Electronic Supplemental Materials

Bonobos and chimpanzees exhibit human-like framing effects

Subjects

We tested 40 semi-free ranging apes (see Table S1): 23 chimpanzees (mean age = 10.5 years; range: 5 to 23 years; 11 females and 12 males) at Tchimpounga Chimpanzee Sanctuary in Pointe-Noire, Republic of Congo, and 17 bonobos (mean age = 8.5 years; range: 5 to 13 years; 7 females and 10 males) at Lola Ya Bonobo in Kinshasa, Democratic Republic of Congo. Animal husbandry and care practices at both locations complied with the Pan-African Sanctuary Alliance (PASA) Primate Veterinary Healthcare Manual, as well as the policies of Tchimpounga Chimpanzee Sanctuary and Lola ya Bonobo Sanctuary respectively. Apes in African sanctuaries are born in the wild, and typically enter the sanctuary after being confiscated at an early age (~2-3 years old) as a result of the trade in wildlife for pets and bushmeat. Previous work indicates that sanctuary apes are psychologically healthy relative to other captive populations [1]. All apes at both sites were socially housed, and the majority free-ranged in large tracts of tropical forest during the day (5-40 hectares across groups). In the evening, all apes spent the night in indoor dormitories (12 m^2-160 m^2). Apes were tested individually in these familiar dormitory buildings. Following testing, most apes were released back with their larger social groups outside. Apes had *ad libitum* access to water and were never food deprived for testing. In addition to the food the apes could eat in their forest enclosures, they were fed a variety of fruits, vegetables, and other species-appropriate foods two to four times daily. Apes were tested on only one session per day and all tests were voluntary: if subjects stopped choosing for more than three trials, the session was halted and repeated the next day.

Subject	*Species*	*Sex*	*Age*	*Loss Condition*	*Gain Condition*
Billi	B	M	9	1.00	0.83
Bisengo	B	M	6	0.33	0.75
Boende	B	M	11	0.83	1.00
Fizi	B	M	11	0.17	0.25
Kalina	B	F	13	0.50	0.50
Kasongo	B	M	9	0.67	0.83
Katako	B	F	7	0.75	0.58
Kikwit	B	M	13	0.92	0.50
Kinshasa	B	F	7	0.75	0.92
Mabali	B	M	8	0.08	0.42
Masisi	B	F	5	0.00	0.17
Matadi	B	M	11	0.25	0.67
Mbandaka	B	M	9	0.25	0.42
Muanda	B	F	7	0.50	0.50
Sake	B	F	6	0.50	0.67
Waka	B	F	5	0.25	0.17
Yolo	B	M	7	0.75	1.00
Elikia	C	M	23	0.00	0.00
Kaoka	C	M	5	1.00	0.92
Likabou	C	F	10	0.42	0.58
Loufoua	C	M	10	0.00	0.58
Louise	C	F	7	1.00	1.00
Lufino	C	M	6	0.50	0.67
Lufumbu	C	M	9	0.17	0.92
Lusingou	C	M	6	0.58	0.92
Maya	C	M	17	0.50	0.83
M'Bolo	C	F	15	0.58	0.58
M'Vouti	C	F	9	1.00	0.75
N'Tsere	C	M	16	0.50	0.67
Nzambi	C	F	9	0.67	0.50
Ouband	C	F	11	0.50	0.50
Pema	C	F	9	0.50	0.58
Poungou	C	F	5	0.50	1.00
Silaho	C	F	13	0.08	0.00
Talian	C	M	11	0.92	0.92
Tambikiissa	C	F	7	0.50	0.67
Tchimaka	C	M	12	0.00	0.00
Ulengue	C	M	7	0.08	0.08
Wounda	C	F	9	0.58	0.58
Yoko	C	M	15	0.00	0.42

Table S1: Subject characteristics and average session performance across conditions. For species, 'C' refers to chimpanzees and 'B' to bonobos. For sex, 'M' refers to males and 'F' to females. Age refers to age estimate in years. Loss condition and gain condition refers to mean proportion choices for the framed option in the two conditions.

Supplemental Methods

1. General setup

Across sessions, the experimenter and the ape sat across from each other at a table (80 cm wide, 40 cm deep, 50 cm tall) with a sliding top, separated by wire mesh or bars. On each trial, subjects saw the experimenter place the available options on the two sides of the table (from left to right, with side assignment for the two options counterbalanced). When the table was slid forward, apes could make a choice by pointing or reaching through the mesh with their fingers. After choosing, the experimenter would always give them their chosen option. Subjects had 30s to choose once the table was pushed forward; if they failed to choose in this period, the trial was repeated. If subjects protruded both hands simultaneously in the task (i.e., tried to choose both options at once), the experimenter pulled the table back and re-presented it after a few seconds until the subjects made a discrete choice. There was a 30s intertrial interval between trials after the ape's chose and received their food reward. To avoid unintentional cuing, the experimenter presented options uniformly across trials, first placing the left option and then the right, with the locations of the stable alternative option and framed option counterbalanced across trials. During presentation, the experimenter looked down, and, once he had pushed the table toward the subject with his hand on the midline of the table, he placed his hands on his lap behind the table and looked straight ahead.

