Five Misunderstandings about Cultural Evolution

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Recent debates about the utility of "memes" have revealed some fundamental misunderstandings about the nature of cultural evolution. Memeticists and their many critics seem to share the view that evolutionary principles can only be applied to cultural evolution if culture can be thought of as arising from the transmission of gene-like replicators. The memeticists believe that such particles (or at least close approximations) exist, and thus Darwinian reasoning—which has proven so useful in biology—can be applied to culture. Their critics argue that replicating particles do not exist, and therefore, that it is inappropriate to apply Darwinian ideas to culture. We think both camps have been misguided by an overly enthusiastic analogy between genes and culture.

Because much of culture can be understood in the most general sense as information stored in human brains—information that got into those brains by various mechanisms of social learning—we think that population-dynamic concepts and evolutionary models are extremely useful for understanding how such processes work. BUT, and this is a big but, we maintain that constructing appropriate models of cultural evolution demands that close attention be paid to the psychological and social processes involved. From this broader approach, both the memeticists and their critics labor under a number of recurrent misunderstandings about cultural evolution. Here we focus on these five:

1. Mental representations are rarely discrete, and therefore models that assume discrete, gene-like particles (i.e., replicators) are useless.

2. Replicators are necessary for cumulative, adaptive evolution.

3. Content dependent psychological biases are the only important processes that affect the spread of cultural representations.

4. The "cultural fitness" of a mental representation can be inferred from its success transmission through the population.

5. Selection can only occur if the sources of variation are random.

These assertions are often used to dismiss whole categories of thinking about cultural evolution. For example, some anti-memeticists have suggested that if there are no cultural replicators, or if selection requires random variation, researchers interested in the distribution of representations can ignore cultural evolutionary models that assume discrete traits. Or, as some memeticists have suggested, if cultural replicators exist and are operating in cumulative evolution, one can ignore a lot of complicated mathematical theorizing—it's just natural selection after all. However, none of these claims are correct. In the rest of this paper, we will try to convince you of this fact.

Discrete, replicator models of cultural inheritance can be useful even if mental representations are never discrete

A great deal of work on cultural evolution assumes that cultural traits can be modeled as discrete, gene-like entities that are faithfully transmitted from one individual to another. Memeticists like Blackmore (1999) and Aunger (2002) believe cultural representations, or as they prefer, *memes* must be particulate for cumulative cultural change to occur. Cultural evolutionary theorists (e.g. Cavalli-Sforza and Feldman 1981, Boyd and Richerson 1995, Henrich and Boyd 1998, 2001, Henrich 2001; Rogers 1989) have devoted much effort analyzing models of cultural evolution in which cultural traits are assumed to be discrete (although it is sometimes overlooked that these theorists have also spent a substantial amount of effort analyzing the evolution of continuous, non-discrete cultural traits).

Cognitive anthropologists have criticized such ‘replicator approaches,’ arguing that such thinking is at variance with two observations. First, Atran (2001, 2002) has indicated that there is no evidence that the mental representations that underpin cultural traits are discrete, gene-like entities. Instead, the he argues that mental representations are continuously graded entities. Second, Sperber (1996), Atran (2001) and Boyer (1998) emphasize that unlike genes, ideas are not transmitted intact from one brain to another. Instead, the mental representations in one brain generate observable behavior, a “public representation” in Sperber’s terminology. Someone else then observes this public representation, and then (somehow) infers the underlying mental representation necessary to generate a similar public representation. The problem is that there is no guarantee that the mental representation in the second brain is the same as the first. Any particular public representation can potentially generate an infinite number of mental representations. Mental representations will be replicated from one brain to another only if most people induce a unique mental representation from a given public representation. Moreover, inferential processes often systematically transform mental representations, so that unlike genetic transmission, the cultural transmission is highly biased toward particular representations. Following Sperber (1996), we call the representations favored by processes of psychological inference (including storage and retrieval) ‘cognitive attractors.’

