**Supplemental Information for:**

Bonobos voluntarily hand food to others but not toys or tools

Christopher Krupenye, Jingzhi Tan, and Brian Hare

Proceedings of the Royal Society B

DOI: 10.1098/rspb.2018.1536

Experiment 1

**Materials and Methods**

Subjects

We tested 18 semi-free ranging bonobos (*Pan paniscus*) living at Lola ya Bonobo sanctuary in Kinshasa, Democratic Republic of Congo (6M:12F, ages 3-15; Table S1). These noninvasive behavioral studies were approved by Duke University (IACUC #A078-08-03) and adhered to the legal requirements of the Ministry of Research and the Ministry of Environment in D.R. Congo (permit MIN.RS/SG/004/2009). Animal husbandry and care practices complied with the policies of Lola ya Bonobo, as well as the Pan-African Sanctuary Alliance Primate Veterinary Healthcare Manual. Bonobos were born in the wild, orphaned by the bushmeat trade, and rescued by the sanctuary at an early age (~2-3 years old). Previous work indicates that sanctuary apes are psychologically healthy relative to other captive populations [1]. All bonobos were socially housed and free-ranged in large tracts of tropical forest during the day (30 hectares across groups). In the evening, they spent the night in indoor dormitories (12 m2-160 m2). Subjects voluntarily participated in the studies in their dormitories. They could leave any time during testing by sitting near the exit. After testing, they re-joined their social groups in the forest. Subjects were fed a variety of fruits, vegetables, and other species-appropriate foods four times daily, and were never food or water deprived for testing. Experiment 1 involved a between-subjects design with two conditions: reaching versus no-reaching, with nine subjects (matched roughly for age and sex) participating in each condition. Each subject participated in a single session on one day of testing.

Procedure

To facilitate a direct comparison with chimpanzees and human infants, we adapted our procedures directly from those used by Warneken, Hare [2]. With the exception of one dependent offspring tested while his mother was in the room and one mother tested with a young infant, bonobos participated alone in a testing room (the subject room). The first experimenter (E1) was positioned in a demonstration area, facing the subject room and a long hallway. This hallway was adjacent to the subject room and separated from the demonstration area by a mesh door (see Figure 1A). All walls were constructed of mesh, allowing subjects visual access to events in the demonstration area and the hallway.

 Test trials began with E1 sitting on the floor playing with a stick. A second experimenter (E2) entered the demonstration area and approached E1. E2 grabbed a hold of the stick (with E1 still holding it as well) and the two struggled over it, pulling each other back and forth three times and making effortful vocalizations. On the third tug, E2 successfully stole the stick from E1. E2 entered the hallway and closed the door behind him. E1 followed E2, whimpering and grabbed onto the closed door. Inside the hallway, E2 placed a small piece of banana under the mesh between the subject room and the hallway to position the subject at the starting location. E2 kept walking through the hallway and placed the stick partially through the mesh about one meter from the banana. E2 then left the testing area by walking down the hallway.

We started timing when the subject took the banana. In the first 30 seconds, E1 leaned against the door, looked, and vocalized toward the stick. If, after 30 seconds the subject had not transferred the stick to E1, E1 became more communicative by calling the subject’s name, banging the door and alternating his gaze between the subject and the stick. In the reaching condition, E1 provided an additional ostensive cue of desire: he reached effortfully toward the stick throughout the duration of the trial. In the no-reaching condition, this additional cue was absent: E1 kept his arms at his side or on the door. Each trial ended when the subject transferred the stick, or after one minute. Subjects were never rewarded for transfers to ensure that any transfer behavior was spontaneous and did not occur in response to rewarding. Each subject participated in a 12-trial session with ten test trials as just described and two baseline trials—one at the beginning and one at the end. Baseline trials were identical to test trials except that E1 was never present. As in test trials, they began when the subject took the banana. These baseline trials served to assess subjects’ baseline motivation to manipulate and transfer the stick. Whenever possible, E2 or the bonobo keepers retrieved any accessible untransferred sticks before the next trial began (i.e. that remained within reach of a caregiver but not the experimenter during the actual trial).

