Studying long-term evolutionary processes over short time scales: methods in cumulative cultural evolution

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Abstract

In this chapter we explore methods used in the field of cultural evolution to investigate the process of cumulative cultural evolution, namely how behaviours and technologies accumulate beneficial modifications over time. Most cultural traits, including language itself as demonstrated in previous chapters, do not emerge in one shot but are improved and refined over time through individual and social learning, over multiple generations. One way to study this process is to conduct experiments designed to track the production, transmission, and modifications of cultural traits. These experiments allow drastic compression of the 'evolutionary' time-scale and allow researchers to observe and investigate the process of cumulative cultural evolution under controlled conditions. In this chapter we cover the general principles underlying cumulative cultural evolution experiments, give examples of such experiments, discuss their strengths and weaknesses, and discuss how the role of human language has thus far been addressed within cultural evolution experiments. To conclude, we discuss avenues for improvement in design and suggest the most fruitful avenues for future designs to test so far untested hypotheses about the relationship between different forms of communication and cultural evolution.

Introduction

Complex cultural traits have allowed humans to settle in habitats for which they are poorly suited genetically (Boyd & Richerson, 1985; Boyd et al., 2011; Henrich, 2015). Bows, kayaks, spears and harpoons are only a few examples among the myriad of technologies that sustain humans in almost every terrestrial environment on earth. These finely-tuned technologies are not produced in isolation by especially gifted individuals but result from a cumulative cultural evolutionary process in which innovations are gradually accumulated across many generations (Boyd & Richerson, 1996; Boyd et al., 2011; Derex et al., 2019).

Social learning is critical to cumulative cultural evolution because it allows innovations to be transmitted between individuals and across generations. Yet, the ability to learn socially appears to be widespread in animals, while the accumulation of cultural innovations is not (Boyd & Richerson, 1996). Moreover, while there is a general trend toward richer and more complex cultural repertoires in humans, it appears that cultural complexity does not increase steadily and monotonically over time. Periods of both sudden cultural accumulation and cultural regression have been documented (d'Errico & Stringer, 2011; Henrich, 2004; Riede, 2014). These observations suggest that cultural accumulation is not a trivial process but occurs only when very specific conditions are met.

Theoretical models have long been used to study the conditions that are conducive to cumulative cultural evolution (Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981). More recently, cultural evolution researchers have used experiments to investigate how beneficial modifications are selectively preserved and accumulated over successive generations (Caldwell et al., 2016; Caldwell & Millen, 2008b). Cumulative culture requires the production of innovations and their propagation within social groups. Thus, experiments that are rigorously designed to track the learning, transmission, and modifications of innovations can shed light on the underlying mechanisms that affect cultural accumulation. These experiments allow drastic compression of the ‘evolutionary’ time-scale and have proved successful in addressing a wide range of questions concerning the production, transmission and maintenance of cultural traits (Beppu & Griffiths, 2009; Caldwell et al., 2019; Caldwell & Millen, 2008a; Derex, Beugin, et al., 2013; Derex et al., 2019; Lucas et al., 2020; Thompson et al., 2022). While early experiments mostly focused on identifying the minimal conditions allowing cultural information to accumulate, recent experiments have started to explore broader factors that affect the dynamics of cumulative cultural evolution. For instance, experimental results indicate that, perhaps counter-intuitively, reducing group connectedness can result in higher levels of cultural accumulation (Derex & Boyd, 2016).

Surprisingly, the relationship between different forms of communication and cumulative cultural evolution has remained relatively under-studied in the cultural evolutionary literature. Indeed, despite recent calls for better integration of communication into cultural evolution experiments (Brand et al., 2021; Singh et al., 2021), experimental studies have only begun to scratch the surface of the complex relationship between communication and cultural evolution. So far, experiments have mostly explored how some forms of pedagogy, such as gestural and verbal teaching, affects the stability of cultural information (e.g. (Lucas et al., 2020; Morgan et al., 2015)).

In this chapter, we present the experimental methodology typically used to study cumulative cultural evolution in the lab (for an introduction/review of individual-based models of Cultural Evolution, see (Acerbi et al., 2022)). We highlight the limitations and challenges associated with this method, discuss how human language has thus far been addressed within cultural evolution experiments, and suggest potential fruitful avenues to test so far untested hypotheses about the relationship between different forms of communication and cultural evolution.

