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Cultural diversity in unequal societies sustained through cross-cultural competence and identity valuation

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In much contemporary political discourse, valued cultural characteristics are threatened by interaction with culturally distinct others, such as immigrants or a hegemonic majority. Such interaction often fosters cross-cultural competence (CCC), the ability to interact successfully across cultural boundaries. However, most theories of cultural dynamics ignore CCC, making cultural diversity incompatible with mutually beneficial inter-group interaction, and contributing to fears of cultural loss. Here, interview-based field methods at an Amazonian ethnic boundary demonstrate the prevalence of CCC. These data motivate a new theoretical mathematical model, incorporating competing developmental paths to CCC and group identity valuation, that illuminates how a common strategy of disempowered minorities can counter-intuitively sustain cultural diversity within a single generation: Given strong group identity, minorities in a structurally unequal, integrative society can maintain their distinctive cultural norms by learning those of the majority. Furthermore, rather than a rejection of, or threat to, majority culture, the valuation of a distinctive minority identity can characterize CCC individuals committed to extensive, mutually beneficial engagement with the majority as members of an integrative, multi-cultural society.

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Introduction

In 2007, the United Nations declared its support for indigenous peoples' efforts to maintain their cultural heritage as full citizens of their respective countries (United Nations General Assembly, 2007). Simultaneously, within many UN member states, nationalist rhetoric warned of the need to protect national culture against an influx of culturally distinct immigrants (Betz and Meret, 2009; Rydgren, 2007). Thus, although all cultures are continuously reconstructed (Jackson, 1995), fears of losing particular cultural manifestations are politically salient (Hainmueller and Hopkins, 2014; Nagel, 1996), and often reference historical precedent (The Truth and Reconciliation Commission of Canada, 2012). Such fears are further supported by most theoretical models of cultural change in the social sciences (Advani and Reich, 2015; Bisin et al., 2011; Boyd and Richerson, 2009; Bunce and McElreath, 2018; Carvalho, 2017; Erten et al., 2018; Kandler et al., 2010; Kuran and Sandholm, 2008; Mesoudi, 2018; Olcina et al., 2018) (Appendix A), in which sustaining a diversity of competing cultural variants in a given domain is impossible in a structurally unequal, integrative society—one accepting of cultural diversity yet encouraging interaction among all constituents that is mutually, optimally, though potentially unequally, beneficial (adapted from Berry, 1997). Explaining the maintenance of cultural diversity, where it occurs in such societies (Brettell, 2003; Nagel, 1996; Wise and Velayutham, 2014), requires new theory. Preventing the loss of distinctive cultural forms, where they are desired in integrative societies plagued by inequality, calls for strategies grounded in theory.

The framework developed here is motivated by the following observations. Cultural diversity is a defining feature of our species, and much of it is structured in groups. These groups, e.g., ethnic groups, distinguish themselves on the basis of cultural norms (Barth, 1998), or beliefs about what constitutes appropriate behavior in a given context (e.g., norms of fair division in the domain of exchange, norms of child-rearing in the domestic domain). Norms structure correlative coordination (O'Connor, 2019) between individuals, such that all interactors (e.g., trading partners, parents) benefit if they share similar norms, and all suffer costs if they do not (Appendix A.4). At boundaries between groups, outward marking of group identity can evolve to reduce the likelihood of miscoordination (McElreath et al., 2003). Such archeologically detectable group identity marking began at least 40,000 years ago in our lineage (Foley and Lahr, 2011), and human psychology has evolved to become very sensitive to it, often requiring only minimal cues of group membership to elicit in-group favoritism (Kranton et al., 2020; Tajfel, 1982) and minimal cultural context-specific cues to serve as the basis of stereotypes (Moya and Boyd, 2016).

Recorded history is a drama of interaction among groups with unequal power, entailing exchange, collaboration, exploitation, and violence (Wolf, 1982). Mutually beneficial inter-group interaction, despite power differences, often requires the development of cross-cultural competence (CCC), the ability to coordinate using more than just the norms (including language) typical of a single group (e.g., indigenous school teachers: Shepard et al. (2010), ethnic entrepreneurs in immigrant communities: Brettell, 2003). CCC is prevalent in historical (Lamana, 2008) and contemporary life (Kopenawa and Albert, 2013; Wise and Velayutham, 2014), and is a current priority in medicine (Anand and Lahiri, 2009) and international business (Johnson et al., 2006). In integrative multi-ethnic societies, CCC can potentially reduce conflict through awareness of out-group sacred values (Ginges et al., 2007), and, by potentiating inter-group coordination, it can facilitate cohesion and prosociality through social and economic inter-dependence (Baldassarri and Abascal, 2020; Mousa, 2020). Furthermore, to the consternation of

some multiculturalism activists, minority groups in integrative societies often view learning majority languages and cultural norms (developing CCC) as a first, and justifiably strategic (Choi et al., 2019; Scott, 1985), priority in their struggle against disempowerment (García, 2005). Interestingly, in certain contexts, the development of CCC by some members of a society (e.g., cultural entrepreneurs: Brettell, 2003) can actually slow the further spread of CCC, as such individuals may defend their privileged position as cultural brokers and middlemen. Bunce (2020) recently demonstrated that CCC is not a unitary phenomenon: Individuals can learn out-group cultural norms while retaining a preference for in-group norms, or they can acquire a preference for out-group norms while not forgetting in-group norms. However, most theoretical models of cultural dynamics ignore CCC, such that all individuals in a population can coordinate only if all but one competing norm, and therefore cultural diversity, is lost in a domain of interaction (Appendix A). Given the prevalence of CCC in the real world, existing theory appears inadequate to understand patterns of cultural sustainability and loss.

