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Societal background influences social learning in cooperative decision making

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ABSTRACT

Humans owe their ecological success to their great capacities for social learning and cooperation: learning from others helps individuals adjust to their environment and can promote cooperation in groups. Classic and recent studies indicate that the cultural organization of societies shapes the influence of social information on decision making and suggest that collectivist values (prioritizing the group relative to the individual) increase tendencies to conform to the majority. However, it is unknown whether and how societal background impacts social learning in cooperative interactions. Here we show that social learning in cooperative decision making systematically varies across two societies. We experimentally compare people's basic propensities for social learning in samples from a collectivist (China) and an individualist society (United Kingdom; total n = 540) in a social dilemma and a coordination game. We demonstrate that Chinese participants base their cooperation decisions on information about their peers much more frequently than their British counterparts. Moreover, our results reveal remarkable societal differences in the type of peer information people consider. In contrast to the consensus view, Chinese participants tend to be substantially less majority-oriented than the British. While Chinese participants are inclined to adopt peer behavior that leads to higher payoffs, British participants tend to cooperate only if sufficiently many peers do so too. These results indicate that the basic processes underlying social transmission are not universal; rather, they vary with cultural conditions. As success-based learning is associated with selfish behavior and majority-based learning can help foster cooperation, our study suggests that in different societies social learning can play diverging roles in the emergence and maintenance of cooperation.

1. Introduction

The adaptability of humans largely depends on their social nature (Boyd, Richerson, & Henrich, 2011; Henrich, 2015). Many people are inclined to cooperate with others and coordinate their actions in groups, allowing them to overcome challenges that would be impossible to tackle alone. The willingness to help others at one's own expense promotes mutually beneficial outcomes and underlies the smooth functioning of societies (Bowles & Gintis, 2011). Human cooperativeness is complemented and facilitated by a great capacity for social learning, that is, adjusting behavior through observing and interacting with others (Hoppitt & Laland, 2013; Tomasello, 2009). Social learning enables individuals to adapt to new social and environmental conditions and allows useful knowledge to accumulate in human populations and be transmitted across generations, forming the basis of human culture (Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981; Derex & Boyd, 2016; Henrich, 2015; Hoppitt & Laland, 2013; Mesoudi, 2011a; Tomasello, 2009).

Theory suggests that individuals should decide strategically from whom to learn (Cavalli-Sforza & Feldman, 1981; Kendal, Giraldeau, & Laland, 2009; Laland, 2004; Rendell et al., 2010). Two prominent strategies are payoff-based learning (Schlag, 1998), in which people imitate successful peers, and majority-based learning (Boyd & Richerson, 1985), where people tend to conform to locally common behavior. These social learning strategies can have profound consequences for the dynamics of cooperation in groups (Boyd & Richerson, 1985; Burton-Chellew, El Mouden, & West, 2017; Burton-Chellew, Nax, & West, 2015; Lehmann & Feldman, 2008; Lehmann, Feldman, & Foster, 2008; Molleman, Pen, & Weissing, 2013; Molleman, Quiñones, & Weissing, 2013; van den Berg, Molleman, & Weissing, 2015). When individuals in a group mutually benefit from coordinating their behavior, the relative frequencies of payoff-based and majority-based social learning can affect the outcome of social interactions and change the stability of equilibria by altering their basins of attraction

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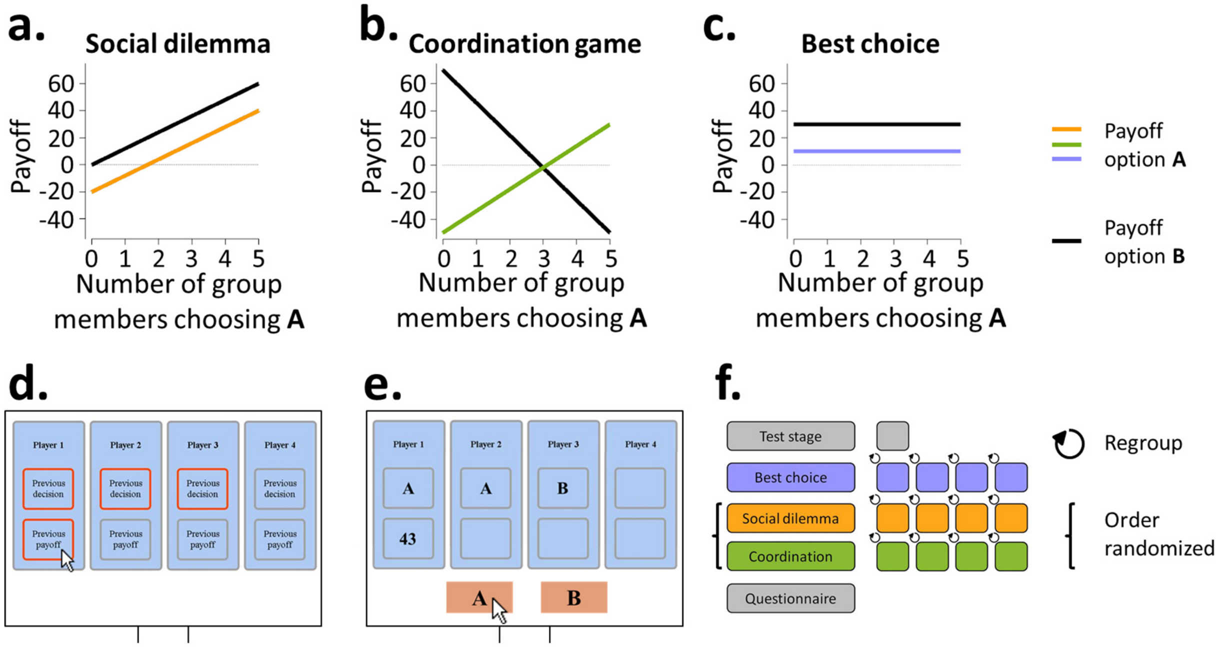