Coding and analysis

Two cameras, one in the demonstration area and one in the hallway, recorded the subject’s behavior. One coder blind to condition and hypotheses reviewed all trials and coded the following behaviors. The subject was marked as having *retrieved* the stick if she picked it up from its starting location. A *transfer* was coded if the subject handed the stick to E1, pushed it through the mesh into the demonstration area, or pushed it into the hallway within E1’s reach. Finally, a *teasing* event was coded if the subject was in the corner near E1, facing him, and gesturing toward him with the stick in hand. A second coder blind to condition coded all trials for 28% of (randomly selected) subjects (*N*=5 of 18) with near-perfect reliability (retrieval: Cohen’s kappa = 0.966; transfer: Cohen’s kappa = 1; teasing: Cohen’s kappa = 0.889) [3]. All statistics were non-parametric and two-tailed. We used Mann-Whitney U tests to compare between conditions the proportion of trials in which each subject performed each type of behavior. We used related samples Wilcoxon signed rank tests to compare between baseline and test trials the proportion of trials in which subjects performed each type of behavior.

**Results**

In the reaching condition, only one bonobo transferred the stick on a single test trial (Figure 1B). In the no reaching condition, no bonobos ever transferred the stick on any test trials. One subject transferred the stick once on a baseline trial. There was no difference in the frequency of *stick retrieval* between conditions (baseline: U = 37.5, N1 = N2 = 9, *p* = NS; test: U = 33.0, N1 = N2 = 9, *p*=NS, Mann-Whitney U tests), or between the baseline and test trials (reaching condition: z = -1.590, N = 9, T+ = 5, ties = 3, *p* =NS; no reaching: z = -0.849, N = 9, T+ = 3, ties = 1, *p*=NS, related samples Wilcoxon signed rank tests). Six subjects (33% of the sample) retrieved the stick in the majority of test trials (two subjects in the reaching condition and four in the no-reaching condition), but still did not transfer it. This suggests that subjects attended to and were interested in the stick, but were not motivated to return it.

Experiment 2

**Materials and Methods**

Subjects

Twelve bonobos (2M:10F; aged 5-15 years; Table S2) participated in Experiment 2, none of whom were subjects in Experiment 1. An additional 6 subjects were excluded because they did not pass one of two pretests (see Procedure below). We selected subjects who were frequently seen cracking nuts in their enclosure to ensure that they were capable of cracking nuts and that they valued the nuts and were motivated to consume them. Subjects had to pass two pretests (see Procedure below) and were then tested in pairs (*N* = 10). Within a pair, which consisted of familiar groupmates, each bonobo was assigned to be either a ‘nut-owner’ or a ‘rock-owner’. Most subjects (*N* = 8) played both roles but in two *different* pairings (i.e., each of these subjects was a nut-owner in one pairing and a rock-owner in another pairing). In this way we maximized the possible number of pairs and controlled for currency-specific reciprocity within the experiment. The pairs were not created based on any other attributes of our subjects (e.g. sex, age, dominance, etc.). The other four subjects were only tested in one pairing due to loss of motivation or insufficient time during our field trip. An additional six subjects were excluded because they failed to pass both pre-tests. Although bonobos have shown some important developmental delays relative to chimpanzees [4-6], a large portion of our subjects were adults based on timing of maturity in bonobos. Hormonal data shows that bonobo and chimpanzee males reach reproductive maturity at comparable ages and that bonobo females mature slightly earlier than chimpanzee females [7]. In the wild, females tend to emigrate from their natal community by age 10 and, at Lola ya Bonobo, many have their first birth as early as age 8 [8, 9 Table S3]. Interestingly, in the wild, adults show the highest rates of food sharing, so, if anything, an older sample of bonobos should exhibit even greater rates of sharing [10]. If larger samples of different-aged bonobos become available, future work could examine whether there are age-related increases or decreases in food transfer in captive individuals—in accordance with data from the wild or with predictions of developmental delays.