For instance, Bunce (2020) measured distributions of a variety of norms and CCC in a population of minority indigenous Matsigenka (group S) and majority Mestizos (group L) in Amazonian Peru. As part of the study, participants stated their personal preference about whether to divide an inheritance among siblings according to need (norm 1) or evenly (norm 2). 75% of 77 Matsigenka preferred norm 1, while 68% of 82 Mestizos preferred norm 2. 103 of these participants then guessed about the most common response in the in- and out-group (Appendix B.1). Here, I assign phenotypes to individuals using the following criteria: Individuals who personally preferred norm 1 or 2, and guessed correctly for both the in- and out-group, were assigned CCC phenotypes $1X$ and $2X$, respectively. Individuals who personally preferred, and guessed (incorrectly) that most members of both the in- and out-group preferred, norm 1 or 2, were assigned uni-cultural competence (UCC) phenotypes 11 and 22, respectively (see Appendix B.1.1 for other phenotypes). Matsigenka–Mestizo interaction in most aspects of life is still infrequent. However, a subset of participants engaged in inter-ethnic education or wage labor, where Matsigenka–Mestizo coordination involving generalized variants of norms 1 and 2 for the fair division of resources is both more common and unequal (Bunce, 2020). Figure 1A shows frequencies of the four norm phenotypes among Matsigenka and Mestizos at the time of data collection. To account for uncertainty, these frequencies are estimated with Bayesian item-response theory (IRT) models (Appendices B.1.6–B.1.8), and demonstrate the prevalence of CCC, especially when inter-ethnic interaction is likely.

To investigate mechanisms contributing to the maintenance or loss of both Matsigenka- and Mestizo-typical norms of fairness, I construct a theoretical mathematical model that specifically incorporates CCC, and permits exploration of non-equilibrium norm dynamics under varying levels of structurally unequal inter-group interaction. I then use the model as a tool to address the more general question: Under which conditions (if any) can a diversity of cultural norms of coordination in a given domain be sustained in a structurally unequal integrative society, i.e., a society where extensive inter-group interaction can occur in the absence of pervasive miscoordination?

