Behavioural homogenisation with spillovers in a normative domain

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Abstract

The importance of culture for human social evolution hinges largely on the extent to which culture supports outcomes that would not otherwise occur. An especially controversial claim is that social learning leads groups to coalesce around group-typical behaviours and associated social norms that spill over to shape choices in asocial settings. To test this, we conducted an experiment with 878 groups of participants in 116 communities in Sudan. Participants watched a short film and evaluated the appropriate way to behave in the situation dramatised in the film. Each session consisted of an asocial condition in which participants provided private evaluations and a social condition in which they provided public evaluations. Public evaluations allowed for social learning. Across sessions we randomised the order of the two conditions. Public choices dramatically increased the homogeneity of normative evaluations. When the social condition was first, this homogenising effect spilled over to subsequent asocial conditions. The asocial condition when first was thus alone in producing distinctly heterogeneous groups. Altogether, information about the choices of others led participants to converge rapidly on similar normative evaluations that continued to hold sway in subsequent asocial settings. These spillovers were at least partly due to the combined effects of conformity and self-consistency. Conformity dominated self-consistency when the two mechanisms were in conflict, but self-consistency otherwise produced choices that persisted through time. Additionally, the tendency to conform was heterogeneous. Females conformed more than males, and conformity increased with the number of other people a decision maker observed before making her own choice.

1 Introduction

The role culture plays in shaping the evolution of human social cognition and social behaviour remains a central question in human evolutionary ecology [1, 2]. If genes tightly constrain culture, we can perhaps ignore culture and pay our respects to the phenotypic gambit in standard fashion [3], whatever the environment for which phenotypes are adapted [4, 5]. If culture generates outcomes that would not otherwise occur, we should consider gene-culture coevolution, with social cognition shaping cultural evolution, and cultural evolution shaping the genetic evolution of social cognition [1, 6].

An especially prominent gene-culture coevolutionary hypothesis is that frequency-dependent social learning strategies like conformity support path-dependent dynamics [7–9]. A rare behaviour becomes increasingly rare; a common behaviour becomes increasingly common.

Path-dependent cultural evolution has at least two broad implications. First, the associated dynamics homogenise groups. Second, provided some other mechanism generates sufficient variation between groups, the dynamics exaggerate and ultimately stabilise between-group variation. The overall pattern is one of limited variation within groups and potentially considerable variation between groups [10]. Most importantly, this pattern might persist even amid the constant flow of cultural information across group boundaries [11]. Genetic transmission cannot do this, and this discrepancy between what culture might do and what genes cannot do lies at the root of much controversy about culture and human evolution via selection at the level of the social group [12–16].

Social norms represent one of the principal ways in which path-dependent cultural evolution should shape behaviour. Social norms refer to locally pervasive, socially learned expectations about how people behave, how people expect others to behave, and how people think everyone ought to behave [17, 18]. A person can adhere to a norm for at least two generic reasons. On the one hand, someone might adhere for extrinsic reasons. For example, if a self-regarding person lives in a group with a norm and associated institution for punishing free riders, she cooperates because she believes she does best by avoiding punishment. Otherwise, she defects [19]. Such a person adheres because she wants group affiliates to see her adhering, or at least because cues indicating that choices might be observable have activated an equivalent psychology [20, 21]. On the other hand, someone might adhere because following the norm becomes intrinsically valuable in the specific sense that the norm spills over to affect behaviour when choices are made in social isolation. Spillovers of this sort might occur because someone comes to value the specific behaviour prescribed by the norm [22], because the person values behaving in a self-consistent fashion [23, 24], or because the person values conforming to the group, whatever that may require [1, 9, 25].

Researchers have hypothesised that spillovers are special because they mean that norm adherence occurs with limited monitoring [26, 27]. This can reduce the costs of enforcing socially beneficial norms because groups waste few resources policing the deviant behaviour of their own members. In this sense, spillovers can be good for the group. Spillovers might also be good for the individual. Researchers have also hypothesised that, if norm violations are sometimes punished, simple adherence might allow the individual to benefit by avoiding the costs of constantly re-evaluating if and when a given norm is worth following [28].

A key question thus concerns whether social information leads to homogeneous norms with spillovers. Experimental research has shown that frequency-dependent social learning strategies are extremely variable both across individuals and from one situation to another

[29–35]. This kind of variation can have a dramatic effect on what happens at the group level [36–38]. In particular, even if conformity is common, the homogenisation of behaviour does not necessarily occur (§ 2, Fig. 1).

Accordingly, we conducted an experiment in Sudan to examine whether homogeneous norms rapidly form in social settings and then spill over to asocial settings. We ask four related questions. First, does social information about the choices of others lead groups to converge quickly on a shared assessment of the correct way to behave? Second, if convergence occurs, do the effects spill over to asocial settings? Third, how does social information affect decision making, and do the effects vary systematically in some way [29, 30]? Finally, if spillovers occur, what are the relevant mechanisms?

Because our study was large in scale, with 878 distinct groups, we can address the first two questions by working directly at the group level. This allows us to sidestep the question of how social learning strategies, which are likely to be highly variable [8, 9, 29, 30], translate into aggregate outcomes. We address the latter two questions by analysing individual choices, which in turn clarifies the processes behind the patterns at the aggregate level.

2 The aggregate consequences of variation in social learning

An analysis at the aggregate level is crucial because the significance of frequency-dependent social learning strategies hinges in part on their hypothesised tendency to reduce behavioural variation within groups [7]. We cannot reliably assume that homogenisation occurs simply because we find evidence for conformist decision making at the individual level. Specifically, a profusion of recent experiments have shown that, although conformity certainly occurs, social learning strategies vary enormously across individuals and from one situation to another [8, 29–35, 39–42]. This variation can dramatically affect cultural evolutionary dynamics, and in particular it can attenuate or eliminate the behavioural homogeneity associated with conformity [36–38].