2. Preference pretest procedure

In an initial *preference pretest*, we assessed each individual's preferences for the intermediate food type versus the highly-preferred types. In particular, each individual underwent an individual titration to determine the number of pieces of intermediate food

(peanuts) that they treated as equivalent to the average payoff from the framed option of 1.5 pieces of preferred food (preferred food for both species: banana for chimpanzees, and apples for bonobos based on their performance in previous food preference tests; [2-4]). That is, we assessed how many pieces of peanuts the ape would need to receive to choose between the peanuts and fruit approximately equally. Here apes completed up to 36 preference trials in which the number of peanuts available was adjusted until the ape's preference stabilized. We used this procedure to ensure that all apes would choose the fruit option approximately half the time in the absence of the framing manipulation. That is, this titration method allowed us to determine for each individual the number of pieces of the alternative food type (peanuts) that the ape treated as subjectively equivalent to the average framed payoff from the framed options (1.5 pieces of fruit), in order to isolate the effect of the framing manipulation. Importantly, the *preference pretest* did not account for subjects' risk preference (since the alternative option was pitted against the average value of the framed option, without any probabilistic variation). It was rather designed to ensure that apes' choices were not at ceiling or floor in the main conditions, in order to maximize the study's sensitivity to detect framing effects.

Apes selected between the average payout of the framed option (1.5 pieces of fruit) and various quantities of peanut halves until a stable equilibrium was reached. The session was administered in blocks of four identical trials, beginning with one peanut half versus 1.5 fruit pieces. If the ape selected the fruit all four times in the initial four trials (which was typical in the first block of trials), the number of peanuts in the subsequent four trials was incremented up by two. If the subject selected the fruit between one and three times in four trials, they completed an additional four trials with the same number of peanuts serving as the alternative. If apes never

selected the fruit on a given block, the number of peanuts was decremented by two in the subsequent four trials.

In order to reach equilibrium, apes had to complete eight sequential trials where they chose approximately equally between the two options (i.e., each option between three and five times out of the eight trials). If apes did not reach this criterion within a set of eight continuous trials with the same number of peanuts available, the number was further adjusted. In particular, if the subject selected the fruit only once or twice in eight trials, the number of peanuts was decreased by one in the next four trials, whereas the number was increased by one if the subject selected the fruit in seven or eight of the trials. Trials continued until equilibrium was reached or until the subject failed to stabilize because they always preferred 1.5 fruit slices (when the number of necessary peanuts exceeded 10) or they never preferred the fruit over even one peanut half. Twelve apes (7 chimpanzees and 5 bonobos) did not stabilize under this procedure, and were not tested in the main study. Three additional apes (1 chimpanzee and 2 bonobos) did stabilize in the pretest, but would not participate in the main task for at least two consecutive days and did not complete the main study sessions. These individuals were therefore excluded from the analyses.

3. Exposure and test session procedures

Following the preference pretest, each ape completed the two test conditions (*Gain condition* and *Loss condition*) in counterbalanced order. Each condition consisted of two sessions that occurred on consecutive days: an exposure session in which only one option (framed option or stable alternative option) was available at a time so that apes were familiarized with the contingencies of each option, followed by a test session. Apes received at least a two-day break

between conditions. To ensure the ape could distinguish the two options, each was presented on a differently-colored rectangular plate (green or white, with color assignment counterbalanced across subjects but held constant across conditions; see Figure S1).