The paper is organized as follows: Below, I present an overview of the theoretical model. In the "Methods" section, I present additional details of the empirical analysis of Matsigenka and Mestizo norm phenotypes, as well as equations underlying several of the main assumptions of the theoretical model. A full elaboration of the statistical analyses, as well as the theoretical model and its variants, is presented in Appendix B. In the "Results"
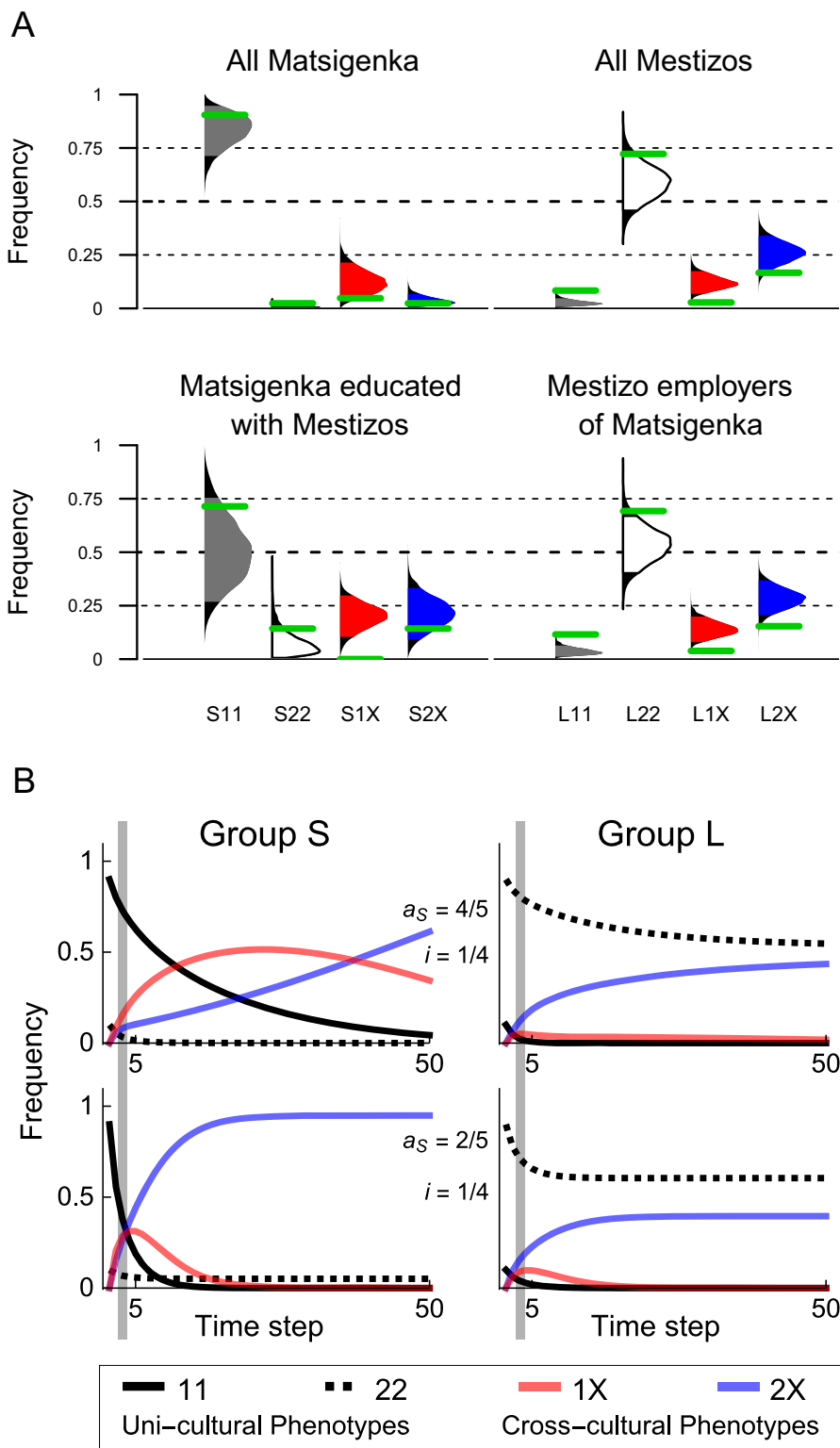
Fig. 1 Comparison of empirical data to the theoretical model. A Posterior IRT estimates of the mean frequencies of CCC (1X and 2X) and UCC (11 and 22) phenotypes (standardized to sum to one) among minority Matsigenka (group S) and majority Mestizos (group L), with respect to norms of fairness. Top row: all individuals. Bottom row: individuals with particular inter-ethnic experiences. Black regions bound 90% highest posterior density intervals (McElreath, 2020). Green: standardized proportions of all 57 Matsigenka and 46 Mestizo participants (top), and the 10 Matsigenka and 34 Mestizos with particular inter-ethnic experiences (bottom). **B** Phenotype frequency trajectories for the low-power minority group (S) and high-power majority group (L) simulated from the full model where: $(b_S, b_L) = (1, 0)$, $c = 0.1$, $\mu = m = 1$, $i = 0.25$, and initial phenotype frequencies $p_{S11} = p_{L22} = 0.9$, $p_{S22} = p_{L11} = 0.1$, for low (top) and high (bottom) inter-group interaction: $(a_S, a_L) = (0.8, 0.9)$ and $(0.4, 0.7)$, respectively. To implement the assumed group size difference, changing a_S necessarily changes a_L (Appendix B.2.1). Vertical gray lines indicate time steps where empirical frequencies and model predictions approximately coincide (see also Appendix B.4.2).

section, I present predictions of the model under conditions inspired by the empirical data. In the "Discussion" section, I explore implications of the model for sustaining cultural diversity in integrative societies, general implications for theories of cultural dynamics at ethnic boundaries, and future directions.

The model. A hypothetical population comprises a smaller group S and a larger group L (Appendix B.2.1). Initially, most people in S prefer norm 1, while those in L prefer the alternative norm 2. These norms represent mutually exclusive beliefs about appropriate behavior in a single domain of interpersonal interaction. In each time step, every person interacts with one other. Both receive payoff 1 if they can use the same norm (correlative coordination: O'Connor, 2019), and payoff 0 if they cannot (miscoordination). A member of group $x = S$ or L interacts with an in- and out-group member with probability a_x and $1 - a_x$, respectively. Individuals with a CCC phenotype always coordinate, but suffer a cost $m \geq 0$ for investing effort to learn an additional norm, and a cognitive dissonance cost $c \in [0, 1]$ if they must coordinate using their non-preferred norm (Festinger, 1962). Note that the constraint on c means that coordination always yields a higher payoff (i.e., >0) than miscoordination (Appendix Table A.2). Two interacting CCC individuals who prefer different norms choose one at random to coordinate. Two CCC individuals from the same group who both prefer a norm that differs from the norm perceived to be most common in their in-group will coordinate using their preferred norm (precluding "preference falsification" (Kuran, 1995) unnecessary to ensure coordination). Individuals with a UCC phenotype can only coordinate using their preferred norm. A member of group x who coordinates with an out-group member receives an additional payoff benefit $b_x \geq 0$. Group-level structural inequality is implemented as $b_S > b_L$, such that S members receive a higher payoff than L members from coordinating with the out-group. Inversely, S members forfeit a higher payoff by miscoordinating with the out-group and thus have a larger incentive to learn L-typical norms for inter-group interaction than L members have to learn S-typical norms. S members, therefore, have lower bargaining power in such interactions (Bunce and McElreath, 2018) because they have a lower disagreement point (O'Connor, 2019). The identity-based valuation of a particular norm also adds to the payoffs of individuals who prefer it, increasing with: (1) the perceived frequency of the norm within the in-group; (2) the perceived rarity of the norm within the out-group; and (3) the degree to which an individual values the cultural identity of her in-group (Akerlof and Kranton, 2000), operationalized as a constant $i \geq 0$ for all individuals. If a person miscoordinates or suffers c at time t, she (as an additive payoff-maximizer) may strategically change her phenotype to maximize payoffs at time $t + 1$, under the constraint that a norm cannot be forgotten. Her decision is based on a comparison of anticipated phenotype payoffs derived only from information about interactions involving in-group members, and is modeled as a logistic function of the payoff difference, with inflection point slope $\mu \geq 0$ interpreted as the payoff bias (Appendix B, with modification of many assumptions above in B.6–B.9).