To provide a simple illustration, assume a population with two types of social learner (Fig. 1(a)). Both types choose a given behaviour with a probability that increases as the behaviour becomes more common, and both types rely on social learning strategies with the sigmoidal shape characteristic of conformist transmission [7, 9]. One type, however, is less responsive to social information than the other [8]. As the distribution over the two types changes (Fig. 1(b)), the steady states of the cultural evolutionary system also change. When the type that responds strongly to social information dominates, two stable steady states

exist near the boundaries, and behavioural variation is limited in either case. However, as the distribution shifts towards the less responsive type, the two stable steady states converge. Behaviour becomes increasingly heterogeneous in equilibrium, and eventually only a single stable steady state remains in which behavioural heterogeneity is at its maximum possible value. This outcome obtains even though all individuals have positively sloped sigmoidal strategies. Possibilities of this sort suggest the importance of directly analysing group-level phenomena in a causal way. With a serendipitous source of exogenous variation and a clever identification strategy, one can do this with observational data [11, 43, 44]. We take an experimental approach. In either case, if aggregate-level analyses show that enculturation has a strong homogenising effect, the result would support one of the basic claims of gene-culture coevolution, the claim that culture reduces the importance of within-group selection in structured populations [14].

3 Methods

We recruited 7087 randomly selected adults in 116 communities distributed throughout the state of Gezira, Sudan, in the localities of Umalgoura (46 communities) and East Gezira (70 communities). Gezira is located between the White Nile and Blue Nile, and it is home to the largest irrigation project in Sudan. Representative survey data show that Gezira is typical of Sudan as a whole in numerous dimensions related to health and education [45]. The dominant economic activity in the area is farming, but people are also engaged in herding, trade, and government [46]. Social and political life tends to centre strongly around the community, and in particular endogamy is extremely common [47]. As is true throughout Sudan, Islam is ubiquitous. Communities in Umalgoura have a reputation locally for being less conservative than communities in East Gezira, especially in matters related to religion and gender.

3.1 Sampling and participation

For sampling, we turned to community leaders, who maintain lists of households and household members in their respective communities. We reviewed these lists with community leaders shortly before the study to ensure the lists were up to date. Depending on the size of the community, we randomly sampled households with the intent of recruiting one participant each from 60, 120, or 180 households[1] per community. After sampling households,

[1] In practice, we set a target of 60 households per community in 103 of the 116 communities. The mean number of actual participants in these communities was 55.09, and the range was from 42 to 62. We agreed on a target of 60 per community after consulting with community leaders to determine the maximum number

we contacted each household individually and invited a single adult to participate. In half of the sampled households in a community, we recruited an adult female. In the other half, we recruited an adult male. Participants received perfume, prayer mats, and kitchenware for participating.

3.2 Decision-making task and experimental design

In sessions of 10 participants or fewer (mean 8.072; std. deviation 2.681; 56.7% of sessions with 10), participants watched a short film about parenting. UNICEF, Sudan, produced the film as one of several short and entertaining productions related to child protection. The footage was recorded inside a family compound, and the setting was deliberately chosen to be a typical example of domestic life in the region. The well-known Sudanese writer Waleed Omer Babikir Alalfi wrote the script for the film, and professional Sudanese actors played the characters in the film.

The film was about a father who gives his young son and daughter 20 Sudanese Pounds to go to the store (Supplementary Material, § 1). The son loses the money on the way. He returns home empty-handed and reluctantly reveals to his father what happened. The father gets quite angry and indicates he will punish his son. The father's friend, who happens to be visiting while this drama unfolds, suggests that the responsibility was too much for children so young, and the father himself bears much of the blame.

After viewing the film, participants were asked if they agreed that the child should be strongly punished for losing the money. As explained below, each participant responded to this question twice under two different conditions. For each repetition of the question, two options were available. A participant could choose to agree, or she could choose to disagree.

Participants made choices in a randomly determined sequence. Each session consisted of two sequences, and thus each participant made two choices. Choices were asocial in one sequence in the sense that each participant had no information about the responses of the other participants for the sequence in question. Choices were social in the other sequence in the sense that everyone in the group could observe the choices of everyone else. Because of comparatively tolerant attitudes in matters related to gender, sessions consisted of both men and women in Umalgoura. In general, however, we were not able to do this in East Gezira, and almost all sessions consisted entirely of either men or women. Accordingly, in our analyses below we control for both region and the gender composition of sessions.

of participants we could work with in one day in a single community. We targeted 120 or 180 households in a handful of larger communities with facilities for running different sessions in different parts of town.

Our design consisted of two treatments distinguished by the order of the asocial and social sequences. One treatment implemented the asocial sequence first and then the social sequence. We refer to this as the "asocial-social" treatment. The other treatment began with the social sequence and then moved to the asocial sequence. This is the "social-asocial" treatment. The resulting four conditions include the asocial sequence when first (A,s), the asocial sequence when second (s,A), the social sequence when first (S,a), and the social sequence when second (a,S).

3.3 Procedures for an experimental session

To conduct sessions, we hired and trained 16 facilitators through the office of the Gezira State Council for Child Welfare. Facilitators were young college graduates who lived in and around the Gezira capital city, Wad Madani. Half of the facilitators were women, and half were men.

Experimental sessions took place primarily in community school buildings. For a given session, one facilitator conducted the experiment. At the beginning of the session, the facilitator set up a computer, a projector, and a set of amplified speakers to show the film. We rented generators for communities off the grid. The facilitator also positioned a large wooden blind (Fig. 2) on a table at the front of the room. This blind allowed participants to make choices in the asocial condition that were unobservable to other participants.

To determine the sequence in which participants responded, the facilitator placed small numbered pieces of paper in a box. Each participant blindly drew one piece of paper from the box. Participants kept these pieces of paper throughout the session. The facilitator used these numbers to seat participants in a randomly ordered sequence. The facilitator did this publicly to show that seating was entirely random. This allowed us to avoid offending participants who might have felt slighted because of where we seated them.

The sequence additionally specified the order in which participants responded to the question about punishing the child. Randomising the sequence allowed us to seed groups with initial choices in a random fashion and thus eliminate in expectation the possibility of seeding sequences with the choices of influential participants. By extension, participants with relatively little influence often went first, which should have reduced the potential for social information to homogenise choices. In this way, our design provides a conservative approach to examining if social information homogenises normative evaluations.

