

When is Similarity-Biased Social Learning Adaptive?

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Abstract

Some cultural evolution theorists claim that humans tend to imitate the traits of people who are similar to themselves—men tend to imitate men, women tend to imitate women, and so on. These theorists further suggest that selection has shaped human psychology to attend to similarities and weigh them when learning from others. The argument typically works like this: if similar people face similar problems, then learning from those people can ensure humans learn the most relevant information to solve problems they will face. Little formal evolutionary modeling has explored the conditions under which this argument is valid. This paper develops a series of models to answer this question. The general insight is that the viability of the evolutionary argument depends largely on what we assume the function of social roles to be. If, as is the default view in the cultural evolution literature, social roles facilitate coordination, then the model is not very robust with respect to the initial conditions, parameter settings, or population structure. On the other hand, if social roles facilitate the division of labour then similarity-biased learning evolves under a wide range of conditions. These results can improve our understanding of the origins of inequality. Some philosophers have proposed evolutionary bargaining models as potential explanations for inequality. These models make frequent use of similarity-biased learning assumptions. I suggest some ways to improve the research program on bargaining models in light of these results.

1 Introduction

2 Model construction

- 3 *Core results*
- 4 *Sensitivity analysis*
 - 4.1 *Random pairing rate*
 - 4.2 *The initial distribution of learning strategies*
 - 4.3 *Population size*
 - 4.4 *The ratio of playing to learning*
 - 4.5 *Spatial structure*
 - 4.6 *Summary of the sensitivity analysis*
- 5 *Conditional strategies*
- 6 *Division of labour games*
- 7 *Conclusion*

1 Introduction

Young children occupy a world surrounded by potential role models. The wealth of available information creates a problem. Different role models do different things. Children need strategies to separate the good role models from the bad ones. For many problems, it is enough to imitate the role models who are most successful. But other problems are harder. What enables success for some people is dependent on what others in the community expect of them. Crucially, different expectations are placed on different people. The success of a behavioural trait depends upon a complex and invisible network of social roles, norms, and expectations. Children need a special learning strategy to acquire just the right behaviours to act consistently with what people will come to expect of them.

Cultural evolution theorists have suggested that we engage in similarity-biased social learning to solve problems like these (Boyd and Richerson [1987]; Henrich [2016], [2007], [2003]; Wood *et al.* [2013]). We pay special attention to and tend to imitate people who are already similar to us. Of course, every pair of two people are similar and dissimilar in

numerous ways. Similarity-biased learning must be confined to certain features which play an important role in expectations, norms, and roles. Similarities associated with gender, ethnicity, and race are leading candidate features for organizing learning. On this theory, we should expect men to primarily learn from men, women to learn from women, and so on.

Evolutionary explanations have been offered for similarity-biased learning (Kinzler *et al.* [2011]). The details of the explanation differ depending on whether the target is gender, race, or ethnicity. Perhaps the clearest articulation of an evolutionary story in any of these cases comes from Henrich and Henrich's book *Why Humans Cooperate*:

Individuals have to figure out what the right norm is for getting along in their social groups, keeping in mind that different social groups culturally evolve different norms. By “right,” we mean the norm that allows the individual to maintain their reputation, avoid punishment for norm violations, and coordinate their behaviour with other members of their social group. . . .

Human psychology evolved to seek out “indicator traits” (language, dress, etc.) that match its own because people who have the same markers tend to also have the “right” norms. Using such markers, individuals can bias both their learning from, and interaction with, those individuals who share their same culturally transmitted indicator traits. (Henrich and Henrich [2007], pp.71-72)

The suggestion is that ethnicity-biased social learning is adaptive because it enables reliable transmission of social roles across generations. This explanation runs into a variety of difficulties.

Some difficulties are theoretical. If someone spends most of their time with people from their own ethnic group, they do not need a special psychological bias to pay attention to their in-group. Co-ethnics are the only people around them. Moreover, in the case where people from multiple ethnic groups are in close contact, people from other ethnic groups might have a new, useful innovation. It would be disadvantageous to ignore them (Howard *et al.* [2015]).

Other difficulties are empirical. Experiments over the last forty years have consistently demonstrated that people exhibit gender-biased social learning (Bussey and Bandura [1984];

Losin *et al.* [2012]; Perry and Bussey [1979]; Shutts *et al.* [2010]). But the experimental literature on racial- or ethnicity-biased learning contains no similarly robust findings. Some experiments find support (Kinzler *et al.* [2011], [2007]; Shutts *et al.* [2009]). Others turn up null results (Howard *et al.* [2015]; Krieger *et al.* [2016]; Shutts *et al.* [2010]). One study finds the effect in some conditions but not others (Buttelmann *et al.* [2013]). If there was some general story about why evolution should favour similarity-biased learning in both cases, one should not expect the two experimental literatures to generate such a different patterns of results. As the experimental literature stands, at least arguments for the evolution of ethnicity-biased learning deserve to be reconsidered.

There has been little effort to formally model the conditions under which similarity-biased learning is evolutionarily adaptive. This is surprising given the tremendous effort dedicated to modeling and testing theories of the evolution of success-biased, conformity-biased, and prestige-biased learning (Boyd and Richerson [1995]; Henrich and Gil-White [2001]; Henrich and Boyd [1998]; Henrich and McElreath [2003]; McElreath *et al.* [2008]). Instead, the literature contains a variety of informal arguments like the block quote above. The informal arguments provide little guidance on how to assess the difficulties. Given the complexity of human societies, it is difficult to verbally reason through the consequences of interacting evolutionary factors (Mayo-Wilson and Zollman [2021]; Smaldino [2020]). This paper rectifies the situation by developing a series of agent-based models to study the evolution of similarity-biased social learning. The general insight is that the viability of the evolutionary argument depends largely on what we assume the function of social roles to be. If, as is the default view in the cultural evolution literature, social roles facilitate coordination, then the model is not very robust with respect to the initial conditions, parameter settings, or population structure. Making small changes to these assumptions can collapse the explanation. On the other hand, if social roles facilitate the division of labour then similarity-biased learning evolves under a wide range of conditions. These results suggest we should be cautious about claims suggesting there is a universal, evolved tendency towards similarity-biased learning.

Developing a better understanding of similarity-biased social learning supports an existing research program in philosophy. Philosophers have turned to bargaining models to generate

possible explanations for the emergence of inequality (Amadae and Watts [2022]; Bright *et al.* [Forthcoming]; Bruner [2019]; Mohseni *et al.* [2021]; O'Connor [2019], [2017]; O'Connor and Bruner [2019], [2017]; O'Connor *et al.* [2019]; Popa and Muehlenbernd [Unpublished]) Under a variety of conditions, representing inequalities in power or demography, it is possible for two populations to develop a stable pattern of exploitative relations. Many of the cited models assume that people engage in gender-biased or racially-biased forms of social learning¹. However, it is often unclear in these papers what justifies this assumption. O'Connor's book, ([2019], p.67), *The Origins of Unfairness*, offers the most explicit justification of this assumption and appeals to the evolutionary reasoning offered by Henrich and Henrich. The line of argument seems to be this: we evolved similarity-biased learning to handle coordination problems. In turn, that bias shapes how we learn bargaining behaviours and creates the conditions for durable inequality. It is worth investigating whether philosophers working on inequality should help themselves to the evolutionary argument or whether there are better ways to justify their models. The end of this paper sketches some suggestions for how research into bargaining-driven explanations of inequality could improve going forward.