Fig. 1. Summary of the experimental setup. (a, b, c) Payoff structure of the three interaction settings. (a) Social dilemma: option A ('cooperate') increases the average payoffs of either option for all group members, while option B ('defect') is individually optimal. (b) Coordination game: option *B* has higher expected payoffs than option A when all group members choose it, but expected payoffs of either option increase with the number of group members choosing it. (c) Best choice setting: expected payoffs are independent of other group members, and one of the options leads to higher payoffs than the other. Panels show the deterministic part of the payoffs; actual payoffs were noisy (Section 2.5). (d, e) Stylized screenshots of the two key experimental screens. In each period of a block (after the first, where no social information was available yet), participants could choose ('yes' or 'no') to pay two points to collect information. If they chose 'yes', they were directed to the screen shown in (d), which allowed them to collect information about the previous decision and previous payoffs of each of their four peers. Participants could select up to four pieces of information by clicking on the boxes. Boxes could be deselected, but the number of selected boxes could never exceed four. The screen in panel (e) subsequently revealed the selected information, and participants made their choice at the bottom. Both screens in (d, e) are stylized for explanatory purposes; in the real experiment participants chose between planting different crops on a virtual farm (Supplementary materials). (f) The overall structure of a session, based on the design of Molleman et al. (2014) and van den Berg et al. (2015). Each square represents a block of five periods in which participants made binary decisions in groups of five. In between these blocks, new groups were randomly formed. Sessions started with an unincentivized test stage to make participants familiar with the decision-making environment. The incentivized part of sessions started with a 'best choice' setting (the simplest setting, as payoffs did not depend on the decisions of others). The order of the subsequent social dilemma and coordination game was randomized between sessions. Sessions concluded with a questionnaire with demographic items, as well as items related to interdependence and attitudes towards conformity (Figs. S1 and S2).

(Molleman, Pen, et al., 2013; Pena, Volken, Pestelacci, & Tomassini, 2009; Skyrms, 2005). Moreover, when individual and group interests are at odds with each other (e.g., in a social dilemma), payoff-based social learning typically undermines cooperation within groups because defectors tend to achieve higher payoffs than cooperators (Burton-Chellew et al., 2015; van den Berg et al., 2015). By contrast, majority-based social learning can help support cooperation when individuals cooperate as long as their interaction partners do so as well (Boyd & Richerson, 1985, 2010). An influential strand of theory holds that when individuals conform to local majorities, stable between-group differences can emerge, fueling a process of 'cultural group selection' where internally cooperative groups outcompete less cooperative groups, ultimately leading to the spread of cooperation on a large scale (Boyd, Gintis, Bowles, & Richerson, 2003; Boyd & Richerson, 2010; Henrich, 2004; Richerson et al., 2016).

Despite the widely acknowledged importance of social learning strategies in human adaptation and cooperation, experimental evidence on the determinants of these strategies is currently lacking (Mesoudi, Chang, Dall, & Thornton, 2016). We use a large-scale decision-making experiment ($n = 540$) to study how the cultural organization of a society (Greif, 1994) shapes social learning in cooperative decision making. We focus on 'collectivism–individualism', a society-wide set of values that govern the role of the individual relative to the group (Greif, 1994; Hofstede, Hofstede, & Minkov, 2010; Markus & Kitayama, 1991; Schwartz, 1994). Collectivist and individualist values have been shown to mold human cognition and social behavior in a range of domains such as thinking styles (Nisbett, 2010), everyday dishonesty (Gächter & Schulz, 2016), and the inclination to trust others (Yamagishi, Cook, & Watabe, 1998).

The central role of the group in collectivist societies plausibly modulates the relevance of social information in people's everyday interactions. In collectivist societies, people tend to see themselves primarily as part of a collective; they tend to value fitting-in and harmony and to derive their own identity from their relationships with others. By contrast, people from individualist societies are inclined to see themselves as independent, to emphasize uniqueness and autonomy, and to regard others as points of social comparison (Markus & Kitayama, 1991). More than individualist societies, collectivist societies emphasize conformist values in upbringing, schooling, and daily life (relying on rote learning and valuing obedience to parents and teachers; Mesoudi, Chang, Murray, & Lu, 2015; Schwartz, 1994). Psychological studies indicate that people from collectivist societies are more likely than people from individualist societies to conform to majority behavior among their peers (Bond & Smith, 1996). Moreover, recent behavioral experiments suggest that collectivist values may enhance individuals' reliance on social learning in solving complex individual tasks (Glowacki & Molleman, 2017; Mesoudi et al., 2015; Toelch, Bruce, Newson, Richerson, & Reader, 2014). Based on these observations, we predict that people from collectivist societies rely more on social information in cooperative interactions, and are more inclined to follow majority behavior than people from individualist societies.

We use a behavioral experiment to assess basic propensities for social learning in cooperative decision making across two very different societies, China and the United Kingdom. We ask to what extent people from a collectivist (China) and an individualist (United Kingdom) society use social information in making cooperative decisions, and whether they use payoff-based or majority-based social learning strategies. Native Chinese (in Ningbo and Shanghai, $n = 320$) and native British participants (in Norwich and Nottingham, $n = 220$) completed a series of tasks (Molleman, van den Berg, & Weissing, 2014; van den Berg et al., 2015) in which they interacted anonymously via web browsers. Participants were placed in groups of five to make a series of simultaneous binary decisions. If societal background matters, we expect similar behavior within a country, but differences between countries.