Key principles and assumptions

A few basic requirements must be met in order to experimentally study cumulative cultural evolution in the lab. For the experimenter, the goal is to create a set-up in which the necessary and sufficient conditions for the gradual improvement of cultural traits are met. These can be summarised as four core criteria: (i) a change in behaviour, (ii) transmission of this change via social learning, (iii) an improvement in performance, and (iv) the sequential repetition of the first three criteria (Mesoudi & Thornton, 2018). It's important to note that, depending on the specific question being addressed, additional criteria may be considered. Indeed, while the conjunction of the aforementioned criteria leads to gradual improvement across generations of learners, they may not comprehensively account for all the facets of human cumulative culture (Derex, 2021). For instance, some have argued that human cumulative culture is characterized by the presence of increasingly complex and harder-to-learn cultural traits (which seems to distinguish it from animals' cultural repertoires that may be composed of multiple but not increasingly complex traits, Dean et al., 2013). Thus, criteria such as functional dependence (where an improvement is functionally dependent on a previous one) or recombination (where a new trait results from the combination of existing traits) are sometimes considered in cumulative cultural evolution experiments (for recent discussions about what constitutes cumulative cultural evolution, see Mesoudi & Thornton, 2018; Derex, 2021; Miton & Charbonneau, 2018).

Regardless of the criteria considered, special attention must be given to both the task and the conditions under which participants will interact to ensure that the conditions are conducive to cumulative cultural evolution. We go through these principles in detail below.

Choosing the Task

What makes a task appropriate to study cumulative cultural evolution ultimately depends on the question at hand. This means that your research question should determine the task on which your experiment will be based, not the other way around. Nevertheless, a few core principles are useful at the design stage.

The nature of the task and its goal, in itself, is not necessarily important and can take many forms. Cultural evolution experiments have relied on tasks as diverse as paper aeroplane building, knot-tying, stone tool making, totem pole building, among many others (Caldwell & Millen, 2008a; Derex & Boyd, 2015; Morgan et al., 2015; Muthukrishna et al., 2014). Experiments have also relied on physical as well as computer-based tasks. What is critical is that the task in question can be solved with varying degrees of success, and, ideally, that variation in success can be evaluated easily and objectively by the experimenter. The task should be difficult enough that participants cannot solve it in a few trials, but easy enough that collective improvements can realistically be expected during the relatively short duration of an experiment. This usually requires the experimenter to pilot the experiment to ensure that the task is in the right difficulty range. For instance, all else being equal, experiments involving sizable groups require more difficult tasks than experiments involving smaller groups to prevent group performance from plateauing before the end of the experiment.

The difficulty with which participants solve the task also depends on how familiar the task is to participants. Ideally, the task should be unfamiliar to prevent participants from relying on previously acquired knowledge to solve it. Using tasks that are too familiar can make it more challenging to observe differences in performance over time because participants with previous experience with the task will perform better than truly naive individuals. This will shift the baseline performance up and will reduce the amount of variation that can be observed during the course of the experiment. Moreover, previously experienced participants will add unwanted noise to the experiment. In a transmission chain design, for instance, experienced participants who already have their own established ways of solving the task may appear at the beginning, end, or middle of an experimental chain and disrupt the process of cultural accumulation by disregarding social information.

Physical vs computer-based tasks

As mentioned above, cultural evolution experiments can be both physical and computer-based, both being common in the literature (e.g. (Derex & Boyd, 2015; Morgan et al., 2015)). Computer-based tasks are often more convenient because they permit rigorous manipulations of payoff structures and can be administered quickly and easily to large numbers of participants. Physical tasks tend to make data collection more time consuming, yet they feature realistic physical principles that were arguably more relevant during our evolutionary history (more 'ecologically valid'). For instance, physical tasks rely on individuals' sensori-motor skills (such as accurately striking a core in a stone tool-making experiment), or understanding of 'folk-physics', which some would argue are more relevant when trying to understand the cognitive biases and reasoning abilities of our evolutionary ancestors. In contrast, whilst computerised tasks can tap into visuo-audio perception abilities, they are often solved by relying on basic motor actions (such as pointing and clicking) which participants already master before taking part in the experiment. This means that physical tasks are more amenable to study the transmission of skills (as opposed to knowledge, or perceptual biases) where face to face interaction and gestural demonstration may be critical.