While the nature of the cognitive processes that give rise to social learning are very much a matter of debate (e.g. Tomasello 1996, Whiten 2000, Rosenthal and Zimmerman 1978), we think it is quite likely that general picture painted by Sperber, Boyer and Atran is correct—cultural transmission does not involve the accurate replication of discrete, gene-like entities. Nonetheless, we also believe that models which assume discrete replicators that evolve under the influence of natural-selection-like forces can be useful. In fact, we think such models are useful *because* the action of strong cognitive attractors during the social learning.

The reason is simple: cognitive attractors will rapidly concentrate the cultural variation in a population. Instead of a continuum of cultural variants, most people will hold a representation near an attractor. If there is only one attractor, it will dominate. However, if, as seems likely in most cases, attactors are many, other selective forces will then act to increase the frequency of people holding one attractor and decrease others. The weak selective forces (‘weak’ relative to the strength of the attractors) will actually determine the final distribution of representations in the population.

In Henrich & Boyd (2002), we analyze a simple mathematical model to show that this verbal reasoning is cogent. In this paper we represent each individual’s mental representation as a numerical value (x) between zero and one. For example, x might represent an individual’s beliefs about the Moon. Individuals with $x = 0$ perceive the Moon as a self-aware, conscious, entity with goals, emotions, and motivations—thus the Moon's behavior can be understood using folk psychology (Leslie 1994). In contrast, individuals with $x = 1$ see the Moon as simply a big rock, lacking goals, consciousness, and emotions. These individuals attribute the Moon's color, shape and movement to the effects of non-agentic interactions with light and the gravity of other mindless bodies, governed by physical laws that operate throughout the Universe. Now, it is possible to imagine Moon-concepts that mix these poles ($0 \le x \le 1$). One could believe, for example, that the moon's movement and shape are out of its control (governed by physical laws), while its color or hue expresses its mood, which in turn influences the weather. Or, perhaps the Moon's color is 23% controlled by its emotions and 77% controlled by the laws of light refraction. One might also believe that on Tuesdays and Thursdays the Moon is a goal-oriented agent, on Mondays, Wednesdays and Fridays the Moon is a big rock, and on the weekends these two alternate minute by minute. Such beliefs might seem odd to us because they violate intuitive expectations, which is why cognitive attractors might transform them. In contrast to intermediate concepts (x values), $x = 1$ or 0 are "easier to think." [1]

In the formalization, individuals acquire their mental representations by observing the behavior of others. Two cognitive mechanisms affect this learning process. First, *inferential transformation* captures the manner in which cognitive processes of acquisition, storage and retieve alter mental representations in ways to favor some representations over others—cognitive attactors. Because the two extreme represetations, "Moon as person" and "moon as rock" are easier to think, they act as cognitive attractors in our example. Individuals who observe behaviors that result from intermediate representations tend to infer mental representations closer to one of the two attractors. The second process, s*elective attention,* captures the tendency for individuals to pay particular attention to some individuals more than others. For example, it could be in a modernizing environment, where the representations favored by science are prestigious, people who hold the "moon as rock" representation are more succesful than those who hold the alternative, and thus they attract more attention (and are more likely to be learned from). Finally we assume the effects of inferential transformation are *much stronger* than the effects of selective attention.

Figure 1 shows what happens to the distribution of mental representations. In the underlying simulation , we assumed every mental representation is equally common initially (this has no impact on the results). The effects of inferential transformation dominate the early part of the trajectory, rapidly causing almost everyone to have a representation close to one of the two attractors. Once everyone is clustered around one of the two attractors, the rest of the trajectory is dominated by the effects of selective attention. In Henrich and Boyd (2002) we showed analytically that the resulting population dynamics and the final distribution of mental representations are *closely approximately by discrete-trait replicator dynamics model.* This result is confirmed by the exact simulation results shown in Figure 1.[2] Two conclusions are important here: First, the selective processes (i.e., paying attention to certain individuals) that generate cumulative adaptive evolution do *not* depend on

[1] Note, in formal model described here we used a one-dimensional representation of x, but our model easily extend to the *n*-dimensions needed to capture the above example.

