Electronic Supplementary Material
Chimpanzees an bonobos distinguish between risk and ambiguity
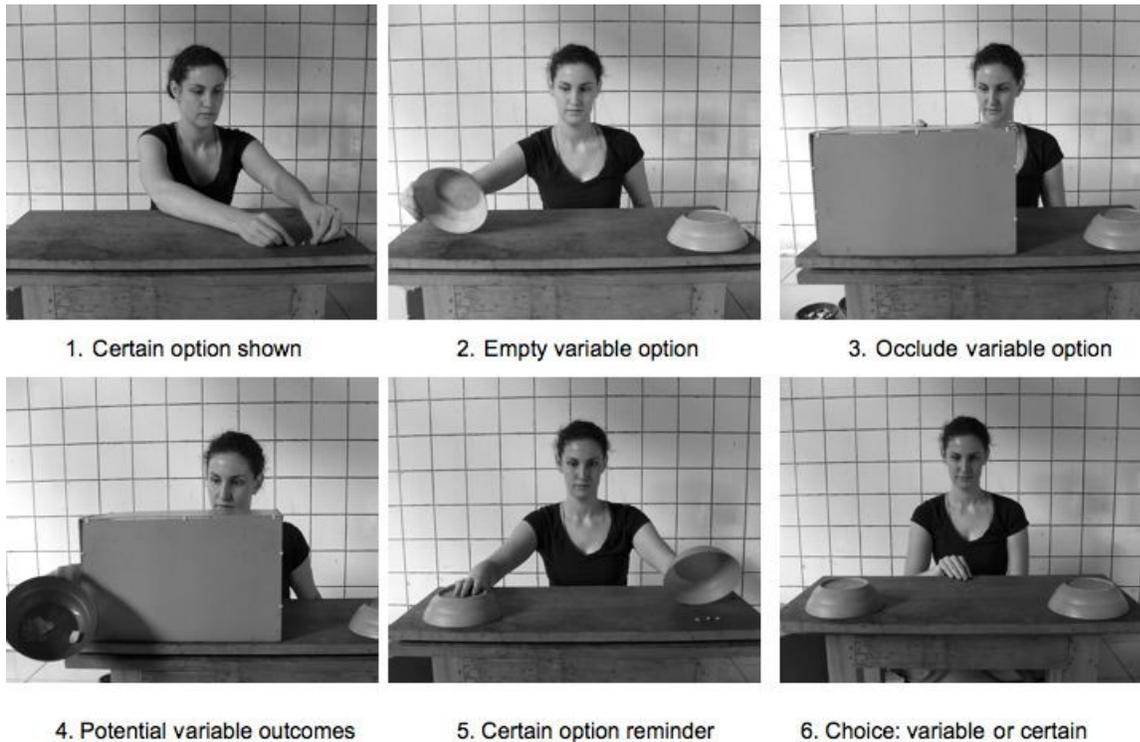A.G. Rosati and B. Hare

Subjects

We tested 30 semi-free ranging adult and sub-adult apes: 16 chimpanzees (7 females; average age = 9.5 years, age range: 7-12) from Tchimpounga Chimpanzee Sanctuary in Pointe Noire, Republic of Congo and 14 bonobos (4 females; average age = 8.2 years; age range = 5-11years) from Lola ya Bonobo Sanctuary in Kinshasa, Republic of Congo. The majority of the apes were born in the wild and came to the sanctuary after being confiscated at an early age (~2-3 years old) as a result of the trade in apes for pets and bushmeat. In the sanctuaries, humans raised them with peers until they were old enough to join a mixed-age social group. In the evening all individuals entered buildings where they normally interacted with human caregivers. All apes were socially housed, and the majority had access to large tracts of land during the day, including primary tropical rainforest (15-40 hectares across groups). All apes had previous experience with the risk task used here from another study they participated in a few weeks prior to the current study. The apes were tested individually by an unfamiliar experimenter in their sleeping areas. They had *ad libitum* access to water and were not food restricted for testing: the majority of their daily diet came multiple daily feedings (2-4) of fruits, vegetables, and other species-appropriate foods. Following testing, most apes were released back with their larger social group outside.