After determining the sequence, the facilitator explained that participants would watch a short film and then twice answer a question about the film. The facilitator did not explain at

this point what the film was about or what the question would be. The facilitator did explain that participants would have two options. Specifically, the facilitator passed out large opaque envelopes to all participants. Each envelope contained two pieces of paper, one with a large "X" and the other with a large "✓". The facilitator explained that the X meant "No, I do not agree", while the ✓ meant "Yes, I do agree". After ensuring that everyone understood the answer categories, the facilitator conducted a short sound check and verified that everyone could see and hear the film. The facilitator re-emphasised that participants had to remain silent for the entire session and started the film. During the film, the facilitator flipped a coin to determine the treatment, asocial-social or social-asocial.

After the film, the facilitator reminded everyone to remain silent as they would only use the two pieces of paper to communicate. The facilitator then asked the question, "Do you agree that the child should be strongly punished"? The facilitator called participants up to the front of the room in sequence to respond. After completing the first sequence, whether asocial or social, the facilitator reminded participants of the question and then continued to the second sequence, which always maintained the same ordering of participants as the first sequence.

Whether first or second, asocial sequences proceeded as follows. The facilitator asked the appropriate participant to come to the front of the room with her envelope. The facilitator took the envelope from the participant, removed the two pieces of paper behind the blind, and placed them on the table (Fig. 2). The other participants could not see the pieces of paper. The facilitator asked the focal participant to point to the correct piece of paper to indicate her choice. The facilitator recorded the choice on a data sheet that none of the participants could see. The facilitator then returned the two pieces of paper to the envelope behind the blind, handed the envelope to the participant, and asked the participant to return to her seat. The facilitator then moved to the next participant in the sequence.

Whether first or second, social sequences were identical to asocial sequences with one exception. Specifically, the participant first indicated her choice behind the blind, exactly as in the asocial treatment. Immediately after this, the facilitator asked the participant to raise the relevant piece of paper so that everyone could see the participant's choice (Fig. 2). As with asocial sequences, participants did not speak. Communication was thus highly regulated. We did this to maximise control and isolate the effects of the one extremely small but critical difference between asocial and social sequences. The critical difference was whether the participant did or did not hold up the piece of paper corresponding to her choice. This design, of course, does not rule out the effects of other decision-making mechanisms,

mechanisms like those related to interacting with an unfamiliar facilitator or being in a room with other members of one's community. Randomisation, however, renders these variables orthogonal to treatment, and thus they cannot explain treatment differences.

3.4 Study approval and supporting data

The Human Subjects Committee of the Faculty of Economics, Business Administration, and Information Technology at the University of Zurich approved the study. In addition, the Sudanese National Council for Child Welfare, the Gezira State Council for Child Welfare, the Gezira Ministries of Health and Education, and all relevant community authorities in all communities approved the study in Sudan. Participation was strictly voluntary and conditional on informed verbal consent. We have uploaded the data supporting this article and the `R` [48] code used for analysis as Supplementary Material.

4 Homogeneous choices within groups

To derive predictions for group-level outcomes, we focus on two separate dimensions of frequency-dependent social influence. First, we distinguish between various social learning strategies in terms of their aggregate consequences. Second, we distinguish between hypotheses stipulating exactly when social information affects choices. We call this the "reach" of social influence. When social influence has extensive reach, social information affects choices under diverse conditions. When social influence has limited reach, its consequences appear under a relatively limited set of conditions. We begin by focusing on the extent to which choices within groups were heterogeneous or homogeneous. The variable of interest is the variance in choices by sequence.

4.1 Types of social influence

Assume participants choose one of two options in sequence, as in our experiment. We label the two options "Y" and "N", as in "Yes, I agree" and "No, I do not agree". In addition, we focus on scenarios in which a single type of social learning dominates. This is only for analytical clarity. Indeed, as explained above (§ 2), experimental evidence indicates that social learning strategies vary considerably [29], and this can have a dramatic influence on cultural evolutionary dynamics (Fig. 1). This is precisely why we analyse group outcomes directly.

1. **Linear transmission.** Linear transmission [7] simply reproduces, in expectation, the current distribution of choices in the group. Linear transmission has no effect on the distribution of choices through time, and thus social information should have no effect on the variance in choices within groups.

2. **Non-conformist transmission.** Non-conformity can take two basic forms. One form [9] leads groups to converge smoothly to an equal accumulated mix of Y and N choices. The other form [8, 41] leads groups to converge in an oscillating fashion to an equal accumulated mix of choices. In either case, the variance in choices should converge to its maximum possible value.

3. **Conformist transmission.** Conformist transmission tends to exaggerate the size of any majority [7, 9], and this pushes the distribution of choices towards one of the boundaries. Groups should become increasingly homogeneous as a result, and the variance in choices within groups should go to zero.

4.2 The reach of social influence

We consider reach by distinguishing between self-consistency, an instrumental response to social information, and spillovers. We focus on scenarios in which one type of reach dominates. This is again for analytical clarity. We do not mean to imply that people do not or cannot vary in terms of when they respond to social information.

1. **Self-consistency.** When self-consistency dominates [23, 24], an individual repeats her previous choice when choosing again. In our asocial-social treatment, asocial choices should determine what happens in the social condition. In the social-asocial treatment, social choices should determine what happens in the asocial condition. Social choices when first, however, need not be similar to asocial choices when first. Altogether, treatment variation in the ordering of the two conditions across participants should be decisive, but the distinction between the asocial and social conditions within any given participant is irrelevant. In terms of reach, social information affects choices in two of the four conditions. The effect is direct in the social condition when first and indirect in the subsequent asocial condition.

2. **Instrumental.** If social influence is instrumental [26], its effects only appear when choices are observable by others in the group. By extension, the consequences of social information should only appear in our social conditions, regardless of whether first or

second. Treatment variation in the ordering of the two conditions across participants is irrelevant, but the distinction between the asocial and social conditions within any given participant is decisive. In terms of reach, social information only affects choices in the two social conditions. The effect is direct in both cases.