2 Model construction

Imagine two ethnic groups settle into a valley. Each group has a distinctive style of greeting. The first group bows while the second group hugs. Most of the time, individuals just interact with members of their own group. In those cases, greetings are smooth and uneventful. Occasionally, people from different ethnic groups will encounter each other. It is deeply awkward to move in for a hug while the other person bows. This is a case of failed

¹Not all of these papers need to assume biased social learning to achieve their core results. For example, the seminal paper by Axtell, Epstein, and Young assumes individualistic learning mechanisms and generates exploitative conventions ([2007]). Abandoning social learning as an interpretation of the bargaining models introduces tradeoffs, however, as we have good reason to think humans rely more heavily on social learning than individual learning (McElreath *et al.* [2008], [2005]).

coordination—a custom that is supposed to be nothing more than a prelude to a conversation has become a source of mutual embarrassment. The greeting problem is an instance of a general class of coordination games. Coordination games have this characteristic payoff table:

	A	B
A	1,1	0,0
B	0,0	1,1

The basic problem in coordination games is knowing what your partner will do. If players have no extra information beyond the table, they are left guessing as to whether their partner will play A or play B. If they guess wrong, they fail to coordinate. Philosophers have long noted that social conventions can provide the missing information by specifying one equilibrium to be the expected one (Lewis [1969]; Schelling [1960]; Skyrms [1996], [1990]). Cultural evolution theorists have followed suit and argued that we culturally evolved ethnic markers (distinctive styles of fashions, makeup, tattoos, etc) to help solve coordination problems. Ethnic identities function to settle coordination problems in advance by specifying the particular operative convention in this community (McElreath *et al.* [2003]). Most obviously, ethnicity helps settle whether the conventional greeting is bowing or hugging. A huge variety of other coordination problems are also settled via ethnically-specific conventions: what language to speak, what dialectic to use, what slang to use, what currency to offer, whose family should offer the marriage dowry, what taboos to avoid, and so on. If altruistic punishment theories of cooperation are to be believed, the class of coordination problems is far larger, as social dilemmas are transformed into coordination problems by the threat of punishment (Henrich and Henrich [2007]; Boyd *et al.* [2003]).

This game provides a foundation for building a model of the conditions under which similarity-biased learning can evolve. Suppose that the two imaginary ethnic groups are composed of a large, finite number of players². Each player is equipped with a strategy. In the

²Concentrating on ethnicity first provides a conceptually tractable entry point into thinking about similarity-biased social learning. However, this paper is interested in a broader phenomenon. For example, similarity-biased social learning also manifests in gender. Section

first version of the model, players have only two behavioural strategies for the coordination game. They can either play A or they can play B. These correspond to always bowing or always shaking hands. Section 5 explores a version of the model in which players can adopt conditional strategies, where players vary their greeting depending on the ethnic marker of their partner. For now, the model assumes players only have access to simple strategies.

The model evolves over a series of rounds. Each round, the players pick a partner. With some probability, that partner is a random player from their group. Otherwise, the partner is selected at random from the whole population. Then they play the coordination game with their strategy and receive a payoff³. The probability of in-group pairing represents the fact people tend to interact with their own ethnic group more often. This might be due to a psychological preference for in-group members (Henrich and Henrich [2007]; McElreath *et al.* [2003]). But the probability could also represent the fact that people who live in the same place will encounter each other more often and ethnic groups tend to live in the same place.

Each individual must reliably identify which strategy they should adopt. They can pursue two learning strategies. They might only learn from people of their own ethnic group. This represents a type of similarity-biased learning. Or, they might learn from whomever they encounter. Regardless of how they select partners, players imitate using ‘pairwise difference imitation’ (Izquierdo *et al.* [2019]). In each round, each player selects a partner, calculates the difference between their own payoff and their partner’s payoff. If the learner’s payoff is greater than their partner’s, then the learner keeps their original behaviour. Otherwise, they imitate their partner’s behavioural strategy with a probability proportional to the difference. The probability of imitating is given by,

6 argues that the model can be abstracted away from interpretation in terms of ethnicity and generalised to any social roles which facilitate coordination.

³Players only record payoffs from coordination games they initiate. In subsequent actions on the round, only one payoff is used to inform learning. This simplifying assumption can be dropped such that players who are selected more than once in a round will use the sum of those coordination games to inform learning. Qualitatively similar results can be achieved with this model.

$$p = \frac{\pi_1 - \pi_0}{\max \pi}$$

where π_1 is the partner's payoff, π_0 is the learner's payoff, and $\max \pi$ is the largest possible payoff. This learning dynamic closely approximates the behaviour of the famous replicator dynamics but in an agent-based context (Izquierdo *et al.* [2019]). For most of the simulations studied below, payoffs are either zero and one so this equation just reduces to the simple rule 'copy the partner if they did better than you. Otherwise, do nothing'. When the payoffs can take a wider range of a values, the degree of differences matters.

To identify the correct learning strategy, players also employ a second-order adaptive process. Learning strategies that tend to lead people to successful strategies are more adaptive. On each round, players select a new random partner⁴. They apply the pairwise difference imitation rule again. The difference is that they copy the learning strategy instead of the behavioural strategy.

There are a variety of ways to interpret this second-order adaptive process. The first option is to treat similarity-biased learning as the outcome of natural selection on genes. This is the route the Henrichs take ([2007]). The second option is to treat it as kind of second-order social learning (Birch and Heyes [2021]). People learn how to learn by observing others⁵. Although second-order social learning is an under-explored topic, some empirical evidence suggests that it is prominent in human societies (Mesoudi *et al.* [2016]). Plausibly, some combination of natural and cultural selection are at work. In theoretical research on the evolution of learning

⁴Normally, the second-order social learning process is indiscriminate. Players can learn their learning strategy from anyone. But some simulations were attempted where the second-order social learning process was tied to ethnic markers. Qualitatively similar results were found.

⁵This interpretation may seem implausible at first glance. Given that learning is not externally visible, it may be difficult to directly imitate the mechanisms by which others learn. However, consider the case where a teacher directs the students' attention to another exemplary student. If the students respond by trying to imitate the exemplar, they are using a kind of second-order social learning.

strategies, the standard methodological choice is to remain agnostic about what precise mechanism implements the learning strategy (Hoppitt and Laland [2013]). It simply does not matter at the level of representation found in these models. The model is merely committed to the claim that if there is a trait for similarity bias in social learning and selection could act on it, then we should expect it to grow in the population.

In constructing this model, I have not tried to motivate each assumption as realistically depicting some historical situation humans actually faced. Many assumptions are simply convenient. It is worth clarifying how a model constructed in this way can advance scientific understanding. The aim is to move from the simple verbal arguments already offered in the literature to a set of simple formal arguments. The first step is to construct any plausible model where Henrich and Henrich's argument works. As such, I have helped myself to assumptions (two groups start with uniform, distinct behaviours, groups are of the same size) that give similarity-biased learning a good chance of evolving. With a model in hand, one can identify implicit assumptions that need to be filled out for the argument to go forward. Then one can work backwards, asking which of these assumptions are necessary and which are well-motivated by our best historical sciences.

To summarize, the initial conditions of the model are:

- There are two groups of equal finite size.
- Players from each group begin with a distinctive behavioural strategy. All players from one group will begin with strategy A. Players from the other group will begin with strategy B.

The dynamics of the model are⁶:

- **Play.** Pick a partner. With some probability, the partner is a member of the same group. Otherwise, they are picked at random from the entire population. Play the coordination game and receive a payoff.

