# Supporting Information

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### SI Methods

**Subjects.** These experiments were carried out with bonobos at the Lola ya Bonobo sanctuary in Kinshasa, Democratic Republic of Congo, and chimpanzees at Tchimpounga chimpanzee sanctuary in Pointe Noire, Republic of Congo. At both sanctuaries, individuals live in social groups that have access to large areas of primary tropical forest (15–40 ha) during the day and sleep in dormitories at night. Nearly all of these apes are wild-born orphans (except for those born at the sanctuary), arriving at the facility after being confiscated by local governments. Thus individuals have experienced some early life trauma in being separated from their mother and potentially kept in deprived conditions. However, our preliminary research suggests that sanctuary individuals show fewer behavioral indications of negative welfare than zoo apes and that the orphans show no cognitive impairment relative to mother-reared infants. Although the effects of early life experience on these individuals' hormonal pathways cannot be known, the two populations tested in this experiment are comparable because both have the same rearing histories and highly similar living environments at the sanctuaries.

**Procedure.** *Dominance test.* Before the food competitions, subjects participated in a test to assess relative dominance in a feeding context in a given pair. Similar to previous work (1, 2), the two individuals in a pair were brought into a test room and fed by caretakers 2 m apart at the mesh wall of the room. As they were being fed, the experimenter placed a large piece of food at the mesh equidistant between the two individuals. Whichever individual obtained this piece of food was scored as the "winner" of that trial. This procedure was repeated eight times, and the individual that obtained the food on more of these eight trials was scored as the dominant in that dyad. If both individuals obtained food on an equal number of trials, the dominant was assigned on the basis of who obtained more food in the food competitions.

Dominants in this test also tended to monopolize more food in the food competitions. There was a significant relationship between the number of trials (out of eight) in which an individual monopolized food in this test and the number of conditions (out of 3 test days) in which that individual monopolized food in the food competitions (we performed a Kendall's $\tau$ ordinal-by-ordinal analysis for this comparison; $\tau = 0.33$, $P < 0.001$, $n = 328$).

*Food competitions.* Three food competition conditions varying the monopolizability of the food were used, following the procedures used in previous experiments (1, 2). Each condition was presented on a separate day, with individuals receiving three trials of the same condition on a given day (resulting in nine total food competition trials over the three conditions). The order in which the conditions were presented was counterbalanced across species, sex, and age. Each species was tested with its most preferred food to produce similar levels of motivation: bananas were used with the chimpanzees and green apples with the bonobos. The relative amount of food used in each condition was similar across the two species. The conditions were as follows.

Dispersed-divisible: two piles of food with eight pieces in each were placed ≈3 m apart inside the test room, with the piece size standardized as each banana was cut up into 8 pieces (chimpanzees) and each apple was cut up into 32 pieces (bonobos) (thus a total of 16 food slices was placed in this condition, 8 in each of the two separate piles).

Clumped-divisible: one food pile was placed in the testing room, with 16 pieces (of the same size as the previous condition) all placed in this one pile.

Clumped-solid: one food pile was placed in the testing room, but rather than being small pieces there were simply two whole bananas (chimpanzees) or two quarters of an apple (with each banana or quarter-apple being the same amount as the eight pieces placed in the other trials).

Subjects were placed in pairs before the pretest saliva sample collection and were kept in an adjacent room to the test room. They did not know the configuration in which the food was going to be presented on a given day when the pretest saliva sample was taken but did know their pairing and could see that food was present when the experimenters brought food into the dormitory building. After the pretest saliva sample was taken, subjects witnessed the placement of the food from the adjacent room, and the pair was then videotaped for 1 min to capture any behaviors exhibited in anticipation of the food competition. Subjects were then released into the test room, and their behavior in the test trial was videotaped as well. The trial was considered finished when both subjects finished eating. Preparation for the next trial began immediately after a given trial ended. After the third and last trial, upon finishing their food, subjects waited in the testing room for 15 min for collection of saliva samples. During these 15 min they sat in their pairing and were not given any additional food, then the posttest saliva sample was taken while they were still in the room with the other individual.

