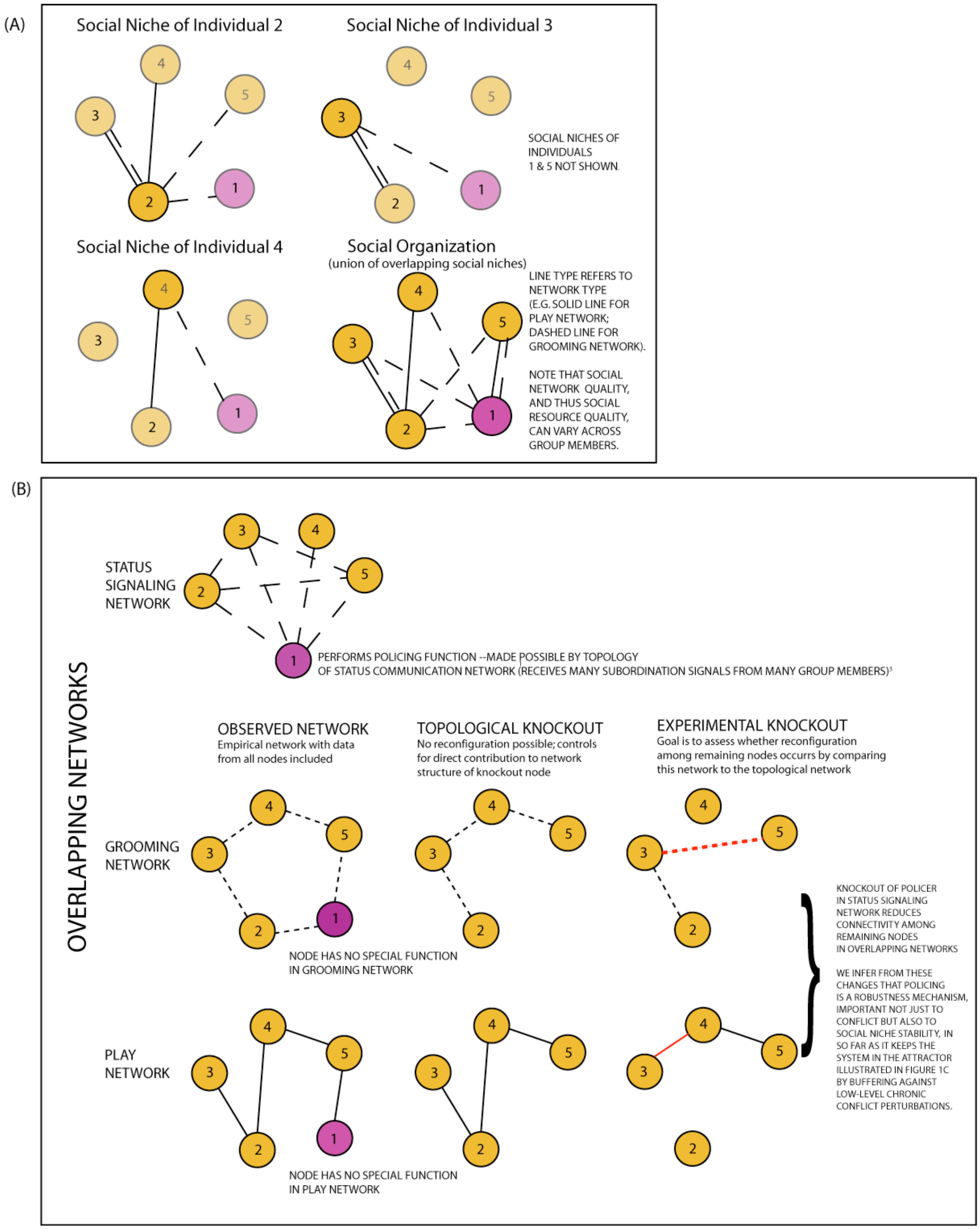
Supplementary Information

1. Supplementary Figure 1S.

Figure 1S. (A) Illustration of the individual's social niche compared to social organization. (B) Illustration of knockout type (topological and experimental) and overlapping social networks.