[2] Our analytical work was identical to the simulation except that we ignored the effects of sampling error (the cultural analog to drift). The difference is only important in small populations.

replication, fidelity or longevity. This model shows that a replicator-approximating process can arise and lead to cumulative adaptation even when representations are non-discrete and are transformed during *every* acquisition. You don't need to assume gene-like replicators exist to deploy replicator dynamics. Second, we showed that the *stronger* the inferential transformations, the *better* the replicator-dynamics approximation. Therefore, contrary to the common assumption that a "rich cognitive architecture" relegates selective process to a limited importance, we showed that such assumptions imply that selective process will be critical to understanding the epidemiology of representations.

Replicators are not necessary for cumulative adaptive cultural evolution

Much confusion about cultural evolution traces to Dawkins (1976, 1982) argument that discrete, accurately copied, long-lived "replicators" are necessary cumulative, adaptive evolution. Dawkins argues that self-replicating entities are a requirement for cumulative evolution and must have the following characteristics:

Fidelity. The copying must be sufficiently accurate that even after a long chain of copies the replicator remains almost unchanged

Fecundity. At least some varieties of the replicator must be capable of generating more than one copy of themselves.

Longevity. Replicators must survive long enough to affect their own rate of replication

This argument has been repeated and elaborated by Dennett (1995), Blackmore (1999), Aunger (2002), among others, and has convince many people that discrete, gene-like particles are a requirement for adaptive cultural evolution.

While we agree that the existence of replicators is sufficient for cumulative adaptive evolution, they are not necessary. Any process of cultural transmission that leads to accurate replication of the average characteristics of the *population* will work. Accurate replication at the level of the gene (or meme) will have this effect, but accurate replication at the population level can arise for other reasons as well. Here are two examples.

Henrich & Boyd (2002) analyze a discrete trait model with very innaccurate transmission. We assume that there are two mental representations, A and B. As before, mental representations are transmitted when one individual observes the behavior of a second individual and attempts to infer the underlying mental representation that gave rise to that behavior. Now, however, we assume that this process is very innaccurate—individuals make the wrong inference with probability m. Formally, m plays a role identical to mutation in a genetic model. Genes are replicators because m is tiny, say 10^{-6}. Here we are going to assume that m is a big number like 0.2. When $m = 0.5$ there is no transmission at all, so $m = 0.2$ represents very low fidelity transmission. Thus, if nothing else were going on, cumulative adaptive evolution would be extremely unlikely. However, we also assume that individuals have a psychological propensity for *conformist transmission*.[3] Suppose that each learner selects *n* different individuals to learn from. For each individual, the learners attempt to infer what their underlying mental reprentation is (either A or B), but make error with probability *m*. Based on these inferences, they then adopt what they think is the most common representation in their sample. For example, suppose a learner selects five individuals. Three of these five hold mental representation A, while remaining two hold B. If our learner estimates all five accurately, he will adopt A. If he gets one of two holding B incorrect (and the rest correct), he will still adopt A. But, if he gets one of the three hold A wrong, he will adopt B. Our results show that conformist transmission effectively corrects even large errors in transmission, even in the case in which the inferential/transmission channel is 60% noise. The reason for this is simple: errors have a bigger effect on populations in which one mental representation is common compared to populations in which both mental representations have similar frequencies. However, when one representation is common, the conformist effect is also stronger and thus systematically corrects for the effect of errors. Conclusion: fidelity of replication is not required for cumulative adaptation.

Here's a second example. For nearly 20 years cultural evolutionary theorists have analyzed blending models of cultural evolution (e.g. Boyd & Richerson 1985: 71-79).[4] In such models, no mental representations are replicated, but nonetheless cumulative evolution is possible. Suppose in deciding what length to make his arrow, a hunter samples *n* models from a larger population and adopts as his mental representation (his arrow length) the average of the lengths of the *n* models. Suppose $n = 3$, and the arrow lengths of the 3 models are 16cm, 20cm and 21cm. This means the hunter adopts an arrow length of 19cm. Note, this 19cm-meme is *not* represented among the *n* individuals sampled—there is no replication, fecundity or longevity. If we further assume that in selecting their *n* models, individual preferentially focus on the best hunters, and that proximity to the optimal arrow length (say 20cm) contributes to one's hunter success (on-average), then blending will generate adaptive evolution on arrow length.