Setup

During the test phase, subjects were situated in adjacent rooms and could only view one another or interact through a mesh 1m2 window between the rooms (see Figure 1B). In the center of the mesh window was a 20 x 20cm hole large enough to permit passage of rocks, nuts, and subjects’ arms but not subjects’ heads or bodies. One experimenter was stationed outside of each room to provide experimental materials to the subjects, and to videotape all trials. Experimental materials included palm nuts and a pair of flat, portable rocks (~20 x 15 x 5cm in size, ~2kg in weight). Palm nuts are a component of our subjects’ daily diet that is acquired through foraging in their forested enclosures. The bonobos consume palm nuts by cracking them with rocks or, occasionally, by crushing them forcefully with their teeth. The rocks used in this experiment were collected within the sanctuary. A hole was drilled in each rock so that a rope could be threaded through the hole and the rock could be tethered to a wall. One rock (the transferable rock) was tethered with a long rope (~5m), allowing it to be transferred to the adjacent room through an opening in the window. The second rock (the nontransferable rock) was tethered with a shorter rope (~1m), so that it could be used to crack nuts but could not be transferred. The tethers also ensured that rocks could be returned to the correct starting location between trials since we could not be sure subjects would help the experimenters retrieve them (see Exp 1).

Procedure

Before qualifying for the test phase, bonobos had to pass two pretests. The *self regard pretest* was designed to ensure that subjects were skilled and motivated nut-crackers. Alone in a testing room, a subject was provided with one rock and three nuts. Subjects participated in two five-minute trials (i.e., six nuts total) and were required to crack two of six nuts to advance to the next pretest. If after two trials, subjects had not done so, they were excluded (*N*=6). In most cases, those that met this criterion immediately cracked all six nuts (*M*=4.83 nuts).

 The *tool mastery pretest* was designed to ensure that subjects understood the importance of the rock to successful nut cracking. Each subject was given three nuts in the testing room, and a rock was placed on the opposite side of the room. Subjects had to transport the nuts to the rock and crack at least one nut within five minutes to succeed on a trial and only needed to succeed on a single trial to advance to the test phase. If after two trials, subjects had failed to meet this criterion, they were excluded (*N*=0).

 In the *test* phase, subjects participated in pairs in adjacent rooms, one as the nut-owner and the other as the rock-owner (Figure 2; Movie S2). The test phase began with a single *motivation* trial in which the rock-owner, who always possessed at least one rock regardless of condition (see below), was given a single nut. This motivation trial ended after three minutes or as soon as the nut had been cracked. It served to enhance attention to and motivation for nut cracking. In most cases, subjects immediately cracked the nut and ate its contents. After the motivation trial, five test trials were administered in one block. Each test trial lasted five minutes. In the experimental condition (Figure 2A), the rock-owner began each trial with both the transferable and nontransferable rocks, while the nut-owner was provisioned with five nuts. In the control condition (Figure 2B), the rock-owner began each trial with only the transferable rock; the nut-owner was now in possession of the nontransferable rock. In addition, both subjects were provided with five nuts. Pairs completed one session per day on four separate days, for a total of two experimental and two control sessions, counterbalanced in ABBA or BAAB order. Each pair thus participated in 10 experimental and 10 control trials.

Subjects who participated in two pairs (once as the nut-owner and once the rock-owner) were tested in both pairs during the same two-week period, maximally participating in one session within each pair on a given testing day. Given the constraints of the testing environment in enclosure 2 (i.e., that subjects needed to pass through the testing rooms in one direction only before being released into the forest for the day), for the 8 pairs tested there (of the 10 total), subjects who participated in two sessions per day were always the rock-owner first and then the nut-owner (although one session may have been experimental and the other control, in either order). Subjects simply advanced through the four sessions within each pair in the pre-determined order and were opportunistically tested in each pair as often as possible (but not more than once per day). However, participating in two sessions per day accounted for less than half of those subjects’ sessions and the opposite order (nut-owner then rock-owner) was used with subjects in the other enclosure. In fact, there were only 6 instances where a subject participated in two test sessions on the same day (in five cases, as the rock-owner first, and in one as the nut-owner first). In general, subjects alternated between sessions as the nut-owner and rock-owner and, importantly, four of the eight subjects who participated in both roles served as the nut-owner in their very first test session and the other four as the rock-owner. Moreover, the subject who delivered the most nuts to her partner, Waka, only participated as the nut-owner, suggesting that high rates of sharing did not reflect generalized reciprocity.

