

Supporting Information

Murray et al. 10.1073/pnas.1409507111

SI Materials and Methods

Behavioral Datasets. We investigated grouping patterns of mothers and their infants (aged ≤ 3.5 y) over a 37-y period (1974–2012), during which the study community contained between 31 and 62 individuals, with 12–25 adult females and 6–14 adult males (adult age ≥ 12 y).

For analyses of maternal grouping patterns, we analyzed data from daily focal follows of individual adults that were collected between 1974 and 2011. A team of (usually two) research staff follows one adult chimpanzee each day (usually from night nest to night nest). They collect continuous data on the feeding and social interactions of the target of the follow and party composition at regular intervals. A party is defined as a subgroup of individuals that travels, forages, and/or rests together. The team visually confirms the identity of any new arrivals and then tracks party membership at 15-min intervals through visual observation or short-range vocalizations. A party member leaves when he or she travels away from the target of the follow or vice versa. Research staff members rotate through adult members of the community with the goal of collecting one follow on each adult per month. In the unusual case of a mother with twin infants, these data were counted once to avoid pseudoreplication.

To examine the relationship between maternal gregariousness and infant social interactions, we used a behavioral dataset focused on mothers and their offspring. Data are collected on the focal mother, youngest dependent offspring, and next oldest offspring at 1-min point samples during these family follows. The targeted follow length varied over the years of the study from 6 h to night nest to night nest. Behaviors recorded include those such as traveling, resting, feeding, and social interactions, including grooming and play. We focused on the 24-y period (1988–2012) when party composition scans were regularly conducted as described above (5-min intervals until 2011 and every 15 min thereafter). In the unusual case of a mother with twin infants, these data were not included in these analyses.

Covariates of Maternal Sociality. Maternal rank was calculated by the direction of pant-grunts (a vocalization that functions as a formal indicator of dominance) in 2-y periods over the study duration (e.g., 1974–1975, 1976–1977, 1978–1979). We assigned binary dominance rank (high or low) based on the Modified David's Score (MDS) (1); high-ranking individuals were at least $1/2$ SD above the mean MDS (2). Season was based on rainfall data and following the precedence of other studies that demonstrate seasonal differences in weight and gregariousness; groups are smaller, and individuals weigh less during the dry season (e.g., refs. 3–5). Each follow was assigned a season based on the month in which it took place: wet (November–April) or dry (May–October).

Additional Analyses on Larger Sample of Mothers. All Maternal Sociality \times Infant Sex results in the main text are from analyses run using data on mothers that had sufficient follows with both sons and daughters. Below, we describe analyses using data from a larger sample of mothers, including mothers that were just observed with offspring of one sex or the other. This dataset included 662 follows on 32 mothers with 42 sons and 30 daughters for the first 6 mo of life and 2,496 follows on 31 mothers with 45 sons and 32 daughters for late infancy. All analyses on the larger sample of mothers were analogous to those in the main text with the addition of mother ID as a random factor to control for uneven sampling on different mothers.

Maternal Time Spent with Others by Sibling Sex. We also extend our analysis of this larger sample of mothers to investigate the potential confound of older siblings by investigating how the time spent in groups relates to sibling sex over the entire infancy (0–3.5 y old). To investigate how the presence of older siblings influenced maternal gregariousness, we tested the relationship of sibling sex and age on maternal time with others in a model analogous to our infant-based analyses. Each follow was scored as containing a sibling if the mother had another dependent offspring < 8 y old. Older siblings generally continue to associate at high rates with their mothers until they reach puberty at 8–10 y of age (6). In the infrequent cases where two dependent older siblings were present, we considered the youngest. For this analysis, we used a LMM that included infant sex, older sibling sex, older sibling age, and maternal rank as fixed effects and season and mother as random effects.