3. **Spillovers.** If social information generates spillovers [26, 28, 49], social information shapes choices when it first becomes available and subsequently, even when no longer available. In our asocial-social treatment, choices should change as individuals move from the condition without social information to the condition with social information. In the social-asocial treatment, however, effects due to social information should appear in the initial social condition and spill over to the subsequent asocial condition. Treatment variation in the ordering of conditions across participants interacts with the distinction between the asocial and social conditions within participants. In terms of reach, social information affects choices in three of the four conditions. The effect is direct in the two social conditions and indirect in the asocial condition when second. Importantly, as discussed in the introduction, spillovers might occur because of a desire to be self-consistent, but the asymmetry in spillovers implies that self-consistency does not dominate other concerns. If self-consistency dominates, choices in the second condition follow from choices in the first condition, regardless of what the first condition is. Spillovers, in contrast, as we use the term, specifically refer to choices in a social setting affecting subsequent choices in an asocial setting.

4.3 Predictions and Results

Crossing three forms of social influence with three types of reach leads to nine different combinations. If social influence is predominantly linear, choice heterogeneity should be the same across all four conditions because linear transmission has no expected effect on the distribution of choices in the group. We can ignore reach because reach concerns the conditions under which the effects of social influence appear.

If non-conformity predominates, it increases choice heterogeneity under some conditions. If conformity predominates, it decreases choice heterogeneity under some conditions. The specific conditions that allow any change in heterogeneity to appear depend on reach. Under self-consistency, the change appears when the social condition is first (S,a), and it extends to the subsequent asocial condition (s,A). Instrumental social influence, in turn, ensures that the effects of social information obtain under social conditions, whenever they occur, (S,a)

and (a,S), but not otherwise. Finally, spillovers mean that social information affects choice heterogeneity under social conditions, (S,a) and (a,S), and when asocial choices follow social choices (s,A).

For each sequence we calculated the final proportion of participants choosing Y. For sequence n in the final position T, call this $q_{n,T}$. Fig. 3 shows the distributions over values of $q_{n,T}$ for each of the four conditions. One condition was clearly different from the others. Namely, the asocial condition when first produced sequences with a clear mix of choices, and thus a relatively high variance in choices, at a much higher rate than the other three conditions. In particular, the other three conditions resulted in $q_{n,T}$ values near the boundaries roughly 45%-50% of the time, while the asocial condition when first only did so roughly 25% of the time.

For statistical inference, we calculated the final variance in choices for sequence n as $q_{n,T}\left(1-q_{n,T}\right)$. We analysed these variance values as dependent variables in regression models (Supplementary Material, § 2) with model selection and multi-model inference [50, 51]. Our primary concern was to examine the experimental treatment effects. We designed the entire study to identify these effects, and we restricted the model selection exercise to include treatment dummies for (s,A), (S,a), and (a,S) in all models (Supplementary Material, § 2). We have also incorporated additional control variables to examine any associated effects in an exploratory fashion. We introduce these control variables here. For the analyses of individual choices below, we discuss these controls further and present relevant hypotheses suggested by earlier studies.

First, we included a dummy indicating if the primary economic activity in the community is agriculture (Agriculture Comm) versus herding, government, and trading. Second, we included a dummy for communities in East Gezira (East Gezira) versus Umalgoura. Our local informants were unanimous in their belief that these two regions are different, with East Gezira viewed as more conservative than Umalgoura. Finally, we included the population size of the community (ln(Population Size)) and the proportion of participants in the session who were female (Prop Females). We systematically included or removed these variables in a model selection exercise explained in the Supplementary Material (§ 2). Because the data comprise multiple observations per session and per community, all models had nested random effects at these two levels.

The analysis confirms that the variance in choices within groups was higher in the asocial condition when first compared to the other three conditions (Table 1). This pattern is only consistent with conformity plus spillovers. Regression results also show that choice

homogeneity was associated with communities in which agriculture was the primary economic activity, with communities in East Gezira, and with relatively large communities. In addition, sessions with a greater proportion of women were more homogeneous than sessions with fewer women. The analyses of individual choices that follow clarify the mechanisms behind these patterns.

5 Analysis of individual choices

Over all conditions, 23.4% of participant choices were Y (i.e. agree with strongly punishing the child). In the asocial condition when first (A,s), 30.1% of participants chose Y, while 20.2% did so in the asocial condition when second (s,A). In social conditions, participants chose Y 23.7% of the time when the social condition was first (S,a) and 18.6% of the time when second (a,S). To analyse individual decision making, we used logistic regressions with Y (1) as the positive response (Supplementary Material, § 3). As above, we used model selection with multi-model averaging [50, 51] for statistical inference.

We analysed individual choices in three different ways. First, we analysed all choices from all four conditions to provide a general overview of how choices varied according to the characteristics of the individual, the community, and the experimental session. Second, we analysed choices from the two social conditions, whether first or second, to examine potentially heterogeneous social learning strategies. Finally, we analysed choices from the second conditions in sessions, whether social or asocial, to identify how self-consistency and social learning may have jointly shaped decision making.

5.1 All choices, all conditions

To analyse all choices from all four conditions, we included treatment dummies for the conditions (s,A), (S,a), and (a,S), and we restricted the model selection exercise to ensure that these dummies appeared in all models (Supplementary Material, § 3.1). Mirroring the aggregate-level analysis above, we also incorporated controls for the community (Agriculture Comm, East Gezira, ln(Population Size)) and the session (Prop Females). Because the analysis focuses on individual choices, we further included a dummy indicating if the decision maker was female (Female). We systematically included or removed control variables according to the model selection exercise detailed in the Supplementary Material (§ 3.1). Because the data for this analysis include multiple observations per subject, per session, and per community, we included random effects at all three levels in all models.

Table 2 shows the model averaged results. All else equal, participants from primarily agricultural communities (Agriculture Comm) were less likely to choose Y than people from other communities, and people from communities in East Gezira were less likely to choose Y than people from communities in Umalgoura. In addition, choosing Y was negatively associated with community size (ln(Population Size)). Because choices were slightly biased away from Y in general (Fig. 3), these results imply, quite apart from any effects related to conformity, relatively homogeneous choices in agricultural communities, in East Gezira, and in large communities (see Table 1). Individual choices had no clear relation with being a female (Female) or with the proportion of women in the experimental session (Prop Females). Finally, compared to the omitted category (A,s), Y choices were less common in both social conditions ((a,S) and (S,a)) and in the asocial condition when second (s,A).

