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Performance of human groups in social foraging: the role of communication in consensus decision making

Andrew J. King[1,2,*], Claire Narraway[2], Lindsay Hodgson[3], Aidan Weatherill[2], Volker Sommer[3] and Seirian Sumner[2]

[1]*Royal Veterinary College, University of London, Hertfordshire AL9 7DY, UK*
[2]*Institute of Zoology, Zoological Society of London, Regent's Park, London NW1 4RY, UK*
[3]*University College London, Taviton Street, London WC1H 0BW, UK*
Author for correspondence (ajking@rvc.ac.uk).

Early hominids searched for dispersed food sources in a patchy, uncertain environment, and modern humans encounter equivalent spatial–temporal coordination problems on a daily basis. A fundamental, but untested assumption is that our evolved capacity for communication is integral to our success in such tasks, allowing information exchange and consensus decisions based on mutual consideration of pooled information. Here we examine whether communication enhances group performance in humans, and test the prediction that consensus decision-making underlies group success. We used bespoke radio-tagging methodology to monitor the incremental performance of communicating and non-communicating human groups (small group sizes of two to seven individuals), during a social foraging experiment. We found that communicating groups ($n = 22$) foraged more effectively than non-communicating groups ($n = 21$) and were able to reach consensus decisions (an 'agreement' on the most profitable foraging resource) significantly more often than non-communicating groups. Our data additionally suggest that gesticulations among group members played a vital role in the achievement of consensus decisions, and therefore highlight the importance of non-verbal signalling of intentions and desires for successful human cooperative behaviour.

Keywords: human groups; coordination; communication; language; consensus; foraging

1. INTRODUCTION

Social foraging in humans has a deep evolutionary history: early hominids searched for dispersed food sources in a patchy, uncertain environment. Modern humans encounter equivalent spatial–temporal coordination problems in a variety of contexts on a daily basis. A fundamental, but untested, assumption is that during such collaborative activities individuals benefit by exchanging information about the quality and location

of resources, making consensus decisions (i.e. choosing collectively between mutually exclusive actions) based on mutual consideration of pooled information [1].

Consensus decisions in humans range from small-scale decisions by groups of friends, to large-scale decisions involving whole populations or nations (see [2] for a discussion). The role of communication in consensus decisions may be crucial. We know that communication can facilitate cooperation in a variety of contexts, and helps in preventing its breakdown [3,4], but exactly how information is shared among group members is critical, and can influence decision outcome and accuracy [1]. In the case of human groups, communication may not only enable cooperators to coordinate their actions, but may involve social pressure and mutual promises that would induce feelings of guilt if broken [5].

Here we used radio tags to monitor the incremental performance of communicating and non-communicating groups during a social foraging experiment, creating a physical foraging arena with foraging patches of differing quality. This unique set-up allowed the first experimental test of the longstanding assumption that communication enhances group performance in humans, and enabled us to specifically test the prediction that communication allows groups to coordinate their actions and reach a consensus decision.

2. MATERIAL AND METHODS

(a) Subjects and experiment

Between 8 August 2008 and 31 August 2008, 43 groups (mean size = 2.83 people, range = 2–7) from a total of 121 English-speaking visitors to ZSL London Zoo ($n = 98$ females, 41 males; aged 18–60) volunteered and participated in a collection task experiment. Only one experiment took place at any one time, and each individual participated in only one experiment. 'Known groups' (KG) visited the zoo together, whereas 'unknown groups' (UG) consisted of unfamiliar members. Final samples consisted of: $n = 10$ mixed-sex KG, $n = 22$ mixed-sex UG, $n = 2$ same-sex KG and $n = 9$ same-sex UG.

Participants were invited into a room containing six 'foraging patches' that were arranged radially at 3.2 m from a central 'home base' and equidistant from one another (3.4 m apart). Foraging patches each contained a mix of 300 'good' (green) and 'bad' (white) cards, and patches varied in quality from 5, 35, 50, 65 to 95 per cent green cards (figure 1a). Individuals were tasked with collecting as many green cards as possible from the foraging patches and return them to the home base. Participants had no restrictions on which patches they visited, and were told that they would take part in a 'short experiment' (so were not aware when the end was approaching). Before beginning the foraging task, participants watched a video describing the overall aim and rules (see electronic supplementary material, for video and additional details), and were randomly assigned as either a communicating ($n = 22$) or non-communicating ($n = 21$) group. Their treatment assignment and the rules of the task were indicated clearly in the instruction video. If any task rules were broken (e.g. carrying multiple cards), a whistle was blown and 10 green cards deducted from the group's end total. All trials lasted 10 min.