Maternal Gregariousness and Infant Social Interactions. We investigated how infant social interactions relate to age and how the number of social partners varied by infant sex, age, and party size using a dataset focused on mothers and offspring. The proportion of time infants spent in social interactions was calculated as the number of 1-min point samples at which the infant was observed interacting (grooming or playing) with a nonmother divided by the total number of 1-min point samples for that infant on a given day. The number of infant social partners per day was calculated as the number of unique individuals of all ages (excluding their mother) that an infant was observed interacting with during a given day. Daily average party size was calculated as the sum of the number of individuals of all age classes present at each party composition scan divided by the number of party composition scans that day. We set a minimum inclusion criterion of 4 h of good observation time per follow to exclude shorter follows where social interactions were unlikely to be captured. Minutes on which the behavior was uncertain because of lost or obscured view were excluded. The resulting dataset included 662 follows on 21 mothers, 29 male infants, and 17 female infants ranging in age from 3 d to ≤ 3.48 y.

SI Results

Maternal Gregariousness \times Maternal Rank from Data on Well-Sampled Mothers. Results of LMMs using data on well-sampled mothers described in the main text are provided in Tables S2 and S3. In late infancy, low-ranking female social patterns follow expectations based on their lower competitive ability as they spend more time alone, have smaller groups, and spend less time with adult males. Avoidance of males is likely related to higher social stress for low-ranking females in mixed-sex groups (2). The results regarding early infancy female-only association patterns are surprising, as high-ranking females appear to adjust their grouping patterns to avoid female-only parties. Future work should investigate the specific female individual mothers group during the first 6 mo of their infant's life to consider how these associations relate to infant socialization and the mitigation of competition and infant risk.

Additional Analyses on Larger Sample of Mothers. In the text below, we present results from the additional analyses run on the larger sample of mothers described in *SI Materials and Methods*.

Maternal Time Spent with Others \times Infant Sex. Our results for the larger sample of mothers demonstrate similar patterns as those reported in the main text for females observed with infants of each

sex. Mothers with sons spent significantly more time with others during late infancy than mothers with daughters ($F_{1, 2,462} = 5.43$, $P = 0.02$; mothers with sons least squares mean = 0.61 ± 0.04 SE and mothers with daughters least squares mean = 0.57 ± 0.04 SE). Compared with mothers with daughters, mothers with sons also tended to be more gregarious during the first 6 mo of life ($F_{1, 627} = 2.65$, $P = 0.10$; mothers with sons least squares mean = 0.56 ± 0.06 SE and mothers with daughters least squares mean = 0.50 ± 0.06 SE). Maternal rank significantly predicted the amount of time spent with others during late infancy ($F_{1, 2,462} = 4.08$, $P = 0.04$) as low-ranking mothers spent more time with others than high-ranking mothers (low-ranking estimate: 0.61 ± 0.04 ; high-ranking estimate: 0.56 ± 0.05 SE).

Maternal Time Spent with Others \times Sibling Sex. Sibling sex did not significantly predict maternal time spent with others ($F_{1, 1,877} = 2.03$, $P = 0.15$), but infant sex remained significant ($F_{1, 1,877} = 4.11$, $P = 0.04$). Time spent with others varied by sibling age ($F_{1, 1,877} = 8.33$, $P = 0.004$), as the time spent with others increased with sibling age. Maternal rank did not significantly predict maternal time spent with others ($F_{1, 1,877} = 1.56$, $P = 0.21$).

1. de Vries H, Stevens JM, Vervaecke H (2006) Measuring and testing the steepness of dominance hierarchies. *Anim Behav* 71(3):585–592.
2. Markham AC, et al. (2014) Rank effects on social stress in lactating chimpanzees. *Anim Behav* 87(1):195–202.
3. Doran D (1997) Influence of seasonality on activity patterns, feeding behavior, ranging, and grouping patterns in Tai chimpanzees. *Int J Primatol* 18(2):183–206.

Maternal Party Size and Composition \times Infant Sex. Our results for the larger set of females again demonstrate the same patterns reported in the main text. Infant sex significantly predicted the average daily party size in both periods (first 6 mo: $F_{1, 567} = 4.30$, $P = 0.04$; late infancy: $F_{1, 2,388} = 7.49$, $P = 0.006$). The average daily party size in each time period was higher for sons than for daughters (Table S1). Maternal rank did not significantly predict the average party size at any stage.