5.2 Social conditions, whether first or second

To model choices in social conditions, we introduced a treatment dummy that indicates if the social condition was the first condition (Social First) in the session (i.e. (S,a)). We restricted the model selection exercise such that this dummy was present in every model. To examine social learning, we also introduced the observed proportion of Y choices for a given decision maker (Lag One Prop Yes) and the decision maker's position in the sequence (Sequence Position). Because social information was not available for the first participant in a sequence, we analysed choices from the second position onwards. With only one observation per participant, models did not include random effects at the individual level, but they did incorporate nested random effects at the session and community levels. We incorporated control variables for the individual (Female), the community (Agriculture Comm, East Gezira, ln(Population Size)), and the experimental session (Prop Females), and we systematically included or removed variables based on the model selection exercise explained in the Supplementary Material (§ 3.2).

Importantly, we also examined interactions between social information (Lag One Prop Yes) and all other variables. We did so to identify any systematic variation in social learning strategies based on the characteristics of the individual, the individual's community, or the experimental session. Although this analysis should be considered exploratory, past studies suggest at least three key hypotheses. First, under some circumstances women tend to conform or rely on social learning more than men [33–35]. In our case, such an effect would amount to a positive interaction between being a female and social information (Female $\times$ Lag One Prop Yes). Second, large groups tend to aggregate information more effectively than

small groups [8, 52]. This suggests that people should show a stronger tendency to conform to the majority of a large group compared to that of a small group, and both classic [53] and recent [30] experimental studies have found this pattern. In our setting, this means that people late in the sequence should have conformed more than people early in the sequence, which implies a positive interaction between sequence position and social information (Sequence Position × Lag One Prop Yes). Finally, a recent experimental study in Ethiopia [42] found that horticulturalists were more independent in their daily lives than pastoralists and other groups, and they relied less on social learning in an experiment. In our context, this logic suggests that participants from agricultural communities should have conformed less than others, which would translate into a negative interaction between agriculture and social information (Agriculture Comm × Lag One Prop Yes).

Model-averaged results show that participants responded strongly to frequency-dependent social information (Table 3). The proportion of preceding Y choices (Lag One Prop Yes) was positively associated with the focal decision maker choosing Y. Positive interactions also reveal that, all else equal, females conformed more strongly than males (Female × Lag One Prop Yes), and participants choosing late in a sequence conformed more strongly than those early in the sequence (Sequence Position × Lag One Prop Yes). We found no evidence for other forms of heterogeneity in social learning. Of particular note, the tendency to conform did not vary based on whether the social condition was first in the session (Social First × Lag One Prop Yes). Nor did it vary based on whether agriculture was the primary productive activity in the community (Agriculture Comm × Lag One Prop Yes).

The strong tendency to follow the trend among previous decision makers suggests that groups with social information should have quickly converged on a shared evaluation of the situation depicted in the film. Indeed, this was typically the case. Of the 878 social sequences in the study, 735 had an unambiguous majority choice (>50% Y or >50% N) at the midway point and the same unambiguous majority choice at the end. Of the remaining 143 social sequences, only 50 had one unambiguous majority choice halfway through, with the other choice clearly in the majority at the end. In effect, shared evaluations quickly established themselves and were self-reinforcing once this happened [10].

5.3 Second conditions, whether asocial or social

To model choices in the second conditions in sessions, we used a treatment dummy indicating if the second condition was social (Social). This dummy was present in every model considered. To examine self-consistency, we incorporated a dummy indicating if the participant's

choice in the paired (first) sequence in the session was Y (Subject Yes (P)). For social learning, we relied as above on the observed proportion of Y choices in the sequence (Lag One Prop Yes)[2]. As in our analyses of social conditions, we restricted attention to choices from the second sequence position onwards. With one observation per subject, we did not include random effects at the individual level, but we did at the session and community levels.

We considered control variables for the individual (Female), the community (Agriculture Comm, East Gezira, ln(Population Size)), and the experimental session (Prop Females). In addition, we considered interactions between the treatment and the participant's first choice (Social × Subject Yes (P)), as well as between the treatment and social information (Social × Lag One Prop Yes). The interaction between treatment and the participant's first choice identifies any variation in self-consistency by treatment. Analogously, the interaction between treatment and social information identifies in variation in social learning by treatment. We included or removed variables based on the model selection exercise outlined in the Supplementary Material (§ 3.3).

Model-averaged results (Table 4) show that individuals made self-consistent choices (Subject Yes (P)), and they followed the trend among previous decision makers in the current sequence (Lag One Prop Yes). Self-consistency did not vary by whether the second condition was asocial or social (Social × Subject Yes (P)). However, the tendency to follow the trend among upstream decision makers did vary by treatment. In particular, a positive interaction (Social × Lag One Prop Yes) indicates that this tendency was stronger in the social condition than the asocial condition.

These results are consistent with the information that was available during the second condition in a session. Specifically, as long as a participant could remember her previous choice, she could make a self-consistent choice regardless of whether she was choosing in an asocial or a social condition. Accordingly, subjects were self-consistent. Moreover, when controlling for social learning (Lag One Prop Yes), the tendency to make self-consistent choices did not vary by treatment. In terms of social learning, however, social information was not available in the asocial condition (s,A), but it was available in the social condition (a,S). Congruent with this discrepancy, the positive interaction between frequency-dependent social information and the social condition (Social × Lag One Prop Yes) reveals that conformity was stronger when social information was available. This result, of course, must hold if people tend to conform when conformity is possible.

[2]We do not include the final distribution of choices from the first sequence in the session as the estimated effect would not be causal due to a form of endogeneity known as the "reflection problem" [54]

6 Discussion

With a large lab experiment in Sudan, we have shown that frequency-dependent social information led participants to converge on a common evaluation of how to behave in a given social situation. Social information essentially doubled the rate at which groups developed a shared evaluation (Fig. 3). Moreover, homogeneous normative evaluations spilled over from a social setting to a subsequent asocial setting. These findings support the hypothesis that social learning generates relatively homogeneous social norms, and humans have a psychology well-disposed to carry these norms with them, even when group affiliates are not watching [22, 26–28, 55].