Participants faced three interaction settings in sequence (Fig. 1): a social dilemma, a coordination game, and a 'best choice' setting. In the *social dilemma*, one option ('cooperate') increased the average payoffs of all group members, while the other option ('defect') improved one's own payoffs in a given period. In the *coordination game*, the expected payoffs of either option increased with the number of group members choosing it. In case all group members coordinated on the same option, one option had higher expected payoffs than the other option (that is, the two pure strategy equilibria have different expected payoffs). In the *best choice setting*, one option was associated with higher expected payoffs than the other option, and payoffs did not depend on the choices of other group members. In each interaction setting participants were informed of the general payoff structure, but actual payoffs were noisy, making social information a potentially valuable source of information for decision making (Methods).

Our best choice setting reflects an individual decision-making situation, as payoffs of behavior are independent of the behavior of others. Interaction settings like these have been studied in experimental work on human social learning (e.g., Efferson et al., 2007; McElreath et al., 2005, 2008; Mesoudi, 2008, 2011b; Toelch et al., 2014). In such situations, social information is mainly useful for improving one's estimates of the payoffs of behavioral alternatives in a noisy or complex environment. Accordingly, when given the choice between various social learning strategies, people tend to use payoff-based social learning (Mesoudi, 2011b). Although these findings give valuable insights into the mechanisms of social transmission and help explain the spread of technological innovations, they have limited relevance to cooperative settings, where payoffs of behavior depend on both the external environment and the behavior of others. This is why the social dilemma and the coordination game take center stage in our paper. In such settings, it becomes important to track the distribution of the behavioral tendencies of one's interaction partners. Experimental evidence suggests that in cooperation settings, many people indeed tend to rely on information about majority behavior rather than information about their peers' payoffs (Molleman et al., 2014).

In our experiment, we measure basic aspects of each participant's social learning strategy by having them choose whether or not to request information about their peers before making their own decisions. Choosing to request social information comes at a small cost, and allows participants to obtain up to four units of social information before making a decision. Each unit reveals the previous decision or the previous payoff of another group member. We characterize each individual's social learning strategy based on two measures: their request rate for social information (i.e., their reliance on social learning) and, conditional upon requesting social information, the fraction of requests including payoff information (i.e., their orientation towards payoffs or the majority). To assess the effect of societal background on social learning in cooperative decision making, we focus on variation within and between countries with respect to individuals' reliance on social learning and orientation towards payoffs or the majority. If societal background matters, we predict high between-country and low within-country variation in social information requests.

2. Methods

2.1. Rationale

Our research strategy was to conduct our experiment using participant pools from the United Kingdom and China, countries on opposite ends of sociological axes of individualism–collectivism (the United Kingdom ranks 3rd and China ranks 58th out of 76 countries listed in a widely used 'individualism index' (Hofstede et al., 2010), with scores of 89 and 20 out of 100, respectively). We followed the standards of cross-cultural experimentation, varying our variable of interest (i.e., collectivism) while aiming to minimize other potentially confounding factors as much as possible (Gächter & Schulz, 2016; Herrmann, Thöni, & Gächter, 2008; Roth, Prasnikar, Okuno-Fujiwara, & Zamir, 1991; for further discussion, see Experimental Procedures in the Supplementary Information). To check whether collectivist values varied across samples in the expected way, we measured two of its key aspects with post-experimental questionnaire items. First, we used established survey items to measure orientations towards conformity and compliance (Schwartz, 1994). Compared to British participants, the Chinese reported a stronger orientation towards conformity (two-sided *t*-test: $t = 11.645$, d.f. 370.5, $p < 0.001$; Fig. S1). Second, as a proxy of interdependence we used the 'Inclusion of the Other in the Self' scale (Aron, Aron, & Smollan, 1992; Gächter, Starmer, & Tufano, 2015), reflecting the closeness that individuals perceive in their relationships to the other participants in their session. Again, the data confirm that participants in our Chinese sample have stronger collectivist orientations, reporting significantly higher perceptions of interdependence than the British participants (two-sided *t*-test: $t = 2.392$, d.f. = 445.11, $p = 0.017$; Fig. S2).

2.2. Participants

A total of 540 participants (mostly students; 56% female; mean age 21.1 years, SD 2.9; see Supplementary Experimental Procedures for demographic details) took part in 24 experimental sessions (China: Shanghai Jiao Tong University, nine sessions, $n = 180$; University of Nottingham Ningbo Campus, five sessions, $n = 140$; United Kingdom: University of East Anglia Norwich, five sessions, $n = 75$; University of Nottingham, five sessions, $n = 145$). Participation was restricted to Chinese and British nationals respectively. There were no further participation restrictions. Participants came from diverse regions within both countries. Informed consent was obtained from all participants before starting the experiment.

2.3. Procedure

Experiments took place in computer laboratories at the four universities between January and April 2015. In each session, 10–30 participants participated and received monetary rewards depending on their performance in the experiment, which in turn depended on their decisions (see Section 2.5). At the start of a session, participants received written general instructions in their own language (sessions in Shanghai and Ningbo: Chinese; Nottingham and Norwich: English), which were also read out loud by a local native speaker (English version in Supplementary Experimental Procedures). During the session participants earned points, the total sum of which was converted into cash at the end of the experiment (in China, 20 points earned 1RMB; in the United Kingdom, 150 points earned 1GBP). Following established standards of conducting cross-cultural economics experiments (Herrmann et al., 2008; Roth et al., 1991), stake sizes were adjusted for local purchasing power. Participants earned 2120 points on average (range: 1286 to 2913), and sessions lasted for about 90 min. We used the experimental software LIONESS (Arechar, Gächter, & Molleman, 2018) to conduct the experiments. For further discussion of our experimental implementation, see Supplementary Experimental

Procedures.