⁶The model was coded in Netlogo. The data analysis was done in Python. Code for both parts is available at <https://github.com/daniel-saunders-phil/dowry-game>

- **Learn.** Pick a partner. If the learner is using a similarity-biased learning strategy, they pick a partner that shares their group identity. Otherwise, they pick a random partner. They copy the partner's behavioural strategy with probability proportional to the difference in payoffs.
- **Learn learning strategy.** Pick a partner. Copy the partner's learning strategy with probability proportional to the difference in payoffs.

3 Core results

The Henrichs suggested that similarity-biased learning strategies are adaptive because they help agents select the 'right' behaviours, where 'right' is defined by ethnically-specific conventions. The model provides a partial vindication of their argument. In some runs of the model, the population evolves toward uniform similarity-biased social learning. Every player only learns from others in their group. This stabilises the ethnically-specific greeting conventions. One group always bows and the other group always shakes hands. Call this the distinctive strategy outcome.

In these runs of the model, similarity-biased learning is adaptive because it steers players away from picking up the other group's greeting. Suppose one individual meets someone from the other group. Given the initial strategy assignment where one group plays A and the other group plays B, this pair will likely fail to coordinate. The defeated player will then be in the market for a new strategy. If they lack the similarity bias, they may observe someone from the other group and adopt their strategy. But this would likely be a mistake. If most of their future interactions will be with in-group members who use a different greeting, switching to the other group's greeting will be disadvantageous in the long run. Thus, selection encourages the growth of the similarity bias to prevent just this scenario. This finding indicates that the model is a charitable, formal reconstruction of the Henrichs' argument.

However, another stable state is possible for the population. The groups could assimilate. All players can simply adopt the same greeting, regardless of the group they belong to. To appreciate how this outcome arises, reconsider the scenario sketched above. This time, imagine our failed coordinator adopts the other group's characteristic behaviour during the

same round that a large number of other people in their group make the same choice. If enough players flip strategies, then playing the most popular strategy across groups is more advantageous than playing the ethnically-specific strategy. This can create a cascade of selection pressure toward the most popular strategy. As more players adopt one greeting, it becomes increasingly important for others to adopt that greeting. In this case, similarity-biased social learning is disadvantageous. It leaves players slow to adopt the most popular strategy. Once a single coordination strategy is adopted uniformly, selection pressure stops. It does not matter how players learn because everyone coordinates on every interaction and everyone has the same behaviour. This is a surprising insight that pushes against simple evolutionary arguments for learning strategies, the kind of insight that only becomes visible in light of formal modeling.

These are the only two possible stable states for the population. Notably, the assimilation outcome generates a higher average payoff for individuals. In the distinctive strategy outcome, players will fail to coordinate whenever they play with people from the other group. The assimilation outcome does not have this feature. Everyone is doing the same thing so coordination failure is impossible. Given that the assimilation outcome has a higher payoff, one should expect it to be more evolutionary attractive, all other things being equal. To reliably generate the distinctive strategy outcome, it is necessary to make further assumptions about the population structure and parameter values. The question, then, is what features control whether assimilation is more or less likely than the distinctive strategy outcome. Understanding the answer to that question will provide a theoretical understanding of when similarity-biased social learning is adaptively advantageous.

Section 4 explores the sensitivity of the model across a range of parameter settings and structural assumptions. A general theme emerges. The distinctive strategy outcome tends to emerge whenever additional features are added to the model to slow the possibility of assimilation enough that the learning bias has time to emerge. However, these additional features raise two new problems. First, the more specific the modeling assumptions need to be, the less generally the model can be applied. We do not know the true parameter values in historical human societies. Nor should one expect any one population structure or

combination of parameters to be the ‘correct’ one for characterising the broad swath of human societies. Second, the very same features that slow assimilation also often weaken the overall force of selection. This raises concerns about whether non-adaptive forces such as mutations, drift, or migration might swamp selection. If that is the case, this type of adaptive explanation has limited explanatory power for human learning strategies.

4 Sensitivity analysis

4.1 Random pairing rate

The model assumes that people have a higher probability of interacting with people from their own group. This is controlled by the random pairing parameter. When it is low, people pair almost exclusively with in-group members. When it is high, players only have a slight preference for in-group pairing. The random pairing parameter has a large impact on whether similarity-biased learning is adaptive. It is beneficial to learn the in-group behaviour if most interactions happen within the group. Otherwise, it is more beneficial to seek out the most popular coordination behaviour. Figure 1 depicts the results of a sensitivity analysis exploring how variation in the random pairing parameter impacts how often the distinctive strategy state emerges.

The probability that the learning bias emerges declines rapidly as pairing with the out-group becomes more common. This fact, taken alone, suggests some limitations on the adaptive explanation but is not too concerning. After all, it does make good sense to think people largely interact with their own group. However, frequent in-group interaction also dampens the strength of selection. If players coordinate most of the time, they have little need to explore new behavioural strategies. Learning, similarity-biased or not, will occur rarely in a population with little random pairing. One indication of the strength of the selection is the number of rounds it takes for the model to reach a stable state. When selection is weak, it takes much longer.

Inspection of figure 1 alongside figure 2 suggests a dilemma: when the distinctive strategy state is most likely, selection is at its weakest. But when selection is weak, other non-adaptive forces can play a determining role. Forces like migration and mutation can introduce random