In terms of the homogenising effects of frequency-dependent social information, we found that subjects exhibited a clear tendency to follow the crowd. This tendency, however, was not uniform. Some participants conformed more than others, and participants conformed more strongly in some situations than in others. In particular, females conformed more than males. This result is fully consistent with some previous studies [33–35], but interestingly a recent review concluded that sex differences in social learning are uncommon [29].

We also found that the tendency to follow the crowd increased with a participant's position in the sequence. To illustrate, a participant tenth in line was more likely to follow a two-thirds majority among the preceding nine decision makers than a participant fourth in line who faced the same relative choice frequencies. This result is consistent with the theoretical argument that large groups aggregate noisy information into a powerful signal [8, 52], and it is consistent with recent [30] and classic [53] experimental findings.

We did not find further evidence for heterogeneity in social learning strategies. In particular, choices were relatively homogeneous in sequences consisting of subjects from agricultural communities, communities in East Gezira, and relatively large communities (Table 1). This homogeneity, however, did not arise from some special tendency among these subjects to conform (Table 3). Rather, homogeneity arose from the fact that these subjects were simply more unanimous in their opinion that the child in the film should not be strongly punished (Table 2). In other words, pre-existing differences in values were responsible, not variation in the tendency to conform.

Finally, we found that the response to social information did not vary according to whether the social sequence preceded or followed the asocial sequence in a session. This finding suggests that in our experiment social learning superseded self-consistency. Altogether our results on social learning show that people followed the majority, but the propensity to do so

varied by both individual and circumstance. Because this kind of variation can shape cultural evolutionary dynamics in a wide variety of ways [36–38, 56], future empirical research should continue to focus on the structure of heterogeneous social learning strategies and their link to aggregate outcomes.

In terms of the spillovers we observed, a key question centres on identifying the underlying mechanisms. As one possibility, the social treatment when first led people to update their beliefs about the opinions and choices of others in the community [17, 18]. In the subsequent asocial treatment, people responded to their updated beliefs because choices about how to discipline one's children involve incentives to coordinate. While possible, participant choices were extremely heterogeneous for the subset of choices in which social information could have had no effect (Supplementary Material, § 4). This suggests that either inaccurate beliefs were pervasive, which seems unlikely with so many small tightly-knit communities, or the movie addressed a domain without strong coordination incentives.

As another possible mechanism supporting spillovers, the social treatment when first led people to change what they value. This mechanism can take at least two forms. On the one hand, perhaps people actually came to value a lenient approach to child rearing after participating in the social condition. The claim, in effect, is that people internalised the value system represented by the collective opinion [22, 26, 27]. Although an intriguing possibility, our data do not allow us to isolate such an effect.

Nonetheless, whatever the role of internalisation, self-consistency seems to have been at least partly responsible for the spillovers observed. In particular, frequency-dependent social learning homogenised choices in social conditions (Table 1). Moreover, the underlying tendency to follow the crowd was equivalently pronounced regardless of whether the social condition came first or second (Table 3), but it was more pronounced in social conditions than in asocial conditions (Table 4). Finally, controlling for the effects of frequency-dependent social information, participants were as equally likely to exhibit self-consistent behaviour in the asocial condition when second as in the social condition when second (Table 4). In other words, once we account for the effects of social information, participants exhibited a stable propensity to make consistent choices through time.

These results suggest a kind of ranked interaction between conformity and self-consistency. When the two mechanisms come into conflict, as in our asocial-social treatment, following the crowd takes precedence. Without such a conflict, as in our social-asocial treatment, self-consistency shapes decision making. Although we cannot say if this kind of interaction was entirely responsible for the spillovers we observed, our analysis of choices in the second

conditions of sessions indicates that it was at least part of the story. More broadly, we found that frequency-dependent social information can rapidly homogenise groups, and the effects of this process persist even when one's choices are hidden from the group. Both findings support a key hypothesis about how culture shapes the overall selective regime by attenuating local variation in structured populations [10, 14].

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Author contributions

CE and SV designed the study, liaised with government officials, and oversaw recruitment and data collection. SV trained the study coordinators and data collectors. CE analysed the data. CE and SV interpreted the results and wrote the paper.

Competing interests

We have no competing interests.

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Table 1: OLS regressions with the variance in choices by sequence as the dependent variable. Results are the full model averaged results based on the model selection exercise detailed in § 2 of the Supplementary Material. Models (§ 4.3) include random effects for sessions within communities, control variables for the community (Agriculture Comm, East Gezira, ln(Population Size)), and a control variable for the experimental session (Prop Females). They additionally include dummies for the asocial condition when second (s,A), the social condition when first (S,a), and the social condition when second (a,S). All continuous variables have been standardised to have a mean of zero and a standard deviation of 0.5, and dummy variables have been translated to have a mean of zero [51, 57]. Blue indicates estimates with confidence intervals that do not include zero.

Parameter	Estimate	Adjusted Std. Error	95% C.I.	Relative Importance
Intercept	0.003	0.020	[-0.035,0.041]	
Agriculture Comm	-0.189	0.060	[-0.307,-0.071]	0.99
East Gezira	-0.198	0.042	[-0.280,-0.115]	1.0
ln(Population Size)	-0.139	0.041	[-0.218,-0.059]	1.0
Prop Females	-0.064	0.031	[-0.124,-0.004]	0.93
(s,A)	-0.256	0.031	[-0.316,-0.195]	1.0
(S,a)	-0.227	0.031	[-0.287,-0.166]	1.0
(a,S)	-0.289	0.020	[-0.328,-0.250]	1.0

Table 2: Logistic regressions for individual choices, with Y as the positive response (1), for all choices in all conditions. Results are the full model averaged results based on the model selection exercise in § 3.1 of the Supplementary Material. Models (§ 5.1) include random effects for participants within sessions within communities, a variable indicating a female participant (Female), control variables for the community (Agriculture Comm, East Gezira, ln(Population Size)), and a control variable for the experimental session (Prop Females). They also include dummies for experimental condition ((s,A), (S,a), and (a,S)). All continuous input variables have been standardised to have a mean of zero and a standard deviation of 0.5, and independent dummy variables have been translated to have a mean of zero [51, 57]. Blue indicates estimates with confidence intervals that do not include zero.