Neither of these mechanisms results in the same kind of "frictionless" adaptation as genetic replication. Highly accurate, unbiased, genetic replication allows minute selective forces to generate and preserve adaptations over millions of years. Error prone cultural replication, even when "corrected" by a conformist bias, imposes modest, but still significant forces on the cultural composition of the population. Similarly, blending inheritance rapidly depletes the variation in a population necessary for selective processes like prestige-biased transmission to have an effect. But, because the inferential processes that underlie cultural transmission are noisy, it is likely that they can maintain lots of variation. However, this also means that they are likely to create evolutionary forces that act to change the mean, and thus compete with selective forces.

The contrasts with genetic evolution provide more reasons, not fewer, for analyzing formal cultural evolutionary models. The forces that are important for understanding cultural evolution (such a non-random errors and blending) are likely

[3] Conformist transmission has solid theoretical and empirical foundations (Henrich & Boyd 1998; Boyd & Richerson 1985: Chapter 7).

[4] These models were borrowed from quantitative character "genetics."

not the same forces that are important for understanding genetic evolution. Population based models of cultural can be useful, but they have to pay careful attention to these differences.

Content dependent psychological biases are not the only processes that affect the spread of cultural traits.

In understanding cultural evolution, how the content of memes "fit into" the cognitive structure of the human mind is not the only important process. From the point of view of genetic fitness, maladaptive memes about religion, food taboos, ghosts, etc. may readily spread because of their ability to exploit aspects of human psychology in ways that make them more likely to be learned and transmitted. However, summarizing evidence from across the social sciences, Henrich & Gil-White (2001) show that that humans are quite selective in picking the individuals they will learn from, or be influenced by ("imitate," if you will). Human psychology seems to be geared up to selectively extract useful (locally adaptive) information from the individual(s) most likely to possess it. Skill, success and prestige all make individuals substantially more likely to be learned from, or imitated. This psychological propensity for 'model selectivity' seems to operate across most, if not all, domains of culture, from dialects and word choice to political opinions, food preferences and technical innovations (like using fertilizer). The classic literature on the diffusion of innovations (Rogers and Shoemaker, 1971) is a rich source of examples. This means that a meme's mimetic fitness (versus genetic fitness) will depend jointly on how attractive its content is to human brains, and how it affects an individual's likelihood of being selected as a cultural model by other individuals.

To illustrate this, consider the following example. In a small fishing village on an Indonesian island, an old man is out fishing at night in small boat. The next morning he is found dead in his little boat, which is filled with a massive catch. A rumor begins to spread that a demon-fish, common is local mythology, sucked out the man's soul because he was fishing at night. Individuals who believe this rumor stop fishing at night (which is often the most productive time to fish, especially for some species). For simplicity, we assume that individuals either believe the meme, or not. The variable p gives the frequency of individuals in this large village who believe in the fish-demon has returned and don't fish at night. From meme's perspective, the relative mimetic fitness of the demon-fish belief is $\omega_f = \alpha + \gamma$, while the relative mimetic fitness of not believing the rumor is $\omega_n = \alpha + \phi$. α is the baseline fitness, γ the strength of the meme's content bias (i.e., how well it fits into the local brains), and ϕ is the cost to an the individual who bears in terms of their likelihood of being selected as a cultural model. An individual's likelihood of being selected as a model is affected because not-fishing at night means fewer fish to sell, and thus less extra money for clothing, sugar, house maintenance, throwing feasts, and the children's health needs—all of which may make one more likely to be selected as a cultural model. Putting these expressions into standard replicator dynamics give us,

$$\Delta p = p(1-p)[\gamma - \phi]$$

where Δp gives the change in the frequency of rumor believers. This equation, as it stands, tell us that there are two potential stable equilibria: either everyone will come to believe the fish-demon story and cease all night fishing, or the success costs of not fishing will dominate and the rumor will not spread. Clearly, just because the demon-fish story is fun to tell, is easy to remember, is built on widely believed local mythologies, and interacts with innate inferential machinery in interesting ways (like ghosts do, Boyer 1994), does not guarantee it will spread if possessing the belief makes one less likely to be selected as a cultural model.[5]

The point of the simple example is to show that the human mind's tendency to preferentially focus attention on certain individuals (independent of memetic content) means the usual approach to memetic reproduction is insufficient. It further means that whether a particular genetic fitness-reducing meme can spread, and how far it will spread, depends on the details—the dynamics of which can only be understood by formally modeling the social and psychological processes involved. No categorical claims based on hand waving arguments about the relationship between genetic and memetic fitness are likely to hold. For example, just because something transmitted "horizontally" within a generation tells us nothing the genetic adaptiveness of those memes.