Still another difference between the two types of tasks is the experimental environment in which they can be deployed. Computerised tasks can easily be deployed in the lab and online. Emerging online recruitment software such as Prolific allows the recruitment of genuinely diverse and representative samples compared to what is often readily available to researchers, allowing samples to be broader than the usual 'university undergrad' default. The possibility to reach a more diverse and geographically distributed sample of participants, combined with the possibility to collect large sample in a cost-effective manner, can allow for greater generalizability of results. Online tasks, however, cannot be used with groups who have limited access to digital technologies in the first place.

Ultimately, the choice to use computerised or physical tasks to study cultural evolution will depend on the specifics of the experimenters' questions and research objectives. If the research question pertains to very abstract, generalisable aspects of cultural transmission, then there is no reason why a computerised task (that is also fun and engaging for participants!) cannot capture the core criteria mentioned above and reveal insights into how people learn and transmit cultural information. If the research question relates to whether prestigious community members make better teachers than non-prestigious members in the context of norms or skills specific to a given community, then of course using a physical task relevant for this community is likely to be more revealing.

Implementing transmission

For cultural evolution to happen, the experimental setup must be conducive to the transmission of information between participants. This information, however, can take different forms and be more or less useful to the learner. Experiments related to the debate about the role of high-fidelity social learning in cumulative cultural evolution, for instance, typically implement a number of experimental treatments whose difference lies in the type of cultural transmission involved (e.g. (Morgan et al., 2015)). Reverse engineering, for instance, involves replicating an outcome without being exposed to the details of how the outcome was achieved, while imitation provides the learner with the specific details of how the outcome was achieved. Still another treatment could involve teaching (either verbal or gestural) in which case the learner would be actively taught the details of how the outcome was achieved.

Although cultural evolution experiments typically focus on one or several of those types of transmission, options for the experimenter are virtually endless. For instance, one might think of comparing a treatment where participants transmit written information using alphanumeric characters to another treatment where participants transmit information using emojis. In experiments investigating the role of variables other than transmission mechanisms, only one transmission mechanism is usually implemented (e.g. (Derex, Beugin, et al., 2013)). An experimenter investigating the effect of group size on cultural accumulation, for instance, might want to compare the performance of individuals who are part of groups of 2, 4 and 6 and decide that participants from all treatments will learn by being provided with each other's outcome without being exposed to the details of how the outcome was achieved.

Transmission Chain vs Closed Group methods

Another choice that the experimenter must make concerns the experimental setting within which cultural transmission will take place. Different experimental settings have been used to study cumulative cultural evolution in the lab.

One of the most widely-used methods is the transmission chain, in which information (e.g., skills, text, images, stories, songs) is transmitted from one generation to the next (e.g. (Caldwell & Millen, 2008a; Derex et al., 2019; Derex & Boyd, 2015; Morgan et al., 2015)). By analysing the changes that occur within the material as it is transmitted from person to person, researchers can infer the operation of systematic biases in cultural transmission, such as the effects of memory, attention, communication, or social learning (see Iterated Learning chapter, Tamariz & Papa, this volume). In cumulative cultural evolution experiments, often first-generation participants are asked to solve the task without any input. Their solution is then passed on to the next participant in the chain. Within that setting, naive, first-generation participants provide the baseline performance against which the performance of subsequent participants can be compared. The researcher can then study how solutions evolve and test whether they become increasingly efficient over time. One limitation of this method is that transmission chains are prone to cultural loss because the process of cultural accumulation depends on a single individual at each generation. This means that discontinuity can be caused by individuals who, for some reason, ignore, forget, or misinterpret social information.

An alternative methodology is the closed group method in which a group of individuals is brought together and repeatedly engages in a task over the course of the experiment (e.g. (Derex & Boyd, 2015, 2016; Mesoudi, 2011)). This method is often used in experiments where researchers want to study social learning strategies, or how some variables affect groups' or individuals' success. Compared to transmission chains, closed groups offer participants the opportunity to learn from multiple cultural models. This offers participants the opportunity to select their cultural demonstrator based on cues such as score or prestige (e.g. (Atkisson et al., 2012; Brand et al., 2020; Chudek et al., 2012; Mesoudi, 2011)). In some experiments, participants can simultaneously learn and combine information from multiple demonstrators (Derex, Beugin, et al., 2013; Kempe & Mesoudi, 2014; Muthukrishna et al., 2014). The closed group method is well-suited to computerised tasks. Indeed, with computerised tasks, it is possible to store all the decisions taken by a player on a server, which allows participants to access their other group members' solutions in real time. An individual learning condition, in which participants engage in the same task but with no social interaction, provides a baseline with which to compare group performance (Mesoudi & Whiten, 2008). These experiments tend to be less time consuming as multiple participants engage with the task at the same time, and are not dependent on the problem of simultaneous recruitment that transmission chain designs require.