In the solo condition subjects underwent the same procedure, being released into the test room for three trials, with a 1-min anticipation period before each trial after the food was placed, except that subjects were alone in the test room during the pretest saliva collection, the food presentations, the 15-min following the test, and the posttest sample collection.

### SI Results

**Cortisol.** *Controls for anticipatory results.* As mentioned in the main article, anticipatory effects in cortisol represented shifts relative to baseline values, rather than differences in basal cortisol levels between individuals (Fig. S1). To control for whether there were differential anticipatory effects in cortisol based on the dominance status of the two individuals in the pair, we used the factor *domsub*, which assigned dominants and subordinates according to the results of the dominance test described above. Performing analyses on the species level for only males (because the main anticipatory patterns were not present in females), we ran a generalized linear model (GLM) analysis on pretest log cortisol with *individual* as a subject factor, and *outcome* and *domsub* as between-subject factors. This analysis revealed no effects or interactions in chimpanzees. In bonobo males, the main effect of *outcome* was still significant [Wald $\chi^2(1) = 10.75$, $P = 0.001$], and there was a significant main effect of *domsub* [Wald $\chi^2(1) = 4.81$, $P = 0.03$], in that subordinate bonobo males had higher cortisol than dominant bonobo males, but the interaction between *domsub* and *outcome* was not significant (Fig. S2). This suggested that dominants and subordinates showed similar endocrine shifts in anticipation of the test.

Another factor that might have impacted cortisol shifts besides dominance status was the number of times the individuals in the pair had been tested. Because this test occurred over the course of multiple sessions, individuals may have reacted more in later sessions, after experiencing sharing (or a lack thereof) with a given partner. Alternatively, individuals may have reacted more in earlier pairings owing to the unfamiliarity of being paired in a dyad with the other individual. To assess this, we incorporated the factor *order*, denoting the first, second, or third test session. We performed a GLM with males only, split by species, of log pretest cortisol with *individual*, *outcome*, and *order* as factors and found no effects or

interactions in chimpanzees. In bonobos, the effect of *outcome* remained significant [Wald $\chi^2(1) = 16.214$, $P < 0.001$], yet there was no significant effect of *order* and no interaction between *order* and *outcome* (Fig. S3). Thus, bonobos showed equal changes in cortisol regardless of the number of times they had been tested with their partner.

A final factor that may have influenced anticipatory cortisol was the type of pair individuals were in—namely, whether they were competing against another male or a female. Unfortunately, this categorization was highly skewed in terms of the *outcome* variable—very few chimpanzee males paired with females shared the food equally. Thus we removed the *outcome* variable to assess whether *pairtype* alone predicted any differences in pretest cortisol. A GLM of log pretest cortisol with *individual* and *pairtype* as factors revealed no significant effect of *pairtype* in either species (Fig. S4). As such, it did not seem that pretest cortisol was altered simply by being partnered with another male vs. a female.

**Testosterone.** *Controls for anticipatory results.* Similar to the cortisol results, the anticipatory shifts in testosterone represented departures from baseline levels (Fig. S5). To examine whether dominance status influenced the effects in anticipatory testosterone, we again used the factor *domsub* as assigned by the results of the dominance test. Performing analyses on the species level for only males, we ran a GLM analysis on log pretest testosterone using *individual*, *outcome*, and *domsub* as factors. In chimpanzee males, there was a significant effect of *domsub* [Wald $\chi^2(1) = 6.460$, $P = 0.010$], in that subordinates had higher testosterone than dominants, and the main effect of *outcome* was also significant, with testosterone higher in both individuals when the dominant monopolized more food [Wald $\chi^2(1) = 12.004$, $P = 0.001$]. However, there was no interaction between *domsub* and *outcome*. Thus, this effect of outcome was equally present in both dominant and subordinate chimpanzees. In bonobo males, there were no significant effects or interactions (Fig. S6). It is notable that dominant chimpanzee males had lower testosterone than the subordinate chimpanzee males, because this contradicts the typical finding that dominance is positively correlated with testosterone in captive and wild male chimpanzees (3, 4). This was likely because our dominance measure was only on the dyadic scale, with the larger group hierarchy potentially showing a stronger relationship with dominance than these dyadic indices. It was not possible to construct a group-level hierarchy because our subjects came from numerous different social groups living at the sanctuaries.