We should also note at this point that the appropriateness of tracking fitness from the perspective of the meme (assigning fitnesses to alternative memes) or to individuals (or groups) is merely a modeling convenience. For example, it is not "more correct" to view fitness in association with memes, individuals or groups. The above model can be fully derived from the perspective of individual, rather than the meme, by specifying the individual's tendency to transmit particular ideas, rather than from the meme ability to transmit itself. This is another confusion that can be traced to people taking Dawkins'pop-science books too seriously.[6]

Successful diffusion is not a measure of fitness

Authors who adopt the selfish meme concept often give us no causal idea of what actually bestows different "fitnesses" of alternative memes. How do we know whether a bit of a tune or a catch phrase is a fit meme? Often, it seems, only by asking whether the meme has successful spread.

This is dangerous territory. Used in this way, natural selection is a useless, or even misleading tautology. For example, a recessive gene causing a severe vision disorder called achromatopsia has spread to roughly 30% of the population on the Micronesian island of Pingelap. Sufferers of achromatopsia cannot see well under any circumstances, but are especially disadvantaged in the bright sunlight of a tropical island. Nonetheless, there is no doubt that this gene spread on Pingelap because

[5] Fishing at night may truly be dangerous even if supernatural sea creatures are not the reason. If it is dangerous, natural selection itself will tend to remove night fishermen from to pool of people to learn from no matter that their catches tend to be large. This effect will add a term to the evolutionary equation that is independent from the sum of all the psychological forces we have considered.

[6] In evolutionary biology, it is a well-established practice that genetic fitness can be tracked though a wide range potential units, including genes, individuals and groups (Hamilton 1975; Queller 1992; Henrich forthcoming). Different fitness tracking systems may allow certain aspects of problem the studied more or less, but they are all formally identical at some level.

people who carried it had more descendants than those who didn't carry the gene. If we were to infer the relative fitness of the achromatopsia and normal alleles from this spread, we would conclude that the achromatopsia allele had higher fitness. However this doesn't mean that achromatopsia was favored by selection because the achromatopsia didn't *cause* their increased reproductive success. Rather, it seems that the gene was carried by members of a chiefly lineage whose social position allowed them to survive the aftermath of a severe typhoon that struck the island during the 1700's—it likely spread by a combination of drift and a chance covariation with social status. The same kinds of phenomena are likely at work in cultural evolution. Otherwise deleterious or unattractive ideas and practices often spread because they happen to be statistically correlated with attractive individuals or successful groups. Why did English rapidly spread across North America during the 18th and 19th centuries? Certainly not because it is an intrinsically more attractive mode of expression than Cherokee or Apache. Rather, it spread because it happened to be associated with the military advantages, technological innovations, and infectious diseases that allowed English speakers to conquer the native cultures of North America. Similarly, the Western business suit has also spread across the world in the 20th century, not, we conjecture, because the four-in-hand tie is intrinsically more attractive than its many alternatives, but because it happens to be associated with the economic and military prowess of the West.

Evolutionary biologists escape this circularity fitness because they have *independent* means of predicting which genetic variants are more fit. Peter and Rosemary Grant's (Grant 1986) famous studies of the evolution of beak depth in Galapagos finches illustrate how this works. During a severe drought, their birds evolved stouter beaks. We know this change is due to selection because the investigation showed that large, tough seeds predominated during the drought, that finches with stouter beaks were better able to crack larger seeds, and that beak stoutness is heritable. Similarly, we know that the human pelvis was shaped by selection because we understand the biomechanics of bipedal locomotion.