Examples

In this section we will walk through the methodology, including data collection and analyses, that were used in two cultural evolution experiments.

Example 1: In-person transmission chains (Morgan et al., 2015)

Question and task

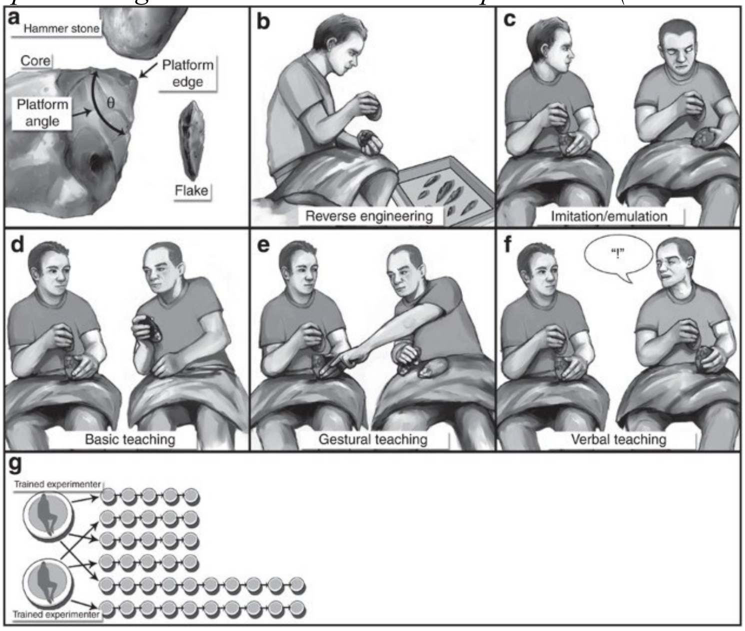
Morgan et al. used an in-person transmission chain design to test the relative success of five social learning mechanisms to transmit stone knapping techniques across multiple transmission events. The authors used a task that has been of critical importance in our evolutionary past: stone-tool making.

Treatments and procedure

The task required adult human participants to learn to produce stone flakes by striking a cobble core with a hammerstone (Fig. 1.a). Each participant learnt from the previous participant in the transmission chain. Experimenters trained in stone knapping acted as demonstrator to the first participant in the chain.

Participants were randomly allocated to one of 5 treatments (Fig. 1.b-f): Reverse Engineering (b): learners were provided with the flakes produced by their demonstrator but could not see the manufacturing process. Imitation (c): learners could observe their demonstrator making flakes but could not interact with them. Basic Teaching (d): demonstrators could manually shape the learner's grasp of their material, slow their own actions, and reorient themselves to allow the learner a clear view. Gestural Teaching (e): learners and demonstrators could interact using gestures but could not talk to each other. Verbal Teaching (f): learners and demonstrators were permitted to speak.

Figure 1: Diagram of Morgan et al's Flint-knapping transmission chain design, taken from https://doi.org/10.1038/ncomms7029 with permission (CC BY 4.0)



The learning/teaching period lasted for 5 minutes. The measure of success was good-quality flakes made from a single core in a 20 minute practice period. To ensure participant motivation, participants were paid according to their performance. To make sure demonstrators were motivated to teach effectively in the teaching conditions, participants' payments also depended on the performance of their pupil.

Data and Analyses

Morgan et al. analyzed 6,214 pieces of flint greater than 2 cm in diameter. All of these pieces were weighed, measured and assessed for viability and quality by human coders. The reliability of flake viability ratings was ensured by double and triple coding by independent raters. Six different measures of individual performance were modeled: (i) the number of viable flakes produced, (ii) the total quality of flakes produced, (iii) the proportion of flakes that were viable, (iv) the rate at which viable flakes were produced, (v) the probability of a viable flake per hit and (vi) the proportion of their core successfully reduced. These measures were modeled as a function of condition, position along the chain, interactions between condition and position, initial core mass and random repeat-level effects.