2. Supplementary Methods

Removal procedure for males

Four individuals were strongly connected nodes in the status-signaling network –the three removed males and the alpha female. Only the males were removed because of the confounding effect removal of the alpha female might have had on the female dominance hierarchy, which is maintained through alliances among females (Aureli & de Waal, 2003). We removed the alpha, beta, and delta males (3rd among males, but fourth ranking overall), all of which were fully-grown. Approximate ages of these males were 13, 13, and 11 years. They were introduced to the group in 1996. The group was familiar with animal removals, which happened routinely for veterinary purposes. However, we randomly chose removal days (once every two weeks) so that the group did not habituate to removal periods. Removal procedure: (i) first author (JF) and research assistant (MS) confined group to outdoor housing area, (ii) JF and MS entered outdoor housing area and quietly walked towards monkeys, encouraging them to congregate on far side of compound, (iii) one of two doors to indoor housing was opened, (iv) JF and MS pointed at males to be removed, singling them out one at a time, until each ran through door into indoor housing, (v) door to indoor housing was shut (males had visual, vocal, and limited physical access to group via space between door and compound walls), (vi) males were provided food, water, and enrichment, (vii) observations began two hours after removal procedure (viii) males were released after observation period ended, and (ix) group was observed for an additional half hour to ensure that no severe conflicts erupted.

3. Supplementary Data

Males not disproportionately favored as grooming partners

We construct an index to assess the degree to which individuals are preferred grooming partners. We evaluate how this index is distributed to determine whether the removed males were in the tails of a distribution (e.g. log-normal or power law) characterized by high variance, and thus were disproportionately favored as grooming partners. The index takes into account two factors: (1) the overall number of grooming bouts an individual receives (r_i^T), and (2) the distribution of these bouts across the population, which is measured using Shannon's Information Index, $H_i(R) = -\sum_{j=1}^{N} r_{ij} \log r_{ij}$, where r_{ij} is the normalized frequency of grooming bouts received from the ith individual by the jth individual. Information content is then multiplied by information value to produce the following index: $P_i = H_i(R) r_i^T$. Individuals with high index scores receive many bouts from many group members. Individuals with low index scores receive few bouts from few individuals. We find that this grooming preference index is normally distributed (n = 48, KS test Z = 1.21, p = .11). This indicates that neither the removed individuals, nor any other individuals, received disproportionate grooming.

We do not evaluate whether the males were disproportionately favored as contact-sitting, play, or proximity partners because their positions in those degree distributions were even less remarkable than for the grooming degree distribution.

Statistical Results for Degree and Clustering Coefficient Analyses

These results were obtained using repeated measures. Play was tested separately from other variables because it was based on a different sample size because some subadults and adults did not engage in play in any of the three conditions. We correct p values for multiple comparisons using the Sidak correction[15]. For **DEGREE**, we found an effect of condition (OC-TK, OC-EK, TK-EK) on the mean degree in the **grooming** network (n = 45, df = 2, F = 21.46, p < .001, partial eta^2 = .33), **contact-sitting** (n = 45, df = 2, F = 3.26, p = .04, partial eta^2 = .07), **proximity** (n = 45, df = 2, F = 10.48, p < .001, partial eta^2 = .19), and **play** (n = 29, df = 2, F = 12.98, p = .004, partial eta^2 = .18).

In the OC-TK comparison, main effects were significant for **grooming** (M_o = 11.98, M_t = 10.62, SEM = 0.17, p < .001), proximity (M_o = 26.47, M_t = 24.18, SEM = 0.12, p < .001), and **contact-sitting** (M_o = 16.00, M_t = 14.93, SEM = .14, p < .001). **Play** was nonsignificant (M_o = 3.69, M_t = 3.59, SEM = .06, p = .08). In the OC-EK comparison, main effects were significant for **grooming** (M_o = 11.98, M_e = 9.33, SEM = 0.49, p < .001), but not **proximity** (M_o = 26.47, M_e = 24.98, SEM = .60, p = .051) or **contact-sitting** (M_o = 16.00, M_e = 14.80, SEM = 0.62, p = .16). **Play** was significant (M_o = 3.69, M_e = 2.48, SEM = .47, p = .016). In the TK-EK comparison, main effects were significant for **grooming** (M_t = 10.62, M_e = 9.33, SEM = 0.47, p = .009), but not **proximity** (M_t = 24.18, M_e = 24.98, SEM = 0.63, p = .51) or **contact-sitting** (M_t = 14.93, M_e = 14.80, SEM = 0.63, p = 1.0). **Play** was significant (M_o = 3.59, M_e = 2.48, SEM = .47, p = .027).

