Evolution and Human Behavior 42 (2021) 104–112

Contents lists available at ScienceDirect

Evolution and Human Behavior

journal homepage: www.elsevier.com/locate/ens

Need-based transfer systems are more vulnerable to cheating when resources are hidden

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ARTICLE INFO

Keywords:
Need-based transfers
Cooperation
Risk pooling
Cheating
Free-riding

ABSTRACT

Need-based transfer systems pool risk among interdependent individuals. Such arrangements are bound by two simple rules: Ask for help only when in need and, if you are able, give help to others who ask. But there may be a temptation for individuals to break these rules for short-term personal profit. Here, we study one factor that may enforce honesty in need-based transfer relationships: the visibility of resources. Across three experiments employing a novel experimental economic game, breaking of both need-based transfer rules increased when resources were hidden rather than visible (Experiment 1: $n = 82$, online convenience sample from the US; Experiment 2: $n = 80$, student sample from the US; Experiment 3: $n = 42$, online convenience sample from the US). Participants with hidden resources were (1) more likely to request help when not actually in need (greediness), and (2) more likely to not fulfill requests from others for help, even when they had sufficient resources available to help (stinginess). These findings highlight the visibility of resources as one potential limitation of cooperative risk pooling systems.

1. Introduction

Humans often inhabit unpredictable, volatile environments. In such risky environments, people are vulnerable to such unforeseen events as earthquakes, hurricanes, droughts, and diseases that may drastically reduce or entirely wipe out accumulated resources. Evolutionary theory suggests that, under conditions like these, cooperative systems of mutual aid can evolve between interdependent individuals who rely on one another to survive (Aktipis et al., 2018).

One such cooperative system is risk pooling: taking on some of another party's risk in exchange for their willingness to take on some of one's own risk (Cashdan, 1985; Dorfman, 2007). Humans across the world pool risk to deal with unpredictable ecological challenges (Cronk, Berbesque, et al., 2019). For example, hunter-gatherer groups engage in egalitarian food sharing at centralised locations to pool the risk associated with hunting highly variable large-game food items (Cashdan, 1985; Gurven, Hill, & Jakugi, 2004; Kaplan & Hill, 1985). This risk pooling is mirrored in modern human societies, with cross-cultural experiments showing that people are more likely to share resources acquired with high unpredictability, such as windfall monetary rewards (Kameda, Takezawa, & Hastie, 2003; Kameda, Takezawa, Tindale, & Smith, 2002; Kaplan, Schniter, Smith, & Wilson, 2012). Many hunter-gatherer groups also have partnership systems that function to pool the risks associated with shortages in food or water, such as *hxaro* sharing relationships among the Ju/'hoansi of Namibia and Botswana (Wiessner, 1982). In a hxaro partnership, if one individual experiences a shortage of food or water, they can ask their partners in unaffected areas for help.

The current study finds its inspiration in a system of cooperative risk pooling found among the Maasai of East Africa. Maasai pastoralists own large herds of cattle, sheep, and goats, but in the volatile ecology of the African savannah these herds may be hit by drought, disease, or theft at

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https://doi.org/10.1016/j.evolhumbehav.2020.08.004
Received 20 January 2020; Received in revised form 9 August 2020; Accepted 11 August 2020
Available online 15 August 2020
1090-5138/

any time. *Osotua*, a Maasai gift-giving system, acts to pool these risks with others. Literally translated as 'umbilical cord,' osotua is characterised by transfers of livestock between social partners with no expectation of repayment. Two very simple rules underlie osotua stock friendships. Rule 1: ask for livestock only if you are in need. Rule 2: give livestock if you are asked and able to do so without threatening your own survival. Recent agent-based models of these computationally simple rules have shown that they lead to successful risk pooling in volatile environments, increasing average herd survival compared to rules involving debts and repayments. The reason for this is simple: agents following a debt-based rule end relationships with those to whom they have given resources if recipients do not repay loans within a fixed number of rounds. As a result, agents following a debt-based strategy have fewer other agents from whom they can request help when they are at risk of falling below the threshold for survival. In contrast, agents following a need-based strategy maintain all their relationships because they expect to be repaid only if they themselves are in need (Aktipis et al., 2016; Aktipis, Cronk, & de Aguiar, 2011; Hao, Armbruster, Cronk, & Aktipis, 2015).

Could these principles of need-based transfers be applied outside of the Maasai, to resources other than livestock? For example, other small-scale societies may measure their wealth in cash or small game animals rather than large herds. However, there is a key difference between these different subsistence types. On the one hand, herds of cattle, sheep, and goats are visible to all risk-pooling partners. This observability makes both genuine need and an inability to help difficult to fake, and so cheating is discouraged. On the other hand, money and small game are concealable. With these kinds of resources, need and inability to help become fakeable, and so cheating is likely to increase. Cheating can undermine the evolution and maintenance of stable cooperative systems (Nowak, 2006). If cheating is frequent enough, the need-based transfer system will collapse and fail as a viable risk pooling relationship.

Here, we ask whether the visibility of resources affects the probability of cheating in need-based transfer relationships. Lab and field experiments have previously shown that anonymity increases cheating in public-goods scenarios (Hardy & Van Vugt, 2006; Yoeli, Hoffman, Rand, & Nowak, 2013). This is the first empirical exploration of factors that increase cheating in need-based transfer systems. Cheating takes subtly different forms in public-goods *versus* need-based transfer systems. In public-good provisioning or traditional social contract scenarios, cheating involves receiving a benefit without paying a required cost (Cosmides & Tooby, 1992). In need-based transfer systems, however, cheating is more nuanced: individuals can break one or both of the underlying rules by (1) asking for help when not in need (*i.e.*, greediness) and/or (2) refusing to give when asked and able (*i.e.*, stinginess). We hypothesise that both kinds of cheating should increase in frequency when resources are concealable.

Cronk, Aktipis, et al. (2019) ran an experiment in which participants were paired with each other and given resources that grew but were also occasionally hit by disasters. Participants could see their own resources and those of the other player at all times, and they did share resources with each other in patterns consistent with a need-based transfer system. To investigate whether the visibility of resources affects the propensity to cheat in need-based transfer systems, we created a simplified version of that experimental economic game to simulate the lives of Maasai pastoralists. In a live interaction, pairs of individuals manage herds of cattle. Their herds grow over time, but are also subject to unpredictable disasters, potentially reducing their herd size below a minimum survival threshold. Individuals must request help from their partners to survive. We manipulated whether or not individuals could observe the resource holdings of their partner during the game. We predicted that the probability of cheating would increase for both need-based transfer rules when resources were hidden as opposed to when they were visible.