Main Result

Results revealed that participants who were taught, as opposed to learning via passive observation, produced more tools, did so more quickly, and made more efficient use of raw materials. These benefits were further enhanced by verbal, as opposed to gestural, teaching.

Example 2: Computer-based closed groups (Derex & Boyd, 2015)

Question and task

Derex et al. used a computer-based experiment to investigate how social learning mechanisms and population size and structure affect the production of a complex virtual artefact (in this case, virtual totem poles, Figure 2). In this task, players were provided six initial basic resources that had to be combined to produce increasingly complex innovations, and the production of these complex innovations depended on the discovery of lower-level innovations (Figure 2). Thus, in comparison to the stone-tool making task described above, the totem task entails features such as *recombination* (where new traits result from the combination of existing traits) and *functional dependence* (where an improvement is functionally or sequentially dependent on a previous one).

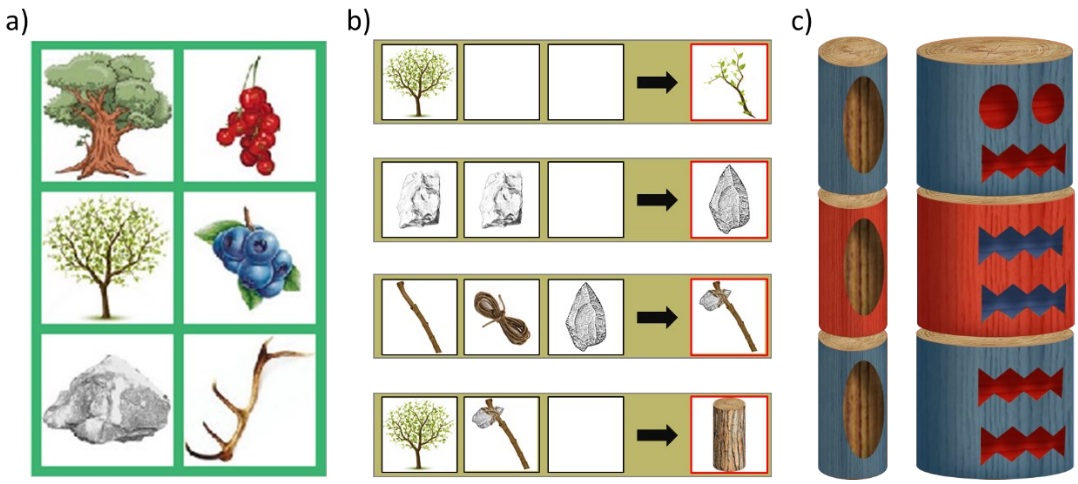


Figure 2: Experimental task of Derex et al's totem pole experiment. The game simulates the real-world innovation process in which the production of complex artefacts (that is, virtual 'totem poles') depends on the discovery of high-level innovations (such as, axes), which in turn is contingent on the discovery of lower-level innovations (such as, stone tools), both low- and high-level innovations resulting from a specific production process. (a) The 'resources panel'. Players were provided six initial basic resources that could be combined using a workshop panel containing four slots (Figure 3). (b) Examples of successful combinations. By placing items into a workshop panel (black squares; only three are depicted here), participants could produce innovations (red squares). Low-level innovations (created by combining basic resources) could be combined to produce higher-level innovations. Further accumulation of innovations could produce complex tools (such as axes) that potentially allowed players to get logs (by cutting trees) to build their totem. (c) Examples of totem poles. Other high-level innovations (such as carving tools or pigments) could be subsequently used to refine totems to increase their value. Players' gain depended on the number of innovations they discovered and the value of their totem.

Treatments and procedure

Participants sat at physically separated, networked computers and were randomly assigned to one of five treatments: individual learning treatment (1): participants were learning in isolation and provided the baseline performance against which the performance of social learners was compared. Full social information / large group (2): participants were part of groups of 6 and could learn both the innovations and the associated production processes discovered by their 5 other group members (example in Figure 3). Partial social information / large group (3): participants were part of groups of 6 and could learn the innovations discovered by their 5 other group members but could not observe the associated production processes. Full social information / small groups (4): participants were part of groups of 3 and could learn both the innovations and the associated production processes discovered by their 2 other group members. Full social information / partially-connected groups (5): participants were part of a metapopulation of 3 groups of 2 participants whose connectedness patterns changed over time. In this final treatment, participants could learn both the innovations and the associated production processes discovered by whoever was part of their sub-group at the time. The experiment lasted 45 min, after which subjects received a reward according to their performance.