2.4. Interaction settings

Participants were allocated to groups of five and repeatedly interacted anonymously via web browsers. Participants faced a total of three interaction settings (a 'best choice' setting where payoffs were independent of the actions of peers, a social dilemma and a coordination game; see Section 2.5 for details). Sessions always started with a test stage in which participants could get used to the decision-making environment, followed by the best choice setting (the simplest setting); the order of the social dilemma and the coordination game was counterbalanced between sessions. In each setting, participants received on-screen instructions particular to the upcoming setting before interactions began. The instructions outlined the general structure of the interactions but did not show any specific details on expected payoffs (see Supplementary Information, Sections 3 and 4 for instructions given on paper and on-screen). Fig. 1 summarizes the experimental setup.

Decision making was framed as choosing to produce one of two crops on a virtual farm. This framing has been commonly used to study social learning in human decision making (McElreath et al., 2005, 2008; Molleman et al., 2014; Toelch et al., 2014; van den Berg et al., 2015). We used real crop names but for simplicity we will here refer to crops A and B. In each period ('season'), all farmers in a group made their decisions simultaneously. All produced crops were sold on the 'market', after which each player saw the payoffs resulting from their own choice. Each interaction setting lasted for 20 periods in total, subdivided in four blocks of five. After each block, new groups were randomly formed and participants were presented with a fresh pair of crops to choose from. Regrouping confronted participants with new social circumstances in which gathering information about peers could be helpful in decision making.

2.5. Parameters

Each of the three interaction settings was characterized by a payoff matrix $\begin{pmatrix} a & b \\ c & d \end{pmatrix}$. Payoffs of choosing A and B were $\pi_A = p \cdot a + (1 - p) \cdot b + \varepsilon$ and $\pi_B = p \cdot c + (1 - p) \cdot d + \varepsilon$, respectively, where p denotes the fraction of participants in the group who chose option A. The ε reflects a stochastic 'noise' component (see below). For the social dilemma, we chose parameters $a = 40$, $b = -20$, $c = 60$, $d = 0$; in a given round, option B ('defect') yielded higher expected payoffs to an individual, but average payoffs increased with the number of group members choosing A (Fig. 1a). For the coordination game we chose $a = 30$, $b = -50$, $c = -50$, $d = 70$; for both options, expected payoffs increased with the number of group members choosing it. Option B had a larger basin of attraction, and if all group members chose the same option, B yielded higher expected payoffs than A (Fig. 1b). Finally, for the best choice setting, we chose parameters $a = 30$, $b = 30$, $c = 10$, $d = 10$, respectively; payoffs for A and B were independent of the choices of other group members (Fig. 1c). On the participants' decision screens (Fig. 1e) the relative positions (left or right) of the crops corresponding to A and B were randomized between blocks of the best choice setting and the coordination game. This ensured that the position (left or right) of the option with the higher expected value (or the larger basin of attraction) could vary between rounds. In the social dilemma, the positions of A ('cooperate') and B ('defect') did not change across blocks.

For each participant in each period, the noise term ε was independently drawn from a normal distribution with a mean of 0 and a standard deviation of 20. This level of noise implies that in each interaction setting, at $p = 0.5$, choosing the individually inferior option nevertheless leads to higher payoffs in 24% of the cases. Noise reflects the fact that outcomes of behavior are often influenced by exogenous factors. Moreover, noise made it harder for the subjects to find out individually the relative payoff of the choice options, thereby increasing the potential usefulness of social information.

2.6. Measures of social learning strategies

Before making their decisions, participants were given the opportunity to collect information about their fellow group members. To make participants actively consider whether or not they would want to use social information, we imposed a cost of two points for choosing to collect it. For each of the four peers in a group, two pieces of information were available: their previous decision and the previous payoff associated with that decision (Fig. 1d), resulting in a total of eight pieces of information to choose from. Participants could select these pieces of information at will, but the number of pieces that could be collected was limited to four; participants had to be selective with regard to the information they wanted to base their decisions on. We characterize the social learning strategy of each participant with regard to (i) frequency of requests (i.e., the fraction of periods in which they decided to collect social information, reflecting their reliance on social learning) and (ii) the fraction of those requests that included information about peer payoffs (i.e., the total number of requests for a peer's payoffs divided by the total number of peers consulted, reflecting their orientation towards payoffs vs. the majority). All statistical analyses were conducted in R v.3.1.3 (R Core Team, 2015).

3. Results

In each of the interaction settings, aggregate behavioral dynamics accorded with the underlying payoff structures, with most groups approaching the Nash equilibria over time (social dilemma: defection; coordination game: either of the two pure-strategy equilibria; best choice setting: choosing the high-payoff option; Figs. S3, S4, S5). In this section we present the key measures of individuals' social learning. We focus on patterns of variation between countries and between cities within countries, comparing social learning strategies in cooperative decision making in the social dilemma and the coordination game. We also present the results of the best choice setting.