2. Experiment 1

2.1. Methods

2.1.1. Participants

We recruited 100 participants on Amazon Mechanical Turk (http://www.mturk.com; henceforth MTurk). This sample size was chosen as the largest feasible sample size for interactive online sessions on MTurk. Eighteen participants dropped out (6 could not be connected to a partner, and 12 abandoned the game due to long wait times), leaving a final sample of 82 participants (41 females). All participants were over 18 years old ($M = 36$ years, $SD = 9$ years, range = 20–62 years) and from the United States. To qualify for the experiment, participants were required to have had at least 50 HITs (Human Intelligence Tasks) approved on MTurk, with a HIT approval rating of 97% and above. Participants did not have prior experience with the game or its purpose prior to participating in the experiment.

2.1.2. Procedure

Participants played an interactive incentivised economic game in real-time with one other participant on MTurk, run using the software oTree (Chen, Schonger, & Wickens, 2016). Before the game, participants first read a consent form, provided some basic demographic information (age, gender, and primary language), and read some instructions about the game that included information about their payment. After reading about the experimental manipulation, participants completed an example round of the game with the computer and answered several comprehension questions about the game to test their understanding. Participants were paid $0.02 for each comprehension question they correctly answered, but they had unlimited tries to get these questions right. Participants were also paid for waiting to be connected to a partner ($0.05 per minute, maximum 10 min waiting time).

In this game, players managed a herd of cattle over time. Each round acted as a 'year' of time. Both players began the game with 70 cattle. Each year, their herds grew by a multiplication factor drawn independently from a Gaussian distribution ($M = 0.034$, $SD = 0.0253$). From this distribution, negative growth was possible but rare (9% probability of negative growth). Herds were also subject to random disasters that occurred with 20% probability each year. If a disaster occurred, the player's herd decreased by a multiplication amount drawn independently from a separate Gaussian distribution ($M = 0.15$, $SD = 0.05$). Gaussian distribution parameters for births and deaths replicated those used in previous modelling work (Aktipis et al., 2011), which were themselves drawn from real data on East African pastoralists (Dahl & Hjort, 1976).

After these births and deaths, players had the opportunity to ask their partners for cattle and respond to their partner's request. If participants stated that they would like to ask for help, they then specified how many cattle they wanted to ask their partner for (any positive number). Their partner then saw the request and could transfer any cattle amount they wanted to (anything from nothing to their current herd size).

After cattle transfers were completed, the year ended. Players were required to keep their herds above the minimum survival threshold of 64 cattle at the end of every year. If their herd size was beneath this threshold, red warning text appeared notifying the player that they had three years to increase their herd size above the threshold or they would 'die' and be removed from the game. A player whose partner died could continue playing and earning money but could no longer ask anyone for cattle. The game lasted for 25 rounds, though to avoid endgame effects participants were informed only that the game would last somewhere between 20 and 30 rounds.

On average, participants spent 23 min completing the experiment ($SD = 8$ min, range = 8–45 min). If a participant's partner dropped out during the game (*i.e.,* stopped responding), the game could not proceed, but participants were given the option to quit the game and skip to the end if they had to wait too long. Participants were paid a show-up fee of

USD $1.00 for participating and could earn bonus payments according to their performance (total number of cattle at the beginning of each year, $0.01 per 10 cattle). On average, participants earned $2.81 in total (*SD* = $0.69, range = $1.39–$4.02). All study materials, including code and instructions for the economic game, can be found at https://osf.io/wt2mq/.

2.1.3. Design

The experiment consisted of two between-subjects conditions: (a) a control condition, where resources in the game were visible ($n = 42$), and (b) an experimental condition, where resources in the game were hidden ($n = 40$). Participants learned about their condition before being connected to another player. Those in the visible condition were informed that their herd size would be visible to their partner at every stage of the game and, likewise, that they would always be able to see their partner's herd size. They were also told that the occurrence of disasters would be visible to all players. Conversely, those in the hidden condition were informed that their herd size would never be visible to their partner and that they would never be able to see their partner's herd size. They were also told that the occurrence of disasters would only be known by the player that experienced them.

2.1.4. Statistical analysis

To determine whether individuals broke the rules of need-based transfers, we compared requesting and giving behaviour between the two conditions. We fitted Bayesian mixed-effects logistic regressions to the data. The slopes for condition were included as fixed effects, in accordance with our between-subjects design. Intercepts and slopes for the round number were included as random effects, grouped by participants nested within dyads. Estimated parameters are reported on the log odds scale, and 95% CIs are credible intervals for posterior distributions. We report Bayes factors (BFs) for comparisons of posterior predicted probabilities between conditions, applying conventional cutoffs: below 0.33 (moderate support for the null hypothesis that the probabilities are equal) and above 3 (moderate support for the alternative hypothesis that the probabilities differ; Lee & Wagenmakers, 2014).

In addition to these main analyses, we also report exploratory analyses of additional dependent variables: (1) herd sizes when requesting, (2) number of cattle requested, (3) differences between amount requested and amount required to reach the minimum survival threshold, (4) differences between amount given and amount requested by partner, and (5) survival rate.

All statistical analyses were conducted in R v3.6.1 (R Core Team, 2018) using the *brms* package (Bürkner, 2017). Hamiltonian Monte Carlo estimation was run with Stan (Stan Development Team, 2018). All models converged normally (R-hat <1.1). Figures were produced with the *ggplot2* package (Wickham, 2009). Data, code, full model fits, details about prior distributions, and MCMC convergence diagnostics are accessible at https://osf.io/wt2mq/.