Evolutionary biologists are also in the habit of sub-dividing their concepts—selection especially—to create a rather diverse family sub-concepts. These include classics like Darwin's two kinds of sexual selection and many more modern concepts like frequency and density dependent selection. The reason is that experimentalists are typically concerned, like the Grants, with concrete details. The concrete cases of selection involve everything that happens to heritably varying organisms as their daily lives unfold. An incredible variety of things can and do happen, and evolutionary biologists collect similar ones together using a rough-and-ready taxonomy to cope with the otherwise overwhelming diversity.[7]

These principles should also apply to the study of memes. The rapid spread of the New World's sweet potato throughout highland New Guinea during the 1700's is easy to understand. Sweet potatoes have higher yields, and grow at higher altitudes than yams, the previous staple. People noticed these properties and avidly adopted the new crop. Here we have a causal theory that links evolved psychology (people like to be well fed) with the preference for one cultural variant over another. In many cases,

[7] Notice that we have been doing the same thing with the psychological forces that affect the distribution of representations. Attractors are different from conformity and both are different from prestige-based imitation.

however, it is difficult to predict which representations will spread because we do not understand much about the underlying psychological or ecological processes (but see for example Martindale 1971, Rogers 1995, and Taylor 1996). Why do we like particular musical forms, or literary devices? Why do some religious beliefs spread while other fail? Why do some religious beliefs spread in some groups (e.g., Christianity in Polynesia) but even while they decline in their homelands (Christianity in Europe)?

Even for technological traits, there are many puzzles like the fact that throughout New Guinea the idea of fletching arrows has never caught on, while just across the Torres Strait the idea of bows and arrow *en toto* never spread; or, why the Tasmanians abandon bone tools, clothing, barbed spears, and fishing during their ten thousand years of isolation (Henrich 2002). These questions are not unanswerable in principle, but meme theory, as it stands, seems ill equipped to tackle them. We believe constructing a full-fledged theory of cultural evolution requires considering a longish list of psychological, social, and ecological processes that interact to generate the differential "fitness" of cultural variants.

Selection does not require random variation

Many people have argued that selection cannot affect cultural evolution because cultural variation is not based on random copying errors, like genetic mutation. Instead, the argument goes, cultural changes are systematic, driven by attempts to innovate or by the cognitive machinery by which individuals make inferences about the beliefs of others, and this means selective processes are not important. For example, Pinker (1997: p209) makes this argument in the following passage:

> A meme impels its bearer to broadcast it, and it mutates in some recipients: a sound of a word, or a phrase is randomly altered. Perhaps, as in Monty Python's *The Life of Brian*, the audience of the Sermon on the Mount mishears the "Blessed are the peacemakers" as "Blessed are the cheesemakers." The new version is more memorable and comes to predominate in the majority of minds. It too in mangled by typos and speako's and hearo's, and the most spreadable ones accumulate, gradually transforming the sequence of sounds. Eventually, they spell out, "That's one small step for man, one giant leap for mankind".
>
> I think you'll agree that this is not how cultural change works. A complex meme does not arise by the retention of copying errors.

We'll agree that Pinker provides an entertaining argument that selection isn't everything. The problem is that he then concludes that it is nothing. If selection does not explain complex design in cultural evolution *by itself*, then it is of no importance. But this is mistaken. There is no doubt that as people acquire and modify beliefs, ideas, and values the variation that is generated can be highly non-random, and these non-selective processes shape cultural variation. But so what? Selection occurs anytime there is heritable variation that effects survival or reproduction (transmission). It doesn't matter whether the variation is random. In fact, genetic variation is often very nonrandom with respect to adaptation (most mutants are harmful). In cultural evolution, unlike genetic evolution, natural selection may compete with other important directional processes created by human psychology. In any given case, whether one or the other forces will predominate is an empirical issue.

As an aside, when it comes to technical change, we think that Pinker (1997: 209) overestimates the importance of conscious innovation. Innovation does not always occur when "some person knuckles down, racks his brain, musters his ingenuity, and composes or writes or paints or invents something." The history of technology and technical know-how shows that accidents, luck and happenstance play an enormous role in the evolution of technical innovations. Petroski (1992) illustrates, using the design of simple bits of technology like table forks and paper clips, how wide a variety of sub-optimal designs inventors produce before customer preference settles upon a reasonably stable design. Even then, a steady trickle of new ideas comes to the market, some to succeed, more to fail. Check out the mousetraps the next time you visit the hardware store.