 To test for any impact of food-dominance on performance in the task, each pair participated in seven dominance trials during a single session, using a standard food competition test [e.g., 11]. All but two pairs completed this session after finishing the test phase of the experiment (i.e., after completing the two experimental and two control sessions). The remaining two pairs had to participate in the dominance test in between the third and fourth session of the test phase, to ensure that the dominance test could be completed before the conclusion of our field trip. Dominance trials were performed in a testing room that experimenters could access from three sides, and both subjects were in the same room. During dominance trials, a pair of experimenters centered the bonobos on opposite sides of the testing room with small pieces of food while a third experimenter positioned a larger—though monopolizable—piece of banana or apple just outside the mesh, centrally between, and roughly two meters from, each of the two bonobos. This third experimenter then said, “ok,” at which time the other two experimenters stepped back and the bonobos were allowed to pursue the food. The subject who retrieved the piece of food was scored as the winner. After this subject had finished consuming the food, both were re-positioned and the next trial began. In all trials, both subjects immediately pursued the food and there was always a clear winner. In each pair, one individual won six or seven of seven dominance contests, indicating clear food dominance relationships (Table S2). All trials were filmed. There was no aggression, fighting, or injuries of any kind during testing.

Coding and Analysis

Two experimenters recorded all experimental and control trials on handheld cameras, focusing primarily on any interactions around the window between the testing rooms. One coder blind to hypotheses reviewed all trials and coded the following transfer behaviors. For reliability, a second blind coder coded all videos from a randomly selected 30% of pairs. Our definitions largely followed de Waal [12]. A transfer was coded as *direct transfer* if the possessor transferred the item through the window into the adjacent room. It was coded as *tolerated theft* if the recipient acquired the item from the possessor’s side of the window (including on the floor and in the hands of the possessor) without resistance from the possessor. Finally, a transfer was coded as a *forced claim* if the recipient acquired an item from the possessor’s side of the window while the possessor resisted by pulling back the recipient’s hand, pulling back the item, or racing to grab the item off the floor. In addition, we coded several communicative behaviors. *Gestures* were recorded whenever an individual reached through the window empty handed, as long as her hand remained empty when she retracted it. We coded *grooming* as manually manipulating the fur or skin of the other subject. *Teasing* was recorded if an actor held an object through the window without releasing it or released the object on the partner’s side but quickly retrieved it.

Data were converted into binary measures (i.e., “1” if a given behavior occurred within a trial, and “0” if it did not). All measures had near-perfect inter-rater reliability (nut direct transfer, rock tolerated theft, teasing by the rock owner: Cohen’s kappa = 1; grooming by the rock owner: Cohen’s kappa = 0.937; gesture by the rock owner: Cohen’s kappa = 0.921; nut tolerated theft: Cohen’s kappa = 0.869; agreement for rock direct transfer was also perfect, but Cohen’s kappa could not be calculated because there were no positive cases among the trials reviewed by both coders) [3].

We also recorded the amount of nuts shared via direct transfer and tolerated theft in each trial (i.e. a continuous variable; reliability on 30% of videos (Pearson’s correlations): direct transfer: *N*=4, *r*=1, tolerated theft: *N*=10, *r*=0.958; Table S3). In 8, 5, 3, 1 and 2 trials, subjects directly transferred one, two, three, four and five nuts respectively. All of these cases occurred in the experimental condition, except one control trial in which a subject directly transferred one nut. In all other trials (*N*=180) subjects directly transferred zero nuts. In 11, 6, 2, 2, and 1 trials, subjects exhibited tolerated theft of one, two, three, four, and five nuts respectively. As with direct transfers, all of these cases occurred in the experimental condition, except one control trial in which tolerant theft of a single nut occurred. In all other trials (N = 177), subjects exhibited zero tolerated thefts. Although overall subjects shared at least one nut by direct transfer or tolerated theft on 17.59% of trials (and 33.33% of experimental trials [these numbers are lower than simply adding the percentages of trials involving direct transfers with those involving tolerated thefts because sometimes direct transfers and tolerated thefts occurred within the same trials]), individual measures of number of nuts shared in a given trial by direct transfer and by tolerated theft were highly skewed toward zero. Therefore, we decided against using them as outcome variables in our models, in favor of the more stable binary measures.

