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Subsistence styles shape human social learning strategies

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Social learning is a fundamental element of human cognition. Learning from others facilitates the transmission of information that helps individuals and groups rapidly adjust to new environments and underlies adaptive cultural evolution[1–6]. While basic human propensities for social learning are traditionally assumed to be species-universal[1,7], recent empirical studies show that they vary between individuals and populations[8–13]. Yet the causes of this variation remain poorly understood[9]. Here we show that interdependence in everyday social and economic activities can strongly amplify social learning. Using an experimental decision-making task, we examine individual versus social learning in three recently diverged populations of a single-ethnicity group, whose subsistence styles require varying degrees of interdependence. Interdependent pastoralists and urban dwellers have markedly higher propensities for social learning than independent horticulturalists, who predominantly rely on individual payoff information. These results indicate that everyday social and economic practices can mould human social learning strategies and they highlight the flexibility of human cognition to change with local ecology. Our study further suggests that shifts in subsistence styles—which can occur when humans inhabit new habitats or cultural niches[2]—can alter reliance on social learning and may therefore impact the ability of human societies to adapt to novel circumstances.

Human ecological success depends on our capacity for social learning, which occurs through interacting with others and observing their behaviour[1–3]. Social learning enables individuals to readily adapt to new environmental circumstances, by allowing them to rapidly acquire useful information while circumventing the costs of trial and error through individual learning[3]. Moreover, the transmission of adaptive information within and between groups through social learning underlies cultural evolution and facilitates the continued accumulation of knowledge and technologies in human populations[2,4,6,14].

Recent experimental evidence has shown that propensities for social learning vary across individuals and societies[8–13]. However, despite the key role of social learning in human culture and adaptation, the factors influencing propensities for social learning remain unknown[9,10,15]. Here we focus on the hypothesis that social learning is shaped by the interdependence in subsistence styles, that is, how much an individual's livelihood depends on others. We experimentally compare social learning strategies in three groups whose subsistence styles exogenously vary with respect to interdependence (for example, their dependence on reciprocal obligations and use of extended social networks).

Subsistence activities form large parts of human everyday social life. Social interactions are thought to have a key role in shaping decision-making heuristics[16], and social learning strategies may be no exception. The frequent social interactions during interdependent activities create opportunities for social learning and individuals can often benefit from attending to their peers and responding to social information as it facilitates successful coordination of behaviour. As a consequence, more interdependent subsistence styles arguably favour the internalization of strategies relying on social learning.

A burgeoning body of research from across the social sciences demonstrates that everyday social and economic practices can strongly influence various other basic modes of cognition and behaviour. One notable study conducted in China found that people from regions historically organized around cooperative rice farming have more holistic and interdependent thinking styles than people from regions traditionally relying on more individualistic wheat farming[17]. These results corroborate observations from Turkey, where interdependent farmers were found to have more holistic cognitive tendencies than more independent herders[18]. Moreover, behavioural experiments suggest that social and economic interdependence correlates with people's social decision-making, and helps account for the wide cross-cultural variation observed in cooperative behaviour[19,20].

To test whether and how interdependence in subsistence styles influences social learning strategies, we experimentally study social learning among members of the Nyangatom, a single ethnic group whose members engage in pastoralism, horticulture or wage labour[21,22]. The Nyangatom live in southwest Ethiopia and self-identify as members of the same culture, speak the same language, and have the social organization of a small-scale society[23,24]. The primary subsistence style of the Nyangatom is pastoralism but a number of individuals are horticulturalists or participate in wage labour due to recent changes in their subsistence style. In both cases, these transitions are usually the result of exogenous factors, primarily the loss of livestock due to theft or disease, and childhood education. Before we introduce our experimental social learning task, we describe the three subsistence styles (pastoralists, horticulturalists and urban dwellers) with varying interdependence in more detail.