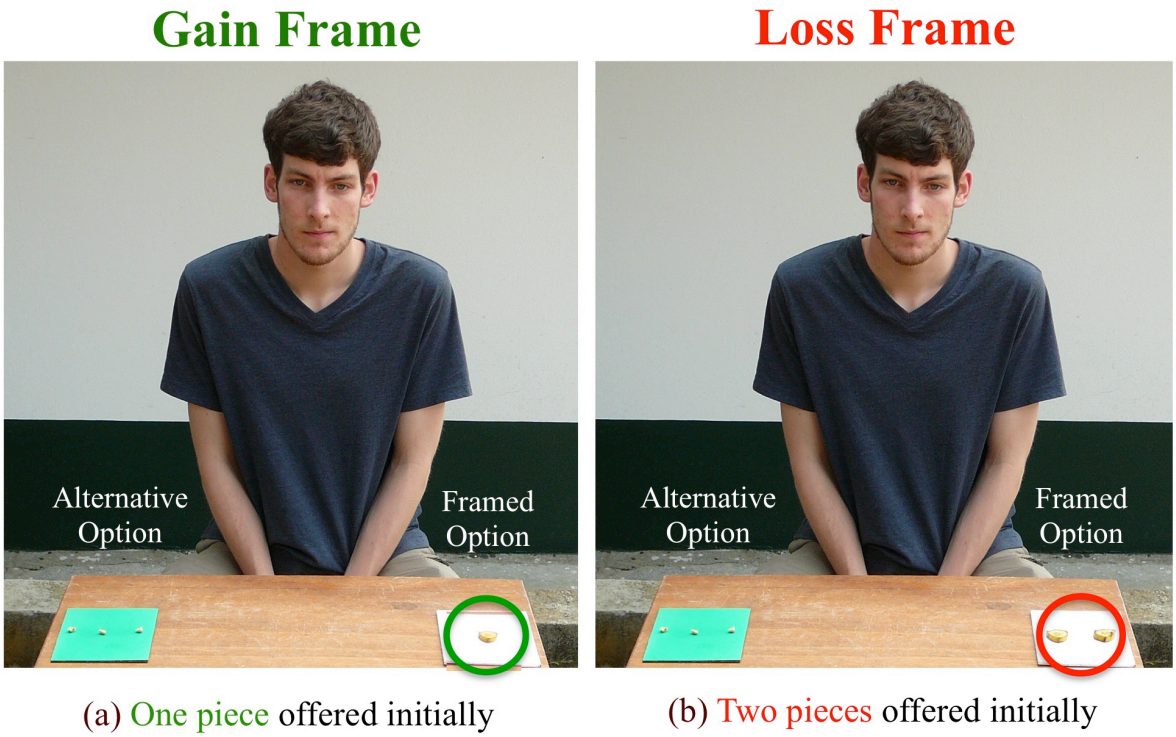

Figure S1: Setup for framing task. (a) In the gain frame, apes saw a framed option (initially seen as one piece of preferred fruit) on one side, and the stable alternative option on the opposite (the number of peanuts determined by that individual's equivalency value; here three peanuts). The experimenter increased the framed option to two pieces after the ape chose it on 50% of trials. (b) In the loss frame, apes saw a framed option (initially presented as two pieces) on one side, and the alternative option on the opposite. The experimenter decreased the framed option to one piece after the ape chose it on 50% of trials. Side assignment of the framed and alternative options were counterbalanced across trials.

In the initial exposure session for each condition, the 24 exposure trials involved the presentation of one option at a time so that the apes could experience the different outcomes before they made direct choices between the two options. We grouped the presentation of the framed and alternative options in blocks of 6 trials, with the two options alternating in an ABAB

order (counterbalancing across subjects whether the framed or alternative option was presented first). Thus, in the exposure session, the apes experienced blocks of 6 trials of either option, alternating between the two. In each trial, the experimenter placed the colored plate in the center of the table, set the food pieces on it, and then moved it forward and to the right or left corner of the table (side assignment counterbalanced within the session). He then pushed the table forward, allowing the ape to select the food. Once the ape had done so, the experimenter gave the ape the reward. If the ape chose the stable alternative option, she received exactly what was displayed, and if she selected the framed option, the experimenter augmented, decreased, or left the same amount of fruit pieces as appropriate according to the predetermined payoff schedule.

The test session began with 12 exposure trials, again grouped in blocks of 6 of the same option (option order counterbalanced across subjects). The final 12 test trials then involved dichotomous choices between the framed and alternative options. Here the experimenter placed the two options on opposite sides of the table from left to right, with side assignment for the two options counterbalanced within a session, and pseudo-randomized such that the same option did not appear on the same side more than two trials in a row. If the subject chose the framed option, it was augmented, decreased, or left the same as appropriate (see Supplementary Figure S1).

4. Coding and data analysis

Choices were scored live by the experimenter. All tests were videotaped, and a second coder blind to conditions and hypotheses scored 20% of sessions with perfect reliability [Cohen's kappa = 1.0]. We analyzed the main choice data using two statistical approaches. First we examined the mean proportions of choices for the framed option across all trials using non-parametric statistics. Second, we used generalized linear mixed models (GLMM) to analyze

choices as a binary outcome variable with a logit link function, while accounting for correlation in responses due to repeated measures within subjects [5]. We analyzed the data using the statistics program R v. 3.1.0 [6]. In particular, we used the function glmer in the *lme4* software package [7] to build models based on maximum likelihood, and used likelihood ratio tests to compare fit across models incorporating different factors [8]. To conduct post-hoc Tukey comparisons of model factors, we used the glht function in the package *multcomp* [9].