As with the cortisol analyses, we also examined the potential effects of order of the testing day on the anticipatory testosterone values. To assess this, we performed a GLM analysis for males only, split by species, of pretest log testosterone with *individual*, *outcome*, and *order* as factors. We found the predicted effect of *outcome* in chimpanzee males [Wald $\chi^2(1) = 4.621$, $P = 0.03$] but no effect of *order* nor any interaction between *order* and *outcome* in either species (Fig. S7).

Finally, we wanted to assess whether pair type impacted males' pretest testosterone. Again, we had to remove the outcome variable because this was skewed according to pair type, and we simply examined whether there were any differences in males paired with other males vs. males paired with females. We performed a GLM analysis of log pretest testosterone separately by species in males only, with *individual* and *pairtype* as factors, and found no effect of *pairtype* in males of either species (Fig. S8). These results suggest that males' differential testosterone based on outcome was not confounded merely by the sex of their partner and was instead sensitive to the identity of that partner.

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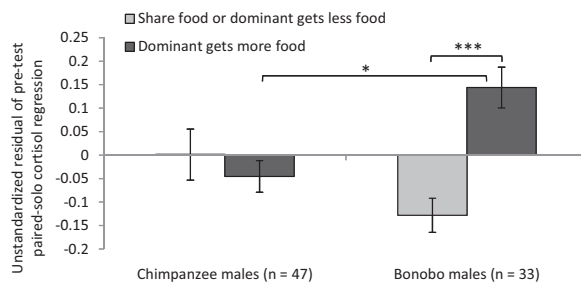
**Fig. S1.** Pretest cortisol values according to species and outcome, males only. These values are expressed as residuals of the log pretest values relative to the log pre-solo (baseline) values. Bars denote SEM. *$P < 0.05$; ***$P < 0.001$.
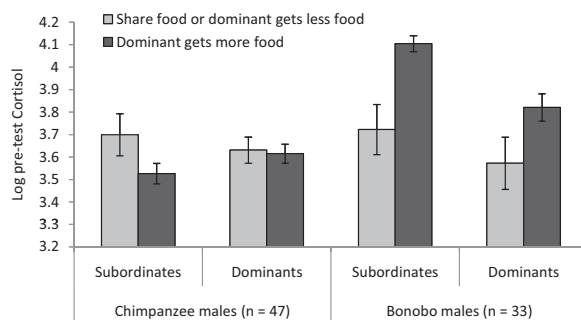


**Fig. S2.** Pretest log cortisol values according to species, outcome, and dominance status in males only. Bars denote SE.

**Fig. S3.** Pretest log cortisol values according to species, outcome, and order in males only. Bars denote SE.



**Fig. S4.** Pretest log cortisol values according to species and pair type in males only. Bars denote SE.



**Fig. S5.** Pretest testosterone values according to species and outcome, males only. These values are expressed as residuals of the pretest values relative to the pre-solo values. Bars denote SEM. The bonobo sample size in this analysis is smaller because some bonobos completed the food competitions but did not produce enough saliva in the solo condition (baseline) to measure testosterone. *$P < 0.05$; **$P < 0.01$.



**Fig. S6.** Pretest log testosterone values according to species, dominance status, and outcome, males only. Bars denote SE.

**Fig. S7.** Pretest log testosterone values according to species, outcome, and order in males only. Bars denote SE.



**Fig. S8.** Pretest testosterone values according to species and pairtype, males only. Bars denote SE.