3.1. Societal background shapes social learning strategies

Request rates for social information strongly differ between China and the United Kingdom (Fig. 2a, b, c). In the *social dilemma*, Chinese participants request social information much more frequently than British participants (Fig. 2a; mean request rates: China 0.551, United Kingdom 0.386). Non-parametric tests comparing the distributions of individuals' request rates reveal highly significant differences between the two countries (Mann-Whitney (MW) test with the $n = 540$ individual request rates as independent observations: $p < 0.001$) and detect no differences between cities in either country (see Table S1 for an overview of test statistics and effect sizes).

We observe similar patterns in the *coordination game*, where Chinese participants once again request social information more frequently than their British counterparts (Fig. 2b; Table S1; MW test: $p = 0.005$). As in the social dilemma, differences between countries are much larger than the differences between cities within countries. Similar results are observed for the 'non-cooperative' *best choice setting*, where Chinese participants also request social information more frequently than their British counterparts (Fig. 2c; Table S1; MW test: $p < 0.001$). The non-parametric test results are confirmed by more fine-grained analyses based on logistic generalized linear mixed models (GLMMs) fitted to individual decisions to request social information (Table S2). In sum, the large differences between countries and small differences between cities within countries indicate a systematic effect of societal background in the importance of social information in decision making.

In the *social dilemma*, the type of social information that people consider differs strongly between societies (Fig. 2d). While the British

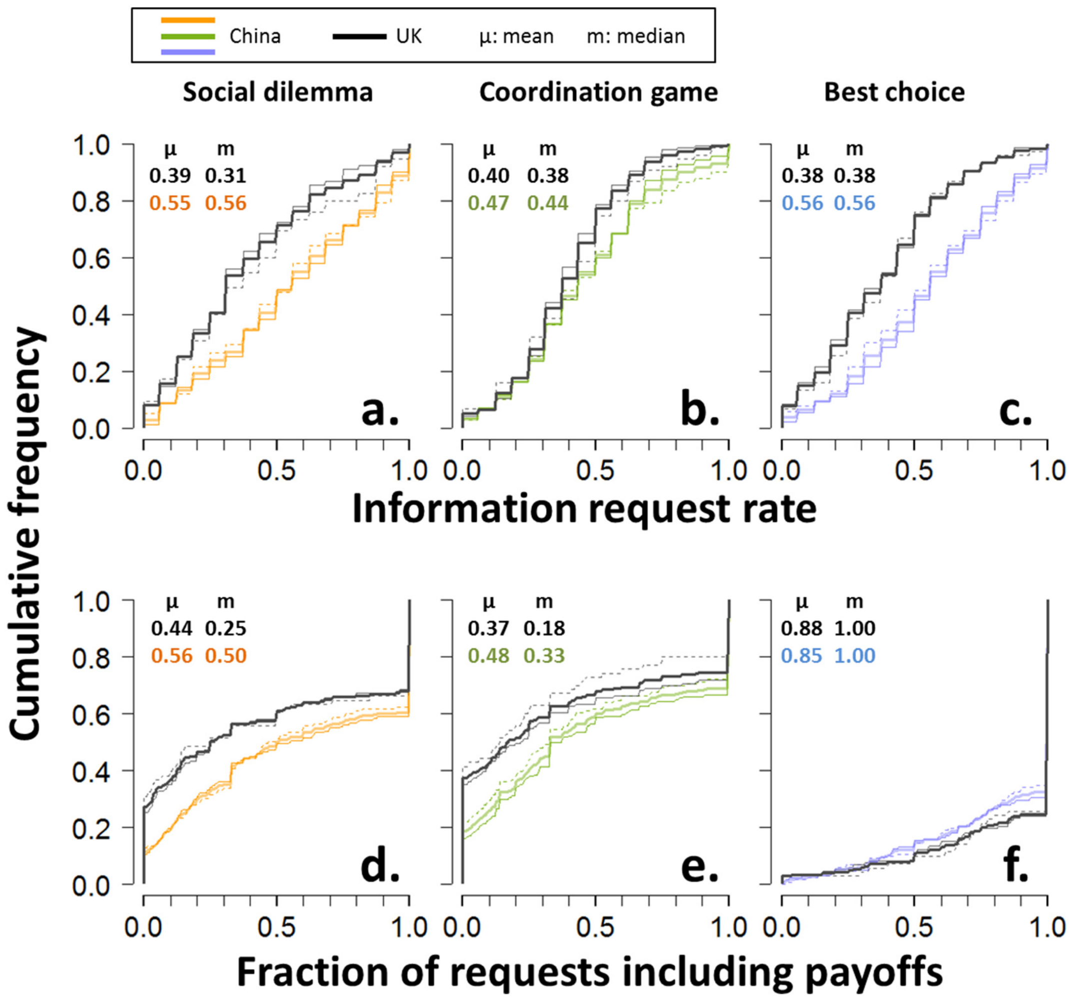

Fig. 2. Social information gathering in decision making across societies. (a, b, c) Lines show cumulative distributions characterizing individuals' social learning strategies in three interaction settings in terms of request rates for social information. (d, e, f) Conditional upon requesting any social information, the fraction of those requests including payoff information (calculated as the number of peers for which a participant requested payoff information divided by the total number of consulted peers; see Methods and Table S5 for details). Colored and black thin lines reflect data from the United Kingdom (solid: Nottingham; dotted: Norwich) and China (solid: Shanghai; dotted: Ningbo), respectively. Thick lines reflect distributions pooled by country. Means (μ) and medians (m) pooled by country are shown in the top left corner of each panel.

participants predominantly request information about the behavior of their peers, Chinese participants base their decisions much more frequently on the payoffs associated with their peers' behavior (Table S1; mean fractions of requests including payoff information by those individuals who requested social information at least once: China 0.559, United Kingdom 0.439; MW test: $p < 0.001$).