The majority of Nyangatom (population approximately 25,000–30,000) are nomadic pastoralists, which is a highly interdependent subsistence style, where individuals and families may move camps multiple times a year. Pastoral livelihoods require access to information that is inherently dispersed and hard to obtain through individual learning. For instance, pastoralists must navigate a complex web of territorial sections and clans, have knowledge about current ecological conditions, such as the availability of grass and water

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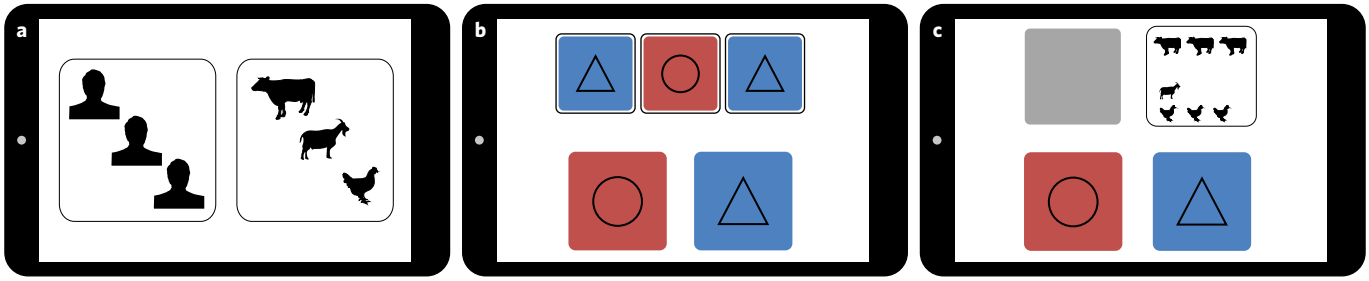

Figure 1 | The decision-making task. a, At the beginning of each period (after the first), participants chose to observe either the decisions of three demonstrators in the previous period (tile with the heads) or the payoffs of their own decision in the previous period (tile with the animals). **b**, When participants chose to observe demonstrator information, the decisions (coloured tiles with shapes) of the three demonstrators in the previous period were shown at the top of the screen. Participants selected their choice for the current period at the bottom. **c**, When participants chose to observe their own payoffs, the outcome of the previous period was given in the area above the tile they chose in the previous period. Payoffs were displayed as cows, goats and chickens because the participants were more familiar with these than local currency. For the tile that was not chosen, a blank grey square was shown without payoff information.

across large distances, and track the likelihood of raids by enemy groups. Access to this type of information requires reliance on social relationships and interdependence not only with immediate family members but also extended kin, members of other territorial sections and clans, and even sometimes members of other ethnic groups.

A number of Nyangatom are horticulturalists whose daily subsistence needs are met by small-scale rain-fed farming supplemented by fishing. The majority of food items are produced for direct consumption and not sold at market. Exogenous factors such as livestock raids and pestilence that decimate a family's herds are the main causes of individuals and families becoming horticulturalists. Because livestock herds are usually composed of cattle belonging to multiple families, the loss of livestock is less likely to be due to personal characteristics of the livestock owner than to stochastic processes. Among the Nyangatom, horticulture requires less interdependence than pastoralism primarily because subsistence needs are met by decisions at the individual and household level, with little cooperation between families or information about ecological or social conditions elsewhere. For instance, pastoralists are collectively responsible for constructing large stockades around villages to protect livestock, dig and maintain large waterholes that hundreds of individuals may use, and manage their herds in social networks of extended kin and unrelated individuals[25]. In contrast, in horticultural villages, there are seldom village stockades, water is easily obtained from the Omo River, and single nuclear families are usually responsible for the entire production of their subsistence needs with little between-family collaboration.

Quantitative interview data support the observation that Nyangatom horticulturalists are less interdependent than pastoralists: during their subsistence activities, horticulturalists have on average fewer interaction partners than pastoralists in both the dry season (7.1 for pastoralists versus 1.8 for horticulturalists) and the wet season (5.7 versus 1.9; see Supplementary Table 1 for statistical summary). Horticulturalists also tend to have smaller social networks, reflected in their average number of self-reported friends (5.0 for pastoralists versus 3.7 for horticulturalists). In both groups, individuals have had very limited formal education (respectively 0.2 versus 0.8 years on average throughout their lifetime). Mean measures of wealth are similar for horticulturalists and pastoralists (Supplementary Table 1). However, horticulturalists live closer to a market town and as a result have more frequent access to small amounts of money (mainly through selling forest products), while pastoralists usually live far from the market town and have infrequent access to money but can occasionally earn large windfalls through selling livestock.