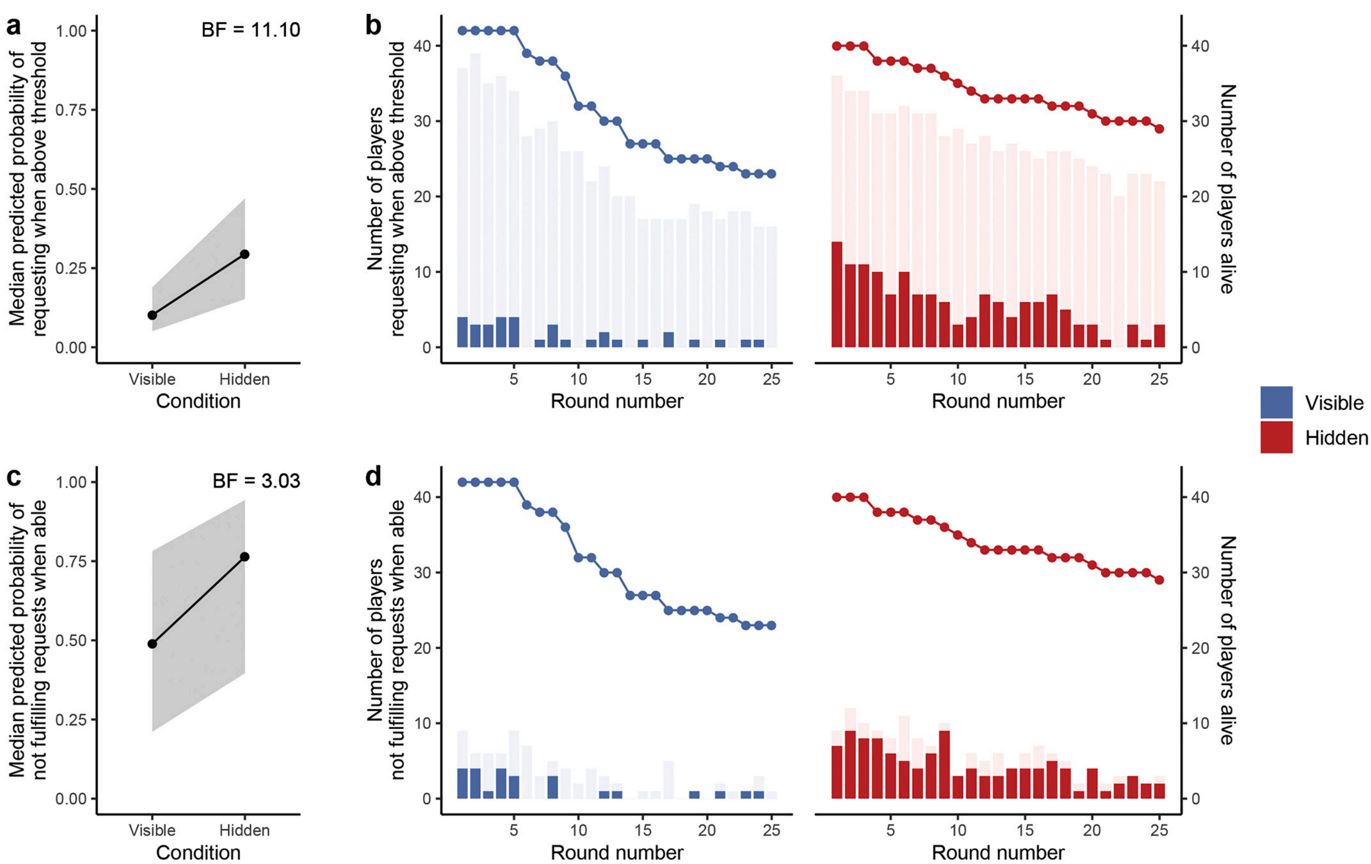

Fig. 1. Greediness and stinginess in Experiment 1 (MTurk). (a) Median model-predicted probability of requesting when above the minimum survival threshold (*i.e.*, greediness) with shaded 95% posterior credible intervals, across both conditions. **(b)** Lines represent the number of players alive in the game. Light bars represent the number of players above the threshold. Dark bars represent the number of players *requesting* when above the threshold. **(c)** Median model-predicted probability of not fulfilling a request when able to do so without dropping beneath the minimum survival threshold (*i.e.*, stinginess) with shaded 95% posterior credible intervals, across both conditions. **(d)** Lines represent the number of players alive in the game. Light bars represent the number of players able to fulfill their partner's request without dropping beneath the threshold. Dark bars represent the number of players who *do not fulfill* their partner's request when able. Code to reproduce this plot at https://osf.io/wt2mq/.

2.2. Results

2.2.1. Breaking of rule 1: do not ask for cattle unless you are in need

To determine whether individuals broke the first rule of need-based transfers when resources were hidden as opposed to visible, we estimated the probability of making a request while above the minimum survival threshold (*i.e.*, greediness) in each condition. Logistic regression revealed that the probability of making a request when above the threshold was greater in the hidden condition than the visible condition (β = 1.30, 95% CI [0.37 2.15]). The model predicts that, when above the minimum threshold, individuals in the visible condition request from their partner with median probability 0.10. In the hidden condition, this probability increases to 0.29 (median posterior probability difference = 0.19, 95% CI [0.05 0.35], BF = 11.10; Fig. 1a and b). Participants in the hidden condition were almost three times as likely to request resources when they were not in need compared to participants in the visible condition. We also found that greediness declined over the rounds (β = −0.12, 95% CI [−0.19 –0.05]) likely because participants accumulated cattle as the game progressed and so felt less need to cheat.

2.2.2. Breaking of rule 2: give cattle if you are asked and able

Next, we asked whether individuals broke the second rule of need-based transfers when resources were hidden as opposed to visible. We estimated the probability of not fulfilling a request (*i.e.*, giving less than what was asked) when the participant was able to do so without going beneath the minimum survival threshold themselves (*i.e.*, stinginess). Logistic regression revealed that the probability of not fulfilling a request when able was slightly greater in the hidden condition (β = 1.22, 95% CI [−0.34 2.76]) and declined over the rounds (β = −0.10, 95% CI [−0.32 0.06]), though these credible intervals crossed zero. The model predicts that, when individuals are asked for cattle and able to give that amount, the median probability of not fulfilling the request is 0.49 in the visible condition and 0.76 in the hidden condition (median posterior probability difference = 0.25, 95% CI [−0.08 0.54], BF = 3.03; Fig. 1c and d). However, the wide credible intervals suggest that these model predictions are uncertain. Thus, the model tentatively suggests that participants are stingier in the hidden condition than the visible condition.

2.2.3. Exploratory analyses

Further exploring greedy behaviour, we found that participants in the hidden condition had more cattle in stock when they decided to request from their partner (median 71 cattle) than participants in the visible condition (median 66 cattle; median posterior difference = 4.98, 95% CI [1.38 8.54]). Participants in the hidden condition also requested slightly more cattle on average than participants in the visible condition (median posterior difference = 1.12 cattle, 95% CI [−0.07 2.40]), though this credible interval crossed zero. When below the minimum survival threshold, participants in the hidden condition requested more cattle than necessary to reach the threshold (median posterior difference between amount requested and amount required = 2.18, 95% CI [0.50 3.88]). In contrast, participants in the visible condition requested just enough cattle to reach the threshold (median posterior difference = −0.33, 95% CI [−1.72 1.16]).

Exploring stingy behaviour, we found that participants in the hidden condition gave on average 3 cattle less than their partner asked for (median posterior difference between amount given and amount requested by partner = −3.13, 95% CI [−4.34 –1.91]). In contrast, participants in the visible condition tended to give the amount that was asked (median posterior difference = −1.00, 95% CI [−2.26 0.19]).

To explore variation in survival rate, we also conducted survival analysis, a regression method that estimates the survival rate while accounting for the right-censored nature of the data (*i.e.*, right-censored participants survived all 25 rounds, the maximum amount, but may have died if the game had continued). This analysis predicted that, if participants were allowed to play for more than 25 rounds, those in the visible condition would have survived 27 rounds (median) while those in the hidden condition would have survived 50 rounds (β = 0.60, 95% CI [−0.28 1.51], median posterior difference = 19.24 rounds, 95% CI [−10.89 138.26]). This is the opposite direction as expected, with individuals surviving for *longer* when resources can be hidden, although the 95% credible intervals crossing zero indicates considerable uncertainty in this estimate.