The between-country differences in orientations towards peer payoffs or peer behavior persist in the *coordination game* (Fig. 2e). Chinese participants show a considerably higher frequency of requests for peer payoffs (Table S1). Again, we observe large and significant differences between countries and relatively small and insignificant differences between cities within countries (Table S1).

In the *best choice setting*, samples from both countries show a pronounced preference for observing peer payoffs rather than peer behavior. Rates of requests for peer payoffs are much higher than in each of the other (cooperative) settings ($p < 0.001$; Table S3), but do not differ significantly between countries (Table S1). This result is in line with previous observations that in such 'non-social' settings (where individuals' payoffs do not depend on the choices of other group members), people tend to use payoff-based social learning (Mesoudi, 2011b; Molleman et al., 2014). The results of the non-parametric tests reported in Table S1 are confirmed by GLMMs fitted to individual requests for peer payoffs (Table S3).

Within each of our samples and for each of the interaction settings, we observe considerable individual variation in request rates, both with respect to the reliance on social information and to orientations towards peer payoffs or the majority (the gradually increasing lines in Fig. 2 reflect wide distributions). Such individual differences are commonly observed in empirical studies of human social information use (Efferson, Lalive, Richerson, McElreath, & Lubell, 2008; McElreath et al., 2005; Molleman et al., 2014; Muthukrishna, Morgan, & Henrich, 2016). In the cooperative settings of the social dilemma and the coordination game, participants scoring high on 'interdependence' tended to base their decisions on social information more frequently (Table S4). We did not detect significant correlations between any of the questionnaire items and participants' orientations towards either the majority or peer payoffs (Table S5).

The societal differences in gathering information about peers indicate systematic differences in social learning strategies: hen cooperative decisions are based on social information, British participants mainly attend to the behavior of the majority, while Chinese participants rely more on peer payoffs. Contrary to our predictions, this result suggests that collectivist values, though more prevalent among our Chinese participants, do not promote majority-based social learning strategies.

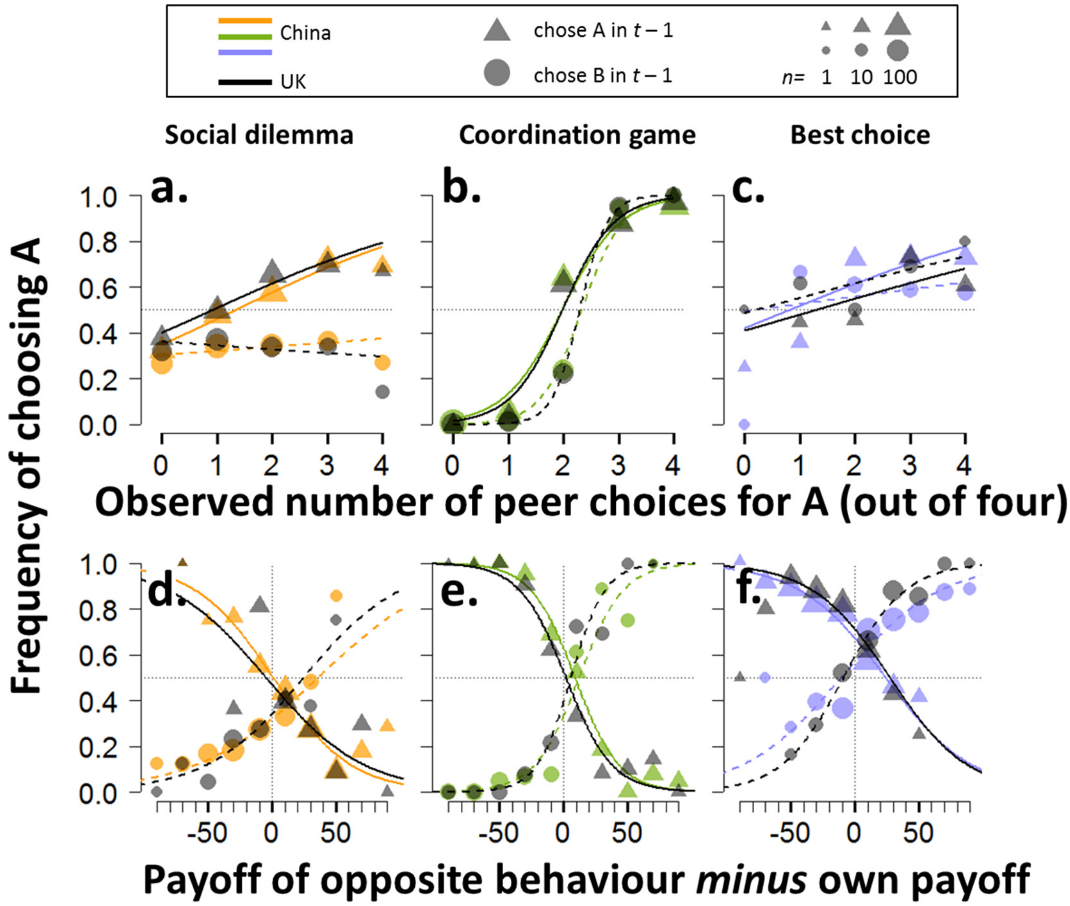

Fig. 3. Responding to social information. (a, b, c) Rates of choosing A as a function of observed peer behavior. We only include cases where participants requested information about the behavior of four of their peers. For the social dilemma, coordination game, and the best choice setting, these cases respectively comprise 46%, 48% and 9% of the periods in which social information was requested. (d, e, f) Rates of choosing A as a function of the observed difference between own payoffs and payoffs of others with the opposite decision. We only include cases where focal participants requested information about the decision and payoffs of two of their peers (and at least one peer made the opposite decision; if two peers who made the opposite decision were observed, we used the average of the two to calculate the payoff difference with the focal participant). For the social dilemma, coordination game, and the best choice setting, these cases respectively comprise 41%, 39%, and 79% of the periods in which social information was requested. In each of the panels, lines reflect logistic regressions, and symbol sizes reflect the number of observations underlying each dot (n). Data are pooled by country.