Finally, a minority of Nyangatom live in an ethnically heterogeneous town where they engage in wage labour and commonly encounter unfamiliar individuals. Wage labour relies on extended webs of social exchange for obtaining lodging, purchasing food and daily working activities. In urban areas, it is common to be exposed to new information and technologies thus creating frequent opportunities for social learning. Relative to pastoralists and horticulturalists in our sample, urban dwellers have typically received more education (8.3 years on average, versus <1 year for the other two groups), which they often require for wage labour. Access to education is primarily determined by exogenous factors such as having a sufficient number of older siblings to care for the family's livestock, freeing a relatively small number of youth for school (see Supplementary Note 1). Although urban dwellers resemble pastoralists in having highly interdependent livelihoods, the fact that they are embedded in market economies, engage in wage labour, and have a social organization that resembles contemporary large-scale populations rather than traditional Nyangatom society limits the suitability of direct comparisons between urban and traditional livelihoods on the basis of quantitative measures of interdependence.

We focus on understanding similarities and differences in social learning strategies between pastoralists, urban dwellers and horticulturalists. Do recent transitions in subsistence affect learning strategies? Is the complexity and interdependency of pastoralist and urban dwellers' subsistence style reflected in increased social learning relative to horticulturalists? Are individuals more or less likely to use social information when it comes from an outgroup member?

To address these questions we developed a tablet-computer-based experimental paradigm in which participants repeatedly faced a binary choice (Fig. 1). One of the two options is associated with higher average payoffs, but actual payoffs are noisy so that participants require multiple trials to learn which option is optimal. In each period, participants can base their decision on either individual or social information about the outcome of the previous period. Choosing individual information reveals the participant's own payoffs from their previous decision (for individual learning), and choosing social information reveals the decisions of three peers who completed the task before the participants (for social learning; see Methods for details). We used a within-subject design to test two demonstrator conditions of 15 periods each, where demonstrators either came from the participant's own ethnic group or were members of an outgroup. We documented each participant's requests for individual versus social information and compared request rates for social information between pastoralists, horticulturalists and urban dwellers.

Social learning strategies strongly differed between subsistence styles (Fig. 2). Horticulturalists and urban dwellers used social information much less frequently than pastoralists. Overall, pastoralists had a pronounced orientation towards social information, basing

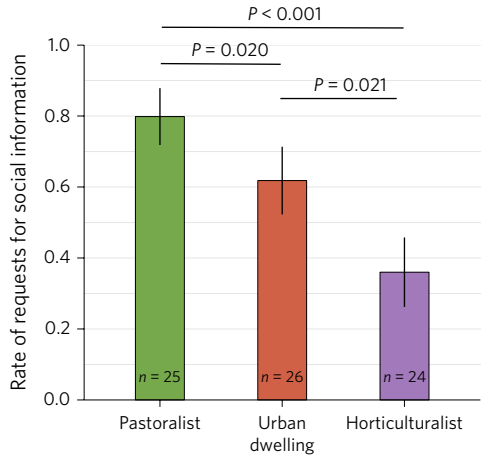

Figure 2 | Requests for social information by subsistence style. Coloured bars show average request rates (± s.e.m.) for social information as opposed to individual payoffs. Bars reflect pooled data from both the 'ingroup' and 'outgroup' demonstrator conditions; for full distributions of individual request rates for social information, broken down for the two conditions separately, see Supplementary Fig. 1. *P*-values reflect Tukey tests from a logistic generalized linear mixed model (Supplementary Table 2).