As a measure of bonobos’ motivation to crack and consume nuts, we coded the number of nuts that subjects cracked during the self-regard pretest. A coder blind to condition and hypotheses coded a randomly selected 30% of trials, achieving perfect agreement. We also recorded all trials of the food-dominance test. The winner in each trial (i.e., the individual who monopolized the food) was live-scored. A coder blind to hypotheses also coded 100% of trials from video, achieving perfect agreement (Cohen’s kappa = 1).

 We used two-tailed related-samples Wilcoxon signed rank tests to compare the frequency of trials involving nut and rock transfer between experimental and control conditions, and to compare, within each condition, the frequency of nut transfer trials with the frequency of rock transfer trials. In addition, we used Generalized Linear Mixed Models (GLMMs) to explore the factors that contributed to nut transfers (with separate models for assessing predictors of direct transfer of nuts and tolerated theft of nuts). GLMMs assess the relative influence of predictor variables on the dependent measure (in this case, nut transfer), while controlling for repeated measures, confounding variables, and covariation between predictor variables. We used the glmer function in the LME4 package in R to fit binomial models with a logit link function. We first performed maximum likelihood tests to establish that our full models were significant improvements relative to null models involving only random effects (i.e., without predictor variables). We then assessed significance of individual predictors using maximum likelihood tests by comparing our full model to models in which individual predictors had been removed.

We considered using mixed models for the first set of analyses as well, but after consultation with a statistician it was clear that mixed models would not be suitable for these analyses and that non-parametric statistics were preferable. A mixed model investigating differences in tendency to transfer nuts vs rocks in the experimental vs control conditions would require two rows of data per trial (one reflecting transfer of rocks or not—1 vs 0—and one reflecting transfer of nuts or not—1 vs 0) with predictors of ‘item’ (rock vs nut), ‘condition’ (experimental vs control), and an interaction between the two, in addition to several random effects. In contrast, a mixed model assessing predictors of nut transfer (i.e., the second set of analyses) requires only one row per trial (reflecting transfer of nuts or not—1 vs 0) and predictors but no interactions and only one random effect. Since transfer is more or less restricted to nuts, the second model has enough positive cases (and is sufficiently simple) to produce stable, reliable results whereas the first does not. Thus, due to the structure of the data (i.e., because cases of sharing of either type largely occurred only with nuts and only in trials of the experimental condition and only in a portion of those trials), mixed models were inappropriate for the first set of analyses and non-parametric statistics were the better tool.

**Results:** Generalized Reciprocity

 As is standard practice, we maximized sample size by permitting each subject to participate in one dyad as the nut owner and in one additional dyad as the rock owner (8 of 12 subjects did this). Statistically, pairs were independent since subjects participated in each role in only a single dyad and we additionally included pair as a random intercept to account for repeated observations of the same dyad. However, because all dyads were tested in the same general period in a total of four sessions that occurred on separate days, these individuals often alternated in their role as nut owner and rock owner (within different dyads). It is, therefore, possible that bonobos’ nut sharing behavior when nut owner was impacted by recent experience in the role of rock owner. To test for generalized reciprocity (i.e., that bonobos were more likely to directly transfer nuts in a session if they had received nuts in the last preceding session in which they were the rock owner), we performed an additional mixed model including those eight subjects who participated in two dyads. The dependent measure was whether or not in a session the nut owner (subject) directly transferred at least one nut on at least one trial (i.e., binary measure). As predictors, we included (1) condition since we knew that transfers occurred predominantly in the experimental condition and (2) whether or not, in the most recent session in which the subject was the rock owner, the subject had received any nuts via theft or direct transfer (i.e., binary measure). To control for repeated observations, we included subject ID as a random intercept. The full model was not significantly different from a null model that included the control predictor of condition and the random effect of subject ID (assessed with a likelihood ratio test; *p* = 0.872). As such, in the full model (Table S6), we found that condition alone was a significant predictor of nut transfer. Bonobos were significantly more likely to directly transfer nuts in sessions of the experimental condition than sessions of the control (*p* = 0.005). However, receiving nuts in the most recent session as rock owner was not related to the likelihood that the subject would then directly transfer nuts in the next session in which they were the nut owner (*p* = 0.872). Thus, we found no evidence that generalized reciprocity impacted our results.