Risk task setup

We used a variation of a decision-making task previously used to assess risk preferences in these species (Rosati & Hare, in review; see Supplementary Figure 1). The basic setup was as follows. First, subjects saw the experimenter place the certain reward on one side of the table, and then cover it with an overturned blue bowl (17.5 cm in diameter, 5.5. cm tall). Next, subjects saw the experimenter place an identical—but empty—bowl on the table (the variable option). The experimenter then occluded the risk option with a small freestanding occluder (40.5 cm wide, 24 cm deep, 24 cm tall). Next the experimenter showed the subject the "outcome" container (a red bowl), initially covered with a black lid so that subjects could not view its contents. The experimenter then lifted the lid to show the subjects the two potential outcomes for that trial. Behind the occluder, the experimenter then placed just one of these items under the variable option bowl. Thus, subjects always knew what they would receive from the certain option, but did not know which of the potential outcomes had been placed under the variable option. Finally, the experimenter touched both cups simultaneously while picking up the certain bowl to remind the subject of the certain option's value. The experimenter then pushed the table forward for choice. To remove the possibility of subtle experimenter cues at the time of choice, the experimenter always touched the center of the table when pushing it forward, and looked down the table's midline during the choice phase. In addition, we note that extensive evidence indicates that apes are unsuccessful at using even very explicit social cues in choice tasks, including gaze, pointing, and placement of object markers (see Tomasello et al., 2003 for a review). This is the case even though these are the only information available in typical social cuing paradigms. In the current study, in contrast, any potential experimenter cues of this nature would further have to override the apes' own knowledge about the options, given that before their choice they see the actual contents of the certain option, and see the potential outcomes of

the variable option. Once the subject pointed at one of the bowls, the experimenter lifted that bowl to reveal the outcome and gave them the food. Subjects were not shown the outcome of the risky option if they did not pick it.

Between each trials there was a 30s inter-trial interval, starting when subjects put the last piece of food in their mouth. Subjects completed no more than one test session per day, and all tests were voluntary: if the ape stopped participating for three trials in which they did not make a choice within 30s of the experimenter pushing the table forward, the session was halted and repeated the next day. The side assignment for the certain and variable option was always counterbalanced and quasi-randomized within a session, with no more that three trials with the same side-assignment in a row in a given session.

1. Certain option shown   2. Empty variable option   3. Occlude variable option

4. Potential variable outcomes   5. Certain option reminder   6. Choice: variable or certain

Supplementary Figure 1: Basic risk task adapted from Rosati & Hare, under review. In test sessions, the variable option was initially show with a lid covering it (see Supplementary Figure 2). The experimenter first placed an intermediate food type on the table (peanuts) in view of the subject, and then covered it with a cup (the certain option). The experimenter then showed the subject the empty variable option bowl and occluded only this bowl. Next, the experimenter showed the subject the variable outcome container; on all-good, all-bad and risk trials the lid was removed to reveal the possible outcomes for that trial, whereas on ambiguity trials the lid was not removed. Behind the occluder, the experimenter then placed one of the outcomes so subjects did not know which one was there. After removing the occluder, the experimenter touched both cups simultaneously, while picking up the certain bowl to remind the subject of what was there. Finally, the experimenter pushed the sliding table forward (touching the center of the table and looking down its midline) so the cups were in reach of the subject to choose.

Food preference pretest

Subjects completed 5 sessions total. Apes first completed a *food preference pretest* to assess their relative preference for three different food options (chimpanzees: preferred was banana, intermediate was peanuts, and non-preferred was cucumber; bonobos: preferred was apple, intermediate was peanuts, and non-preferred was lettuce). Subjects completed 18 *food preference* trials in a pretest session. Different foods were used for each species in the food preference pretest due to differences in availability at the two sanctuaries. In preference trials, the experimenter showed the subject two different types of food, and then placed them on the two sides of the table. The experimenter then covered them with identical bowls to introduce the bowls used in the risk task, and pushed the table forward. Apes choose between each possible pairing six times, with side assignment counterbalanced and a randomized order of food-pairings.

Risk introductory session

As there were several differences between the certain and variable options in our paradigm, apes next completed a *risk introduction session*. Here, the variable option was always presented without the lid (which was first introduced in the ambiguity introduction session). The session consisted of an initial 12 *exposure trials* (only one option available at a time; eight risk option-only trials randomly intermixed with six certain option-only trials) followed by control trials that were similar to those the apes experienced in the test session, but the types and quantities of food provided by the certain and risky option varied to assess their comprehension. As in the risky choice trials, subjects always received only one of the possible outcomes from the risky option. In four c*omprehension-1 trials,* the certain option provided two pieces of a preferred food, and subjects saw two pieces of the same food in the risk outcome container. If subjects understood that the risky option only provided one of the possible outcomes they saw, they should prefer the certain option (even though they saw the same amount of food associated with both). In four *comprehension-2 trials,* the certain option provided a small piece of a preferred food, and the risky outcome container contained two larger pieces of the preferred food. If subjects compared the two options, they should prefer the risky option because it delivered a bigger piece of preferred food. Finally, four *inhibition trials* proceeded as normal choice trials, but in a final step the subject saw the experimenter removed the certain option's food. If subjects could inhibit reaching for the last location where they saw food if now it is gone, they should choose the risky option.