For **CLUSTERING coefficient**, there was an effect of condition (OC-TK, OC-EK, TK-EK) on the mean degree in the **grooming** (n = 47, df = 2, F = 6.94, p = .002, partial eta^2 = .14) and **proximity** networks (n = 47, df = 2, F = 8.23, p = .001, partial eta^2 = .16), but not the **contact-sitting** (n = 47, df = 2, F = 0.80, p = .45, partial eta^2 = .02), or **play** networks (n = 23, df = 2, F = 0.03, p = .97, partial eta^2 = .001).

In the OC-TK comparison, main effects were significant for **proximity** (M_o = 0.65, M_t = 0.61, SEM = 0.003, p < .001), **contact-sitting** (M_o = 0.43, M_t = 0.44, SEM = 0.004, p = .028), and **grooming** (M_o = 0.38, M_t = 0.34, SEM = 0.008, p < .001). **Play** was nonsignificant (M_o = 0.30, M_t = 0.30, SEM = 0.01, p = .94). In the OC-EK comparison, main effects were not significant for **proximity** (M_o = 0.65, M_e = 0.64, SEM = 0.01 p = 1.0) or **contact-sitting** (M_o = 0.43, M_e = 0.42, SEM = 0.015, p = .99), but were significant for **grooming** (M_o = 0.38, M_e = 0.30, SEM = 0.024 p = .008). **Play** was nonsignificant (M_o = 0.30, M_e = 0.29, SEM = 0.08, p = .87). In the TK-EK comparison, main effects were significant for **proximity** (M_t = 0.61, M_e = 0.64, SEM = 0.011 p = .03), but not for **contact-sitting** (M_t = 0.44, M_e = 0.42, SEM = 0.02, p = .70), **grooming** (M_t = 0.34, M_e = 0.30, SEM = 0.025 p = .36), or **Play** (M_t = 0.30, M_e = 0.29, SEM = 0.09, p = .86).

Low Ranking Female Control analyses

During the final weeks of the study, the veterinarians permanently removed a low-ranking adult female (LRF) due to illness. LRF did not perform effective conflict management and was a weakly connected node in the status communication network. She was absent for 41.5 of 156 OC hours, and 26 of 78 EK hours. We evaluated whether changes to the four social networks were induced by her removal by comparing network data from the period in which she was absent (LRFA) to network data from the period in which she was present (LRFP), using only data from the OC condition. The LRF removal differed from the male removal in that the LRF was removed once, permanently. The removal was therefore (a) long-term, rather than temporary and repeated, and (b) occurred during the second half of the study, which was characterized by a lower mean temperature than occurred during the part of the study when the LRF was present (77.5 F compared to 94.0 F). Although not an ideal control analysis, it provides preliminary indication of whether removal of any node, or only removal of important nodes with defined functions, affects network structure.

We had more data from the LRFP period. We sampled randomly from this data set until we obtained the same number of samples as were available for the LRFA period. The same repeated measures procedure was used to analyze the effects of LRF removal on mean degree and mean clustering coefficient. Play, which has a smaller sample size (some individuals do not play in any of the conditions), was analyzed separately. P values of pair-wise comparisons were corrected for multiple tests using Sidak correction.

Degree distribution results for LRF removal

We found no effect of condition (OC-TK, OC-EK, TK-EK) on the mean degree of the grooming ($\underline{n}$ = 47, $\underline{df}$ = 2, $\underline{F}$ = 0.07, $\underline{p}$ = .93, partial eta^2 = .00) or contact-sitting ($\underline{n}$ = 47, $\underline{df}$ = 2, $\underline{F}$ = 0.17, $\underline{p}$ = .85, partial eta^2 = .004). There was a significant effect for proximity ($\underline{n}$ = 47, $\underline{df}$ = 2, $\underline{F}$ = 5.40, $\underline{p}$ = .006, partial eta^2 = .11) and play ($\underline{n}$ = 26, $\underline{df}$ = 2, $\underline{F}$ = 3.85, $\underline{p}$ = .028, partial eta^2 = .13). Below we report pair-wise comparison results. We correct for multiple test using Sidak correction.