2.3. Discussion

These results suggest that individuals are more likely to break the rules of need-based transfers when resources can be hidden from their partners compared to when resources are visible. Participants in the hidden condition were more likely to request from their partners when they were not in need, had more cattle when requesting, and requested more cattle. The data also suggest that participants were more likely to not fulfill the requests of their partners (if they could safely do so) in the hidden condition, but if they did attempt to fulfill the requests they then gave less cattle than was asked of them. In other words, participants were greedier and stingier in the hidden condition. In order to ensure that these findings held under more controlled settings, we next attempted to replicate this experiment under laboratory conditions with a within-subjects design.

3. Experiment 2

3.1. Methods

3.1.1. Participants

80 Arizona State University students (27 female) were recruited to participate in the experiment, all of whom were over 18 years old (*M* = 21 years, *SD* = 5 years, range = 18–55 years). This sample size was deemed appropriate as it was sufficient to estimate the effects of condition in Experiment 1. Participants did not have prior experience with the game or its purpose prior to participating in the experiment.

3.1.2. Procedure and design

Experiment 2 was largely identical to Experiment 1, with a few important changes. First, participants completed the experiment in the laboratory, rather than online. All participants arrived at a waiting area prior to their scheduled participation time and were asked to refrain from communicating. If there was an odd number of participants, one participant was asked to reschedule. Participants were then seated at computers one-at-a-time and truthfully informed that (1) they would be playing a two-person computer game with a participant in another room, (2) the research assistant did not know who their partner was, and (3) they would not be told who their partner was during the game. Second, unlike Experiment 1, participants played two games in the same session rather than just one. We utilised a within-subjects design, randomly counterbalancing the order of the visible and hidden games. Participants were informed that they would play both games with the same partner. Third, participants were compensated for their time differently. In Experiment 1, MTurk participants were paid directly for their performance in the game. Here, participants received either course credit or a flat $8 payment (plus a $4 fee if asked to reschedule). However, to continue incentivising play in the games, we truthfully informed participants that their performance would also determine the number of tickets entered into a raffle on their behalf for a $20 gift voucher that they could win after data collection had been completed. On average, participants spent 32 min completing the experiment (*SD* = 7 min, range = 15–49 min).

3.1.3. Statistical analysis

The same Bayesian mixed-effects logistic regressions from Experiment 1 were fitted to the data. However, slopes for condition were included as random effects, grouped by participants nested within dyads, in accordance with our within-subjects design. As before, estimated parameters are reported on the log odds scale, 95% CIs are credible intervals for posterior distributions, and Bayes factors determine whether posterior predicted probabilities are different or equal across conditions. All models converged normally (R-hat <1.1). Data, code, full model fits, details about prior distributions, and MCMC convergence diagnostics are accessible at https://osf.io/wt2mq/.

3.2. Results

3.2.1. Breaking of rule 1: do not ask for cattle unless you are in need

Our first model suggested that the probability of making a request when above the minimum survival threshold (*i.e.*, greediness) declined over the rounds (β = −0.10, 95% CI [−0.16 –0.05]) but, in contrast to Experiment 1, was *equal* across conditions (β = 0.19, 95% CI [−0.83 1.09]; median posterior probability difference = 0.02, 95% CI [−0.08 0.17], BF = 0.32). However, a follow-up model interacting condition with counterbalancing order revealed a substantial order effect. When participants played the visible game first, the median model-predicted probability of greediness was 0.11 in the visible condition and 0.08 in the hidden condition (median posterior probability difference = −0.03, 95% CI [−0.11 0.06], BF = 0.31; Fig. 2a) suggesting that the probability of greediness was equal across conditions. By contrast, when participants played the hidden game first, the probability of greediness was 0.13 in the visible condition and 0.34 in the hidden condition (median posterior probability difference = 0.20, 95% CI [0.01 0.43], BF = 3.07) indicating an increase in greediness in the expected direction. These hidden-first participants were almost three times as likely to request when above the threshold in the hidden condition compared to the visible condition.

3.2.2. Breaking of rule 2: give cattle if you are asked and able

Replicating Experiment 1, our first model revealed that the probability of not fulfilling a request when able (*i.e.*, stinginess) declined over the rounds (β = −0.13, 95% CI [−0.26 –0.04]) and was greater in the hidden condition than the visible condition (β = 0.94, 95% CI [0.12 1.68]). A follow-up model revealed a similar order effect as for greediness. When participants played the visible game first, the median model-predicted probability of stinginess was 0.32 in the visible condition and 0.47 in the hidden condition (median posterior probability difference = 0.15, 95% CI [−0.09 0.36], BF = 1.38; Fig. 2c) indicating only anecdotal evidence for a difference between conditions. By contrast, when participants played the hidden game first, the probability of stinginess was 0.43 in the visible condition and 0.69 in the hidden condition (median posterior probability difference = 0.26, 95% CI [0.03 0.46], BF = 6.88) providing strong evidence for an increase in stinginess across conditions. These hidden-first participants were almost twice as likely to not fulfill their partners' requests in the hidden condition compared to the visible condition.