(b) Data collection

Participants wore radio-frequency identification (RFID) wristbands on their dominant arm, and all good forage cards were fitted with RFID tags. The RFID tags are less than 1 mm thick and could not be detected by participants. Antennae positioned at foraging patches and home base recorded time of entry/departure of all wristband and card tags, allowing time to consensus (t) (greater than 90% of 'foraging events' on a single patch) to be determined. At 1 min intervals, instantaneous scan observations recorded the number of hand gestures being used, and the noise level via a decibel meter situated in the centre of the room. This noise level was used as an indicator of level of spoken communication (see our electronic supplementary material for further details on our measure of spoken communication).
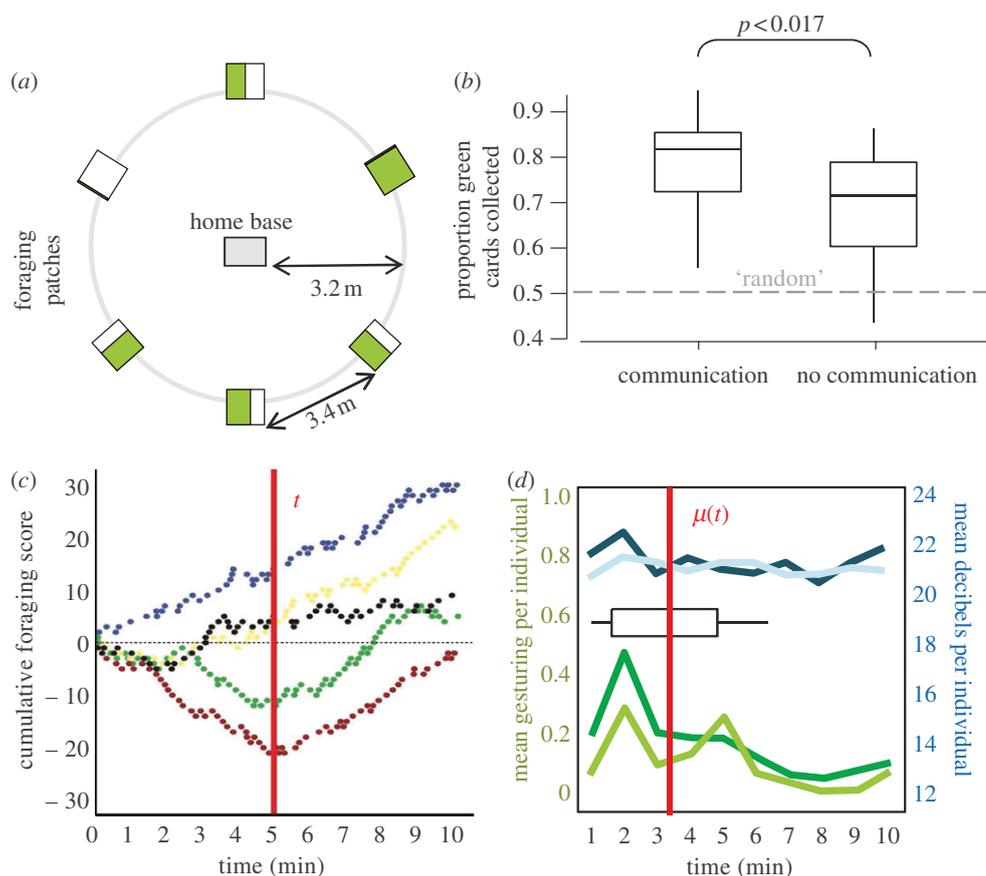
Figure 1. (*a*) Physical foraging arena with six foraging patches. Green shaded portion, good forage; unshaded portion, bad forage. (*b*) Groups in both conditions collected more green cards than expected by chance (binomial test $p < 0.0001$ in each case), but communicating groups performed better ($p < 0.017$; table 1). (*c*) Real-time cumulative foraging efficiency (i.e. $+1$ for green cards, -1 for white cards) for participants ($n = 5$, coloured lines) in a communicating group. Upward trajectory for all participants indicates consensus is reached at $t = 5$ min (red line). (*d*) Mean number of hand gestures (light/dark green) and decibel reading indicating the level of verbal communication (light/dark blue) throughout experiments. Consensus groups are shown in dark shades. Mean consensus time, $\mu(t)$, indicated by the red line, tended to occur shortly after the peak gesture rate: box and whiskers show the full range of time to consensus (t) for communicating groups.

(c) *Data analyses*

Bivariate tests identified differences across treatments/experiments, and all measures were corrected for group size. Generalized linear mixed models (GLMMs), performed in MLwiN v. 2.18, tested for the influence of factors on (1) proportion of good cards collected and (2) achievement of consensus decisions. Models had binomial error structure with logit link function. For each model, independent (control) variables were: group familiarity (UG, KG), group composition (mixed, same sex), group size (continuous) and number of penalties (continuous). Communication (yes, no) was entered into model (1), with mean level of gestures (continuous) and mean decibel level (continuous) entered in model (2). In both models, 'experiment number' was entered as a random effect to control for potential variation across experiments. Minimal model results are presented, and significance tested using the Wald statistic. The results of the models were not qualitatively different when the significance was tested using the full models (i.e. inferences drawn with all predictors present).