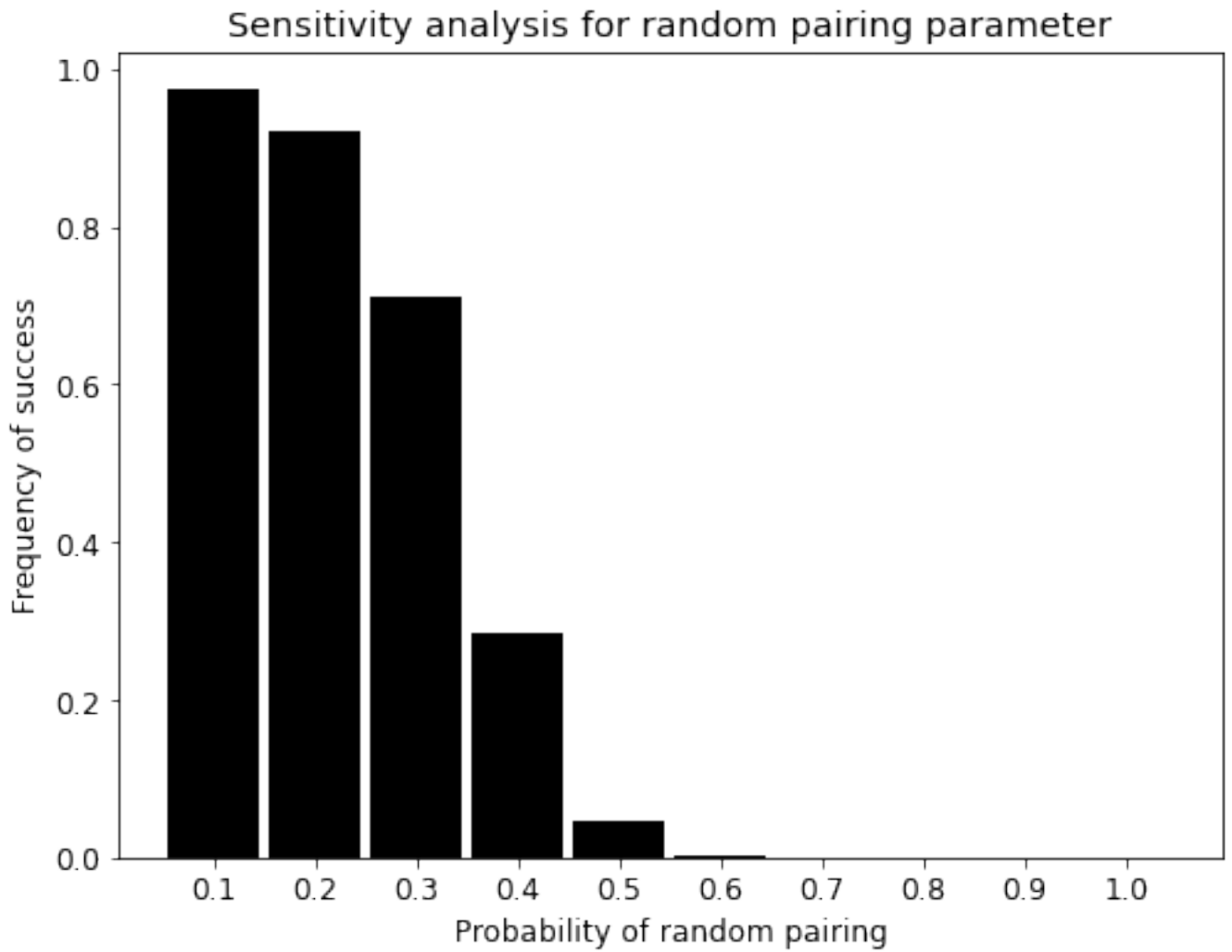


Figure 1: Bar heights represent the frequency of simulation experiments that ended in uniform similarity-biased social learning. 500 trials were conducted at each 0.1 increment of the random pairing parameter between 0 and 1. The results show similarity-biased social learning is more likely to evolve when most interactions take place within the group.

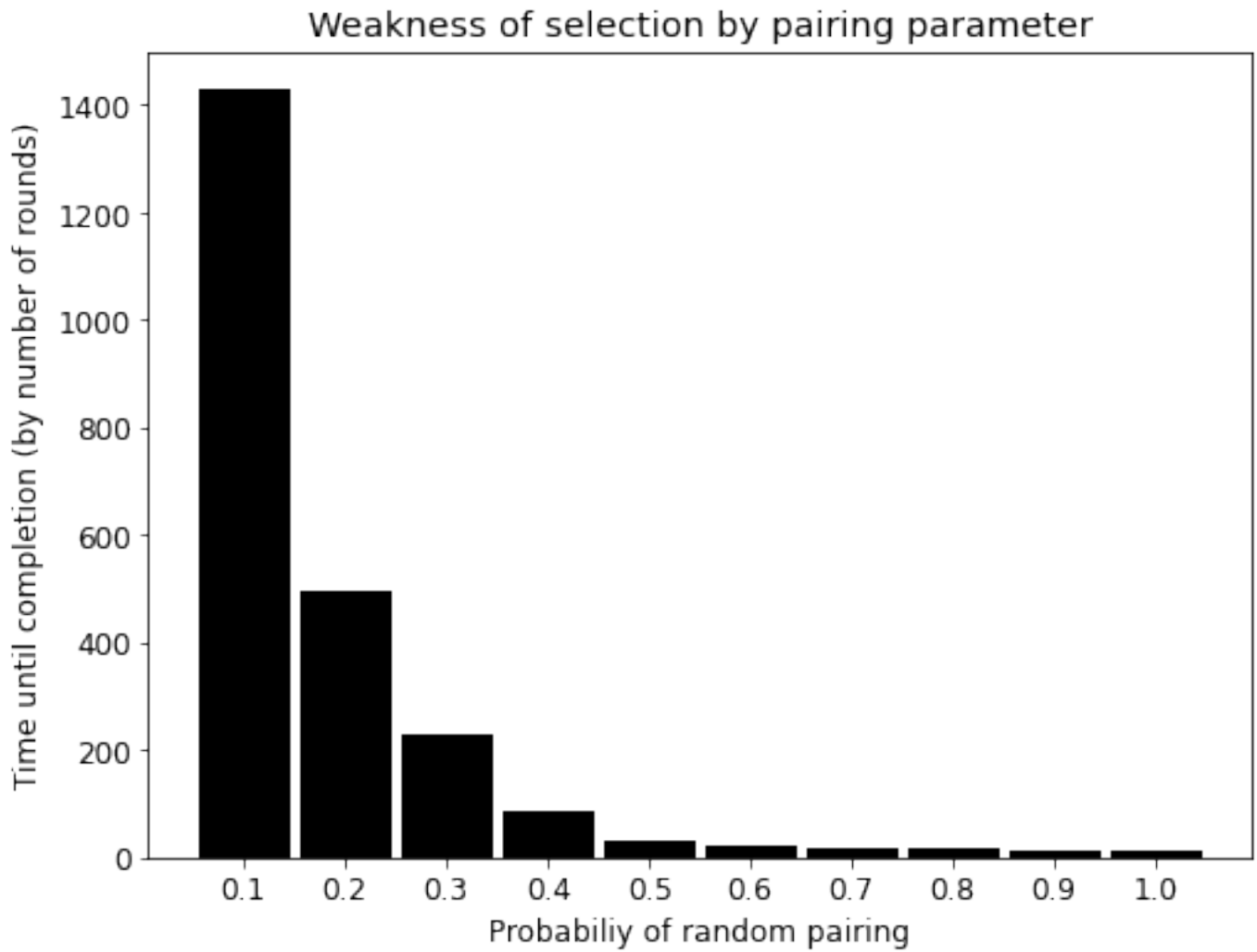


Figure 2: Bar heights represent the average number of rounds it takes the model to reach a stable state, either the distinctive strategy outcome or the assimilation outcome. These data were extracted from the same experiments depicted in figure 1. As random pairing decreases, the model takes exponentially more time to reach a stable state. Tall bars indicate weak selection.

variation into the distribution of strategies and pull the population toward assimilation. As an empirical generalisation, in small, non-isolated, human populations the force of migration is typically stronger than the force of selection (Boyd *et al.* [2003]; McElreath and Boyd [2007]).

4.2 The initial distribution of learning strategies

When the population is initially generated, some frequency of the learning bias is already present. In the previous section, the model fixed half the players to start with the learning bias. It turns out that a high level of initial bias is necessary for the distinctive strategy outcome. If the population starts with low frequency of the learning bias, assimilation becomes more likely. Figure 3 depicts how often similarity-biased learning evolves across a range of initial frequencies.

This effect arises because a high level of learning bias is necessary to prevent fast assimilation. If too many players begin copying behavioural strategies from the other group, then that behaviour may become popular in both groups. In turn, it becomes more advantageous to learn the most popular strategy rather than the ethnically-specific one. By contrast, if most people already learn from their in-group, then behaviours tend to cluster tightly with ethnic groups and it is more advantageous to conform to the ethnically-specific convention.

The strong sensitivity of the model to the initial conditions is troubling for evolutionary explanations. If the trait does not tend to evolve when it is rare, it is hard to understand how it ever became common in the first place⁷.

4.3 Population size

The model assumes the two ethnic groups are of equal size. In the historical record, this assumption is likely never satisfied. When two different ethnic groups come into contact, we should expect one to be larger than the other, sometimes significantly so. Demographics

⁷It is possible that the trait arose through exaptation - a similar psychological trait evolved for one reason but was repurposed to modify learning. While plausible, this story remains to be told in the scientific literature.