80% of their decisions on the behaviour of the demonstrators rather than their own individual payoffs. In contrast, the horticulturalists predominantly based their decisions on individual payoffs, requesting social information in only 36% of the periods. With 62% of their requests being for social information, the urban dwellers were less oriented towards such information than the pastoralists, but more so than the horticulturalists. These observations were confirmed by a logistic generalized linear mixed model detecting significant between-sample differences in request rates for social (as opposed to individual) information ($P<0.022$; Supplementary Table 2). Surprisingly, we did not observe any differences in request rates for social (as opposed to individual) information when demonstrators were members of the participants' ingroup or outgroup (Supplementary Fig. 1 and Supplementary Table 2).

Although our samples differed in their reliance on social information or individual payoffs, responses to individual and social information were similar across samples (Fig. 3). Overall, participants from each of the three samples strongly responded to social information that revealed the behaviour of demonstrators (Fig. 3a). Participants chose the optimal option in only 10% of the cases after observing none of the three demonstrators choosing the optimum. This increased to 90% for cases in which participants observed all three demonstrators choosing the optimum (for aggregate dynamics of choices over time, see Supplementary Fig. 2). Fitting a basic model[26,27] to individual data indicated that most individuals showed conformist responses to social information, being disproportionately likely to adopt majority behaviour (Supplementary Fig. 3).

Participants also strongly responded to individual information about their own payoffs (Fig. 3b). Across each of the samples, rates of switching were very high after observations of low payoffs, and decreased to almost zero after high payoffs were observed. The results shown in Fig. 3 are supported by generalized linear mixed models which detected strong effects for the contents of the social and individual information ($P<0.001$), but no differences between the three groups for the way in which individuals responded to this information (Supplementary Tables 3 and 4).

We found that the use of social information in our experiment enhanced performance (Supplementary Fig. 4). Individuals that more frequently requested social (as opposed to individual) information chose the optimal option more frequently. A linear model fitted to data revealed that consistently choosing social rather than individual information was associated with an increase of 20 percentage points in the rate of choosing the optimal option. The positive effect of using social information stems from the fact that the demonstrators, who only had access to their individual payoffs, chose the optimum relatively often. Overall, 65% of the demonstrators'