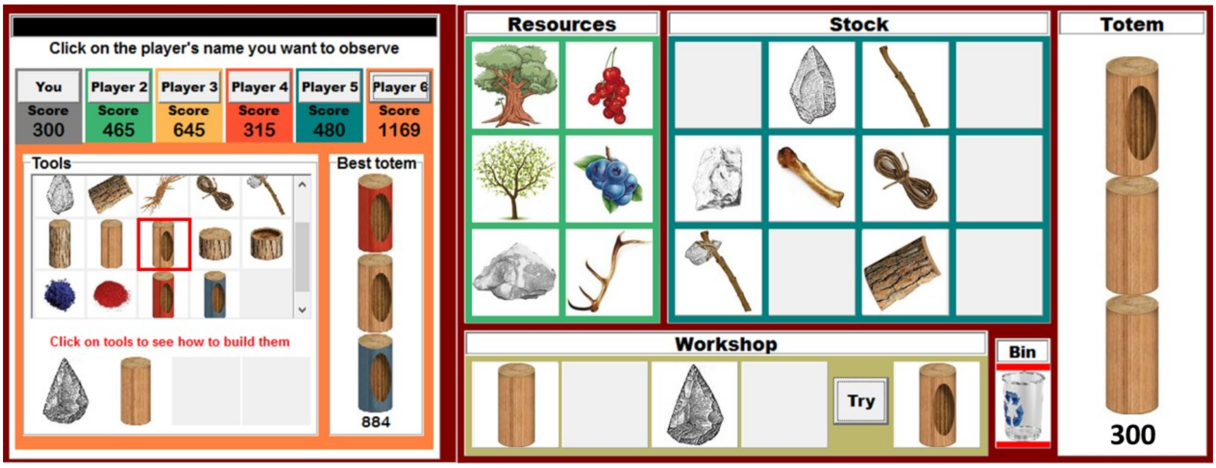


Figure 3: Game interface. Resources could be dropped into the 'workshop panel' to be refined. Players could trigger an automatic refining process by clicking on the 'try' button. Successful combinations resulted in a new item that could be dropped into the 'stock panel' or in the 'workshop panel' to be further refined. Logs were the minimal elements that could be dropped into the 'totem panel' and provided players with a totem score. The panel on the left provided players with social information. The panel depicted here illustrates the 'Full social information / large group' treatment in which players benefited from five constant sources of information. By clicking onto an anonymised name, players could see the innovation record of the corresponding player. By clicking onto an item (for example, the carved log outlined in red), players could observe the underlying combination that resulted in this item (depicted at the bottom of the left panel). Players from the partial information treatment did not benefit from the information depicted in the bottom of the left panel. Players from the small group treatment benefited only from two constant sources of information. Players from the low connectivity treatment benefited only from one changing source of information (among five). Isolated players could only observe their own record.

Data and Analyses

Derex et al. analysed participants' total score which was made up of the score of their totem (if any) plus a fixed number of points per innovation discovered. To test the effect of variables such as group size and group connectedness, analyses were run on specific datasets. To test the effect of group size, the model was run on a dataset comprising data from the "individual learning", "full social information / small group" and "full social information / large group" treatments. "Individuals' total score" was the dependant variable and "group size" (1, 3 or 6) was introduced as a continuous independent variable, with "group identity" as a random effect. To test the effect of group connectedness, the model was run on a dataset comprising data from the "full social information / large group" and "full social information / partially connected group" treatments. "Individuals' total score" was the dependant variable and "full connectedness” (0 or 1) was introduced as a binary independent variable, with “group identity” as a random effect.

Results

Results indicate that individuals who are part of groups can produce totems that are more complex than any isolated individual can produce during the same amount of time. Moreover, the analyses of the different treatments reveal that this group-level ability to produce complex solutions is maximized when individuals are provided with full social information and when they are part of large and partially connected groups.

Limitations of these methods

Cultural evolution experiments have proved powerful in studying how individuals learn, transmit and modify cultural information. Yet, as any method, cultural evolution experiments are associated with limitations of which experimenters must be aware. We go through the main limitations of these methods below.