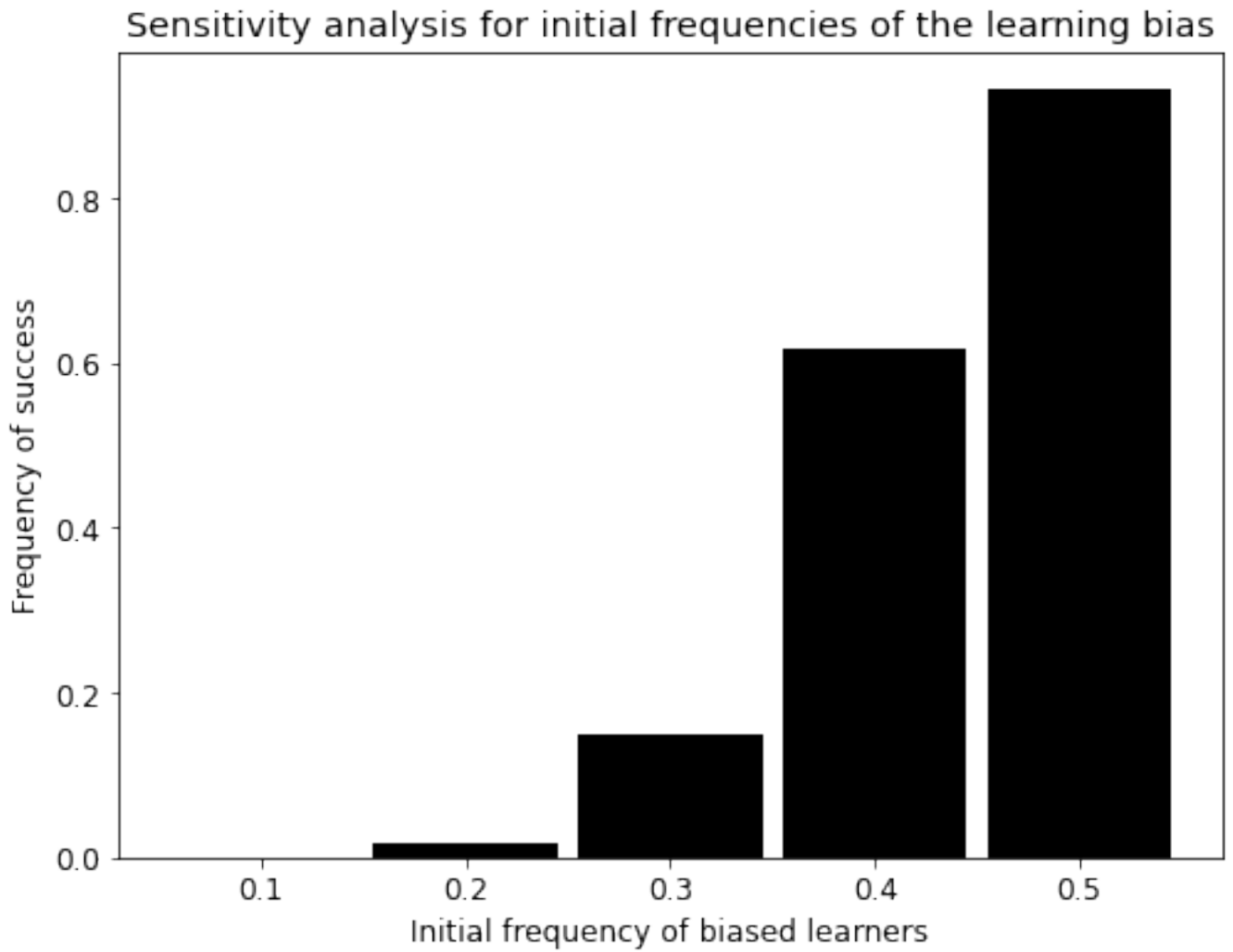


Figure 3: Bar heights represent the frequency of simulation experiments that ended in uniform similarity-biased social learning. 500 simulations were run at each parameter value. The random pairing parameter was set to 0.2. As the initial frequency of the learning bias decreases, so does the probability that learning bias will spread.

differences should have a large effect on the evolution of ethnicity-biased social learning. In the prior simulations, assimilation outcomes result because players find it more advantageous to pick a strategy that enables coordination with the most number of people rather than pick a strategy that just enables coordination with their co-ethnics. When one group is larger than the other, the draw of assimilation is stronger. Adopting the behaviour of the larger group ensures players can coordinate with more people.

Simulations confirm that introducing unequal population sizes hampers the evolution of the learning bias. Figure 4 depicts a simulation experiment where one group was 55% of the total population. To facilitate clear comparisons, it displays the same information as figure 1, the sensitivity of the model across pairing parameters. For all parameter values, the frequency of successfully evolving ethnicity-biased learning decreases⁸.

4.4 The ratio of playing to learning

The model assumes that players play once and learn once in each round. This assumption is fairly arbitrary. Players could go through many interactions before they consider changing their behavioural strategy. Adjusting the ratio of playing to learning could represent how stubborn or open-minded the players are. They might keep their strategy over the course of many interactions and only consider giving it up if it proves disadvantageous in the long run. The model was modified so players would execute n play actions per round and only one learn action. They would repeatedly select partners, interact, and receive payoffs. Both learning processes were modified so players compare the sum of payoffs across n interactions.

⁸One effect of adjusting the population size is that it also skews the initial ratio of behavioural strategies. I also conducted a sensitivity test that explores the effect of the initial proportion of behavioural strategies more directly. Rather than change then number of people in each ethnic group, some players from one group start with the 'wrong' behaviour. The result is the same as adjusting the population size. Similarly, if the model randomly sampled initial strategies, it would hurt the probability of selection for ethnicity-biased learning. Whenever one behaviour is substantially more common than the other, assimilation tends to result.

