

# Evolved Open-Endedness in Cultural Evolution

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## Abstract

Whilst artificial evolutionary systems are almost never open-ended, the evolution of biological organisms seems to always be open-ended. Is it possible to have a middle ground, where an evolutionary system exhibits both bounded and unbounded evolution? Here we argue that we only need to look at culture to see this middle ground being played out. Culture is argued to be the second evolutionary system on Earth, working alongside genetic evolution in a co-evolutionary manner (often described as dual inheritance). It is now broadly accepted that most social animals have culture, with that culture evolving over time, but it is clear that human cultural evolution differs substantially from even the most complex animal cultures. It was thought that the division between human and non-human culture was that human cultural evolution alone was cumulative, this view has now been challenged with many aspects of animal cultures also being viewed as cumulative. Our contention is that only humans exhibit open-ended (cumulative) cultural evolution, with all non-human cultures being bounded. The consequence of this view is two-fold: 1) that we have an evolutionary system that is both bounded and unbounded depending on the species and behavioural domains being observed, 2) within our own recent hominin evolutionary history evolved open-endedness has occurred within the domain of cultural evolution. We argue that further analysis of culture across social species, and artificial life modelling of social learning, cultural transmission, and cultural evolution, will benefit not only the artificial life community but also augment the study of cultural evolution across the behavioural sciences.

**Keywords:** Cultural Evolution; Evolved Open-Endedness; Zone of Latent Solutions; Cumulative Culture; Bounded Cultural Evolution

## Introduction

According to the Cultural Evolution Society “If we define culture as information capable of affecting individuals’ behavior that they acquire from other members of their species through teaching, imitation and other forms of social transmission, cultural evolution is fundamentally just the change of culture over time.” (Cultural Evolution Society, 2021). Although cultural evolution is often described as being analogous to genetic evolution (Cavalli-Sforza and Feldman, 1981), there are clear differences in the way cul-

ture is transmitted - where genetic evolution relies on typically two (sometimes one) parent(s) there are a potentially unlimited number of cultural parents, where genetic transmission is vertical from parent to child cultural transmission is often horizontal between conspecifics, where genetic change happens between generations cultural change happens within generations.

Over the past 40 years there has been increasing recognition that culture is widespread among animal species (Whiten, 2021a,b), and that culture not only exists as a result of genetic adaptation but also plays an important co-evolutionary role in guiding genetic evolution (Whitehead et al., 2019). This co-evolutionary relationship is sometimes known as gene-culture co-evolution or dual inheritance (Boyd and Richerson, 1985).

Whilst many animal species exhibit culture, it is clear that human cultural evolution is different. For a long time the dividing line between human and animal cultures was thought to be the cumulative nature of human culture – with human culture accumulating modifications over time with a ratchet like effect of modifications building upon one another (Tomasello, 2009). However, as more observations of cultural evolution in other species have been made, it has become increasingly apparent that cumulative cultural evolution is not reserved for human culture alone (Mesoudi and Thornton, 2018). This leaves us with the question: what, if anything, is unique about human cultural evolution?

## Open-Ended (Cumulative) Cultural Evolution

Whilst human culture may not be unique in being cumulative, it may be unique in being open-ended. Recent work by Bedau et al. (2019) indicates that human technological innovation contains all of the hallmarks of an open-ended system, whilst others have pointed out the transformative effects of social institutions and symbolic communication on the complexity of human social organisation and communication, opening up new cultural avenues and niches unseen in other social species (Pattee and Sayama, 2019; Szathmáry, 2015). Recent work by Motes-Rodrigo and Tennie (2021) has gone on to argue that all predictions of an open-

ended cumulative cultural systems are met in humans, but interestingly not in great apes.

Work by Tennie and colleagues (Tennie et al., 2020, 2018, 2009; Motes-Rodrigo and Tennie, 2021) suggests that innovations in great ape culture are limited within a *zone of latent solutions* and therefore great ape culture cannot be open-ended. The “Zone of Latent Solutions” (Tennie et al., 2009) is essentially a group of cultural innovations that, if lost by a population, could be learnt or re-innovated without the need for social learning or cultural transmission. These innovations could be spread, adjusted and refined by cultural evolutionary processes, but ultimately none of the resulting innovations would be impossible to discover without social learning. The clear implication here is that whilst human cultural evolution is open-ended, great ape cultural evolution is bounded (Motes-Rodrigo and Tennie, 2021). Artificial evolutionary systems are almost never open-ended, the evolution of biological organisms seems to always be open-ended, but cultural evolution seems to be unique in that it exhibits both bounded and unbounded examples within the same evolutionary system.

### Evolved Open-Endedness in Action

If human culture is open-ended and animal cultures are not, then within recent hominin evolutionary history we have a clear example of evolved open-endedness in action (Pattee and Sayama, 2019). Over time both biological adaptations that enable more complex and open-ended social and cultural behaviours (bigger brains, opposable thumbs, changes in the shape of the larynx, ...), and cultural adaptations that open up access to new domains of knowledge (symbolic language, the scientific method, music and art, complex social institutions, ...) have been selected for in a clear demonstration of selection in favour of open-endedness, with this same selection pressure being seemingly absent in our closest genetic relatives. Pattee and Sayama (2019) argue that what is common amongst adaptations for open-endedness is:

1. they were definitely acquired through evolution
2. their appearance made a disruptive change in the landscape of the game of evolution, and
3. each of them significantly expanded what would be possible for organisms to accomplish.

We think these features are clearly apparent in numerous (if not all) aspects of human cultural evolution.

### Why is this important for Artificial Life

Along with the research questions identified by Pattee and Sayama (2019), by incorporating evolved open-endedness of cultural evolution into our thinking about open-ended evolution we can ask new and important questions about the nature of open-ended evolution:

- Do the mechanisms underpinning cultural evolution more easily lead to open-endedness than those underpinning genetic evolution?
- What happens when a bounded aspect of an evolutionary system (i.e. animal cultural evolution) comes up against an unbounded aspect of the same evolutionary systems (i.e. human open-ended cultural evolution)? Is there a sudden pressure for evolved open-endedness to emerge amongst species that have so far only exhibited bounded cultural evolution? Or does the emergence of open-endedness always lead to the extinction of its bounded counterpart?
- Are there any bounded aspects of human cultural evolution?
- Does an evolutionary system need to be cumulative to be open-ended?
- Are cumulative evolutionary systems always open-ended?
- Is it possible to have non-cumulative open-ended evolution?

We believe that by modelling cultural evolution and by incorporating the potential for cultural evolution alongside genetic evolution in our artificial evolutionary systems (thus enabling gene-culture co-evolution), we can open up a new avenue in open-ended evolution research that can shed further light on evolved open-endedness, the processes by which major evolutionary transmissions occur (Szathmáry, 2015), and alternative routes to open-ended evolution (Taylor, 2019).

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