CUMULATIVE CULTURAL EVOLUTION OF SYSTEMATIC STRUCTURE AND GRAMMATICAL COMPLEXITY IN HUMANS AND BABOONS

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Human language exhibits widespread systematicity at all levels of analysis. In phonology, syntax, and semantics, we see constraints on the allowable forms in the language such that the existence of some expression in the language is dependent on other expressions in that language. For example, the past tense ending "-ed" in English on a particular verb is used because of its appearance on other verbs in the language. This systematicity, a defining feature of language but rare in the behavioural repertoires of other animals, is a major focus of research in the field of language evolution. One approach shows that cultural evolution favours systematic structure when sets of behaviours are transmitted by iterated learning (e.g., Kirby et al., 2015). Cornish et al. (2013) explore the origins of systematicity in sets of sequences transmitted by iterated learning. Participants (adult humans) were shown and immediately attempted to recall a sequence of coloured lights. They are exposed to 60 such sequences and given feedback after each attempted recall. For the first participant in each chain of transmission, the 60 sequences were completely independent and random, but subsequent participants were given the sequences of the previous participant to copy. Although the sequences in the set are initially independent of each other, after several generations of transmission, they have become systematically structured, with commonalities across the strings making them easier to copy. As a result, the set of strings becomes increasingly *compressible* over generations.

Results like this have led researchers to propose that a universal learning bias for simplicity, driving cultural evolution through iterated learning, can explain a wide range of linguistic phenomena (see, e.g. Culbertson & Kirby, 2016). In this

view, systematic languages have lower *grammatical complexity* than unsystematic ones: systematicity allows for a more concise set of rules to generate a language. However, we reanalyse the data from Cornish et al. (2013) to show that the increasingly compressible sets of sequences that emerge are actually underpinned by *more* complex grammars. We estimate grammatical complexity by using hidden markov model (HMM) induction (DeDeo, 2016) and find a gradual, cumulative increase in the complexity over generations (figure 1). Culture leads to increasingly compressible languages, but achieves this by introducing cumulatively more complex underlying structure.

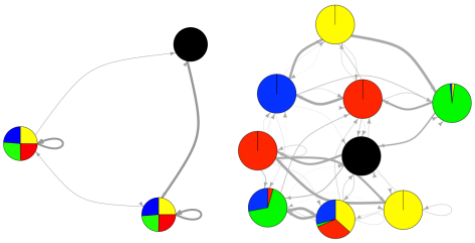

Figure 1. A typical HMM induced from the start of the human experiment (left) and one after 10 generations of cultural transmission (right). The probabilities of each of the colours being emitted by the hidden state are shown as pie charts, and the probabilities of transition from state to state by thickness of lines. The black node corresponds to the sequence separator. Over generations, complexity as measured by the number of hidden states increases.

To see if this process of cumulative evolution of systematicity underpinned by increasing grammatical complexity is unique to humans or a result of more widespread cognitive processes, we replicated the iterated sequence learning experiment in a population of captive baboons (Fagot & Bonté 2010), using a minimally adapted version of the paradigm from Cornish et al (2013). As in the human experiment, systematic structure in sequences emerged cumulatively over generations, resulting in compressible sets of behaviours. Once again, this is not the result of the underlying grammars becoming simpler over generations. However, unlike in the human data, there is no evidence for a cumulative increase in grammatical complexity, indicating a difference between humans and baboons in the way sets of structured behaviours culturally evolve.

These results add nuance to our understanding of what cultural evolution does to sets of behaviours as they are passed on by iterated learning. They support our conclusion that cultural evolution leads to increasingly compressible behaviour over generations, explaining the origins of systematicity in language. However, this does not necessarily mean that grammars will always become simpler, particularly in the case where the starting point is highly stochastic. We suggest that in some cases grammatical complexity might be an adaptation by cultural evolution to create rich, expressive languages that are nevertheless predictable. Understanding precisely what the situations are where grammatical simplicity or complexity is expected is an important target for future experimental research.

References

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