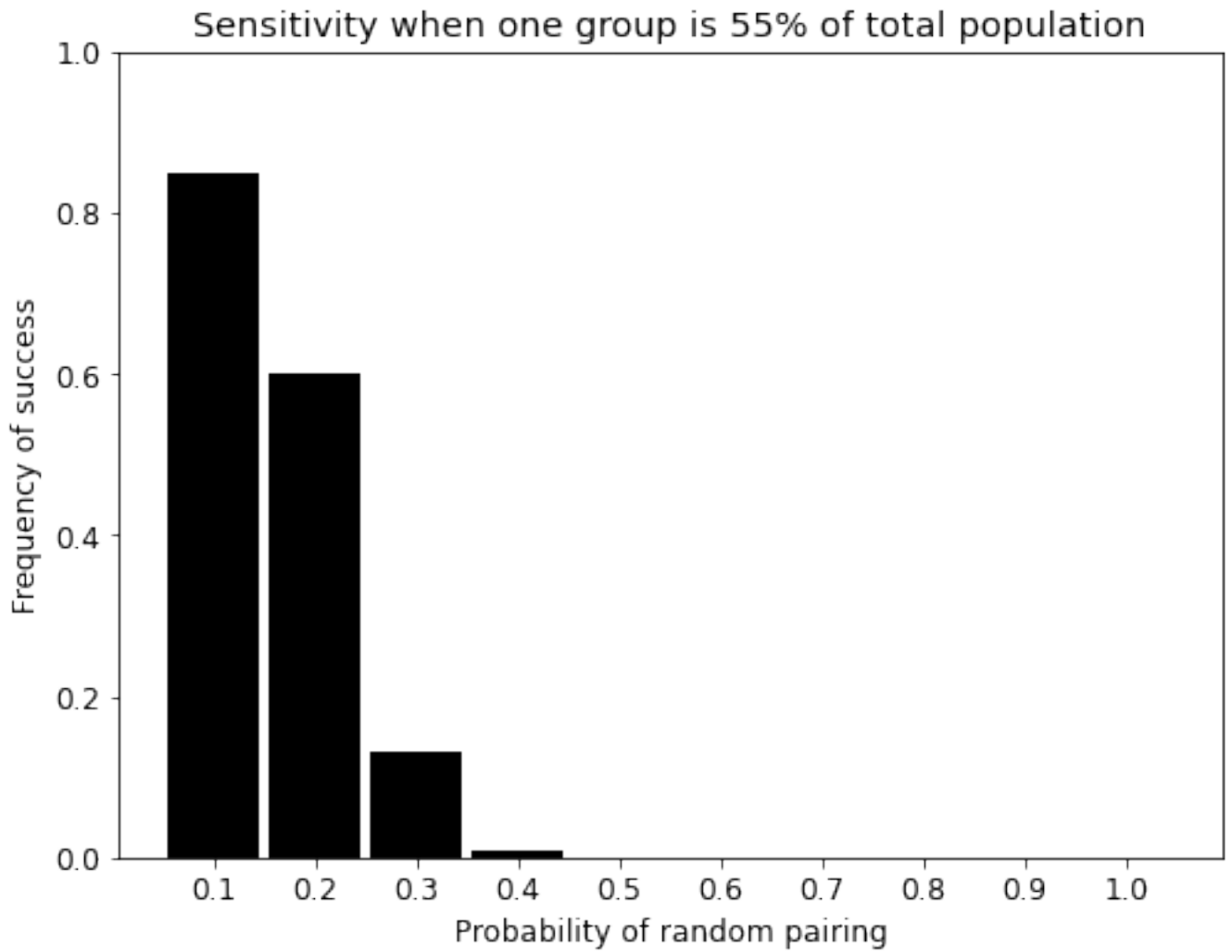


Figure 4: Bar heights represent the frequency of simulation experiments that ended in uniform similarity-biased social learning. 100 simulations were run at each parameter value. The initial frequency of the learning bias was set to 0.5. Comparison with figure 1 reveals unequal population sizes have a substantial negative impact on the probability of success.

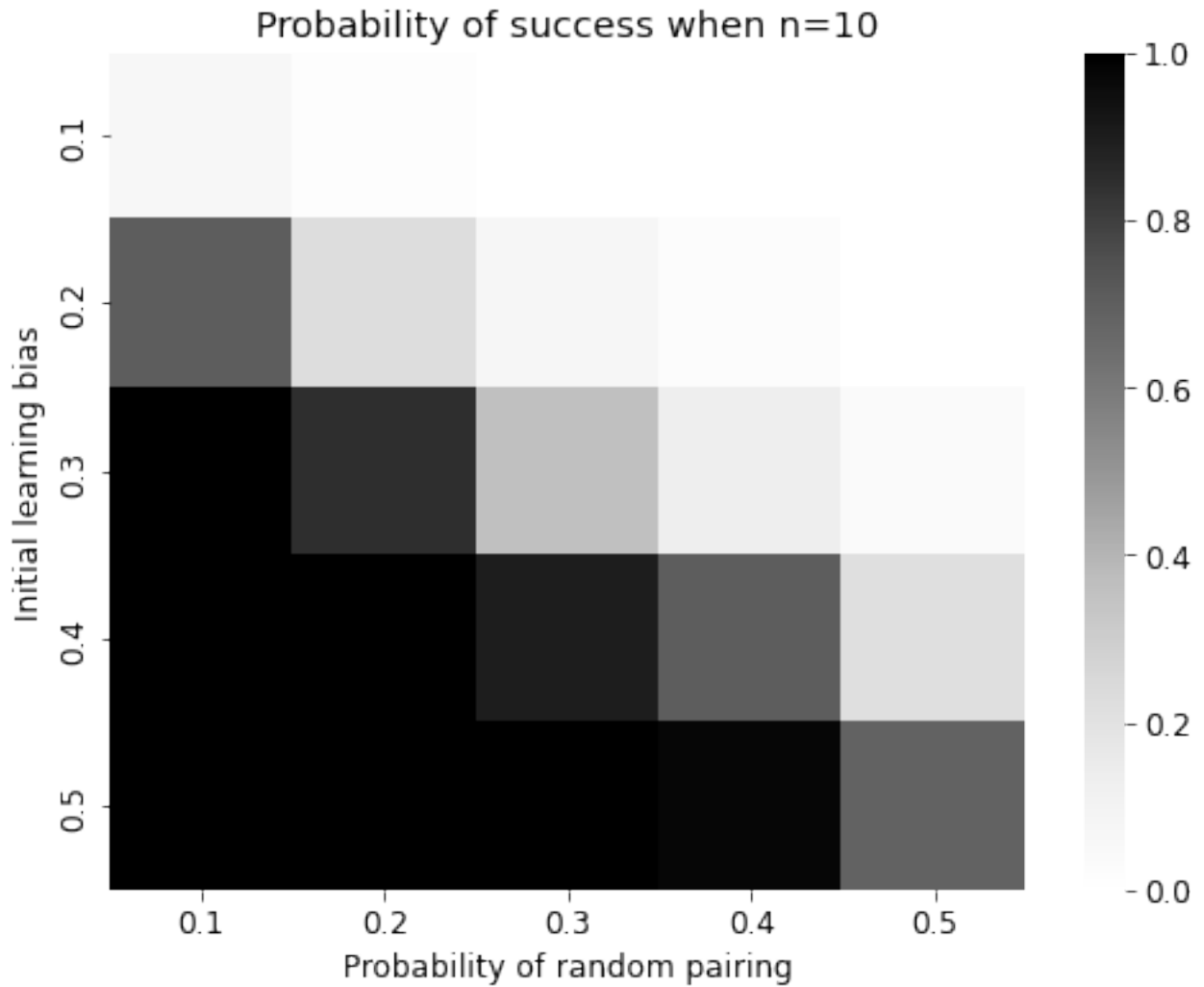


Figure 5: The heatmap represents the frequency of simulation experiments that ended in uniform similarity-biased social learning. Light colours represent high frequency while dark colours represent low frequency. 100 trials were conducted at each pair of parameter values. The figure suggests a high n improves the overall frequency of successful trials, although its effect is limited when the initial frequency of learning bias is close to 0.1.

Unlike the previous sensitivity tests, this modification improves the probability that similarity-bias learning emerges. When players play more often, there is a higher penalty for picking up the other group's behaviour. Given that most interactions still occur within the group, picking up the other group's behaviour will lead to coordination failure in most interactions. Changing the ratio also slows down the rate of assimilation. Assimilation outcomes depend on the possibility of players flipping en masse. When out-group learning is so heavily penalised, few agents will be inclined to flip.

Figure 5 depicts how the results of the two previous sensitivity analyses change when

$n = 10$. The figure demonstrates that increasing n can facilitate the evolution of similarity-biased learning at higher rates of random pairing. Increasing n can also push back against the problem of initial conditions but only to a modest degree.