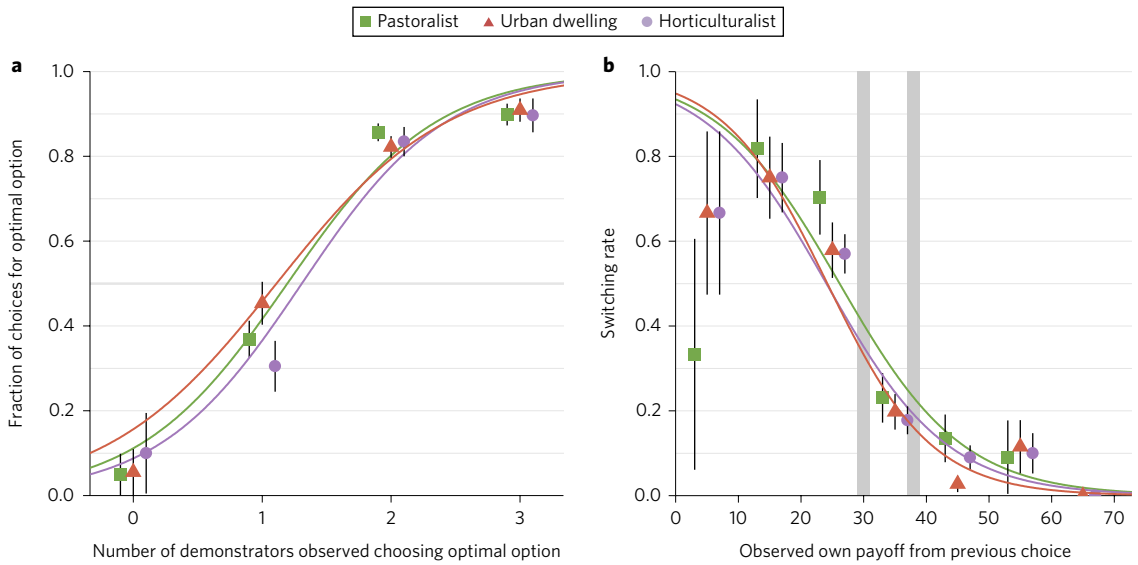

Figure 3 | Responses to social and individual information. a, Fraction of choices (± s.e.m.) for the optimal option as a function of the observed number of demonstrators choosing it. Dots are based on data from those individuals who chose to observe individual payoffs at least once (pastoralists, $n=18$; urban dwellers, $n=25$; horticulturalists, $n=24$). Across samples, participants reacted strongly to the behaviour of the demonstrators. **b**, Rates of switching choices based on observing previous payoffs. Dots represent means (± s.e.m.) from cohorts of ten points, and are based on data from those individuals who chose to observe social information at least once (pastoralists, $n=25$; urban dwellers, $n=23$; horticulturalists, $n=21$). The vertical grey bars indicate the two expected values (30 and 38) of the options in the task. Across samples, participants reacted strongly to observations of previous payoffs. Conditional on observing either type of information, we found no differences in responses across samples (Supplementary Tables 3 and 4; $P>0.353$). In both panels, the lines represent logistic regressions for each sample separately. Overall, participants chose the optimal option in 64% of the cases.

decisions were for the optimal option while in 75% of the periods in the task, the majority of demonstrators (at least two out of three) chose the optimum (Supplementary Fig. 2).

For the Nyangatom, the transition from interdependent pastoralism to relatively independent horticulture is a recent development. However, when confronted with the same abstract problem, participants with these different subsistence styles tend to use different heuristics in their decision-making. Our data suggest that reliance on social learning is driven by changes in interdependence due to this transition rather than other factors such as age or education, which did not differ substantially between pastoralists and horticulturalists. Although mean income levels were also similar between these groups, our study cannot exclude the possibility that differences in monetary wealth plays some role. Horticulturalists live closer to a market town providing them with more regular access to money, while pastoralists can earn greater windfalls through selling livestock. Horticulturalists and pastoralists systematically differed in their interdependence, reflected in pastoralists having substantially larger social networks and having a higher number of partners during their subsistence activities (for example, herding livestock as part of a group versus planting crops alone).

Our results strongly suggest that preference for social information reflects people's everyday social and economic activities: highly interdependent pastoralists and urban dwellers predominantly rely on social information, while horticulturalists, with a more independent subsistence style, tend to base their decisions on the payoffs of their own individual behaviour. Interdependence probably increases the availability and value of social information in everyday life due to the frequency of social interactions and the potential benefits of coordinating behaviour. Our observation that social learning strategies vary with interdependence suggests that humans are capable of adjusting basic cognitive processes to local circumstances and flexibly switch between sources of information in making their decisions. These results provide strong support for the recently proposed claim that social learning strategies can change as a function of local ecology, and are (socially) learned themselves[9,28].

Our results suggest that rates of cultural transmission can be diminished by changes in subsistence styles, which were frequent in human evolutionary history[2]. In the long run, a decreased reliance on social learning can lead to reduced speed of adaptive cultural evolution as well as the loss of culturally acquired knowledge and skills[2,29–31]. This may be one reason why small and isolated populations can lose basic technology important for subsistence, including the ability to make fire[2]. Decreased rates of cultural transmission may also make room for increased individual learning, promoting the introduction of innovations into populations that recently transitioned into new habitats and cultural niches. Our results indicate that subsistence styles can alter the reliance on individual or social learning and can therefore strongly impact the dynamics of cultural evolution that determine the ability of societies to adapt to novel situations.

Methods

The Nottingham School of Economics Ethics Committee and the Institutional Review Board of Harvard University approved this project. Verbal informed consent was obtained from all participants. The study was administered with the assistance of a translator who was familiar with the task. In pilot research, we found that older individuals had difficulty comprehending the task and pressing buttons on the tablet so we recruited only participants that appeared below the age of 40. Although, on average, urban dwellers in our sample tended to be younger than pastoralists and horticulturalists (see below), we do not think that our recruitment procedure led to disproportionate exclusion rates for any of the three groups. Members of the Ngingaric section and the Kwegu were excluded from participation in the study because they traditionally tend to be horticulturalists and not pastoralists, making them less eligible for direct comparisons than individuals who recently transitioned to horticulture. No other exclusionary criteria were used.