3.2.3. Exploratory analyses

Based on the results of our main analyses, we report results of our

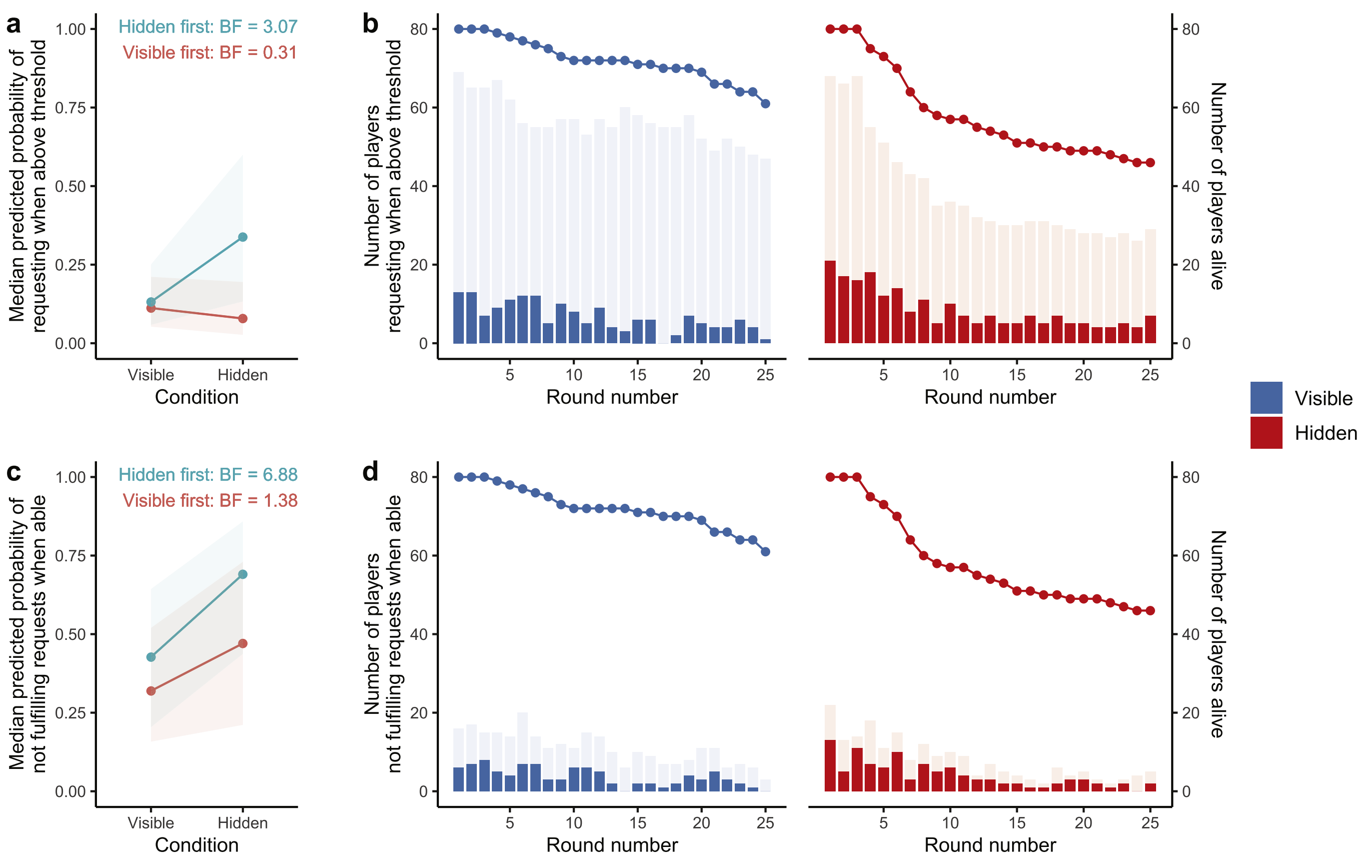

Fig. 2. Greediness and stinginess in Experiment 2 (Lab). (a) Median model-predicted probability of requesting when above the minimum survival threshold (*i.e.*, greediness) with shaded 95% posterior credible intervals, across both conditions and counterbalancing orders. **(b)** Lines represent the number of players alive in the game. Light bars represent the number of players above the threshold. Dark bars represent the number of players *requesting* when above the threshold. **(c)** Median model-predicted probability of not fulfilling a request when able to do so without dropping beneath the minimum survival threshold (*i.e.*, stinginess) with shaded 95% posterior credible intervals, across both conditions and counterbalancing orders. **(d)** Lines represent the number of players alive in the game. Light bars represent the number of players able to fulfill their partner's request without dropping beneath the threshold. Dark bars represent the number of players who *do not fulfill* their partner's request when able. Code to reproduce this plot at https://osf.io/wt2mq/.

exploratory analyses only for participants who played the hidden game first. Exploring greedy behaviour, we found no difference between conditions in the amount of cattle in stock when deciding to request (median hidden condition = 65 cattle; median visible condition = 63 cattle; median posterior difference = 2.03, 95% CI [−1.81 5.71]). There was also no difference between conditions in the amount requested (median posterior difference = −0.66, 95% CI [−1.91 0.60]), and participants in both conditions requested just enough to reach the minimum survival threshold (median difference between amount requested and amount required: visible = 0.09, 95% CI [−0.92 1.14]; hidden = 0.62, 95% CI [−0.34 1.64]).

Exploring stingy behaviour, we found that participants in the visible condition gave on average 0.61 cattle less than their partner asked for (median difference between amount given and amount requested by partner = −0.61, 95% CI [−1.16 –0.02]). Participants in the hidden condition gave on average 2.40 cattle less than asked for (median difference between amount given and amount requested by partner = −2.40, 95% CI [−3.33 –1.47]), fewer than in the visible condition (median difference between conditions = −1.79, 95% CI [−2.66 –0.99]).

Survival analysis revealed that participants in the hidden condition died at a faster rate than participants in the visible condition. This analysis predicted that, if participants were allowed to play for more than 25 rounds, those in the hidden condition would have survived 28 rounds (median) while those in the visible condition would have survived 81 rounds (median posterior difference = −47.15 rounds, 95% CI [−489.13 –1.18]). Unlike Experiment 1, this result is in the expected direction.

3.3. Discussion

The results of this laboratory experiment replicate and extend the findings from Experiment 1. Again, we find that individuals are more likely to break the rules of need-based transfers when resources can be hidden from their partners, compared to when resources are visible. Interestingly, however, this effect only holds when individuals have no prior experience with a partner (*i.e.*, they play the hidden game first). When participants played the visible game first, the probabilities of greediness and stinginess did not increase when they proceeded to play the hidden game with the same partner, suggesting that earlier rounds may have built trust between the two interdependent parties and suppressed later cheating. Unlike Experiment 1, we did not find differences between conditions in the amount of cattle in stock when requesting, the amount requested, or the difference between amount requested and amount required to reach the minimum survival threshold; however, we did find that participants in the hidden condition gave fewer cattle than requested by their partner.

Experiments 1 and 2 have shown that breaking of both need-based transfer rules increases when resources can be hidden. Breaking of rule 1 (*i.e.*, greediness) can readily be interpreted as active cheating for short-term personal profit. However, breaking of rule 2 (*i.e.*, stinginess) is not necessarily evidence of cheating. A hesitancy to fulfill partners' requests may instead be a rational response to the suspicion that the other player is being greedy. Experiments 1 and 2 do not allow us to disentangle these two possible explanations of stingy behaviour: *suspicion vs. cheating*. To illuminate the motivation for stingy behaviour, we compared play in a standard control version of the game (in which both players' resources were visible) with an asymmetric version of the game (in which Player 1's resources were visible and Player 2's resources were hidden). Our focus is on Player 2's behaviour. If stinginess is the result of suspicion, then Player 2's stinginess should not increase in the asymmetric game, as Player 1's resources remain visible. Conversely, if stinginess is the result of active cheating, then Player 2's stinginess should increase in the asymmetric game.

4. Experiment 3

4.1. Methods

4.1.1. Participants

We recruited 98 participants on the online platform Prolific (http://prolific.ac). This sample size was deemed appropriate as it was sufficient to estimate the effects of condition in the previous experiments. 14 participants dropped out (5 could not be connected to a partner, and 9 abandoned the game due to long wait times), leaving a final sample of 84 participants (51 females). All participants were over 18 years old (M = 31 years, SD = 10 years, range = 18–65 years) and from the United States. To qualify for the experiment, participants were required to have a minimum 95% approval rate on Prolific. Participants did not have prior experience with the game or its purpose prior to participating in the experiment.