**References:**

1. Wobber V.T., Hare B. 2011 Psychological health of orphan bonobos and chimpanzees in African sanctuaries. *Plos One* **6**(6), e17147.

2. Warneken F., Hare B., Melis A.P., Hanus D., Tomasello M. 2007 Spontaneous Altruism by Chimpanzees and Young Children. *PLoS Biology* **5**(7), e184.

3. Landis J.R., Koch G.G. 1977 The measurement of observer agreement for categorical data. *Biometrics* **33**(1), 159-174.

4. Behringer V., Deschner T., Murtagh R., Stevens J.M., Hohmann G. 2014 Age-related changes in thyroid hormone levels of bonobos and chimpanzees indicate heterochrony in development. *J Hum Evol* **66**, 83-88. (doi:10.1016/j.jhevol.2013.09.008).

5. Wobber V., Wrangham R., Hare B. 2010 Bonobos exhibit delayed development of social behavior and cognition relative to chimpanzees. *Current Biology* **20**(3), 226-230. (doi:Doi 10.1016/J.Cub.2009.11.070).

6. Hare B., Wobber V., Wrangham R. 2012 The self-domestication hypothesis: evolution of bonobo psychology is due to selection against aggression. *Animal Behaviour* **83**(3), 573-585. (doi:10.1016/j.anbehav.2011.12.007).

7. Behringer V., Deschner T., Deimel C., Stevens J.M., Hohmann G. 2014 Age-related changes in urinary testosterone levels suggest differences in puberty onset and divergent life history strategies in bonobos and chimpanzees. *Horm Behav* **66**(3), 525-533. (doi:10.1016/j.yhbeh.2014.07.011).

8. Furuichi T. 2011 Female contributions to the peaceful nature of bonobo society. *Evol Anthropol* **20**(4), 131-142. (doi:10.1002/evan.20308).

9. Tan J., Hare B. 2013 Bonobos share with strangers. *PLoS One* **8**(1), e51922. (doi:10.1371/journal.pone.0051922).

10. Yamamoto S. 2015 Non-reciprocal but peaceful fruit sharing in wild bonobos in Wamba. *Behaviour* **152**(3-4), 335-357. (doi:10.1163/1568539x-00003257).

11. Wobber V., Hare B., Maboto J., Lipson S., Wrangham R., Ellison P.T. 2010 Differential changes in steroid hormones before competition in bonobos and chimpanzees. *Proc Natl Acad Sci U S A* **107**(28), 12457-12462.

12. de Waal F.B.M. 1997 Food transfers through mesh in brown capuchins. *J Comp Psychol* **111**(4), 370-378.