Ambiguity introduction session

Following the risk introductory session, subjects completed an *ambiguity introductory session* with 24 trials to familiarize subjects with the particulars of the ambiguity manipulation. Here, the variable option was always initially presented with the lid (which was then removed on some trial types). The first 8 trials were intermixed *risk exposure trials*—6 variable-only trials (2 per probability of receiving the good outcome—0%, 50%, and 100% where the lid was removed so that subjects could view the bowl's contents) and two certain-only trials. Subjects then completed 4 *ambiguity exposure trials* where the lid was never removed. These trials therefore ensured that subjects were willing to choose the ambiguous option despite never seeing its contents. Then subjects completed 12 intermixed control trials to confirm that subjects were willing to chose the ambiguous option when it potentially paid to do so because the alternative provided a bad outcome. *Ambiguity inhibition trials* (4 trials) were identical to the previous

inhibition trials, except that the variable outcome had a lid on it. Since the alternative provided no food, subjects should chose the ambiguous option even though they could not see its contents. In *ambiguity versus good trials* (4 trials), the variable option has lid on it, and the certain option provided a preferred food. Since they now they can get a preferred food, subjects should pick the certain option. Finally, in *ambiguity versus bad* trials (4 trials), the variable option has lid on it, but the certain option is non-preferred food. Here, the apes should pick the ambiguous option, because they know they will get something bad from the certain option.

Test sessions

Finally, subjects completed two *test sessions*, each with 24 trials. In each test session, subjects completed 6 trials of each type: all-good trials, where, both potential outcomes were preferred food (100%); all-bad trials, where both potential outcomes where non-preferred food (0%); risk, where there was a good and bad potential outcomes (50%); and ambiguity, where subjects did not have knowledge about the potential outcomes. In all trials the outcome container was initially presented to the subject with the lid on it, which was then removed for al-god, all-bad, and risk trials (but not ambiguity trials). Trial side assignment was counterbalanced within a session and occurred in quasi-randomized order, with no more than 2 trials of the same type in a row within a session. Thus, subjects ultimately completed 12 trials of each type across the two sessions (see Supplementary Figure 2).
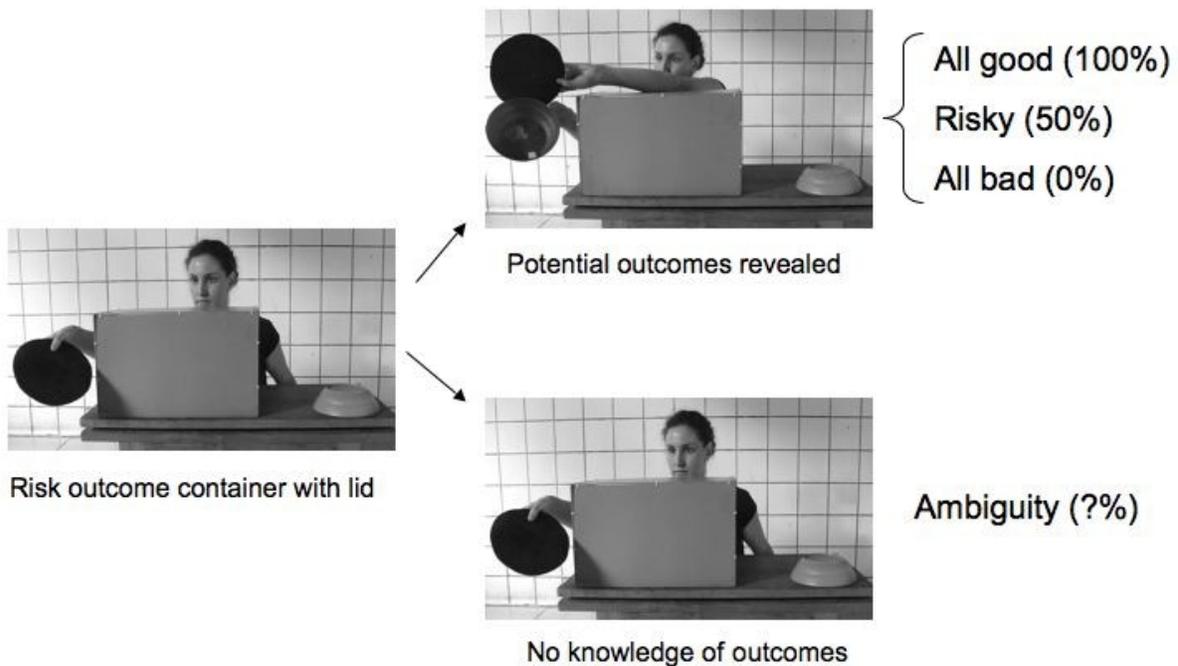
Supplementary Figure 2: Task setup for all-good, all-bad, risky, and ambiguous trials. In all-good, risk, and all-bad trials the lid on the variable "outcome" container was opened to reveal the potential outcomes for that trial (100% preferred food, 50% preferred food, and 0% preferred food, respectively). In ambiguity trials, in contrast, the experimenter did not lift the lid and consequently the apes had no information about the probability of receiving a good option on those trials.