<u>Results can be task-specific</u>

It can be argued that for many cultural evolution experiments, the results are heavily dependent on the idiosyncrasies of the specific task used in the experiment. Studies investigating the role of various transmission mechanisms on cumulative culture, for instance, have yielded inconsistent results. Some studies found that providing participants with the specific details of how an outcome was achieved has a strong effect on the pace of cumulative cultural evolution (Derex & Boyd, 2015; Derex, Godelle, et al., 2013; Wasielewski, 2014) while others did not (Caldwell & Millen, 2009; Caldwell et al., 2012). Similarly, studies that have found empirical support for the transmission enhancing effects of teaching and language in the context of tool making (Morgan et al., 2015) have not consistently replicated across tool types (Pargeter et al., 2023; Putt et al., 2014; Whiten, 2015). Part of the explanation is that cultural traits vary in their complexity and the extent to which specific transmission mechanisms are helpful to learners has been shown to vary with tool complexity (Lucas et al., 2020). Nevertheless, this illustrates the difficulty of choosing a task that appropriately captures the features of real-life cultural traits and poses the question of the ecological validity of the experimental tasks that are used to study cumulative cultural evolution (Derex, 2021; Miton & Charbonneau, 2018).

<u>Lack of tasks’ ecological validity</u>

Drastic compression of the ‘evolutionary’ time-scale is convenient for experimenters but it often forces them to rely on tasks that are simple compared to the type of problems that individuals must solve in the real world. This lack of complexity has been pointed out before (Caldwell et al., 2019; Miton & Charbonneau, 2018; Derex, 2021) and authors have argued that for a task to truly capture the complexity of most human technology, it must be opaque enough that one individual cannot decipher how to reproduce a solution without observing the underlying production process (e.g. Derex, Godelle, et al., 2013). For instance, the production of sophisticated stone tools requires a considerable amount of otherwise unobservable skills, such that a naive observer would not know how to produce these via observation alone. The same is not necessarily the case for paper aeroplanes, or many other cultural evolution tasks.

Another limitation that has been pointed out recently is that many tasks focus on the marginal improvement of already existing solutions (how fast can a plane fly, how fast can a wheel spin). These so-called optimisation tasks prevent experimenters from studying actual innovation events through which novel behaviours and/or tools are created (Derex, 2021). Compared to optimisation, innovation events tend to result in more complex solutions which might be harder to learn than the pre-existing solutions they have been built upon. This suggests that the process of optimisation might rely on a different set of socio-cognitive abilities than the process of innovation, which has been arguably more important in our evolutionary history.

Cognition remains in a black-box

One of the most prominent criticisms of cultural evolution experiments remains that the evolution of human cognition, and the cognitive mechanisms required for learning and transmitting these complex technologies, remain in a 'black box,' (Clarke & Heyes, 2016; Heyes, 2016, 2018; Singh et al., 2021). That is, due to the experiments' reliance on cultural transmission alone, these methods have not helped to elucidate the precise cognitive mechanisms necessary for imitating and transmitting skills in general. For example, the cognition required to identify what a successful tool looks like, or what a successful behaviour looks like, are left unexplored. In most experiments discussed so far, some marker of 'success' of either the tool or model is provided. This is an unlikely scenario in 'the real world' when deciding whom to learn from, or which item to copy, is crucial. Being able to recognise or assess what "success" looks like is a given assumption in most experiments. To give a crude and oversimplified example, when choosing whose canoe, or which canoe, to copy, perhaps it depends on which one goes fastest, how many people can fit inside, how long it lasts? How much variation in canoe design or success determines copying one person's canoe design/technique over another? Indeed, even this crude relationship between tool and success is oversimplified and does not capture the fact that *some* underlying knowledge of a tool/behaviour is needed to be able to aptly assess who or what is most successful compared to another, even if total causal understanding of the entire system is not (Derex et al., 2019).

Future Directions for examining the Relationship between Language and Cultural Evolution

Surprisingly, the relationship between different forms of communication and cumulative cultural evolution has remained relatively under-studied in the cultural evolutionary literature and experiments have only begun to scratch the surface of the complex relationship between communication and cultural evolution. In this section, we highlight avenues for improvement in our understanding of the relationship between language and cultural evolution.