4.1.2. Procedure and design

Participants were paid a show-up fee of $3.25 for participating and could earn bonus payments throughout. On average, participants earned $4.99 in total ($SD$ = $0.75, range = $3.70–$6.13). Experiment 3 was identical to Experiment 1, except that the visibility of resources was manipulated for Player 2 only in each dyad. Player 1's resources were always visible. In a between-subjects design, this resulted in (a) a control condition where Player 2's resources were visible (number of Player 2s = 20), and (b) an experimental condition where Player 2's resources were hidden (number of Player 2s = 22).

4.1.3. Statistical analysis

As before, Bayesian mixed-effects logistic regressions were fitted to the data. Because Player 1's resources were always visible and we manipulated whether Player 2's resources were visible or not, we analysed data for Player 2s only. Estimated parameters are reported on the log odds scale, 95% CIs are credible intervals for posterior distributions, and Bayes factors determine whether posterior predicted probabilities are different or equal across conditions. All models converged normally (R-hat <1.1). Data, code, full model fits, details about prior distributions, and MCMC convergence diagnostics are accessible at https://osf.io/wt2mq/.

4.2. Results

4.2.1. Breaking of rule 2: give cattle if you are asked and able

We asked whether Player 2s were stingier when their resources were hidden as opposed to visible, even when Player 1's resources remained visible. Logistic regression revealed that the probability of not fulfilling a request when able (*i.e.*, stinginess) was slightly greater in the hidden condition (β = 0.84, 95% CI [−0.44 2.05]), though the 95% credible interval crossed zero. The model predicts that, when Player 2s are asked for cattle and able to give that amount, the median probability of not fulfilling the request is 0.37 in the visible condition and 0.58 in the hidden condition (median posterior probability difference = 0.20, 95% CI [−0.10 0.46], BF = 1.98; Fig. 3a and b). The smaller sample size from focusing on half the sample (Player 2s only) results in more uncertain model predictions and thus a reduced Bayes factor and wider credible intervals. Nevertheless, the effect is in the expected direction, with Player 2s in the hidden condition being almost twice as likely not to fulfill requests when asked.

4.2.2. Exploratory analyses

In line with the direction of our main result, we also found that Player 2s in the hidden condition gave on average 1.72 cattle less than their partner asked for (median difference between amount given and amount requested by partner = −1.72, 95% CI [−2.59 –0.83]). In contrast, participants in the visible condition tended to give the amount that was asked (median difference = −0.28, 95% CI [−1.19 0.66]).

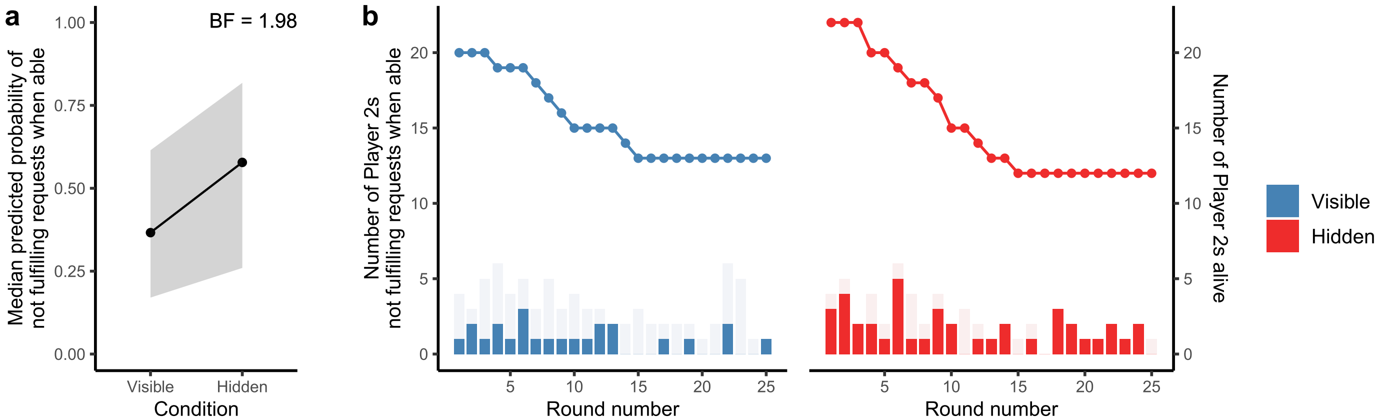

Fig. 3. Stinginess in Experiment 3 (Prolific). (a) Median model-predicted probability of Player 2 not fulfilling a request when able to do so without dropping beneath the minimum survival threshold (*i.e.*, stinginess) with shaded 95% posterior credible intervals. **(b)** Lines represent the number of Player 2s alive in the game. Light bars represent the number of Player 2s able to fulfill their partner's request without dropping beneath the threshold. Dark bars represent the number of Player 2s who *do not fulfill* their partner's request when able. Code to reproduce this plot at https://osf.io/wt2mq/.

However, we did not find any evidence that the experimental conditions affected the survival rate of Player 2s (median posterior difference in rounds survived = −6.96 rounds, 95% CI [−410.83 75.01]).

4.3. Discussion

In this final experiment, Player 1's resources remained visible while the visibility of Player 2's resources was manipulated. We found that there was a slight increase in the probability of stinginess among Player 2s when their resources were hidden, even when Player 1's resources remained visible. Although uncertain due to the small sample size in our restricted analyses, this effect size is comparable to that found in previous experiments. Player 2s in the hidden condition, but not the visible condition, also gave less than their partner asked for. These results suggest that simply manipulating the visibility of one's resource holdings, even when others' are visible, is enough to induce stingy behaviour. In other words, this experiment tentatively supports the *cheating* hypothesis of stingy behaviour over the *suspicion* hypothesis.

5. General discussion

In volatile environments, need-based transfer systems such as osotua allow individuals to pool risk with others (Aktipis et al., 2011; Aktipis et al., 2016; Hao et al., 2015). Two simple rules underlie such relationships: (1) ask only when in need and (2) give when asked and able. But, as with any social dilemma, the temptation to break these rules and exploit the generosity of others is ever present. Here, we found that people were more likely to break need-based transfer rules when resources were hidden as opposed to visible. When others could not evaluate their resource holdings, individuals tended to be greedier (*i.e.,* more likely to ask for help even when they were not in need) and stingier (*i.e.,* more likely to not fulfill requests from their partner even if they could do so without going under the survival threshold themselves). These results are in line with previous empirical work on cheating in public-goods provisioning (Hardy & Van Vugt, 2006; Yoeli et al., 2013) and evolutionary modelling showing that the possibility for reputation management favours the evolution of cooperation (Nowak & Sigmund, 2005). Experiment 3 tentatively suggested that stingy behaviour is due to active cheating and not simply suspicion of one's partner, but the 95% credible interval for this result crossed zero and so more data will be needed to confirm this.