The results point to a way forward for evolutionary explanations of similarity-bias learning. If we make the plausible assumption that people interact at a faster rate than they learn, it alleviates some problems the original model faced. However, one should be cautious about hanging their hat on any specific set of parameter values. It is not at all clear how we might decide what the right ratio of playing and learning is. Moreover, the bias is still not usually selected for when it is rare, leaving that challenge unsolved.

4.5 Spatial structure

One lesson has become clear: when it is too easy to adopt the neighbouring group's behaviours, assimilation is likely. If there was some additional feature of the model that could slow the assimilation process, it might give similarity-biased learning a better chance to survive. A spatial structure could serve just this role. Suppose the population is laid out on a grid and they can only play with and learn from the eight players around them. This generates a kind of 'ethnic-frontier' where players from each group can interact with the out-group. Players at the border have to progressively flip for assimilation to occur.

Introducing spatial structure induces two simultaneous effects. First, it decreases the rate of cross-group interaction. For most agents, they have no neighbours of the other ethnic group so they still pair with the in-group no matter the level of random-pairing. Only agents who live on the frontier have a chance of interacting across ethnic groups. Second, it spatially concentrates selection activity. If ethnicity-biased social learning has higher fitness, it has fitness because border agents benefit from it. Agents who are spatially removed from the frontier might adopt ethnicity-biased social learning only by observing its fitness-enhancing effects on others.

Spatial structure does not change the basic problem confronted by non-spatial models. It merely provides an alternative way of pushing the effective random-pairing parameter down. Pushing it down structurally certainly makes the evolution of ethnicity-biased social learning more likely across a wider range of pairing parameters. But it amplifies the problem of weak

selection. Given that spatial structure limits selection activity, it also takes the model far longer to converge to a stable state.

4.6 Summary of the sensitivity analysis

Formalising the Henrichs' argument illuminates a variety of limitations. First, in all versions of the model explored, learning bias is selected against when it is rare. If the trait arose through selection, it must have spread through a group via mutation and drift when a group was isolated. Later on, if two groups come into contact, similarity-biased learning could be propelled throughout the population. This explanation is fragile. If things do not go just right, the learning bias is weeded out of the population.

Second, there is a general dilemma for this style of explanation. When selection pressure is strong, assimilation is likely. The assimilation state has the higher average payoff so uncontrolled selection will usually end there. One could introduce other factors that slow the assimilation process. But those same factors weaken selection. This raises problems with whether non-adaptive forces might overwhelm the force of selection. Spatial structure is a good illustration. Introducing spatial structure helps keep groups distinct while taking the burden off of social learning biases. But taking the burden off learning also takes away the incentive to improve learning strategies.

There are countless other ways to modify the population structure. The above argument provides some reason to be skeptical that there is an unexplored model which provides a clear and consistent narrative for the evolution of similarity-biased social learning, at least for coordination games. Modifications will either increase selection pressure or decrease it. Either direction raises its own challenges. At any rate, the more specific the population structure needs to be, the less generally applicable the model is. Ethnic groups have co-existed in a huge variety of ways across history. No one population structure should be taken to be the uniquely representative model.

5 Conditional strategies

In the original model, players can only adopt one behavioural strategy for coordinating. They cannot learn to adopt different strategies for different communities. This assumption is quite silly in some contexts. It is as if learning to bow would cause you to forget about hugging. Of course, people can learn the customs necessary to live in two communities. Bilingual people solve coordination problems in two different ways, depending on who they are speaking with. The model can be expanded to incorporate conditional strategies. Agents now modify their strategy based on whether they play with an in-group agent or an out-group agent.

As before, the model aims to represent a situation in which two ethnic groups have already developed a stable in-group convention. This is implemented by setting the two groups to have distinct and uniform initial in-group behaviours. However, they face uncertainty about what is the best out-group behaviour. This is represented by randomising the initial out-group component of their strategy. The two learning strategies are similarly modified. Some players only observe in-group members and others observe players indiscriminately. Deploying the same pairwise difference imitation rule, they copy the whole package of in-group and out-group behaviours. The end of this section explores a model in which players are selective about what parts of the behavioural package they hope to imitate.

Introducing conditional strategies shifts the set of evolutionary problems for ethnicity-biased social learning. First, assimilation outcomes are still possible. The population could decide that conditioning is not worth the effort. If everyone adopts the same behaviour, that is just as good as adopting a complex coordination convention. Second, the distinctive strategy outcome looks substantially different in this setup. Each group can have their own particular convention they utilize when interacting with themselves while having a shared convention they utilize when interacting across the groups. Players are not forced to choose between assimilation and forgoing coordination with the other group. They can develop a pair of behaviours that ensures coordination with everyone. The result is like a *lingua franca*. The scientific community has adopted English as the shared international language for publication. But scientists will continue to speak their native language with others from their community.

The possibility of having two conventions (one for in-group interaction and one for

out-group interaction) can reduce selection on learning strategies. Every learning strategy has the same payoff once the conditional distinctive strategy outcome is achieved. Speaking English with scientists and English-speakers is just as good as speaking English with scientists and Spanish with Spanish-speakers. Everyone always successfully communicates because coordination is too easy. But selection only operates when there is variation in the fitness of traits. If a behavioural convention is established before ethnicity-biased social learning has a chance to spread through the population, then everyone coordinates all the time. Selection on social learning stops in this scenario.

These considerations suggest that, perhaps counter to intuition, introducing conditional strategies hurts the chances for the evolution of ethnicity-biased social learning. Now there are two sequential evolutionary problems to confront. First, the population has to maintain distinctive group behaviours against the pressure toward assimilation. Simulations show that populations accomplish that at a similar rate to the original, unconditional strategies model and experience similar sensitivities to parameter values. Second, if the population develops a pair of behavioural coordination conventions, it eliminates selection for learning strategies altogether.

There is one scenario that offers a potential, but ultimately unsuccessful, path for the evolution of ethnicity-biased social learning. Suppose two groups have well-established behavioural conventions and a newcomer migrates into one of the two groups. The newcomer has an incentive to learn the conventions quickly. If they learn from the players in the other ethnic group, they will systematically fail to coordinate with their in-group members. Newcomers can be represented in the model by adding a small probability that players adopt random behavioural strategies on each round. These small probabilities could represent mutations in the genetic basis of behaviour, random behavioural experimentation, or the migration of naive players into the environment.

Over time, mutations can create positive selection for the learning bias and eventually drive it to spread through the whole population. However, selection under these conditions is very weak. When there is only a low rate of mutation, there is little opportunity for selection to favour ethnicity-biased learning. Arguments built on weak selection should not be reassuring

to a proponent of ethnicity-biased social learning. Adding a small mutation rate for learning strategies counteracts the effect of adding a mutation rate for behavioural strategies and pushes the distribution of learning strategies into a random walk.

When there is a larger rate of mutation, selection is stronger but assimilation outcomes, once again, become more likely. Newcomers enter the community very quickly and can disrupt the existing conventions within a group. Once the initial cohesion of in-group behavioural conventions dissolves, the population moves toward the assimilation state. If there is little correlation between behaviour and ethnic group membership, the best course of action is to adopt the most popular coordination behaviour. Assimilation has a certain evolutionary gravity that is hard to escape. At this point, the pattern of arguments should be familiar - ethnicity-biased social learning can, in principle, evolve by selection but only if it strikes just the right balance in terms of parameter values and good luck.