Methods

Empirical analysis. Bunce (2020) describes the Matsigenka and Mestizo communities in Peru, the field methods employed there during data collection in 2012–2014, and the Bayesian IRT models from which estimated phenotype frequencies are derived. Note that that study used people's responses to a variety of norm vignette questions (including the inheritance question described here) to develop an experience-level measure of relative cross-cultural competence. In contrast, the present study derives an absolute measure of cross-cultural competence from a single norm vignette in order to facilitate direct comparison with the theoretical model.

Appendix B.1 describes this derivation and the special considerations required for the interpretation of such an absolute measure. In each ethnic group, the two CCC phenotypes (1X and 2X) and two UCC phenotypes (11 and 22) described here are a subset of the phenotypes actually observed among participants. The other phenotypes occur at non-trivial frequencies, but are difficult to classify as CCC or UCC and are therefore excluded from comparison with the theoretical model. As discussed in Appendix B.1.1, these phenotypes may be artefacts of the data collection methods. Alternatively, an explanation for their existence and dynamics may require refinement of current theory.

It is important to point out that the ethnographic context and cross-sectional data presented here motivate and focus the theoretical model (e.g., suggesting appropriate constraints on, and relationships among, parameters, as well as important phenotypes to track), rather than facilitate a test of the model. The model may be deemed plausible if patterns in the cross-sectional data, such as differing phenotype frequencies among Matsigenka with high and low levels of inter-ethnic interaction, can be reproduced by the model using parameter values that appear ethnographically reasonable. I present such a subjective plausibility check in the "Results" section (below), and use Bayesian estimation of model parameters conditional on the cross-sectional data (observed phenotype frequencies) as a more objective plausibility check in Appendix B.4.1. However, a rigorous test of the predictions of this dynamical model of culture will require parameter and phenotype frequency data collected at multiple time points (Appendix B.4.2). Reciprocally, the predictions of the theoretical model can now serve as motivation for the effort to collect subsequent rounds of such data in the Matsigenka and Mestizo communities, as well as in other populations, in order to assess the validity of the theory in these contexts.

Payoff assumptions of the theoretical model. As explained in Appendix B.2.2, it is assumed that individuals cannot see the personally preferred norms of others. Thus the actual frequency (p) of a phenotype in the population is unknown to its constituents. Individuals must infer the preferred norms of others from observation of the norms they use during attempted coordination in the current time step (see Gavrilets, 2021 for a similar theoretical approach). Individuals use these inferences to develop expectations about the norms they are likely to encounter when paired with in- and out-group members in the next time step. Equations (1) and (2) give, respectively, the probability ($\tilde{p}$), as perceived by a member of group S, that a fellow S member will attempt to use norm 1 and the probability that an out-group L member will attempt to use norm 2 when paired with a member of group S in the next time step. These are simply the probabilities of these norms being used with group S members in the current time step. Reasonably accurate information of this type could plausibly be available to in-group members as a result of community gossip (Gluckman, 1963; Wiessner, 2005).

$$
\begin{aligned}
\tilde{p}_{S1\text{in}} = {} & p_{S11}\left(p_{S11} + p_{S1X} + p_{S2X} + p_{S22}\right) \\
& + p_{S1X}\left(p_{S11} + p_{S1X} + \tfrac{1}{2}p_{S2X}\right) \\
& + p_{S2X}\left(p_{S11} + \tfrac{1}{2}p_{S1X}\right)
\end{aligned}
\tag{1}
$$

$$
\begin{aligned}
\tilde{p}_{L2\text{out}} = {} & p_{L22}\left(p_{S22} + p_{S2X} + p_{S1X} + p_{S11}\right) \\
& + p_{L2X}\left(p_{S22} + p_{S2X} + \tfrac{1}{2}p_{S1X}\right) \\
& + p_{L1X}\left(p_{S22} + \tfrac{1}{2}p_{S2X}\right)
\end{aligned}
\tag{2}
$$

The probabilities $\tilde{p}_{S2out}$ and $\tilde{p}_{L2in}$ (from the perspective of a member of group L) are found by reversing all group and norm indices in the subscripts of Eqs. (2) and (1), respectively.

