Regulatory Traits in Cultural Evolution

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Abstract. We call "regulatory traits" those cultural traits that are transmitted through cultural interactions and, at the same time, change individual behaviors directly influencing the outcome of future cultural interactions. The cultural dynamics of some of those traits are studied through simple simulations. In particular, we consider the cultural evolution of traits determining the propensity to copy, the number of potential demonstrators from whom one individual may copy, and conformist versus anti–conformist attitudes. Our results show that regulatory traits generate peculiar dynamics that may explain complex human cultural phenomena. We discuss how the existence and importance of regulatory traits in cultural evolution impact on the analogy between genetic and cultural evolution and therefore on the possibility of using evolutionary biology–inspired models to study human cultural dynamics.

Keywords: cultural evolution, cultural transmission, social learning, genetic evolution, openness, conformism

1 Introduction

One of the most important recent development in studies of cultural transmission and evolution is represented by the possibility of using tools borrowed from evolutionary biology to model cultural dynamics [8, 9]. This possibility rests on the assumption that the process of cultural change shares some fundamental properties with the process of genetic change: namely, variation, inheritance, and competition [14, 15].

While many acknowledge that cultural change satisfies those requisites, a considerable debate exists on how the differences between cultural and genetic transmission impact on the validity of the analogy between the two [17, 18, 10]. Some differences between the two processes are obvious: for example, whereas genetic transmission is necessarily from parents to offspring, cultural transmission can, in principle, be from any individual to any other individual [3]. Evolutionary biology–inspired models of cultural evolution hence certainly necessitates to be modified in some details to take into account those differences. However, the question is whether there are characteristics of cultural transmission that give

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[⋆] Author for correspondence: `alberto.acerbi@gmail.com` rise to more fundamental differences, that prevent the integration of the two processes in the same evolutionary framework.

Here we examine one of these possible differences. Genetic information is acquired by individuals only once, but cultural information can be both abandoned and reacquired during lifetime [18]. Moreover, the lifetime modifications of individual's culture may have an impact on future cultural interactions of the individual [12]. Many examples are possible: in modern western societies, say, parents actively transmit to their children the idea that learning from school teachers is good. Or, depending on our experiences, we can learn to be conformist or anti–conformist, which, in turn, will modify our attitude in the upcoming interactions. We call "regulatory traits" those cultural traits that can be acquired and modified through cultural interactions by the individual, and that, at the same time, modify in some way the future cultural interactions of this individual.

In what follows we present three basic models of three regulatory traits and we show the consequences they have in simple cultural dynamics. The first model simulates the evolution of a cultural trait regulating the individuals' propensity to copy from others. The second model takes in consideration a trait who determines from how many demonstrators one individual will copy. The third model, lastly, considers a cultural trait that makes individuals conformist or anti–conformist. Next we show, drawing on our previous works [1, 11, 2], how it is possible to extend one of those simple models so to reproduce more realistically some typical human cultural phenomena. Finally we discuss our results, and we return to the question of how the existence and the importance of regulatory traits in cultural evolution impact on the on the analogy between genetic and cultural evolution.

2 Models

2.1 Openness and conservatism

We consider a population of $N = 100$ individuals that interact in discrete time steps. At each time steps any individual (the *learner*) is randomly paired with another individual (the *demonstrator*) and may, or not, copy its cultural trait. Individuals are characterized by a single cultural trait p, that determines their probability to copy, that we call *openness*. With a probability $\mu = 0.01$ per time step, individual may innovate their p, which is in this case re-initialized. At the beginning of the simulation all ps are randomly drawn from an uniform distribution between $p_{min} = 0$ and $p_{max} = 1$ (the analytical treatment of this simulation can be found in [12]).

The results of this simple model (see Fig. 1) show that the population quickly converges towards complete conservativeness (as opposed to openness), that is, all individuals are unwilling to copy others. To understand this result, one has to consider what happen when two individuals interact. When an open individual meets another individual, it will be likely to copy its cultural trait, but, when a conservative one will meet another individual, it will not: open individuals keep on changing until they became conservative, for the very reason that lower ps inhibit social learning. In other words, conservatism is an attractor of this systems.