In the OC-TK comparison, main effects were significant for grooming ($\underline{M}_o$ = 10.62, $\underline{M}_t$ = 10.47, $\underline{SEM}$ = 0.05, p = .02), proximity ($\underline{M}_o$ = 22.72, $\underline{M}_t$ = 22.30, $\underline{SEM}$ = 0.07, $\underline{p}$ < .001), and contact-sitting ($\underline{M}_o$ = 13.53, $\underline{M}_t$ = 13.32, $\underline{SEM}$ = .06, $\underline{p}$ = .003). Play was nonsignificant ($\underline{M}_o$ = 3.35, $\underline{M}_t$ = 3.35, $\underline{SEM}$ = 0.0, $\underline{p}$ = 1.0).

In the OC-EK comparison, main effects were nonsignificant for grooming ($\underline{M}_o$ = 10.62, $\underline{M}_e$ = 10.46, $\underline{SEM}$ = 0.57, $\underline{p}$ = .99), proximity ($\underline{M}_o$ = 22.72, $\underline{M}_e$ = 24.09, $\underline{SEM}$ = .69, $\underline{p}$ = .16) and contact-sitting ($\underline{M}_o$ = 13.53, $\underline{M}_e$ = 13.28, $\underline{SEM}$ = 0.58, $\underline{p}$ = .96). Play was nonsignificant ($\underline{M}_o$ = 3.35, $\underline{M}_e$ = 4.15, $\underline{SEM}$ = .41, $\underline{p}$ = .06).

In the TK-EK comparison, main effects were nonsignificant for grooming ($\underline{M}_t$ = 10.46, $\underline{M}_e$ = 10.46, $\underline{SEM}$ = 0.56, $\underline{p}$ = 1.0) and contact-sitting ($\underline{M}_t$ = 13.32, $\underline{M}_e$ = 13.28, $\underline{SEM}$ = 0.57, $\underline{p}$ = 1.0), but significant for proximity ($\underline{M}_t$ = 22.30, $\underline{M}_e$ = 24.09, $\underline{SEM}$ = 0.70, $\underline{p}$ = .04). Play was nonsignificant ($\underline{M}_t$ = 3.35, $\underline{M}_e$ = 4.15, $\underline{SEM}$ = .41, $\underline{p}$ = .06).

Clustering coefficient results for LRF removal

We found no effect of condition on the mean clustering coefficient of the grooming ($\underline{n}$ = 47, $\underline{df}$ = 2, $\underline{F}$ = 2.87, $\underline{p}$ = .06, partial eta^2 = .06), contact-sitting ($\underline{n}$ = 47, $\underline{df}$ = 2, $\underline{F}$ = 1.85, $\underline{p}$ = .16, partial eta^2 = .04), or play ($\underline{n}$ = 20, $\underline{df}$ = 2, $\underline{F}$ = 2.26, $\underline{p}$ = .12, partial eta^2 = .11). There was a significant effect for proximity ($\underline{n}$ = 47, $\underline{df}$ = 2, $\underline{F}$ = 7.49, $\underline{p}$ = .001, partial eta^2 = .14). Below we report pair-wise comparison results. We correct for multiple tests using Sidak correction.

In the OC-TK comparison, main effects were nonsignificant for grooming ($\underline{M}_o$ = 0.34, $\underline{M}_t$ = 0.34, $\underline{SEM}$ = 0.003, p = .99), proximity ($\underline{M}_o$ = 0.55, $\underline{M}_t$ = 0.55, $\underline{SEM}$ = 0.002, $\underline{p}$ = .85), and contact-sitting ($\underline{M}_o$ = 0.38, $\underline{M}_t$ = 0.39, $\underline{SEM}$ = .0.002, $\underline{p}$ = .17). Play was nonsignificant ($\underline{M}_o$ = 0.46, $\underline{M}_t$ = 0.46, $\underline{SEM}$ = 0.0, $\underline{p}$ = 1.0).

In the OC-EK comparison, main effects were nonsignificant for grooming ($\underline{M}_o$ = 0.34, $\underline{M}_e$ = 0.31, $\underline{SEM}$ = 0.22, $\underline{p}$ = .26) and contact-sitting ($\underline{M}_o$ = 0.38, $\underline{M}_e$ = 0.36, $\underline{SEM}$ = 0.02, $\underline{p}$ =

.50), but significant for proximity ($\underline{M}_o$ = 0.55, $\underline{M}_e$ = 0.58, SEM = 0.01, p = .015). Play was nonsignificant ($\underline{M}_o$ = 0.46, $\underline{M}_e$ = 0.29, SEM = .11, p = .15).