Using these perceived probabilities of encountering certain norms, individuals infer the average payoffs that are likely to accrue to a given phenotype in the next time step, given their knowledge of the base coordination and miscoordiantion payoffs (1 and 0, respectively), the probability of interacting with an in-group member (a), the extra benefit of out-group coordination (b), the cognitive dissonance cost of coordinating using one's non-preferred norm (c), the cost (distributed over the lifespan) of learning an additional norm in order to attain CCC (m), and the value derived from identifying with one's in-group (i). These average anticipated payoffs ($\tilde{w}$) for each phenotype of group S, are given in the following Eqs. (3)–(6), and are derived in Appendix B.2.

$$\tilde{w}_{S11} = a_S\tilde{p}_{S1in} + (1 - a_S)(1 - \tilde{p}_{L2out})(1 + b_S) + i\tilde{p}_{S1in}\tilde{p}_{L2out} \tag{3}$$

$$\tilde{w}_{S1X} = a_S\left[\tilde{p}_{S1in} + (1 - \tilde{p}_{S1in})(1 - c)\right] + (1 - a_S)\left[(1 - \tilde{p}_{L2out})(1 + b_S) + \tilde{p}_{L2out}(1 + b_S - c)\right] - m + i\tilde{p}_{S1in}\tilde{p}_{L2out} \tag{4}$$

$$\tilde{w}_{S2X} = a_S\left[(1 - \tilde{p}_{S1in}) + \tilde{p}_{S1in}(1 - c)\right] + (1 - a_S)\left[\tilde{p}_{L2out}(1 + b_S) + (1 - \tilde{p}_{L2out})(1 + b_S - c)\right] - m + i(1 - \tilde{p}_{S1in})(1 - \tilde{p}_{L2out}) \tag{5}$$

$$\tilde{w}_{S22} = a_S(1 - \tilde{p}_{S1in}) + (1 - a_S)\tilde{p}_{L2out}(1 + b_S) + i(1 - \tilde{p}_{S1in})(1 - \tilde{p}_{L2out}) \tag{6}$$

Anticipated payoffs to phenotypes in group L are found by reversing all group and norm indices in the subscripts. Note that the effect of the valuation of in-group identity (i) on payoffs is scaled by the degree to which a phenotype's personally preferred norm distinguishes the in-group from the out-group (the perceived frequency of the norm within the in-group multiplied by the perceived rarity of the norm within the out-group). Individuals who miscoordinate or suffer the cognitive dissonance cost c in the current time step, mentally compare these anticipated payoffs when making their (payoff-biased) decision to change (or not) their phenotype in the next time step. Recursions resulting from these decisions are derived for the full model in Appendix B.2.2.

Dynamics of a simplified model. Under the simplifying assumptions that majority group L comprises only UCC individuals who prefer norm 2, and there are no (longer) UCC members of minority group S who prefer norm 1 ($p_{L2X} = p_{L1X} = p_{L11} = p_{S11} = 0$), the system dynamics can be expressed as a single difference equation, derived in Appendix B.3, representing transitions between the two CCC phenotypes in group S (i.e., $S1X$ and $S2X$):

$$\Delta p_{S1X} = a_S p_{S1X} p_{S2X}\frac{1}{2}P \\ - p_{S1X}\left[a_S p_{S2X}\frac{1}{2} + a_S(1 - p_{S1X} - p_{S2X}) + (1 - a_S)\right](1 - P) \tag{7}$$

where

$$P = \frac{1}{1 + e^{-\mu[iF + c(2a_S F - 1)]}} \tag{8}$$

is the probability of a transition $S2X \rightarrow S1X$ conditional on $S2X$

and $S1X$ coordinating on norm 1, and where

$$F = p_{S1X}\left(p_{S1X} + \frac{1}{2}p_{S2X}\right) + p_{S2X}\left(\frac{1}{2}p_{S1X}\right) \\ = p_{S1X}(p_{S1X} + p_{S2X}) \tag{9}$$

is the probability with which norm 1 is observed to be used in group S.

The first term in Eq. (7) is the probability of an interaction between $S1X$ and $S2X$ individuals, multiplied by the probability that they coordinate using norm 1 (i.e, $\frac{1}{2}$), multiplied by the probability that $S2X$ transitions to $S1X$ conditional on such an interaction (i.e., P). The second term is the probability that $S1X$ coordinates with any in-group or out-group member using norm 2, multiplied by the probability that $S1X$ transitions to $S2X$ conditional on such an interaction (i.e., $1 - P$). Note that $p_{S22} = 1 - p_{S1X} - p_{S2X}$ and all members of the out-group, with whom interaction occurs with probability $1 - a_S$, have phenotype $L22$. Also note that structural power differences between groups S and L, represented by b terms, do not appear in these dynamics, as explained in the "Results" section and Appendix B.3. Explanation of Eq. (8), as well as equilibrium and sensitivity analyses, are presented in Appendix B.3.

Prospects for inter-generational sustainability. This is a model of cultural dynamics within a single generation. A rigorous investigation of dynamics across generations is beyond the scope of this paper and will require an age-structured model incorporating assumptions about demographic processes, marriage assortment, child socialization, and teaching/learning strategies (e.g., Bisin and Verdier, 2001). However, the simplified model (above) can be used to find conditions under which cross-culturally competent $S1X$ individuals in a disempowered minority group, acting only according to what they perceive as their anticipated children's best interests, would prefer to create $S1X$ rather than $S22$ or $S2X$ offspring, given conditions in the next generation identical to those in the present.