Parameter	Estimate	Adjusted Std. Error	Unconditional 95% C.I.	Relative Importance
Intercept	-9.683	0.223	[-10.120,-9.246]	
Female	0.045	0.119	[-0.187,0.278]	0.28
Agriculture Comm	-0.852	0.247	[-1.337,-0.367]	1.0
East Gezira	-0.612	0.194	[-0.991,-0.233]	1.0
ln(Population Size)	-0.658	0.184	[-1.018,-0.299]	1.0
Prop Females	0.021	0.092	[-0.160,0.202]	0.21
(s,A)	-1.775	0.223	[-2.212,-1.338]	1.0
(S,a)	-0.565	0.191	[-0.939,-0.191]	1.0
(a,S)	-4.745	0.244	[-5.222,-4.268]	1.0

Table 3: Logistic regressions for individual choices, with Y as the positive response (1), in the social conditions. Results are the full model averaged results based on the model selection exercise in § 3.2 of the Supplementary Material. Models (§ 5.2) include random effects for sessions within communities, control variables for the participant (Female, Sequence Position), control variables for the community (Agriculture Comm, East Gezira, ln(Population Size)), and a control variable for the experimental session (Prop Females). They additionally include a dummy variable indicating if the social condition in question was first in the session (Social First) and the proportion of Y choices among preceding subjects in the sequence (Lag One Prop Yes). Interactions involving this latter variable (Lag One Prop Yes) identify any heterogeneity in social learning strategies. All continuous input variables have been standardised to have a mean of zero and a standard deviation of 0.5, and independent dummy variables have been translated to have a mean of zero [51, 57]. Blue indicates estimates with confidence intervals that do not include zero.

Parameter	Estimate	Adjusted Std. Error	95% C.I.	Relative Importance
Intercept	-1.737	0.068	[-1.870,-1.603]	
Female	-0.093	0.126	[-0.340,0.154]	1.0
Sequence Position	-0.516	0.077	[-0.668,-0.364]	1.0
Agriculture Comm	-0.527	0.179	[-0.877,-0.176]	1.0
East Gezira	-0.442	0.134	[-0.704,-0.179]	1.0
ln(Population Size)	-0.367	0.129	[-0.620,-0.115]	1.0
Prop Females	-0.061	0.122	[-0.301,0.513]	0.51
Social First	0.153	0.087	[-0.017,0.323]	1.0
Lag One Prop Yes	1.243	0.118	[1.012,1.474]	1.0
Social First × Lag One Prop Yes	0.193	0.148	[-0.098,0.483]	1.0
Female × Lag One Prop Yes	0.692	0.214	[0.273,1.110]	1.0
Sequence Position × Lag One Prop Yes	0.551	0.176	[0.205,0.896]	1.0
Agriculture Comm × Lag One Prop Yes	0.115	0.189	[-0.255,0.484]	0.7
East Gezira × Lag One Prop Yes	0.255	0.214	[-0.164,0.674]	0.7
ln(Population Size) × Lag One Prop Yes	0.050	0.130	[-0.205,0.305]	0.7
Prop Females × Lag One Prop Yes	0.102	0.210	[-0.309,0.513]	0.3

Table 4: Logistic regressions for individual choices, with Y as the positive response (1), in the second conditions in sessions. Results are the full model averaged results based on the model selection exercise in § 3.3 of the Supplementary Material. Models (§ 5.3) include random effects for sessions within communities, control variables for the participant (Female, Sequence Position), control variables for the community (Agriculture Comm, East Gezira, ln(Population Size)), and a control variable for the experimental session (Prop Females). They additionally include a dummy variable indicating if the second condition in question was social (Social), a dummy indicating if the subject chose Y in the first condition of the session (Subject Yes (P)), and the proportion of Y choices among preceding subjects in the current sequence (Lag One Prop Yes). Interactions involving these latter two variables identify variation in self-consistency or social learning by experimental condition. All continuous input variables have been standardised to have a mean of zero and a standard deviation of 0.5, and independent dummy variables have been translated to have a mean of zero [51, 57]. Blue indicates estimates with confidence intervals that do not include zero.

Parameter	Estimate	Adjusted Std. Error	95% C.I.	Relative Importance
Intercept	-2.532	0.083	[-2.695,-2.369]	
Female	0.104	0.166	[-0.222,0.431]	1.0
Sequence Position	-0.221	0.094	[-0.405,-0.038]	1.0
Agriculture Comm	-0.457	0.172	[-0.794,-0.121]	1.0
East Gezira	-0.521	0.132	[-0.780,-0.262]	1.0
ln(Population Size)	-0.298	0.124	[-0.541,-0.055]	1.0
Prop Females	-0.509	0.186	[-0.873,-0.145]	1.0
Social	-0.813	0.126	[-1.059,-0.566]	1.0
Subject Yes (P)	3.599	0.119	[3.366,3.832]	1.0
Lag One Prop Yes	0.773	0.108	[0.561,0.985]	1.0
Social × Subject Yes (P)	0.014	0.112	[-0.205,0.233]	0.27
Social × Lag One Prop Yes	0.935	0.199	[0.546,1.324]	1.0