In the TK-EK comparison, main effects were nonsignificant for grooming ($\underline{M}_t$ = 0.34, $\underline{M}_e$ = 0.31, SEM = 0.02 p = .26) and contact-sitting ($\underline{M}_t$ = 0.39, $\underline{M}_e$ = 0.36, SEM = 0.02, p = .41), but significant for proximity ($\underline{M}_t$ = 0.55, $\underline{M}_e$ = 0.58, SEM = 0.01, p = .037). Play was nonsignificant ($\underline{M}_t$ = 0.46, $\underline{M}_e$ = 0.29, SEM = .11, p = .15).

No significant effects to grooming, play, or contact-sitting networks occurred following LRF removal in the TK-EK comparison. However, LRF removal was followed by a significant increase in the mean degree of the proximity network (individuals had more partners following LRF removal). If LRF presence contributed to robustness, we would have expected a decrease in mean degree following her removal. As with the policer's removal, LRF removal was followed by a significant increase in clustering in the proximity network. This change might have been due to (a) a general lack of robustness of the proximity network to node removal, regardless of node function, (b) the lower mean temperature that occurred during the LRF period (77.5 F compared to 94.0 F), or (c) small sample size available for LRF analyses.

It is unlikely that temperature change could have caused an increase in clustering in the proximity network that was observed when the policers were removed because the repeated removal procedure integrated over warm and cooler periods. However, given that clustering also increased in the proximity network following LRF removal, we took the precautionary measure of dividing the data set in half (with all individuals included) to evaluate whether the cooler weather during the second half of data collection was responsible for changes to the networks. We found no significant differences.

4. Supplementary Table 1S.

Table 1S. Descriptive results for reach. Reach is not calculated for proximity because by step 2 the networks are fully connected.

	Condition	Mean Node Reach Empirical	Mean Node Reach Randomizations	Diameter Empirical
Contact- Sitting	OC	0.99	1.00	3
	TK	0.97	0.99	3
	EK	0.97	0.98	3
Grooming	OC	0.92	1.00	3
	TK	0.90	0.93	3
	EK	0.79	0.83	4
Play	OC	0.19	0.34	6/Infinite
	TK	0.20	0.22	5/Infinite
	EK	0.11	0.15	9/Infinite
Proximity	OC	NA	NA	2
	TK			2
	EK			2

5. Supplementary Notes

Random graph generation for reach and assortativity (male removal)

We generated random graphs for each network in each condition (i.e. grooming observed, topological, and experimental; contact-sitting observed, topological, and experimental). There is a standard algorithm used for this that works as follows: if a node has degree k, place k copies of it in a bag (so to speak). Pick E pairs of labels from the bag. Draw an edge in the network between each pair that has been picked. This works well in generating networks if either we don't mind double edges (that is the pair A-B might come up more than once) or they're rather unlikely. There is also a problem with self-loops. For the small networks, like those studied here, the above scheme does *not* work. Instead, we start with the initial graph and then swap edges according to the following scheme: Pick two edges at random, such that the first edge is called A-B and the second edge, C-D. Check if the following conditions are met (they *all* must be met to continue): 1) A and C cannot be the same node 2) B and D cannot be the same node 3) A is not already connected to C and 4) B is not already connected to D. If these conditions are met, remove edges A-B and C-D and replace them with edges A-C and B-D. This process conserves the degree distribution and prevents double edges. Repeat swap process a large number of times (i.e. 10,000).

The assortativity measure was constructed such that the average assortativity for an Erdos-Renyi random graph is zero. If we construct random graphs with conserved degree distribution and allow for double edges and self-loops then we again observe an average assortativity of zero. If, however, we do not allow for double edges or self-loops, the average assortativity of the ensemble of randomized graphs becomes negative (Park & Newman, 2003).

Aureli, F., and de Waal, F. B. M. Inhibition of social behavior in chimpanzees under high-density conditions. *Amer. J. Prim.* ***41,*** 213-228 (1997).

J. Park and M.E.J. Newman, "The origin of degree correlations in the Internet and other networks," Phys. Rev. E 68, 026112 (2003).