Within the basin of attraction for stable mixed equilibria containing $S1X$, shown in Fig. 2C, the average perceived payoff to $S1X$ exceeds that to $S2X$, i.e., $\tilde{w}_{S1X} > \tilde{w}_{S2X}$. Thus, within this region, $S1X$ parents are expected to prefer $S1X$ offspring, rather than $S2X$ or $S22$ offspring, as long as $\tilde{w}_{S1X}$ is also greater than $\tilde{w}_{S22}$. Solving the inequality $\tilde{w}_{S1X} > \tilde{w}_{S22}$ yields the threshold value of i, above which the $S1X$ phenotype is expected to be favored over $S22$ in the next generation, all else being equal:

$$i > \frac{m + c(1 - a_S F) - a_S F}{F} \tag{10}$$

where F is defined in Eq. (9). As can be seen in Eq. (10), parents' decision to produce $S1X$ offspring is expected to be sensitive to (among other things) the learning cost (m) that such cross-culturally competent children are likely to incur. When m is high, the value placed on cultural identity (i) must also be high in order to prevent $S1X$ parents from teaching their children only a single norm and thereby raising uni-culturally competent offspring. Note that in this simplified model, the power difference between groups has no effect on parents' decisions (i.e., Eq. (10) contains no b terms), as all phenotypes that they would consider for their offspring ($S1X$, $S2X$, and $S22$) can successfully coordinate with all possible interaction partners.

Figure 2C shows, for given values of i and m (and the other model parameters), the range of phenotype frequencies such that $\tilde{w}_{S1X} > \tilde{w}_{S22}$ (gray regions). When phenotype frequencies fall within the intersection of this gray region and the basin of attraction for the mixed equilibria, parents would be expected to prefer $S1X$ offspring, thereby potentially sustaining the minority-typical norm 1 across
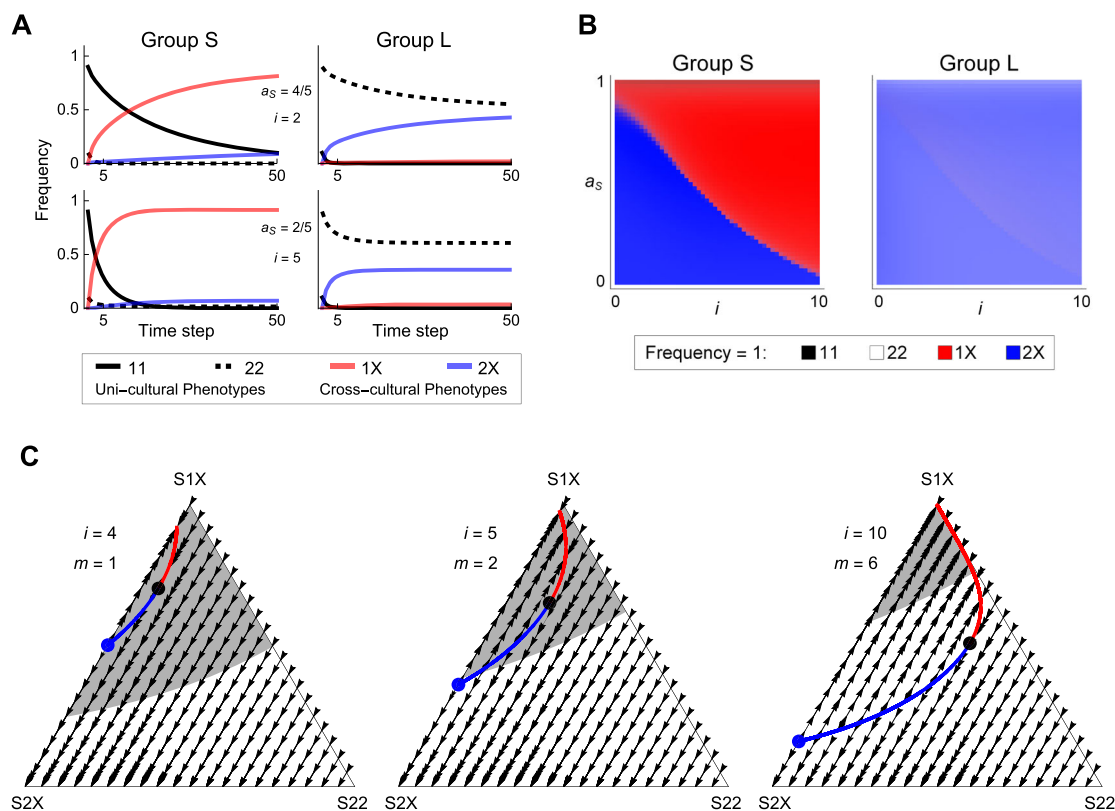
Fig. 2 Model simulations. A Phenotype frequency trajectories for model parameterizations in Fig. 1B, given greater valuation of group identity (i). **B** Phenotype frequencies after 100 time steps simulated from the model in **A**, but varying a_S and i. Note that, after so many time steps, the 11 phenotype (black) is absent, and the 22 phenotype (white) remains at relatively high frequency in Group L (diluting the other colors, see also Appendix Fig. A.13). As the probability of in-group interaction (a_S) decreases, greater in-group identity valuation (i) is required to maintain norm 1 at equilibrium. **C** Ternary plots for a simplified model ($p_{S11} = 0$, $p_{L22} = 1$). Phenotype frequencies in group S are 1 at their respective vertices, and 0 at the opposite side. Unstable (blue) and stable (red) mixed equilibria contain the CCC phenotype $S1X$, where the blue line and the $S1X - S22$ axis bound the basin of attraction for a given frequency of $S22$. Points are the highest initial frequencies of $S2X$ (blue) and $S22$ (black) where $S1X$ is still sustained at equilibrium. The intersection of the gray region (a function of m and i: Appendix B.3.2) and the basin of attraction is the set of phenotype frequencies where anticipated payoffs $\bar{w}_{S1X} > \bar{w}_{S22}$ and $\bar{w}_{S2X}$ (see the "Methods" section), and thus inter-generational transmission of $S1X$ is plausible. In this model, for a given frequency of $S22$, the lowest frequency that the $S1X$ phenotype can fall to, yet still be both sustained at equilibrium and potentially transmitted to the next generation, is represented by a point on the blue line or on the lower edge of the gray region, whichever is higher. At $S22$ frequencies above that corresponding to the black point, $S1X$ cannot be sustained, no matter what its frequency. Parameters a, b, c and μ match the bottom row of **A**.