3.2. Responding to social information does not vary with societal background

Although our Chinese and British samples differ strongly in their orientations towards the majority or peer payoffs, responses to gathered information are virtually indistinguishable across samples. Fig. 3 shows that participants from China and the United Kingdom condition their decisions on the observed behavior in their group in very similar ways (Fig. 3a, b, c). In the *social dilemma*, participants from both samples are much more likely to continue their cooperation after observing more of their peers cooperating as well (Fig. 3a). After defection, the frequency of observed cooperation does not affect average levels of cooperation in either sample.

In the *coordination game*, in both China and the United Kingdom, responses to the behavior of others show a strong non-linearity: participants are disproportionately likely to match their behavior with the majority of their group (Fig. 3b). In the *best choice setting*, requests for peer behavior only are relatively scarce, and we only observe weak effects of observed frequency of peer behavior on own choices. These observations are supported by logistic GLMMs fitted to cases where participants requested the choices of all four of their peers (Table S6). We conducted an additional analysis based on a probability model (McElreath et al., 2005) to examine whether responses to observed peer behavior show signs of non-linearity – that is, whether common behavior could be disproportionately less or more likely to be adopted (Supplementary Analysis). For samples from both China and the United Kingdom, this alternative approach suggests that in the coordination game, participants are indeed disproportionately more likely to conform to majority behavior. This is not the case for the social dilemma and the best choice setting.

Responses to observing relative payoffs of decisions that are opposite to one's own are also very similar in both China and the United Kingdom for each of the interaction settings (Fig. 3d, e, f). In both samples, rates of switching increase in a similar fashion after participants observe that peers choosing the opposite behavior achieved higher payoffs (Table S7). In cases where no social information is requested, behavioral responses to individual payoffs (i.e., individual learning) also tend to be very similar in both countries (Table S8).

Overall, in the social dilemma, individuals with higher request rates for peer payoffs tend to cooperate less (linear model fitted to individuals' cooperation rates in the social dilemma for all participants: $p = 0.003$), supporting the claim that focusing on the success of others tends to induce selfish behavior (Burton-Chellew et al., 2015, 2017; van den Berg et al., 2015). In this setting, individuals' performance (aggregate payoffs) was not predicted by social learning strategies (reliance on social information or orientation towards either the majority or peer payoffs); neither did we observe any systematic differences in performance between China and the United Kingdom (see S3, S4 and S5 for further details and correlations for the other settings).

4. Discussion

Our results reveal systematic societal variation in the role of social information in cooperative interactions. In line with our expectations, cooperation decisions in the social dilemma and the coordination game were much more frequently based on social information in our collectivist samples (China) than in our individualist samples (United Kingdom). This was also the case for the best choice setting, supporting findings derived from individual decision-making tasks (Mesoudi et al., 2015). Contrary to our expectations and commonly held views (Bond & Smith, 1996), cooperation decisions in our collectivist sample were much less based on information about majority behavior but more on peer payoffs.

We designed our experiment with the aim of measuring individuals' basic propensities for social learning. To obtain such measures in a highly controlled manner, we made participants interact anonymously in computer laboratories, presenting them with stylized settings in which they made binary decisions. Of course, our experiments are simplifications of real-world social settings in which people cooperate and coordinate their actions; however, these abstract setups allow us to avoid a range of issues that would arise from using richer, more contextualized interactions, which might have different confounding effects for participants from different societal backgrounds. Our abstract setups also enable us to observe the simple building blocks of people's decision-making heuristics. Specifically, by tracking each individual's requests for social information prior to making a decision, our experiment allowed us to measure people's inclinations to use theoretically relevant social learning strategies in cooperative and coordinating interactions (i.e., payoff-based or majority-based social learning). That said, we feel that it would be valuable to test the robustness of our basic results in more realistic settings outside of the laboratory.

In our experiment, participants were re-grouped after each block of five periods. We used multiple short blocks of interactions to avoid that social information would reduce in value as groups approached equilibrium (e.g., 'defection' in the social dilemma; Fig. S3); this allowed us to repeatedly observe people's social information use in new social environments with a great deal of uncertainty about the actions of others. We designed our experiment to directly assess individuals' social learning behavior rather than full-fledged group dynamics under various forms of social learning. Previous studies focusing on such dynamics in a social dilemma setting have indicated that groups of payoff-based social learners tend to achieve lower levels of cooperation than groups of majority-based learners (Burton-Chellew et al., 2017; van den Berg et al., 2015). In our experiment, individuals who focused more on peer payoffs did cooperate less on average, but we did not find any systematic relationship between cooperation levels in groups and the social learning strategies of their members. This is most likely due in large part to the short time frame of group interactions (i.e., blocks of five periods rather than 20, as in van den Berg et al. (2015)).