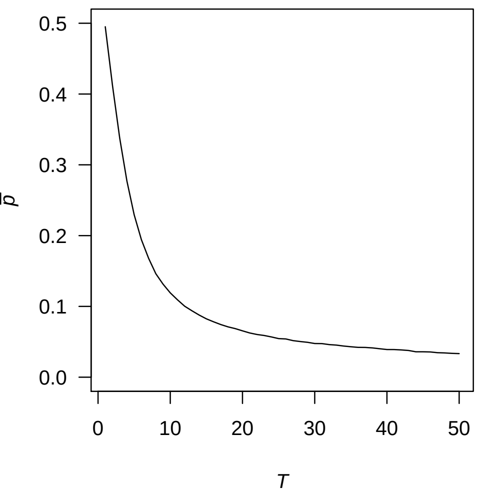

Fig. 1. Average value of p (openness, X axis) through time (Y axis), starting from an uniform distribution between $p_{min} = 0$ and $p_{max} = 1$. The data are an average of 100 simulation runs.

Of course, the results of this simple model appear unrealistically too extreme. People, in real–life, do not indiscriminately reject cultural information, and human populations do not became completely conservative. However, we believe that a tendency towards conservativeness may represent a strong underlying factor in cultural evolution, and in Section 3 we show how this model can be extended to take into account more realistic dynamics.

2.2 Number of Demonstrators

We now consider another regulatory cultural trait, that we call d, that determines from how many demonstrators one individual will potentially copy. d ranges from 1 to 100, i.e. the whole population. Therefore, all individuals have a "pool" of possible d demonstrators, randomly chosen in the population, and when an individual is paired with another, the former will copy only if the demonstrator belongs to its pool. Everything else is as described in the previous simulation.

The results show that the population converges towards lowest values of d (see Fig. 2). The logic underneath this result is the same as already explained for the openness/conservatism dynamics. Lower ds are less likely to be relinquished in favor of higher ds, and, with repeated social interactions, tend to accumulate.

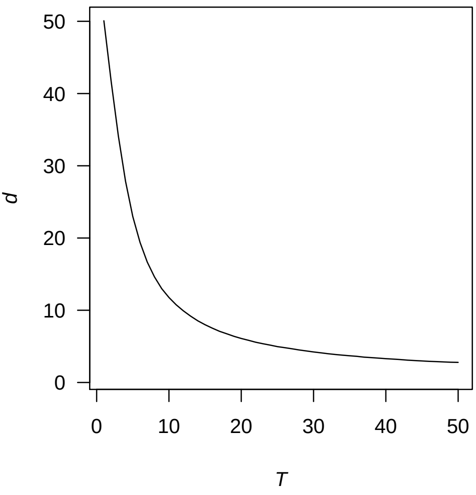

Fig. 2. Average value of d (number of demonstrators, X axis) through time (Y axis), starting from an uniform distribution between $d_{min} = 1$ and $d_{max} = 100$. The data are an average of 100 simulation runs.

Here, for reason of generality, we assumed that the pool of possible demonstrators is randomly chosen in the population, but it is worth to note that one may consider that individuals could use various cues to determine the subset of the population from whom to copy. In this perspective, these results may shed some light on well–known phenomena in human culture. For example, one might assume that the subset is determined using its own social/ethnic group, that is the individuals who are considered as sharing the same ethnic membership or social affiliation. In this case, our simulation predicts that nothing more is needed to culturally evolve a preference from in–group copying, as opposed to indiscriminately copy from the whole population. Analogously, if perceived prestige is used, a "prestige bias", i.e. a tendency to imitate prestigious individuals [8], will automatically emerge, independently on any consideration of its adaptiveness. While we not claim that this simple model *explains* in-group preferences or various model–based biases, it is not implausible that those and other tendencies may be at least reinforced by the effect of cultural regulatory traits.

2.3 Conformism

We finally simulate the cultural evolution of a trait determining conformist and anti–conformist attitudes. Conformity, in cultural evolution, is interpreted as the tendency to copy the most common variant of a cultural trait, while anti-conformity (sometimes called "rarity bias") is the opposite tendency, i.e. the preference towards rarest variants. Here, the trait c is a binary variable equals to 1 when an individual is conformist and to 0 when is anti–conformist. When two individuals that have different values of c meet, the probability that the learner will copy depends on the frequency of the demonstrator's trait in the population and, as in [8], it is given by:

$$x + x(1 - x)(2x - 1) \ . \tag{1}$$

Where x is the proportion of individuals with the anti–conformist trait when the learner is conformist, and $1 - \mathit{proportion}$ of individuals with the conformist trait, when the learner is anti–conformist. It is quite straightforward to see that if the majority of the population is composed by individuals with conformist attitudes, few cultural transmission will happen because conformist individuals will prefer to not copy the minority of anti–conformists, and anti–conformists will prefer to not copy the majority of conformists. However, when the majority of the population is anti–conformist, conformist individuals will, say, adequate to the majority, becoming anti–conformists, but anti–conformist individuals, for the very reason they are anti–conformists, will copy the minority of conformists.