Our experimental sample consisted of $n=75$ Nyangatom men, including 25 pastoralists, 24 horticulturalists and 26 urban dwellers with mean ages (±s.d.) of 28.6 (±7.6), 25.1 (±8.2) and 21.2 (±2.6), respectively. To control for gender differences in Nyangatom society and across subsistence strategies we focused on men. The study took place in the town of Kangaten and surrounding villages. Participants were told that ingroup demonstrators were Nyangatom recruited from the town of Jinka while outgroup demonstrators were members of the Daasanach also recruited from Jinka (see Supplementary Note 1). Each participant completed the task individually in a private area with only the translator and researcher present. Participants initially completed an unincentivized test stage to familiarize themselves with the decision-making environment, consisting of 2 blocks of 15 periods each. During this test stage, participants were free to ask questions about the task and as they progressed the participant had the procedures explained to them again.

In the task, participants completed the ingroup and outgroup condition (1 block of 15 periods each) in sequence, the order of which was counterbalanced between participants. At the beginning of each block, the researcher orally informed the participants of the identity (ingroup or outgroup) of the demonstrators. In the task screens, the distinction between conditions was signalled by indicating ingroup and outgroup members with different colours (black and blue, respectively; Fig. 1a shows ingroup demonstrators). At the end of each block, participants were informed of their total earnings in that block. Sessions concluded with a series of questions pertaining to the participants' subsistence styles, age, education, village and residence. Participants were dismissed after the task and were asked to not share information about the task with others.

In each period of the experiment, participants faced a binary choice (Fig. 1). Throughout each 15-period block, one of the two options was associated with a higher expected payoff (38 points) than the other (30 points). Actual payoffs were noisy, reflecting the fact that behavioural outcomes are often influenced by exogenous factors. This noise made it harder for the participants to learn which choice was optimal. Noise was implemented by adding a stochastic term to the payoffs: an integer taken from a normal distribution with a mean of 0 and an s.d. of 12, which was interdependently drawn for each participant in each period separately. This stochastic component was truncated such that actual payoffs in any given period were an integer value between 1 and 69 points[32]. This noise level implies that the option with the higher expected payoff yields higher payoffs in 67% of the cases (and a lower payoff in 31% of the cases; the remaining 2% yielding the same payoff). Payoffs were displayed as cows, goats and sheep indicated by icons, whose values were ten, five and one points, respectively. Points accumulated over the course of the experiment were converted into local currency at the end of the task (100 points = 1 birr).

Demonstrators included 3 Nyangatom (ingroup) and 3 Daasanach (outgroup) who completed the experimental task without access to social information. We chose the Daasanach as an outgroup as they have long-standing enmity with the Nyangatom. Demonstrators received information about their own payoffs in each period. In subsequent sessions, the experimental participants could access the decisions of these demonstrators. Supplementary Fig. 2 shows the decisions of demonstrators as well as those of experimental participants over the course of time.

For the quantitative interdependence measures reported in the main text and Supplementary Table 1, we interviewed an additional $n=55$ Nyangatom men (25 pastoralists and 30 horticulturalists; mean ages were 27.4 and 35.1, respectively) who did not participate in the experimental task. These interviews took place in and around the town of Kangaten and also included items on monetary income. Data on education was collected in our experimental sample.

All statistical analyses were conducted using R v.3.1.3 (R Foundation). For the analysis of conformist responses to social information (Supplementary Fig. 3), we pooled the data of all three sample groups and included only those participants who observed social information at least ten times. One participant was excluded because he did not have a positive reaction to social information, that is, he chose the optimum less rather than more frequently after observing more demonstrators choosing it.

Code availability. The experimental software based on LIONESS[33] as well as the code used in our analyses are available on request from the corresponding authors.

Data availability. Data are available on request from the corresponding authors.

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Author contributions

L.G. and L.M. jointly designed the study. L.G. collected the data and L.M. analysed the data. Both authors wrote the manuscript.

Additional information

Supplementary information is available for this paper.

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Competing interests

The authors declare no competing interests.