These results may explain the collapse of real-world risk pooling systems when resources can be concealed. Consider, for example, demand-sharing, a cooperative risk pooling system among foragers in which individuals are forced *via* social pressure to distribute any surplus food from hunts to other camp members (Peterson, 1993). While individuals could free-ride on demand-sharing arrangements by refusing to give and hiding resources, such cheating is made difficult by the visibility of large game. However, increased monetisation in egalitarian societies has often led to the collapse of such demand-sharing systems. For example, after traders began buying meat from Mbuti hunter-gatherers, the amount of meat shared within camps decreased (Ichikawa, 1991). Similarly, the introduction of cash and commoditization into Baka communities in Southeastern Cameroon encouraged market economy exchange and money hoarding, resulting in declines in demand-sharing of meat (Kitanishi, 2006; Townsend, 2015). Thus, when resources become easily concealed, as monetisation allows, cooperative risk pooling arrangements can be difficult to maintain.

We expected that the same effect would occur in our economic game: hidden resources would result in the complete collapse of the need-based transfer system. However, while the probability of cheating tended to increase when resources could be hidden, participants in the hidden condition gave at least *some* cattle to their partners (otherwise the probability of stinginess would be 100% in the hidden condition across all experiments). Why didn't the cooperative system collapse entirely when resources could be hidden? This is likely because individuals were still aware that they were interdependent with their only risk pooling partner (Aktipis et al., 2018; Roberts, 2005) and that some cattle transfers must still occur if they were to survive the game. Thus, at least in dyads, there is a conflict between breaking the rules to earn the most short-term profit and ensuring that one's partner survives to keep them available as a long-term risk pooling partner. However, this tension may be lessened, and the probability of cheating increased, if individuals have more outside options (*i.e.*, group size >2), as the target of any cheating is just one of many interdependent risk pooling partners. Future research could test this prediction by extending our methodology to larger groups of players.

Need-based transfer systems are predicted to improve survival rates in harsh ecologies. If the rules of need-based transfers are being broken when resources are hidden, it follows that survival rate should also decrease. However, we found mixed evidence for a link between resource visibility and survival rate in this study. In Experiment 2, our survival analysis revealed that participants who played the hidden game first died faster in the hidden condition, as expected, but we did not replicate this finding in Experiments 1 or 3. One potential explanation for these mixed findings is that our simulated ecology was not harsh enough to measure the beneficial effects of need-based transfer systems on survival. This is supported by the fact that many participants in our experiments survived all 25 rounds of the game (63% of participants in Experiment 1, 67% in Experiment 2, and 60% in Experiment 3).

Participants in both conditions were also able to stockpile a large amount of cattle, sometimes ending the game with over double the minimum survival threshold. This limits the conclusions that we can make regarding the long-term effects of need-based transfer relationships on survival. Indeed, simulations of the Maasai need-based transfer system show that differences in survival between strategies are only apparent when volatility rate and volatility size are intermediate; if they are not harsh enough, all individuals survive and no differences can be seen among the strategies (Aktipis et al., 2016). Although our chosen game parameters were based on real data on African pastoralist societies, future studies could systematically vary the harshness of the simulated ecology (*e.g.* increasing the probability of disasters, reducing the birth rate every year) and increase the number of rounds to better study the effects of need-based transfers on survival.

Despite the temptation to cheat, several mechanisms may stabilise need-based transfer systems with easily concealable resources. First, as highlighted by Experiment 2, repeated interactions can develop trust between individuals, reducing the temptation to cheat later. Such repeated bond-based transfers, as seen in gifts between Ju/'hoansi *hxaro* partners (Wiessner, 1982), establish and maintain relationships between risk pooling partners. Second, cultural evolution may imbue need-based transfer systems with religious or spiritual significance, such as sacredness (Cronk & Aktipis, 2018; Norenzayan et al., 2016). Consider, for example, the Ik of Uganda. As small-scale farmers, hunters, and gatherers, what few resources the Ik possess are much easier to hide than the livestock of the Maasai. Nevertheless, they do have a strong ethic of sharing with those in need. This is supported by an Ik belief that the landscape is inhabited by earth spirits known as *kijawikå*. The Ik believe that the kijawikå bring misfortune to people who fail to share with others and reward those who are generous. Resources may be hidden to people, but the kijawikå can be counted on to see them no matter where they are (Cronk, Berbesque, et al., 2019). Third, need-based transfer systems could require that participants in risk pools reveal their wealth. This is the strategy used by Pando, a US company that creates risk pools among people in occupations, such as professional baseball, in which it is difficult to predict who will become very wealthy. In the case of Major League Baseball, players cannot hide their income because their contracts are public knowledge. When Pando creates risk pools for people in other occupations, they require participants to share their income tax returns (personal communication).

In conclusion, we have shown across several experiments that if resources are hidden, individuals are greedier and stingier in economic games modelling risk pooling scenarios. Thus, while osotua is an effective means of pooling the risks associated with Maasai livestock herding, similar need-based transfer systems may be less likely to evolve and stabilise in societies in which resources are more easily concealed.

Data availability

The data associated with this research are available at https://osf.io/wt2mq/.

Author contributions

S. Claessens, L. Cronk, and A. Aktipis conceived of and designed the experimental economic game. J. D. Ayers collected data in the laboratory at Arizona State University and helped set up data collection on Prolific. S. Claessens wrote the code for the game, collected data on Amazon Mechanical Turk and Prolific, conducted all statistical analyses, and wrote the manuscript. All authors approved the final version of the manuscript for submission.

Ethics statement

Ethical approval was granted by Arizona State University Institutional Review Board for Experiment 1 (ref: STUDY00007432), Experiment 2 (ref: MOD00008507), and Experiment 3 (ref: STUDY00007432).

Funding

This work was supported by the John Templeton Foundation [grant number: 46724]. Any opinions, findings, conclusions, or recommendations expressed in this article are those of the authors and do not necessarily reflect the views of the John Templeton Foundation. The John Templeton Foundation had no involvement in study design; in the collection, analysis and interpretation of data; in the writing of the report; or in the decision to submit the article for publication.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Aktipis, A., Cronk, L., Alcock, J., Ayers, J. D., Baciu, C., Balliet, D., … Winfrey, P. (2018). Understanding cooperation through fitness interdependence. *Nature Human Behaviour, 2*(7), 429–431. https://doi.org/10.1038/s41562-018-0378-4.

Aktipis, A., Cronk, L., & de Aguiar, R. (2011). Risk-pooling and herd survival: An agent-based model of a Maasai gift-giving system. *Human Ecology, 39*(2), 131–140. https://doi.org/10.1007/s10745-010-9364-9.