generations. Further details are provided in Appendix B.3.2. Estimation of model parameters using the empirical data is presented in Appendix B.4.1. Robustness of results to changes in individual memory, replication assumptions, non-additive payoffs, and stochastic perception error is explored in Appendices B.6–B.9. All data, empirical and theoretical analyses, and simulation scripts in R (R Core Team, 2017), Stan (Stan Development Team, 2018), and Wolfram Mathematica (Wolfram Research, Inc., 2019) are available at https://github.com/jabunce/Bunce-2020-xcultural-competence.

Results
Figure 1B shows that the measured phenotype frequencies among Matsigenka and Mestizos correspond with model predictions early in the pre-equilibrium dynamics given low (large a, top row) and high (bottom row) probabilities of inter-group interaction, and low valuation of group identity (i) (see also Appendix B.4). This supports the plausibility of the model as one representation of causal processes at work in the ethnographic context for which the model was developed (and potentially more broadly). The model predicts that, given sufficient interactions (time steps) under these assumptions, eventually Matsigenka-typical norm 1

will remain only in the memories of CCC individuals who neither prefer nor use it ($S2X$ and $L2X$), and this happens faster when most interactions occur with the out-group. Although the model represents a single generation of people who, once they learn a norm, cannot forget it, such an equilibrium would represent the effective extinction of norm 1, as its transmission to the next generation is unlikely.

However, Fig. 2A and B demonstrate that a preference for, and use of, norm 1 can be maintained at high frequency in group S in the form of the CCC phenotype $S1X$ when in-group identity is sufficiently valued (large i), even when S members have low bargaining power ($b_S > b_L$) and interact more often with the out-group than the in-group ($a_S < \frac{1}{2}$). Additionally, this analysis suggests that maintenance of norm 1 is determined primarily by competition between the two CCC phenotypes $S1X$ and $S2X$. A simplified model focusing on these dynamics (Fig. 2C) shows that $S1X$ can be potentially sustained across generations if group identity is valued and the learning cost of CCC (m) is sufficiently low (see the "Methods" section). Importantly, group-level structural inequality does not directly affect competition between CCC phenotypes, as both receive b_S from out-group interactions.

Thus, a general insight from this model is that CCC may effectively insulate minority norm dynamics from some group-level power differences, known to be potent drivers of cultural change (Bunce and McElreath, 2018; O'Connor, 2019). In this model, to sustain initial cultural diversity, the identity-based valuation of the minority-typical norm must be sufficient to outweigh the cognitive dissonance cost (c) suffered by minority CCC individuals who coordinate with the out-group using their non-preferred norm. Results are largely robust to changes in assumptions about norm adoption decisions, non-additive payoffs, and stochastic perception error (Appendices B.7–B.9), and demonstrate the potential importance of CCC for our understanding of human inter-group cultural dynamics. In summary, in this model, cultural diversity is maintained through a combination of CCC and group identity valuation, even when inter-group coordination is both intense and unequal.

Discussion

My objective was to use a mathematical model to better understand conditions under which cultural diversity can be sustained in a domain of mutually beneficial, though unequal, inter-group interaction. If Matsigenka and Mestizos, like many minority and majority groups in structurally unequal integrative societies, wish to maintain their distinctive cultural norms while engaging in mutually beneficial inter-group interaction, this model suggests a plausible intervention strategy in the short term (i.e., within one generation and/or prior to successful inequality reduction): Foster development of CCC in (at least) the low-power group to reduce the influence of structural power inequality on norm preference dynamics. Simultaneously, strengthen identity-based valuation of in-group norms so that CCC individuals prefer them, for instance, by emphasizing norm distinctiveness while celebrating group identity (i). If model predictions are validated, intervention effectiveness can be assessed by re-measuring $S1X$ and $S2X$ frequencies and comparing them against the modeled pre-equilibrium trajectories. Importantly, many disempowered peoples already employ these strategies, voluntarily learning the language and norms of the powerful (García, 2005; Portes and Rumbaut, 2014; Scott, 1985), while developing identity-affirming institutions (e.g., cultural centers, festivals, literature: Brettell, 2003; Nagel, 1996) that showcase the prevalence and distinctiveness of their own norms, such as language and dietary preferences, otherwise unobserved during everyday out-group interactions. This model is one way of understanding how, counter-intuitively for many outsiders (García, 2005), developing CCC by learning majority norms may complement such local institutional strategies to sustain cultural diversity in integrative societies. Furthermore, the model shows how, rather than a threat to the majority culture, the valuation of minority-typical norms and identity can be a characteristic of CCC individuals committed to extensive mutually beneficial engagement with the majority as members of an integrative, multi-cultural society. When confidence in the durability of cultural diversity replaces fear of, or resignation to, cultural loss, the structural inequality to which such societies are perpetually prone (O'Connor, 2019) may, it is hoped, be more easily confronted.