Infant sex also predicted the average daily number of maternal kin present in the first 6 mo and late infancy (first 6 mo: $F_{1, 567} = 10.31$, $P = 0.001$; late infancy: $F_{1, 2,388} = 32.74$, $P < 0.0001$). Mothers with sons had a significantly higher number of maternal kin present on average than mothers with daughters (Table S1).

There was a significant difference by infant sex on the daily average number of nonkin during late infancy and a tendency during the first 6 mo (first 6 mo: $F_{1, 567} = 3.31$, $P = 0.07$; late infancy: $F_{1, 2,388} = 4.16$, $P = 0.04$). Mothers with sons had a higher average number of nonkin present than mothers with daughters (Table S1). Maternal rank did not significantly predict the average number of nonkin present in the party.

4. Pusey AE, Oehlert GW, Williams JM, Goodall J (2005) Influence of ecological and social factors on body mass of wild chimpanzees. *Int J Primatol* 26(1):3–31.
5. Murray CM, Eberly LE, Pusey AE (2006) Foraging strategies as a function of season and rank among wild female chimpanzees (*Pan troglodytes*). *Behav Ecol* 17(6):1020–1028.
6. Pusey A (1990) Behavioural changes at adolescence in chimpanzees. *Behaviour* 115(3-4):203–246.

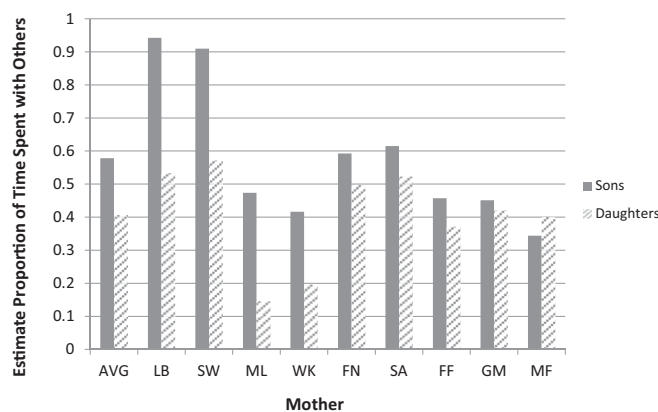


Fig. S1. Time spent with others for well-sampled mothers during the first 6 mo of life. Least square means for each mother with an infant of each sex were generated from the Mother ID \times Infant Sex interaction term in a LMM that also included maternal rank as a fixed effect and season as a random effect. Figure includes data from 459 follows on nine mothers with 25 sons and 18 daughters.

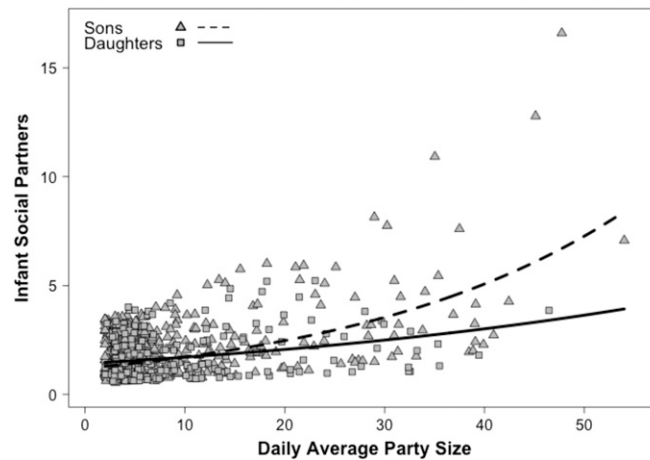


Fig. S2. Infant Social Interactions \times Party Size. Predicted number of daily nonmother infant social partners for each sex given the partial effect of average daily party size (including individuals of all age classes) from the GLMM. Each point represents an individual follow day ($n = 662$ follow days; 14.4 ± 13.2 mean \pm SD follows per infant; 46 infants). The interaction between infant sex and average daily party size was significant ($\chi^2_1 = 5.99$, $p = 0.014$). See main text for more detailed results.