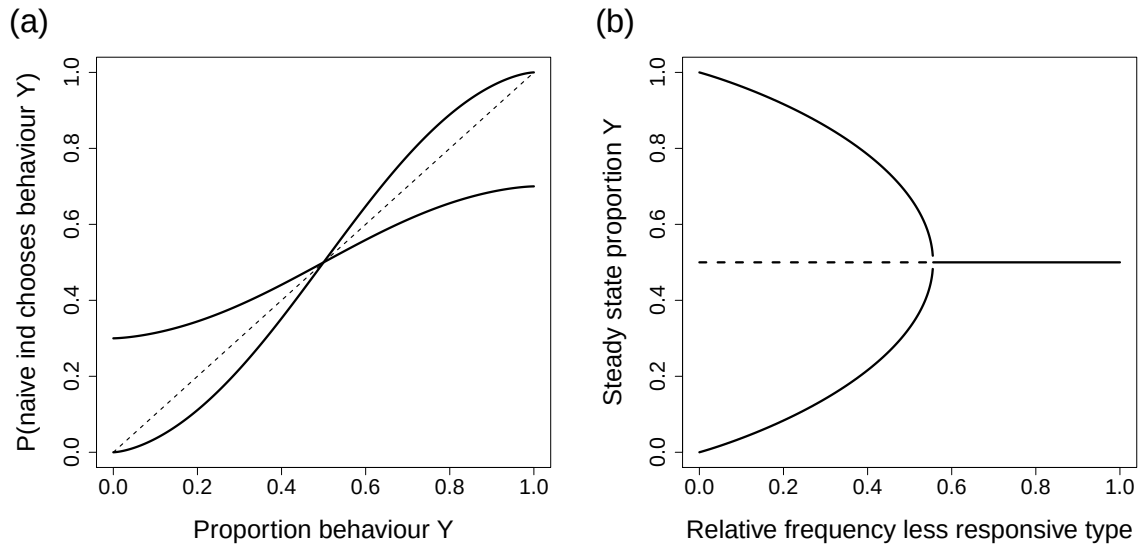

Figure 1: The long-run aggregate effects of social learning strategies that vary. Assume two possible behaviours, Y and N. Panel (a) shows two types of frequency-dependent social learner. Each type chooses Y with a probability that increases as Y becomes more common, and both do so according to a strategy with the sigmoidal shape characteristic of conformist transmission [9]. The probability of choosing Y rises relatively steeply for one type, and this type responds more strongly to social information. The other type is less responsive. Panel (b) shows the steady states of the associated cultural evolutionary system. Solid lines are locally stable steady states, and the dashed line is locally unstable. As the relative frequency of the less responsive type increases, the stable steady states converge, and at some point the system has a unique stable steady state with a uniform mix of Y and N. At this point, behavioural heterogeneity takes its maximum possible value.

Figure 2: An experimental session. The photo shows procedures for a social sequence in which participants displayed their choices to everyone in the group. Thank you to Amy Elhadi for permission to use the photo.

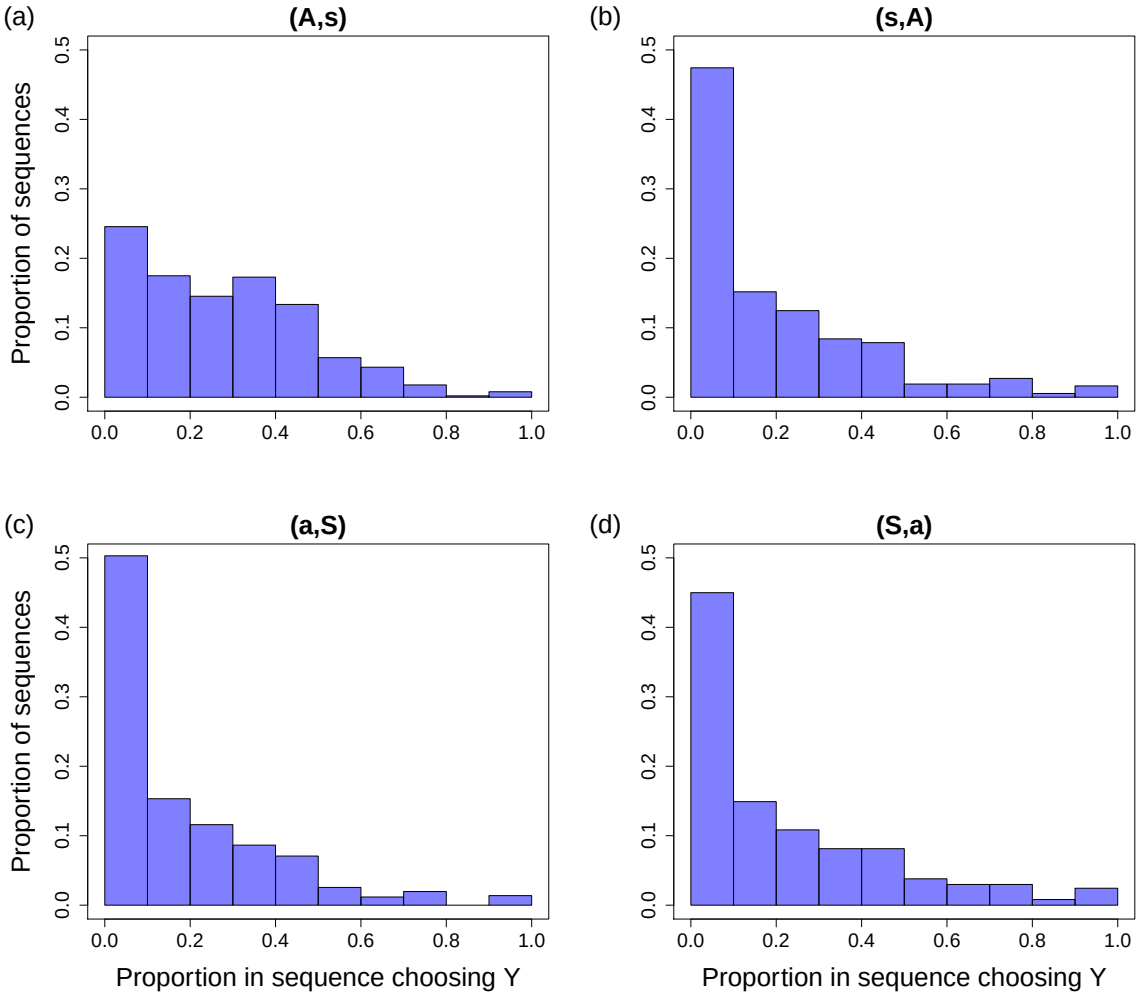

Figure 3: Final aggregate outcomes by condition. Each sequence resulted in a final proportion of participants choosing to agree with strong punishment of the child in the film (Y). Call this proportion $q_{n,T}$ for sequence n. Histograms show distributions over $q_{n,T}$ values by condition. Panel (a) shows the asocial condition in the asocial-social treatment (A,s), and panel (c) shows the corresponding social condition (a,S). Panel (b) shows the asocial condition in the social-asocial treatment (s,A), and panel (d) shows the corresponding social condition (S,a). Choices within groups were relatively heterogeneous in the asocial condition when first and relatively homogeneous in the other cases. This result shows that social information homogenised choices within groups, and this homogenising effect spilled over to the subsequent asocial setting.