Our experimental design controlled how participants could gather information about their peers and allowed them to respond to information that was largely endogenous to the experiment. Individual payoffs included a stochastic component independently drawn for each participant in each period (Section 2.5), and the social information available to participants was generated during the course of the interactions. Responses to social information (Fig. 3) in a given period were potentially influenced by factors beyond the information presented to participants when they made their decision, such as their experience in previous periods or their own previous payoffs. Insights from regression analyses controlling for such factors (Tables S6, S7) and modelling exercises aimed at estimating non-linearity in responses to social information (Supplementary Analysis) would ideally be complemented by additional, dedicated experiments providing controlled measures of individuals' responses to the full range of possible content of social (and individual) information in a given setting. Of particular conceptual interest would be a direct test assessing whether and to what extent, in the context of social dilemmas, responses to behavioral information tend to be 'conformist' (Boyd & Richerson, 1985). Experiments could establish whether people are disproportionately likely to adopt majority behavior in cooperative interactions, or whether additional mechanisms (such as punishment of deviant behavior or reputational concerns) would be required to generate conformist responses and stabilize between-group differences.

Contrary to our predictions, our experiment indicated that individuals in our collectivist samples are more oriented towards peer payoffs than majority behavior. One potential explanation for this unexpected finding is that in collectivist societies, conformity is limited to in-groups where people have established social relationships (Yamagishi et al., 1998). Our participants did not know one another and decided under anonymity—two features that inhibit strong in-group perceptions. Personal reputation was not directly at stake in our experiment, which may have reduced perceived needs to conform, especially among our Chinese participants (Yamagishi, Hashimoto, & Schug, 2008). Experiments under less anonymous conditions might shed light on the role of in-group psychology in shaping social learning strategies in general, and people's inclination to conform to majorities in particular. The enhanced focus on peer payoffs in cooperative decision making might also reflect that social learning in our Chinese sample was more rigid than in our U.K. sample, with many Chinese participants applying a similar (payoff-based) learning strategy in individual decision-making and in social settings, where payoffs depend on the behavior of others.

Our choice of subject pools (China and the United Kingdom) aimed to vary our variable of interest (i.e., collectivism) and our experimental procedures attempted to minimize other potentially confounding factors. While we control for a number of such factors in our analyses (Tables S4, S5), Chinese and British society likely differ in other respects that are unaccounted for in the current study but which might influence individuals' social learning. For example, the use of social information might vary with alternative cultural dimensions (Hofstede et al., 2010; Singelis, Triandis, Bhawuk, & Gelfand, 1995), and might be impacted by other ecological, institutional, or historical circumstances that shape the structure of people's day-to-day interactions (Gelfand et al., 2011; Glowacki & Molleman, 2017; Talhelm et al., 2014). Although we chose our samples from highly selective universities, with the majority of students coming from middle-class backgrounds within their countries, we cannot fully exclude the possibility that our results might be influenced by systematic cross-sample variation in individual traits that are not accounted for in our study, such as IQ, socio-demographics or personality characteristics. Moreover, our results from student samples in two cities in a country cannot, of course, be easily generalized and taken to be typical for a whole country. This is especially the case for countries as vast and diverse as China. The fact that observed patterns of social learning are very similar at a local Chinese university (Shanghai) and an overseas campus from a Western university (Ningbo), suggests that, at least among student samples, our results are robust. In sum, we believe that further cross-cultural comparisons of social learning strategies would help provide a more detailed picture of what drives the population differences observed in this study.

Regardless of its proximate causes, the observed cross-societal variation has important implications for our understanding of human cooperation and cultural evolution. First, our finding that social learning strategies vary along the axis of individualism–collectivism provides novel support for a recent claim that social learning is not a genetically fixed, species-universal human trait (Heyes, 2012; Mesoudi et al., 2016). Indeed, the systematic between-population differences observed in our study suggest that social learning strategies can get tuned to local (societal) conditions. Second, the higher frequencies of social information use in our collectivist sample indicate increased rates of transmission of information between individuals. In turn, this can lead to enhanced rates of cultural evolution, facilitating a more rapid spread of useful knowledge through a population (Henrich, 2015; Mesoudi et al., 2015).

Third and finally, the systematic cross-societal differences in focus on peer payoffs suggest that the rules governing the transmission of social behaviors vary substantially between populations. Theory predicts that different individual social learning strategies lead to a different direction and outcome of the cultural evolution of cooperation. To our knowledge, our study is the first to empirically identify population differences in basic propensities for social learning in the context of cooperative interactions, with people from a collectivist society being more strongly inclined to observe peer payoffs and people from an individualist society focusing more on majority behavior. Our findings regarding these basic elements of social learning strategies raise the question of whether groups from different populations may vary in their potential to bolster within-group cooperation through conformist social learning, which is thought to be a crucial prerequisite for the cultural evolution of large-scale cooperation (Henrich, 2004; Henrich & Boyd, 1998). Our observation of between-population differences in social learning strategies warrants theoretical work exploring the implications of these differences for the establishment of between-group differences and the evolution of cooperation through cultural group selection (Boyd & Richerson, 1985; Henrich, 2004; Lehmann et al., 2008; Richerson et al., 2016).

Authors' contributions

LM and SG designed the experiments. LM programmed the experiment, supervised data collection and analyzed the data. LM and SG wrote the manuscript.

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Ethics statement & data and code availability

Ethical approval was given by the Nottingham School of Economics Research Ethics Committee. The experimental data and the analysis code for this paper are available via DOI: 10.5281/zenodo.1249891. The experimental software is available upon request from the corresponding author.

Appendix A. Supplementary data

Supplementary information is provided in a separate document. It contains Supplementary figures and tables including the details of the statistical analyses reported in the main text; it also details the Supplementary Analysis and experimental procedures. Supplementary data to this article can be found online at https://doi.org/10.1016/j.evolhumbehav.2018.05.007.

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