3. RESULTS

In support of our prediction, we found that communicating groups collected a higher proportion of good forage (green cards) than non-communicating groups (table 1 and figure 1*b*), irrespective of group size, familiarity between members, or gender composition, and after controlling for penalties incurred (table 1). We found that communicating groups performed well because they reached consensus (figure 1*c*), with all

Table 1. Results of an GLMM explaining the proportion of good foraging items collected by groups ($n = 43$ groups).

fixed effect[a]	estimate	s.e.	Wald	p-value
communication (no, yes)[b]	0.34	± 0.15	5.72	0.017
number of penalties	-0.39	± 0.14	7.51	0.006
known group members (no, yes)[b]	-0.12	± 0.16	0.52	0.471
group composition (mixed, same sex)[c]	-0.14	± 0.17	0.44	0.802
group size	-0.06	± 0.07	0.68	0.410

[a]Effect $\pm$ s.e. of random effect 'experimental session number' was 0.00 ± 0.00.
[b]Reference category was 'no'.
[c]Reference category was 'mixed sex group'. Breaking the same-sex category into all-male and all-female groups did not alter the result.

individuals converging on the single most profitable patch (15 of 22 groups), while non-communicating groups did not (three of 21 groups). The sole factor explaining the probability of achieving consensus among communicating groups was gesture usage

Table 2. Results of an GLMM explaining the achievement of consensus decisions by communicating groups (n = 22 groups).

fixed effect[a]	estimate	s.e.	Wald	p-value
gestures/individual/ minute	11.18	±4.84	5.11	0.023
decibels/individual/ minute	−0.19	±0.20	0.01	0.974
number of penalties	−0.47	±0.89	0.27	0.603
known group members (no, yes)[b]	−2.09	±1.28	2.68	0.102
group composition (mixed, same sex)[c]	−1.19	±1.05	1.28	0.258
group size	−1.47	±1.11	0.02	0.888

[a]Effect ± s.e. of random effect 'experimental session number' was 0.03 ± 0.78.
[b]Reference category was 'no'.
[c]Reference category was 'mixed sex group'. Breaking the same-sex category into all-male and all-female groups did not alter the result.

(table 2). Gestures were observed to be almost entirely directional (e.g. pointing, directed waving); mean gesture use peaked in the minutes preceding consensus time (mean = 3.16 min, range = 1.09–6.09 min; figure 1d) and was higher in the first half of the experiment ($t = 2.79$, $p = 0.018$). In contrast, levels of verbal communication were less variable (figure 1d) and no significant differences were observed when comparing each half of the experiments ($t = 1.42$, $p = 0.189$).

4. DISCUSSION

We used bespoke radio-tagging technology to monitor the incremental performance of communicating and non-communicating human groups in a social foraging task. Communicating groups reached mutual decisions ('consensus') more often than non-communicating groups and ultimately foraged more effectively. We found that the achievement of consensus decisions was not predicted by noise levels (our indicator of spoken communication), but by the frequency of gesticulations. When gesture is used spontaneously along with speech, it can convey information not found anywhere in the speakers' words [6,7]. Here, gestures appear crucial to the coordination of small human groups (similar to party sizes for human hunter–gatherer foragers: [8]), and our findings provide novel insights into the significance of gestural communication in both ancestral and modern-day human societies [9].

It is possible to extend our test to larger group sizes, and see whether gestures—which are a relatively local signal, available only to individuals in close proximity to the actor—are as important in groups of tens or hundreds. We can make two alternate predictions based on our findings. On the one hand, a spoken contribution may allow information exchange across many members in a short time frame, diminishing the importance of local gestures as groups get larger, and allowing individuals to learn about other group members' success more rapidly [8]. On the other hand, if gestures

are universally important to spatial–temporal coordination (e.g. if they convey crucial, extra information), individuals may only consider those in their immediate surroundings [10]. Consequently, subgroups may emerge. It will be interesting to test between these two outcomes experimentally in the future, while taking more explicit measures of communication, e.g. continuous monitoring of gestures via motion capture video, or of the number of words exchanged and their meaning (rather than only the level of verbal communication used here).

Our results are also of interest to those studying human cooperation. Here, we deterred rule-breaking (e.g. collection of multiple cards at once) by blowing a whistle, but we did not enforce cooperation. Participants could, if they liked, simply stand in the arena and do nothing: none did. Since collective action can be easily undermined by free-riders, individuals who reap the benefits from others' efforts without contributing anything themselves, we would predict that such levels of cooperation would not be maintained in larger group sizes given the importance of reputational concerns and anonymity in human cooperative behaviour [11,12]. The group size at which cooperation levels decline may have important implications for understanding both the evolution of hominid foraging party size, and the functioning and efficiency of modern-day teams.

In summary, we provide the first experimental evidence that communications (and especially gesticulations) are a crucial aspect of the organization of social coordination in small groups of humans. The mode of communication should therefore be considered carefully in future studies of human cooperative and collaborative acts.

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