Charting a Course: Foundations for unified science of cultural phenomena

In this final section we briefly sketch the essential components for a successful research program in cultural evolution and human behavior.

1. *Rich Psychology:* Two key components of psychology are of most direct relevance to understanding cultural evolution. The first involves understanding how cognition directs social learning towards particular individuals or ideas, beliefs, etc., and how cognition extracts, or make use of, the socially available information in a population. For example, evolutionary theory applied to social learning predicts that individuals should pay particular attention to skilled, successful and/or prestigious individuals. Substantial amounts of evidence support this theoretical work (Henrich & Gil-White 2001). Similarly, theory also indicates that individuals should, in the absence of decisive social information from skilled (or successful, etc.) individuals and high quality environmental information, rely on copying the majoritian behavior—conformist transmission (Henrich & Boyd 1998; Boyd and Richerson 1985). Substantial amount of evidence from psychology are consistent with this source of conformity.

The second component of psychology involve inferential and storage processes. Putting aside the issue of attention, how to cognitive process organize and interpret information coming in from the social world? The idea here is to open the black box of imitation. In acquiring something like tool-making skill, how do individuals decompose a continuous stream of behavior into steps (do minds do this?)? How do individuals infer the goals of the individual they attempt to imitate? How do the building blocks of inference (e.g., theory of mind, naïve physics, folk biology, etc.), if they exist, shape the inferences individuals draw from observing these selected cultural models. Given that public representations of underlying mental representations are nearly always incomplete, how to inference process deal with this? How inference processes deal with the range of different public representations produced by a single individual? How do some culturally acquired representations influence subsequent learning processes?

2. *Population Processes:* Knowledge of psychological mechanisms and cognitive structure is insufficient to predict the epidemiology of cultural

representation in most cases. Understanding the population-level consequences of individuals, each possessing such learning psychologies and differentially interacting, requires the construction formal cultural evolutionary models. Even with simple psychological assumptions such models have proved useful in understanding of wide range of phenomena (Boyd & Richerson 1985), including the origins of ethnic groups (McElreath et. al. 2003), the evolution of economic specialization and cooperation (Boyd & Richerson 1992; Henrich & Boyd 2001), the "clumpiness" of cultures (Henrich & Boyd 1998), the conditions for technological accumulation (Henrich 2002), and the dynamics of the diffusion of innovations (Henrich 2001).

3. *Ecological-Economic Processes*. The functionality of cultural variants may sometimes be determined entirely by psychological forces, but more commonly different variants have consequences in the environments in which people live. These consequences will often interact with psychological forces, as when economic success translates into prestige, but residual effects not accounted for by psychology are also liable to be common. The many forms of natural selection *are* candidates to influence cultural evolution and to produce cultural fitnesses that *are* close analogs to genetic fitnesses. But these effects are importantly different from those generated by psychological processes (Richerson & Boyd, forthcoming).

4. *Evolutionary Origins*: What are the evolutionary origins of the psychological capacities that give rise to cultural evolution? Understanding the origins of the psychological mechanisms discussed above goes hand-in-hand with hypothesizing what the details of those mechanisms might be. To date, we and our colleagues have explored the evolution of parent-offspring transmission, conformist transmission, prestige-biased transmission, prosocial preferences and ethnic psychology. We have also sought to understanding why human-like cultural and cognitive abilities are so rare in nature (Boyd & Richerson 1996).