Differently from the two previous simulations, the cultural evolution of conformism and anti–conformism does not tend towards an equilibrium, but produces an oscillatory dynamic that depends on the frequency of the traits in the population (see Fig. 3).

3 Openness, Conservatism, and Fashion Cycles

It is possible to extend the results shown in the previous sections to take into account more complex human cultural dynamics. In particular, in previous works, we extended the openness/conservatism model described in Section 2.1, in order to understand in which conditions cultural forces could maintain relatively open populations.

In a first study [1], we allowed individuals to possess multiple cultural traits, and we assumed that preferences (positive or negative attitudes towards cultural traits) were associated to each of them. We assumed that individuals observed cultural traits displayed by others and decided whether to copy them or not based on their overall preference for the displayed traits. Finally, preferences, too, could be transmitted between individuals in cultural interactions.

In this more complex scenario, low preferences corresponded to a general conservative attitude, i.e. individuals with low preferences were less likely to copy others, and we expected that, given that preferences could be copied, for the reasons explained in Section 2.1 cultural dynamics would have favored the

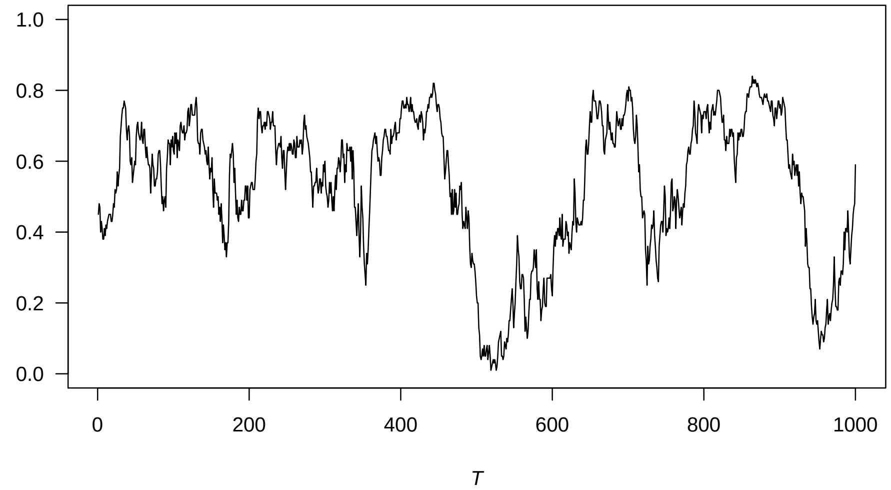

Fig. 3. Average value of c (conformism, X axis) through time (Y axis), starting from a population where c is randomly distributed ($c = [0; 1]$). Note that time scale is stretched in respect to Fig. 1 and Fig. 2. The data represent a typical simulation run.

spreading of low preferences. However, in this model, individuals also needed to acquire cultural traits to be copied by others. An individual with no cultural traits, no matter the preferences' values of the observer, could not be copied.

We first showed that in the simplest case—only one preference/trait pair—cultural dynamics in fact produced conservative individuals (see also [12]). However, increasing the number of cultural traits in the populations, and/or decreasing the efficiency of transmission, was enough to maintain relatively open populations. Figure 4a shows how average openness varies through time in two populations in which 10 cultural traits are present, but that differ in respect to the efficiency of transmission (p_{adopt}). The increase of the number of cultural traits and the decrease of the efficiency of transmission have indeed an analogous effect on individual development: they both increase the number of interactions that an individual needs in order to acquire a substantial part of its culture. Individuals with more cultural traits have more possibilities of being copied by others, and individuals that remain relatively open have more cultural traits. They will thus be, on average, better "cultural models" than heavily conservative individuals, and this favors the spread of their traits, including the preferences that make them open.

Another possibility is to consider the fact that new cultural traits are from time to time introduced in the population, with preferences for those traits randomly assigned to individuals [2]. It may happen that efficient "cultural models"