Coding and data analysis.

All sessions were videotaped and coded live by the first author. Additionally, for reliability 20% of sessions were randomly selected and the apes' choices were coded from videotape by a second experimenter who was blind to condition (e.g., trial type) and the hypotheses of the study. All percentages were arc-sin square-root transformed to normalize the data.

Reliability results

Agreement between the live coding and the second coder was perfect [Cohen's Kappa = 1.00].

Food preference pretest results

Overall, both species showed clear patterns of preferences across the food tpes, and there was no species differences in the rate that they chose the different types (see Supplementary Table 2). In addition, both species chose the preferred food type more than the intermediate type (one-sampled t-tests: chimpanzees: $t(15) = 100.98$, $P < 0.001$; bonobos: $t)14) = 6.20$, $p < 0.001$; two tailed) and both chose the intermediate option over the non-preferred food (one-sample t-tests: chimpanzees: $t(16) = -6.04$, $p < 0.001$; bonobos: $t(14) = -21.66$, $p < 0.001$; two-tailed). Thus, apes of both species showed clear patterns of preference across the three food types, with no differences between species in how much they preferred their food types. We therefore assigned the preferred food as the good (variable option) outcome, the non-preferred food type as the bad (variable option) outcome, and the intermediate type as the certain option.

Outcome Category	Chimpanzees: food type and percent choice	Bonobos: food type and percent choice	Sig. (two-tailed)
Preferred (good outcome)	Banana 94.3 ± 2.0%	Apple 92.3 ± 3.1%	p = 0.58, n.s.
Intermediate (certain option)	Peanut 48.4 ± 4.1 %	Peanut 55.4 ± 3.2%	p = 0.20, n.s.
Non-preferred (bad outcome)	Cucumber 11.7 ± 2.9% r	Lettuce 2.4 ± 1.0 %	p = 0.15, n.s.

Supplementary Table 1: Performance in the food preference pretest and comparison of the two species' preferences for the three outcome categories (independent samples t-test).

Control trial results

Apes showed high levels of performance across all six types of control trials, and the two species did not differ in their performance on any individual type (see Supplementary Table 2). In addition, both species were above chance at selecting the correction option for all six types ($p < 0.001$ for all comparisons; one-sample t-tests).

Control trial type	Chimpanzees % correct	Bonobos % correct	Sig. (two-tailed)
Inhibition	98 ± 2%	96 ± 3%	p = 0.59, n.s.
Comprehension-1	86 ± 5%	93 ± 4%	p = 0.31, n.s.
Comprehension-2	86 ± 6%	93 ± 3%	p = 0.31, n.s.
Ambiguity inhibition	98 ± 2%	96 ± 2%	p = 0.48, n.s.
Ambiguity vs. good	80 ± 5%	84 ± 5%	p = 0.56, n.s.
Ambiguity vs. bad	98 ± 2%	100 ± 0%	p = 0.36, n.s.

Supplementary Table 2: The two species choices on six control trial types, and comparison of their performance (independent samples t-test).

Impact of previous trial's outcome

We conducted an analysis to assess how the outcome of the previous trial (e.g., good outcome, bad outcome, or picked certain, regardless of previous trial type) drove the apes' choices on the subsequent trial. In an initial analysis we collapsed across all trial types (e.g., all-good, all-bad, risk, and ambiguity trials) to assess whether previous outcome influenced choice regardless of the current trial type apes were faced with; one chimpanzee was excluded from this analysis as she never chose the certain option. A repeated measures ANOVA with previous outcome as a within-subjects factor indicated that previous outcome did not influence the apes' choice overall [$F_{(2, 56)} = 0.731$, p = 0.485, n.s.].

We next targeted only ambiguity and risk trials to assess whether previous outcome impacted specifically these decisions. As repeated measures ANOVA with trial type (risk or ambiguity) and previous outcome (good, bad, or certain)) as within-subject factors indicated that there was no main effect of previous outcome [$F_{(2, 34)} = 1.409$, p = 0.258, n.s.] a strong trend for a main effect of trials [$F_{(1, 17} = 4.419$, p = 0.51], and no significant interactions. Together, this suggests that trial type was the main factor influencing apes' choices, not the outcome of the previous trial. That is, apes' choices reflected differences in their preferences for the various options, (all-good, all-bad, risk, and ambiguity), not a simple rule such as win-stay loose-shift.

References

Tomasello, M., Call, J. & Hare, B. (2003). Chimpanzees understand psychological states—the question is which ones and to what extent. *Trends in Cognitive Sciences*, 7, 153-156.