Comparison with previous models: escaping a tradeoff. It is important to emphasize that CCC is neither the only, nor perhaps the easiest, way to sustain a diversity of cultural norms in a population. Indeed, in many previous theoretical models of norm dynamics that do not include CCC, stable mixed equilibria may be common outcomes when: (1) there is a constant influx of culturally distinct minority individuals into the population from some external source (Boyd and Richerson, 2009; Erten et al.,

2018; Kuran and Sandholm, 2008; Mesoudi, 2018); (2) errors in learning norms impede inter-ethnic coordination (Carvalho, 2017); (3) in some domains, distinctive cultural norms are associated with a highly valued group identity, which outweighs benefits to inter-ethnic coordination in those domains (Advani and Reich, 2015; Bisin et al., 2011); (4) individuals cannot easily assort on norm, and boundaries between groups limit inter-ethnic interaction (Bunce and McElreath, 2018); (5) social network structure consisting of weakly connected subgroups reduces the opportunities of some minority individuals to engage in inter-ethnic coordination (Olcina et al., 2018); or (6) coordination is complementary rather than correlative (O'Connor, 2019), such that coordination benefits accrue to interactors who hold different, rather than similar, norms (Erten et al., 2018; Henrich and Boyd, 2008) (additional details in Appendices A and B.5). In all of the above models (excluding those with complementary coordination: Appendix A.4), the sustainability of cultural norm diversity at mixed equilibria comes at the cost of inter-ethnic coordination, because it is assumed that individuals with different norms cannot coordinate. This contributes to the notion of a fundamental tradeoff between sustaining cultural diversity and facilitating mutually beneficial inter-ethnic interaction (Kuran and Sandholm, 2008). Such a tradeoff would preclude the possibility of an integrative society (as defined above). An important contribution of the present model is to demonstrate, theoretically, and within a single generation, that such a tradeoff is not inevitable: accounting for CCC and identity valuation can result in stable mixed equilibria with universal coordination in a given domain, conditions conducive to an integrative society.

Limitations and future directions. The model described here is an initial step in the study of the population-level consequences of CCC, and the generality of the results presented above is potentially constrained by this model's many simplifying assumptions. To address this, future theoretical work is needed to more rigorously explore modifications to this model with potentially important real-world implications, including the reciprocal effects of CCC and identity valuation on inter-generational norm dynamics (Appendix B.3.2), the non-random forgetting of norms (Appendix B.6), an evolving preference for in-group (versus out-group) interaction (Appendix B.2.1), the non-random assort of interaction partners within the in- and out-groups (i.e., social networks: Olcina et al., 2018), the permanent migration of individuals between groups (Boyd and Richerson, 2009) potentially contingent on norms, the signaling of coordination norms with covarying overt and covert markers (Bell and Paegle, 2021; McElreath et al., 2003; Smaldino et al., 2018), linkage between distinct norms (Yeh et al., 2019), preference falsification (Kuran, 1995) on the part of CCC individuals preferring norms different from those of their in-group, and the incorporation of continuous (rather than discrete) norms, which may facilitate the retention of some minority influence on the (homogeneous) norm characterizing the population at equilibrium (Kuran and Sandholm, 2008), but that may also impede coordination (Hoffman et al., 2020).

In addition, empirical studies suggest an even wider array of CCC-related phenomena for which the formulation of theoretical mathematical models could aid understanding. For instance, Brettell (2003) describes how the development of CCC can initially contribute to inequality within a group as CCC individuals attain wealth and influence through their role as both patrons and brokers at the cultural boundary. In other cases, strategic inter-group miscoordination by CCC individuals (e.g., African- and Hispanic-American students who avoid "acting white": Fryer and Torelli, 2010) may yield benefits to

individuals for signaling a commitment to disempowered minority groups, a mechanism which could sustain cultural diversity at the cost of inter-group coordination. Grounding theoretical models in a particular ethnographic context, such as these, may result in additional insight into the role of cross-cultural competence and group identity valuation in the dynamics of human culture.

Data availability
All data, empirical and theoretical analyses, and simulation scripts in R, Stan, and Wolfram Mathematica are available on GitHub at https://github.com/jabunce/Bunce-2020-xcultural-competence, and on the Open Science Framework at https://doi.org/10.17605/OSF.IO/A3YD4.

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Author contributions

JAB designed and conducted the research and wrote the paper.

Competing interests

The author declares no competing interests.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1057/s41599-021-00916-5.

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