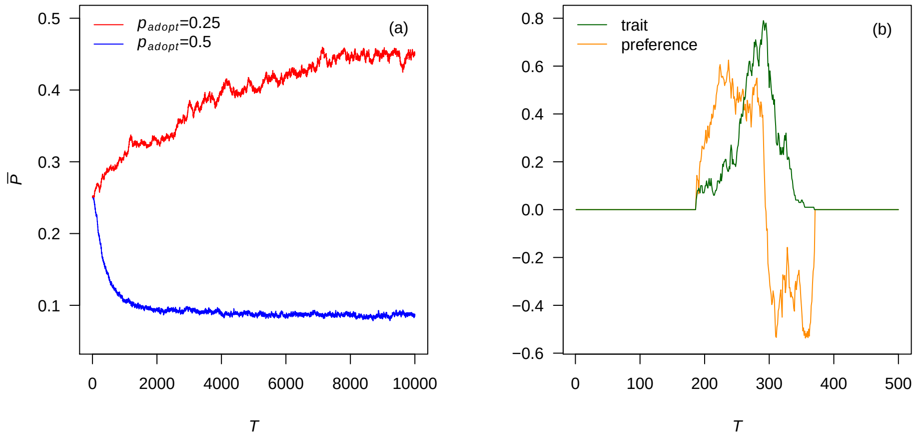

Fig. 4. (a) Average value of P (openness, X axis) through time (Y axis) in a population in which 10 cultural traits are present, for an intermediate rate of transmission (red line: $p_{adopt} = 0.25$) and for an higher rate transmission (blue line: $p_{adopt} = 0.5$). (b) An example of "fashion cycle". The green line shows the frequency of the trait in the population through time, and the orange line the average value of the preference associated to the trait. The graphs are redrawn from simulations detailed in [1] and [2], respectively.

have high preferences for a new introduced trait. In this case the high preferences can spread in the population and consequently drive the increase in frequency of the associated trait. However, as soon as the trait starts to be common, the above mentioned advantage for conservative individuals—in this case, individuals with a low preference for the common trait—starts to influence cultural evolution. As a consequence, the preference falls down, quickly followed by the trait itself. Figure 4b shows an example of this dynamic.

We noticed how this cycles in popularity of cultural traits closely resemble to fashions and fads dynamics in human culture. Fashion and fads are characterized by volatile dynamics, whereby cultural traits rise and fall in popularity for reasons that appear unrelated to the traits themselves [2]. We tested this model in respect to two empirical findings that characterize those dynamics: the power-law distribution of frequency of cultural variants [5, 6, 4], meaning that only very few cultural traits become very common while the vast majority remains rare, and the finding that cultural traits that increase rapidly in popularity are also abandoned quickly, while slow increase in popularity correlates with slow decrease (shown for first names in the U.S. and France [7], and for the popularity of dog breeds in the U.S. [2]). We were able to show that this model account for empirical data better than other predominant views of fashion, namely that they are a product of individuals copying randomly from each other (neutral model of cultural evolution [5]), or a result of social stratification [16].

4 Discussion

In this paper we extended our previous works to present a more general argument about the importance of regulatory traits in cultural evolution. Our models show that regulatory traits may have a potent, and perhaps surprising, impact on cultural dynamics. Cultural evolution, in other words, can generate its own rules [12] in absence of “external” driving forces, such as genetic influences or differences in the adaptive values of cultural traits. This does not mean that these factors are not important, but the possibility to artificially study pure cultural forces with simulation models may help us to isolate the effects of cultural remodeling of cultural transmission rules. While the models presented here describe extremely simplified dynamics, we had shown how they can be extended, and how they can describe more complex human phenomena. Theses range from the evolution of openness and conservatism in populations characterized by cultural repertoires of different size and by more or less efficient transmission mechanisms, to peculiar shift in popularity of cultural traits, usually dubbed fashions and fads.

The more general question is now how the existence of regulatory traits impacts on the analogy between cultural and genetic evolution and, specifically, on the possibility to model cultural dynamics using evolutionary biology–inspired tools. The existence of regulatory *genes* suggests that a somehow analogous phenomenon happens in genetic evolution. Regulatory genes are genes that control the activity of other genes during individuals’ lifetime, by activating or inhibiting their functioning [19]. While it would certainly be interesting to evaluate the scope of this analogy, the point we want to make here is that the matter of debate is not whether cultural and genetical evolution are exactly equivalent in all aspects (they are probably not), but if the relative simple and abstract models that have been successful in evolutionary biology can be equally successful for the study of cultural evolution.

While regulatory genes may influence profoundly genetic evolution, most of the population genetics models assume—successfully—that considering the rules of transmission as stable and context–independent is a useful approximation (see also [10]). Evolutionary biology–based models of culture consequently generally assume that the rules of transmission are stable, often under genetic influence [8, 9]. This has not to be necessarily true and, as our models illustrate, the consequences may strongly affect resulting cultural dynamics.

The criticism of evolutionary biology–based models of culture is often associated, especially in anthropology, with a more general denial of the importance of modeling, or even with a marked anti–scientific attitude (see for example [13]). This is certainly not our conclusion. From a purely pragmatic point of view, the possibility of applying models already developed in other disciplines to the study of culture is certainly positive. However, we believe progresses could be made with a richer characterization of cultural dynamics, and without being necessarily constrained by the analogy between cultural and genetic evolution.

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