5. *Gene-Culture Coevolution*: In our view one of the most important, and least explored, avenues of evolutionary inquiry in human behavior and psychology are the "Baldwinian" processes that arise from the interaction of cultural and genetic transmission. For a variety of reasons, cultural transmission changes the environments faced by human genes (Henrich & Gil-White 2001; Henrich & Boyd 2001; McElreath et. al. 2003; Richerson & Boyd 1998, 1999; Laland *et.al.* 1999). This opens novel evolutionary pathways that are not available to species that are not heavily reliant on social learning for acquiring phenotype. Human teeth, lack of body hair, digestive processes, malaria resistance and manual dexterity certainly cannot be understood with realizing that genes responded to the cultural transmission of clothing, the ability use fire, agriculture and tools. Similarly, culture has likely shaped cognition, both directly, and by indirectly by changing the selective environment faced by genes. Despite numerous physiological examples of gene-culture coevolution and a rock-hard theoretical foundation, mainstream evolutionary psychology continues to ignore the importance of such Baldwinian processes (e.g. Tooby & Cosmides 1992).

6. *Methodological Pluralism:* The theoretical and empirical demands of this program exceed those available in any one discipline. Theoretically, tools have been drawn from population genetics, communication theory, epidemiology, learning theory, statistics and evolutionary game theory. In the future, insight may come from fields as diverse as information theory and statistical mechanics. Empirically, our program demands the integration of both observational and experimental data from

psychology, economics and anthropology, as well as studies of long-term change processes from history and archaeology.

Conclusion

We believe that the Darwinian approach differs from traditional social sciences approaches in ways that are not yet fully appreciated. All five misunderstandings we describe here have a common theme. They result from a tendency to think categorically rather than quantitatively.[8] Take the meme controversy. The disputants take the main issue to be whether culture is highly analogous to genes or not. If so, then their evolution is to be explained by fitness, if not, Darwinism is useless. If we are correct, this debate is an utter red herring. The proper approach is to recognize that the analogy between genes and culture is quite loose, and to build up a theory of cultural evolution that takes into account the actual properties of the cultural system. Culture rather obviously has a much richer array of psychological processes with population level consequences than is the case for genes. But neither particular psychological forces, nor the integrated effect of all such forces, in any way rules out a role for natural selection or vice versa. The matter turns entirely on how the numbers work out in the particular case at hand. Culture, because it is nearly confined to our species, can hardly prove to be as diverse in its behavior as organic evolution. However, we expect that it will turn out to be a baroque system. The balance of evolutionary forces on culture no doubt changed with the advent of mass literacy and mass media, no doubt economically important traits differ from symbolic ones, and so forth. To paraphrase something J.B.S. Haldane is supposed to have said: Culture is not only queerer than we imagine but, as of this moment, queerer than we can imagine.

[8] Thanks to Charles Efferson for this insight.

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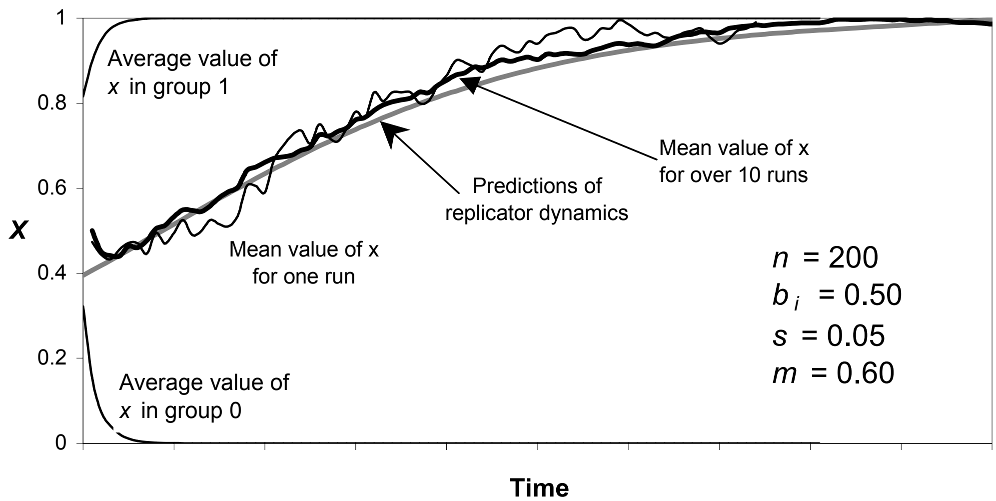

Figure 1 Results from simulating model described in text. The overall evolution of the population is very well approximated by a discrete model in which only weak selective forces are present.