Despite all the permutations of the core model explored so far, the kind of learning strategies these artificial agents deploy are fairly simple. It is possible that fairly sophisticated learning strategies that incorporate ethnic information may be selectively advantageous under very general conditions. Birch and Heyes suggest many social learning biases are explicit rules of thumb of the form, ‘find individual X, Y or Z to observe the manufacture of cleavers, and individual A, B or C to observe the manufacture of handaxes’ ([2021]). A version of ethnicity-biased learning may take a similar form⁹. Throughout this section, players have learned conditional strategies as a package—when they decide to imitate another player, they copy both the in-group and out-group behaviour. But, plausibly, it is better to learn the in-group behaviour from in-group members and the out-group behaviour from out-group members. Players would learn how to interact with a type of person by imitating only the behaviour relevant to interacting with that type.

Despite the intuitive appeal of this learning strategy, it does not alter the basic evolutionary

⁹It is worth noting that this sort of learning bias has a very different structure than the one suggested by Henrich and Henrich. They seem to suggest ethnicity influences who we attend to. When players learn with this strategy, they can attend to anyone. They are just selective about what information they pick up.

problems explored throughout this section. Assimilation remains an attractive outcome when the level of initial learning bias is not strong enough. Similarly, if behavioural conventions develop too quickly, they dampen the force of selection on learning strategies. Coordination is easy with or without the learning bias. Finally, adding mutations can reintroduce selection but only a very weak kind that can easily be disrupted by other forces.

6 Division of labour games

The original motivation for this paper is to understand similarity-biased social learning in general. Yet the preceding discussion focused exclusively on ethnicity-related interpretations of the bias. This limited focus provides a tractable entry point into thinking about the evolutionary dynamics around learning strategies. But it ignores the possibilities of gender-biased and racially-biased social learning strategies. This section considers how one might generalise this model to thinking about other forms of similarity-biased learning.

There is nothing about the model that is intrinsically tied to ethnicity. The model is an abstract computational algorithm that can be interpreted in various ways. The same model could be interpreted to apply to gender or race. Whether this application is appropriate or not depends on whether coordination games represent some function of gender or race that is important. Suppose there was some strategic problem in which men need to coordinate with other men and people of the same sex tend to interact more often. Then it might be advantageous to have a special learning strategy that transmits strategies amongst the men in a community. This is one way of building out an evolutionary explanation for gender-biased social learning. Given the above discussion, this explanation requires a variety of other, strong assumptions and does not seem like a very promising path.

There is another story one might tell about gender. O'Connor argues that one function of gender is to coordinate the division of labour¹⁰ ([2019]). A huge variety of human societies

¹⁰Division of labour, in this context, should be interpreted broadly. Market and subsistence labour is a key example. But this usage should also include anytime people perform different roles. For example, if a dance has two sets of moves and each gender conventionally performs one set, that is also a kind of division of labour.

employ a gendered division of labour. Divisions of labour offer a variety of benefits in terms of specialization, risk management, and efficiency. But they require coordination. Societies need conventions to specify who should perform which tasks. O'Connor explores a series of evolutionary game theory models to show that populations can latch onto sexual difference to stabilise this kind of convention and suggests gender roles may be a cultural adaption for this reason. In game-theoretic terms, division of labour problems can be represented as an anti-coordination games:

	A	B
A	0,0	1,1
B	1,1	0,0

If each player knows the sex of their partner and they know the convention that women perform A while men perform B, they can reliably coordinate.

Moving from traditional coordination games to anti-coordination games provides a more promising explanation of similarity-biased social learning. Previous modeling shows gender-biased social learning can co-evolve with a gendered division of labour (Saunders [2022]). These results are particularly robust - the explanation does not break down under reasonable adjustments to parameter values or structural assumptions. This suggests a fairly compact evolutionary explanation of gender-biased social learning: if gender functions to solve division of labour problems, then the learning bias comes for free.

This result also suggests a path forward for ethnicity-biased or racially-biased social learning. If a primary cultural evolutionary function of ethnicity or race is to divide labour and people can adopt different behaviours based on who they are interacting with, then the gender-biased learning model can be exported to those contexts. Suppose two ethnic groups live in close proximity. Each group collects a distinct kind of resource and they regularly trade. Under these circumstances, one should expect ethnicity-biased social learning to evolve. The same could be said for race. This kind of ethnic division of labour is not ubiquitous in the same way the gendered division of labour is but is still observed in some cases (Bunce and McElreath [2017]). If we assume that ethnic divisions of labour are uncommon, at least

relative to gendered divisions, it explains why the experimental literature on learning biases finds inconsistent results. There is a very general evolutionary story to tell for gender-biased social learning. Ethnicity-biased learning is possible under the logic of evolution. But the conditions that favour its evolution are only found in some societies, at some points in time.

It might be puzzling why switching from coordination to anti-coordination games avoids the myriad problems described in section 4 and 5. Anti-coordination games with conditional strategies are only stable when there is a population-level division of labour. There is no analogy to assimilation in the division of labour. Players only receive benefits when they perform different actions. They need similarity-biased learning strategies to ensure that behaviours are distributed along group lines. So even when forces like mutation and drift are introduced into the model, the population will explore possible distributions of behavioural and learning strategies until it discovers a division of labour. Once this state is achieved, it is difficult to undo it.

7 Conclusion

The aim of this paper is not to accept or reject any one particular model. Rather, exploring a series of models can show when similarity-biased social learning is selective advantageous and when it is not. That insight can, in turn, reveal the strengths and weaknesses of various evolutionary stories found in the literature. It turns out that much depends on whether one thinks the primary function of social roles is to facilitate coordination or the division of labour. Coordination-driven explanations require a very specific population structure: groups must interact but not too much. Whether the goldilocks conditions required for this kind of evolutionary story are empirically realistic is a fairly speculative judgment, one best left to the reader. By contrast, stories that center the division of labour as the function of social roles fair much better. Given that assimilation outcomes are not possible in the division of labour, few strong assumptions about the population structure are necessary.

Philosophers studying game-theoretic models of the origins of inequality would benefit from these insights. As noted in the introduction, some (but not all) of these models make use of strong similarity-biased social learning assumptions. These models are also intended to be

fairly general, representing a possible mechanism for generating gendered, racial, or ethnic inequality in both historical and contemporary societies.

The results of this paper encourage greater nuance here. The story we tell about learning strategies might need to be very different for gender and ethnicity. The experimental literature shows that gender-biased learning is far more easily generated in a lab than ethnicity.

Similarly, if we assume, following Henrich, Henrich, McElreath, Boyd, and Richerson, that the primary function of ethnicity is to solve coordination problems, we should be cautious about the evolutionary explanation. Furthermore, if one thinks that coordination problems early in human evolutionary drove the development of a domain-general learning bias that provides the scaffolding for culturally evolved bargaining systems, then bargaining models of inequality are more easily applied to gender-based inequalities than ethnic or racial ones.

If, instead, we assume that both gender and ethnicity function to divide labour, then a consistent story can be told in both cases. It is unclear whether ethnicity performs a division of labour role in a very general way across human societies. If we want to apply evolutionary bargaining models to any real cases of racial- or ethnicity-based inequality, then we should make efforts to show a division of labour actually does characterize the historical relationship between the two groups.

Finally, there is the possibility of providing non-adaptive justifications for learning assumptions. For example, racial residential segregation or social network segregation might control the flow of information in a way that mirrors similarity-biased learning. Here, population structure does all the necessary work and psychological traits are largely irrelevant. Plausibly, people share stories about bargaining for wages or resources with their friends and friends tend to be of the same social group. Regardless of what set of assumptions one finds most plausible, modelers who study inequality should be more specific about what they are assuming about learning strategies and why.

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