The coevolution between language and cumulative culture

Morgan et al's experiment demonstrates the importance of language for transmitting complex stone-tool making techniques (Morgan et al., 2015). However, results from another experiment that compared the acquisition of stone tool-making among learners who were taught using speech alone (unassisted by gesture), gesture alone, or 'full language' (gesture plus speech) indicate that individuals who were taught using speech alone performed poorly compared to individuals instructed through either gesture alone or 'full language' (Cataldo et al., 2018). This suggests that learners might derive limited benefits from language, in the absence of demonstration, because the complex actions involved in skills may be too difficult to put into words. However, a scenario in which humans were communicating solely with language and in the absence of any gesture, body language or physical demonstration seems wholly unrealistic for understanding our evolutionary past. Indeed, in this and many cultural evolution experiments, language is often either entirely absent, or full-blown modern-day human language is permitted. These are two unrealistic comparisons given that we know that human language went through prolonged periods of verbal protolanguage, most likely in co-evolution with gestural proto-languages (Bickerton, 2007; Fitch, 2017; Jackendoff, 1999). Indeed, it is commonly argued that complex tool-making and proto-language co-evolved (Fitch, 2010, 2017; Ghirlanda et al., 2017; Kolodny & Edelman, 2018). For cultural evolution experiments to gain more ground in understanding not only the evolution of language but the role of communication in transmitting complex information in general, they will need to incorporate findings from cognitive science and language evolution to modify their methods. For example, incorporating 'protolanguage' conditions as a realistic comparison between full-blown language and gesture-only conditions.

The use of 'communicative gadgets' to promote learning

It has recently been hypothesised that cognitive mechanisms such as analogy, scaffolded by protolanguage, that allow the compression and communication of the kind of information needed for transmitting complex tool-making skills (see (Brand et al., 2021) for review) might have played a significant role in the advent of cumulative cultural evolution. For example, a commonly used analogy for transmitting the tying of a bowline knot includes describing the string-end as a rabbit, a loop as a burrow, and the other string end as a tree, so that the complex ordering of the action-sequence can be compressed and transmitted as “the rabbit comes out the burrow, goes around the tree, and back down the burrow.” This is clearly easier to remember, communicate and transmit than describing the precise actions of your fingers, hands, and each section of string in precise language. The use of ‘communicative gadgets’ such as analogies, recipes, stories, rules and general principles, to ease the memory load of learning and communicating complex information sequences, will need to be investigated in future experiments (Ghirlanda et al., 2017; Kolodny & Edelman, 2018). Diving into the cognitive mechanisms behind our ability to compress and chunk complex information, supporting our ability to socially learn with such high-fidelity, will also require better integration with findings in cognitive science (Brand et al., 2021).

The role of communication in transmitting complex information

Finally, exploring our full-range of communicative strategies, including body language, eye-contact tone of voice, choice of language, gesture, and exaggeration that teachers use to emphasise certain actions or important details will also be crucial for a full understanding of our high-fidelity transmission abilities (Singh et al., 2021). In typical cultural evolution experiments, participants are often presented with a single task and have no other choice but to perform that task. In more realistic settings, participants might decide to give up on complex tasks and pursue simpler tasks, which could result in the disappearance of hard to learn traits. Yet, types of communication can be used to encourage learners and support the acquisition of skills that require a large amount of deliberate practice (Stout, 2005), which in turn may affect the probability of adoption of hard to learn traits. Overtly intentional communication (and particularly language) also allows potential learners to query what they do not understand and allows experienced individuals to explain, justify and instruct, as appropriate to the needs of the learner. This might be especially important for behaviours that do not have immediate benefits, as inexperienced learners may be more likely to ignore them in favour of options that have more apparent benefits (Singh et al., 2021).

Conclusion

Experimental methods provide powerful ways to address a wide range of questions concerning the production, transmission and maintenance of cultural traits. In this chapter we have laid out the main principles and possibilities of cumulative cultural evolution experiments. To successfully implement these methods, certain core criteria must be present, and careful attention must be paid to ensuring the choice of task is appropriate for the question being asked. How transmission is implemented, how participants interact, and whether the task is presented physically or via computer are all options that are worth exploring, in accordance with how suitable each is to the research question. Current methods provide many rich opportunities for exploring the evolution of human cumulative culture but both experimental tasks that better reflect the complexity of human technology and experimental settings that implement evolutionary relevant communication mechanisms are warranted. Furthermore, the propensity for humans to transmit complex knowledge and skills with high fidelity is not only reliant on communication strategies but is also a fundamental aspect of how language itself evolves. Methods that better integrate the findings from the fields of language evolution, cognitive science, and cultural evolution will be necessary in acquiring a full picture of how human behaviour, cognition and communication has evolved, and is evolving.

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