**Table S1. Experiment 1 data.** For sex, F denotes female and M male. Age is reported in years. We also report condition and the number of trials in which each subject returned the stick to the experimenter in the baseline (2 trials per subject) and test (10 trials per subject) as well as the number of test trials in which the subject teased the experimenter.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  | **Stick Return** | **Teasing during:** |
| **Name** | **Sex** | **Age** | **Condition** | **Baseline** | **Test** | **Baseline** | **Test** |
| Api | M | 12 | No Reaching | 0 | 0 | 0 | 0 |
| Ilebo | M | 10 | No Reaching | 0 | 1 | 0 | 1 |
| Kananga | F | 5 | No Reaching | 0 | 0 | 0 | 0 |
| Kasongo | M | 10 | No Reaching | 0 | 0 | 0 | 0 |
| Kipolo | M | 8.5 | No Reaching | 0 | 0 | 0 | 0 |
| Kole | M | 3 | No Reaching | 0 | 0 | 0 | 1 |
| Lisala | F | 11 | No Reaching | 0 | 0 | 0 | 0 |
| Mabali | M | 10.5 | No Reaching | 0 | 0 | 0 | 0 |
| Sandoa | F | 7.5 | No Reaching | 0 | 0 | 0 | 0 |
| Bolomba | F | 6 | Reaching | 0 | 0 | 0 | 0 |
| Dilolo | M | 11 | Reaching | 0 | 0 | 0 | 0 |
| Katako | F | 8 | Reaching | 0 | 0 | 0 | 1 |
| Kikwit | M | 15 | Reaching | 0 | 0 | 0 | 5 |
| Lomako | M | 5.5 | Reaching | 0 | 0 | 0 | 0 |
| Lukuru | F | 6.5 | Reaching | 1 | 0 | 0 | 4 |
| Matadi | M | 13 | Reaching | 0 | 0 | 0 | 1 |
| Oshwe | M | 4 | Reaching | 0 | 0 | 0 | 0 |
| Wongollo | M | 4.5 | Reaching | 0 | 0 | 0 | 0 |

**Table S2. Experiment 2 subject and dyad characteristics, dominance, and sharing.** Name, age (in years), and sex (M = male, F = female) of each participant in each dyad. As a measure of motivation for cracking and consuming nuts, pre-test refers to the number of nuts an individual cracked during the two trials of the self-regard pretest (out of a possible 6). Rock-owner dominance refers to the number of food-dominance test trials in which the rock-owner (i.e., sharing recipient) monopolized food (out of 7).

|  |  |  |  |
| --- | --- | --- | --- |
| **Nut Owner** | **Rock Owner** | **Rock-Owner Dominance** | **Dominant Individual** |
| **Name** | **Age** | **Sex** | **Pre-test** | **Name** | **Age** | **Sex** | **Pre-test** |
| Bili | 11 | M | 6 | Malaika | 5 | F | 4 | 1 | Nut-Owner (Donor) |
| Eleke | 8 | M | 6 | Sake | 7 | F | 6 | 7 | Rock-Owner (Recipient) |
| Kalina | 14 | F | 5 | Bili | 11 | M | 6 | 0 | Nut-Owner (Donor) |
| Kinshasa | 12.5 | F | 5 | Likasi | 12 | F | 3 | 6 | Rock-Owner (Recipient) |
| Kisantu | 14 | F | 5 | Eleke | 8 | M | 6 | 0 | Nut-Owner (Donor) |
| Likasi | 12 | F | 3 | Isiro | 15 | F | 2 | 1 | Nut-Owner (Donor) |
| Masisi | 7 | F | 5 | Kisantu | 14 | F | 5 | 7 | Rock-Owner (Recipient) |
| Muanda | 9.5 | F | 5 | Kalina | 14 | F | 5 | 7 | Rock-Owner (Recipient) |
| Sake | 7 | F | 6 | Muanda | 9.5 | F | 5 | 7 | Rock-Owner (Recipient) |
| Waka | 7 | F | 6 | Masisi | 7 | F | 5 | 7 | Rock-Owner (Recipient) |

**Table S3. Experiment 2 nut sharing.** Trials involving nut sharing refers to the number of trials of each condition (experimental and control) in which the nut-owner shared at least one nut via direct transfer or tolerated theft. All dyads participated in ten trials of each condition, except Kinshasa-Likasi who were only administered nine experimental trials due to experimenter error. Number of nuts shared refers to the number of nuts that each nut-owner shared in each condition via direct transfer and tolerated theft. The maximum number of shareable nuts was 50 per dyad per condition (except for Kinshasa-Likasi who had 45 in the experimental condition).