Table S1. Estimated average party size and kin composition from data on larger sample of mothers

Life period	Offspring	Party size	Maternal kin	Maternal nonkin
First 6 mo	Sons	6.40	0.87	5.61*
	Daughters	5.29	0.61	4.64*
Late infancy	Sons	5.88	0.58	5.41
	Daughters	5.15	0.35	4.90

Estimated least square means were generated from a LMM that included maternal rank as a fixed effect and mother ID and season as random effects. All comparisons between mothers with sons and mothers with daughters were significant ($P < 0.05$), except for a tendency for more nonkin adult associates with sons during the first 6 mo of life (indicated with an asterisk).

Table S2. Fixed effects results from LMMs on data from well-sampled mothers

Response variable	Life period	Explanatory variable	Numerator df	Denominator df	F	P
Time with others	First 6 mo	Infant sex	1	447	13.00	0.0003
		Mother's rank	1	447	1.12	0.2898
	Late infancy	Infant sex	1	1,824	9.90	0.0017
		Mother's rank	1	1,824	5.57	0.0184
Party size	First 6 mo	Infant sex	1	400	8.47	0.0038
		Mother's rank	1	400	2.34	0.1272
	Late infancy	Infant sex	1	1,750	8.64	0.0033
		Mother's rank	1	1,750	3.74	0.0532
Maternal kin	First 6 mo	Infant sex	1	400	12.14	0.0005
		Mother's rank	1	400	0.03	0.8646
	Late infancy	Infant sex	1	1,750	24.92	<0.0001
		Mother's rank	1	1,750	2.46	0.1170
Maternal nonkin	First 6 mo	Infant sex	1	400	6.36	0.0121
		Mother's rank	1	400	1.27	0.2614
	Late infancy	Infant sex	1	1,750	5.45	0.0196
		Mother's rank	1	1,750	2.52	0.1123
Mixed-sex parties	First 6 mo	Infant sex	1	447	15.16	0.0001
		Mother's rank	1	447	1.13	0.2881
	Late infancy	Infant sex	1	1,824	2.39	0.1221
		Mother's rank	1	1,824	7.70	0.0056
Female-only parties	First 6 mo	Infant sex	1	447	0.13	0.7188
		Mother's rank	1	447	7.02	0.0083
	Late infancy	Infant sex	1	1,824	26.42	<0.0001
		Mother's rank	1	1,824	1.54	0.2147

Estimated averages for each measure of gregariousness in each life period by mother's rank are provided in Table S3. Estimated averages by infant sex are presented in Figs. 1 and 2 and Table 1.

Table S3. Estimated average measures of gregariousness by mother's rank from data on well-sampled mothers

Response variable	Life period	Mother's binary rank	
		High	Low
Time with others	First 6 mo	0.55 (0.07)	0.50 (0.06)
	Late infancy*	0.56 (0.05)	0.50 (0.05)
Party size	First 6 mo	7.4 (1.3)	5.4 (1.1)
	Late infancy [†]	5.2 (0.69)	4.2 (0.60)
Maternal kin	First 6 mo	1.1 (0.27)	1.1 (0.22)
	Late infancy	0.91 (0.16)	0.75 (0.15)
Maternal ninkin	First 6 mo	5.6 (0.95)	4.5 (0.84)
	Late infancy	4.2 (0.55)	3.5 (0.47)
Mixed-sex parties	First 6 mo	0.33 (0.07)	0.28 (0.06)
	Late infancy*	0.27 (0.05)	0.20 (0.05)
Female-only parties	First 6 mo*	0.12 (0.04)	0.22 (0.03)
	Late infancy	0.31 (0.04)	0.28 (0.04)

Estimated least square means (SE) were generated from LMMs from data on well-sampled females that included infant sex and maternal rank as fixed effects and year nested in season as the random effect. Results presented in Table S2.

*Indicates comparison between high- and low-ranking mothers was significant ($P < 0.05$).

[†]Indicates tendency ($P = 0.053$).