to defining what precisely makes a cultural process cumulative. A widely accepted criterion is the accumulation of improvements across generations. However, recent work suggests reframing the discussion in terms of *open-endedness*, that is, the capacity of a system to continually generate novel and increasingly diverse outputs (Derex, 2021; Morgan & Feldman, 2025). This broader view raises the possibility that open-ended cumulative culture depends on more demanding sociocognitive abilities such as goal creation, compositionality, and analogical reasoning [see Analogy; Compositionality].

Broader connections

Cumulative culture lies at the intersection of multiple fields, shedding light on how humans solve an open-ended range of problems across diverse domains (Derex, 2021; Morgan & Feldman, 2025). One prominent

area of overlap is research on collective intelligence and distributed cognition, which emphasize how complex solutions emerge from interactions among individuals. Research on cumulative culture also draws on insights from social cognition, including theory of mind, joint attention, and shared intentionality, which help explain how individuals transmit knowledge and pursue collective goals [see Shared Intentionality; Theory of Mind]. Developmental psychology contributes further, by showing how children acquire cultural knowledge through guided learning [see Cognitive Development]. In the domain of language evolution, cumulative culture offers a framework for understanding how linguistic systems gradually adopt structures that are both learnable and communicatively effective [see Iterated Learning]. Finally, cumulative culture connects with work on open-ended learning in artificial intelligence, in which researchers aim to develop systems capable of autonomously acquiring an open-ended repertoire of skills (Colas et al., 2022). From this perspective, cumulative culture not only helps explain how humans adapt to diverse environments but also provides a model for building more adaptive and generative artificial systems.

Acknowledgments

The author is supported by Institute for Advanced Study in Toulouse funding from the French National Research Agency (Grant No. ANR−17-EURE−0010 and Grant No. ANR−21-CE28−0019−01). The author acknowledges the use of an artificial intelligence tool to suggest improvements in the writing style during the final stage of preparing this chapter.

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