Aktipis, A., de Aguiar, R., Flaherty, A., Iyer, P., Sonkoi, D., & Cronk, L. (2016). Cooperation in an uncertain world: For the Maasai of East Africa, need-based transfers outperform account-keeping in volatile environments. *Human Ecology, 44*(3), 353–364. https://doi.org/10.1007/s10745-016-9823-z.

Bürkner, P.-C. (2017). brms: An R package for Bayesian multilevel models using Stan. *Journal of Statistical Software, 80*(1), 1–28. https://doi.org/10.18637/jss.v080.i01.

Cashdan, E. A. (1985). Coping with risk: Reciprocity among the Basarwa of northern Botswana. *Man, 20*(3), 454–474. https://doi.org/10.2307/2802441.

Chen, D. L., Schonger, M., & Wickens, C. (2016). oTree-an open-source platform for laboratory, online, and field experiments. *Journal of Behavioral and Experimental Finance, 9*, 88–97. https://doi.org/10.1016/j.jbef.2015.12.001.

R Core Team. (2018). R: A language and environment for statistical computing. Vienna, Austria. Retrieved from https://www.r-project.org/.

Cosmides, L., & Tooby, J. (1992). Cognitive adaptations for social exchange. In J. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind: Evolutionary psychology and the generation of culture* (pp. 163–228). New York: Oxford University Press.

Cronk, L., & Aktipis, A. (2018). Sacredness as an implied threat of supernatural punishment: The case of need-based transfers. *Religion, Brain & Behavior, 8*(3), 282–285. https://doi.org/10.1080/2153599X.2017.1302978.

Cronk, L., Aktipis, A., Gazzillo, S., White, D., Wutich, A., & Sopher, B. (2019). Common knowledge promotes risk pooling in an experimental economic game. *PLoS One, 14*(8), Article e0220682. https://doi.org/10.1371/journal.pone.0220682.

Cronk, L., Berbesque, J. C., Conte, T., Gervais, M., Iyer, P., McCarthy, D., … Aktipis, A. (2019). Managing risk through cooperation: Need-based transfers and risk pooling among the societies of the Human Generosity Project. In L. R. Lozny, & T. H. McGovern (Eds.), *Global perspectives on long term community resource management*. Springer. https://doi.org/10.1007/978-3-030-15800-2_4.

Dahl, G., & Hjort, A. (1976). *Having herds: Pastoral herd growth and household economy*. Department of Social Anthropology: University of Stockholm.

Dorfman, M. S. (2007). *Introduction to risk management and insurance*. Prentice Hall.

Gurven, M., Hill, K., & Jakugi, F. (2004). Why do foragers share and sharers forage? Explorations of social dimensions of foraging. *Research in Economic Anthropology, 23*, 19–43. https://doi.org/10.1016/S0190-1281(04)23001-3.

Hao, Y., Armbruster, D., Cronk, L., & Aktipis, A. (2015). Need-based transfers on a network: A model of risk-pooling in ecologically volatile environments. *Evolution and Human Behavior, 36*(4), 265–273. https://doi.org/10.1016/j.evolhumbehav.2014.12.003.

Hardy, C. L., & Van Vugt, M. (2006). Nice guys finish first: The competitive altruism hypothesis. *Personality and Social Psychology Bulletin, 32*(10), 1402–1413. https://doi.org/10.1177/0146167206291006.

Ichikawa, M. (1991). The impact of commoditization on the Mbuti of eastern Zaire. In N. Peterson, & T. Matsuyana (Eds.), *Cash, commoditisation and changing foragers, Senri ethnological studies* (pp. 135–162). https://doi.org/10.15021/00003137.

Kameda, T., Takezawa, M., & Hastie, R. (2003). The logic of social sharing: An evolutionary game analysis of adaptive norm development. *Personality and Social Psychology Review, 7*(1), 2–19. https://doi.org/10.1207/S15327957PSPR0701_1.

Kameda, T., Takezawa, M., Tindale, R. S., & Smith, C. M. (2002). Social sharing and risk reduction: Exploring a computational algorithm for the psychology of windfall gains. *Evolution and Human Behavior, 23*(1), 11–33. https://doi.org/10.1016/S1090-5138(01)00086-1.

Kaplan, H. S., & Hill, K. (1985). Food sharing among Ache foragers: Tests of explanatory hypotheses. *Current Anthropology, 26*(2), 223–246. https://doi.org/10.1086/203251.

Kaplan, H. S., Schniter, E., Smith, V. L., & Wilson, B. J. (2012). Risk and the evolution of human exchange. *Proceedings of the Royal Society B: Biological Sciences, 279*(1740), 2930–2935. https://doi.org/10.1098/rspb.2011.2614.

Kitanishi, K. (2006). The impact of cash and commoditization on the Baka hunter-gatherer society in Southeastern Cameroon. *African Study Monographs, 33*, 121–142. https://doi.org/10.14989/68472.

Lee, M. D., & Wagenmakers, E. J. (2014). *Bayesian cognitive modeling: A practical course*. New York: Cambridge University Press. https://doi.org/10.1017/CBO9781139087759.

Norenzayan, A., Shariff, A. F., Gervais, W. M., Willard, A. K., McNamara, R. A., Slingerland, E., & Henrich, J. (2016). The cultural evolution of prosocial religions. *Behavioral and Brain Sciences, 39*, 1–19. https://doi.org/10.1017/S0140525X14001356.

Nowak, M. A. (2006). Five rules for the evolution of cooperation. *Science, 314*(5805), 1560–1563. https://doi.org/10.1126/science.1133755.

Nowak, M. A., & Sigmund, K. (2005). Evolution of indirect reciprocity. *Nature, 437*(7063), 1291–1298. https://doi.org/10.1038/nature04131.

Peterson, N. (1993). Demand sharing: Reciprocity and the pressure for generosity among foragers. *American Anthropologist, 95*(4), 860–874. https://doi.org/10.2307/683021.

Roberts, G. (2005). Cooperation through interdependence. *Animal Behaviour, 70*(4), 901–908. https://doi.org/10.1016/j.anbehav.2005.02.006.

Stan Development Team. (2018). RStan: the R interface to Stan. Retrieved from http://mc-stan.org/.

Townsend, C. (2015). *The emergence of inequality in a former hunter-gatherer society: A Baka case study.*. Doctoral Dissertation. University College London.

Wickham, H. (2009). *ggplot2: Elegant graphics for data analysis*. Springer-Verlag New York. Retrieved from http://ggplot2.org.

Wiessner, P. (1982). Risk, reciprocity and social influences on !Kung San economics. In E. Leacock, & R. Lee (Eds.), *Politics and history in band societies* (pp. 61–84). New York: Cambridge University Press.

Yoeli, E., Hoffman, M., Rand, D. G., & Nowak, M. A. (2013). Powering up with indirect reciprocity in a large-scale field experiment. *Proceedings of the National Academy of Sciences of the United States of America, 110*, 10424–10429. https://doi.org/10.1073/pnas.1301210110.