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Trials involving Nut Sharing** | **Number of Nuts Shared** |
|  |  | **Experimental** | **Control** | **Experimental** | **Control** |
| **Nut-Owner** | **Rock-Owner** | **Direct Transfer** | **Tolerated Theft** | **Direct Transfer** | **Tolerated Theft** | **Direct Transfer** | **Tolerated Theft** | **Direct Transfer** | **Tolerated Theft** |
| Bili | Malaika | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Eleke | Sake | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| Kalina | Bili | 2 | 1 | 0 | 1 | 4 | 1 | 0 | 1 |
| Kinshasa | Likasi | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| Kisantu | Eleke | 1 | 6 | 0 | 0 | 1 | 7 | 0 | 0 |
| Likasi | Isiro | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Masisi | Kisantu | 7 | 1 | 0 | 0 | 14 | 3 | 0 | 0 |
| Muanda | Kalina | 1 | 4 | 0 | 0 | 2 | 12 | 0 | 0 |
| Sake | Muanda | 1 | 3 | 0 | 0 | 1 | 8 | 0 | 0 |
| Waka | Masisi | 6 | 5 | 0 | 0 | 18 | 9 | 0 | 0 |

**Table S4. Factors influencing likelihood of tolerated theft of nuts in Experiment 2.** Condition (with control as a baseline), trial (1-10), gesturing by the rock owner, rock transfer (tolerated theft and direct transfer of rocks combined), and dominance (with the rock owner being dominant as baseline) were included as fixed effects, and dyad ID as a random effect, in the model. P-values were generated with likelihood ratio tests. Significant p-values are bolded.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *Factor* | *Estimate* | *S.E.* | χ2 | df | *p-value* |
| Intercept | -4.970 | 1.294 |  |  |  |
| Condition  | 3.245 | 1.069 | 19.332 | 1 | **<0.001** |
| Trial number | -0.036 | 0.091 | 0.160 | 1 | 0.689 |
| Gesture | -0.062 | 0.574 | 0.012 | 1 | 0.913 |
| Rock Transfer | 1.764 | 0.875 | 4.222 | 1 | **0.040** |
| Dominance  | 0.350 | 0.771 | 0.212 | 1 | 0.645 |

**Table S5. Factors influencing likelihood of direct transfer of nuts in Experiment 2.** Condition (with control as a baseline), trial (1-10), gesturing by the rock owner, rock transfer (tolerated theft and direct transfer of rocks combined), and dominance (with the rock owner being dominant as baseline) were included as fixed effects, and dyad ID as a random effect, in the model. P-values were generated with likelihood ratio tests. Significant p-values are bolded.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *Factor* | *Estimate* | *S.E.* | χ2 | df | *p-value* |
| Intercept | -6.705 | 1.616 |  |  |  |
| Condition  | 3.484 | 1.085 | 22.235 | 1 | **<0.001** |
| Trial number | 0.034 | 0.100 | 0.115 | 1 | 0.734 |
| Gesture | -0.100 | 0.673 | 0.022 | 1 | 0.882 |
| Rock Transfer | 0.319 | 1.016 | 0.097 | 1 | 0.756 |
| Dominance  | 1.581 | 1.125 | 1.927 | 1 | 0.165 |

**Table S6. Investigation of generalized reciprocity.** The dependent measure was whether or not a nut owner (subject) directly transferred any nuts within a session. Predictors were condition (with control as a baseline) and generalized reciprocity (i.e., whether or not the subject had received any nuts via theft or direct transfer in the most recently preceding session in which she was the rock owner); subject ID was included as a random intercept. P-values were generated with likelihood ratio tests. Significant p-values are bolded.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *Factor* | *Estimate* | *S.E.* | χ2 | df | *p-value* |
| Intercept | -50.0170 | 993.426 |  |  |  |
| Condition  | 49.506 | 993.426 | 7.802 | 1 | **0.005** |
| Generalized reciprocity | -0.182 | 1.131 | 0.026 | 1 | 0.872 |



**Figure S1.** An infant bonobo observed carrying a stone hammer of similar size to those used in Experiment 2.