Supplemental results

1. Preference pretest

We examined apes' performance in the preference pretest, used to determine the number of items provided by the stable alternative. Apes had an average equivalence quantity of 2.5 ± 0.3 pieces (range: one to eight pieces), and took an average of 13.1 ± 1.0 trials to stabilize (range: 8 to 36 trials). In terms of their equivalency value, there were no differences in the number of peanuts that individuals considered equivalent to the average fruit reward provided by the framed option either between species [Mann-Whitney U = 136.00: $z = -1.72$, $p > 0.10$, n.s] or between males and females [Mann-Whitney U = 176.50, $z = -0.62$, $p > 0.56$, n.s.]. There were also no differences in the average number of trials subjects completed to reach stability between species [Mann-Whitney U = 156.50: $z = -1.13$, $p = 0.29$, n.s] or between males and females [Mann-Whitney U = 176.50, $z = -0.62$, $p > 0.56$, n.s.]. Overall, this suggests that our titration procedure was successful in identifying reward values for the stable alternative option used in the main task.

2. Average payoffs from the framed option

The payoffs that apes received from the framed option were predetermined (such that apes would receive an average of 1.5 pieces of fruit from the framed option in both conditions, if they always chose it). As apes varied in how often they actually choose the framed option in a session, their average payoffs consequently fluctuated around 1.5 pieces of fruit. On average, apes received 1.49 ± 0.02 pieces of fruit from the framed option on choice trials. A comparison of choice trials resulting in high versus low payoffs revealed that apes received the high payoff on 51% of trials, which did not differ from chance [binomial test: $p = 0.54$, n.s.], indicating that the apes could not detect the ultimate value of the framed reward across trials using some other cue. Moreover, neither males nor females tendency to receive the higher payoff differed from chance [males received the high payoff on 53% of trials; binomial test: $p = 0.40$, n.s.; females received the high payoff on 50% of trials; $p = 1.0$]. Thus, a difference in average payoffs is unlikely to account for our main findings concerning differences between males' and females' susceptibility to framing.

Importantly, the 12 choice trials in the test sessions were contiguous with the initial 12 exposure trials (where only one option was available; six trials involved the framed option, with equal number of high and low payoffs). Those exposure trials were therefore designed to provide feedback that the framed option provided an average of 1.5 pieces of fruit. We therefore examined the average payoffs an individual received across all trials in a given session to account for the ape's complete feedback. This also accounted for the fact that some apes never chose the framed option in the choice trials following their initial experience. On average, apes received 1.50 ± 0.01 pieces of fruit in gain frame sessions [range: 1.43 to 1.64], and 1.48 ± 0.01 in the loss frame [range: 1.33 to 1.58]. In an examination of each sex, we found no difference in

total average payoffs between the loss and gain condition for males [average total payoffs in gain condition = 1.49 ± 0.01, loss condition = 1.48 ± 0.01; Wilcoxon: N = 22, T+ = 11, 6 ties, Z = -0.80, p > 0.42, n.s.] or females [gain condition = 1.51 ± 0.01, loss condition = 1.49 ± 0.01; Wilcoxon: N = 18, T+ = 6, 7 ties, Z = -0.89, p = 0.37, n.s.]. In addition, there were no differences in either chimpanzees [gain condition = 1.49 ± 0.01, loss condition = 1.48 ± 0.01; Wilcoxon: N = 23, T+ = 9, 10 ties, Z = -1.26, p = 0.21, n.s.] or bonobos [gain condition = 1.51 ± 0.01, loss condition = 1.49 ± 0.01; Wilcoxon: N = 17, T+ = 8, 3 ties, Z = -0.67, p = 0.51, n.s.]. We used the average total payoffs as a covariate in the GLMM analyses reported in the main text. Note that as this did not account for the additional feedback apes received in the introductory all-exposure session (which were predetermined to provide each payoff exactly half the time), the values used in the GLMM analyses were conservative and overweighed any individual variation in payoffs.

3. Age

In an additional set of analyses, we examined whether age had any impact on apes' responses to framing in an initial analysis. There was no relationship between individual ape's difference score (choices for framed option in the gain condition minus in the loss condition) with their age [r_p = -0.09, p = 0.60, n.s.], suggesting that age did not impact susceptibility to framing. An analysis using GLMM to model trial-by-trial choices confirmed this. While age was an additional significant predictor when added to the full model described in the main text (all reported effects also remained significant predictors), it was driven by the fact that the oldest chimpanzee in our study never chose the framed option in either condition. Running the analyses after removing this outlier individual resulted in age being a non-significant predictor and not improving model fit compared to the final model reported in the main text in Table 1 [χ^2 = 0.74,

df = 1, p = 0.39, n.s]. As such, there is no evidence that age is an important predictor of responses to framing from this study.

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