Supplemental Data: Social status gates social attention in monkeys

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Supplemental Experimental Proceedures

Seven pair-housed male rhesus macaques (*Macaca mulatta*) from our colony at the Duke University Medical Center Vivarium served as subjects; each was assessed as high-status or low-status relative to its cagemate based on unidirectional submissive displays[S1]. Moreover, pairwise status extended to all other members of the colony (i.e., all low-status monkeys averted gaze from all other high-status monkeys) during controlled confrontation tests[S1]. All animals were originally reared in naturalistic social groups; cage position and composition for the macaques in our colony remained unchanged for more that three years prior to the initiation of this study. All animal procedures were approved by the Duke University Medical Center Institutional Animal Care and Use Committee and were designed and conducted in compliance with the Public Health Service's Guide for the Care and Use of Animals.

Experiments were run on a Dell Precision 220 Pentium IV computer using custom software (ryklinsoftware.com). Monkeys viewed stimuli on a 24" Sony Trinitron monitor running at a resolution of 1024x768 and refresh rate of 60 Hz. Subjects were seated with their eyes 45 cm from the center of the monitor. Eye position was monitored using a magnetic search coil surgically implanted beneath the conjunctiva of one eye and sampled at 500 Hz[S2, S3] while head position was maintained with a surgically implanted stainless steel prosthesis (Crist). All surgical procedures were performed aseptically, followed with appropriate analgesics and antibiotics, and in all other ways followed standard protocols described previously[S4].

Monkey faces displayed at fixation were drawn from 32 images of four familiar macaques (two high- and two low-status) looking either left or right. Each monkey and gaze direction was represented with two eye-averted and two head-and-eyes-averted images. Face images were standardized by cropping the head from the background, centering the midpoint of the eye region (eyes-only) or the centermost eye corner (head-and-eyes), and resizing to 115x115 pixels, approximately 5°. All stimuli were presented on a black background. All monkeys, both subjects and cues, were approximately 8 years old at the time they participated in this experiment.

We operationalized gaze-following as a decrease in reaction time for saccades toward targets at the location viewed by the cue image relative to saccades toward targets located opposite the direction of gaze in the cue image. All statistical tests consisted of ANOVA, with post-hoc tests between groups by Fisher's Least Significant Difference (LSD) or by Mann-Whitney U, as noted. Statistical tests were performed as follows: first we confirmed the presence of time-varying gaze-following across all our macaque subjects, controlling for variation in the number of trials successfully completed by each macaque whenever possible (ANOVA, normalized RT by congruence by cue duration with subject ID as variable of no interest). Significant differences between individuals were present and were found to vary significantly with social status (ANOVA, normalized RT by subject status by congruence by cue duration). Gaze-following dynamics of low- and high-status monkeys were probed separately using ANOVA (normalized RT by congruence by cue duration with subject ID as variable of no interest).

We additionally examined the responses of low- and high-status subjects to cues from monkeys of differing social status. We first separately analyzed low- and high-status individuals pooled across cue viewing times (ANOVA, normalized RT by cue social status by congruence with subject ID as variable of no interest), and then examined the overall responses of pooled low- and high-status monkeys as a function of time (ANOVA, normalized RT by cue social status by cue duration with subject identity as a variable of no interest).

Finally, we examined the impact on gaze-following of low-level cue features, including luminance, contrast, head area, and saturation, using multiple regression and found no significant effects. Although we examined the distribution of eye positions during cue fixation, both from each monkey and relative to each specific cue image, we were unable to find any systematic differences relating to either social status or reaction time. However, we do not currently exclude the possibility that fixations toward the cuing monkey's eye region may correlate with subsequent gaze-following (e.g. [S5]): We note that for the images and fixation windows used in this experiment, successful task performance generally positioned at least part of the cuing monkey's eye-region within the subject's fovea.

Onset and offset of task-related saccades were defined using a velocity criterion (onset, $\geq$60°/s for $\geq$8 samples; offset, $\leq$30°/s for $\geq$3 samples). We gathered 1000-7000 successful trials from each macaque, excluding saccades initiated faster than 90 ms or slower than 280 ms. The average number of successful trials collected in a single session was 754, with no session contributing more than or 35% the subject's total. "Incidental" successes, defined as successful trials that occurred despite a ≥50% fail rate within ±2.5-minute time window, were excluded from analysis. To minimize the variance in reaction time due to transient spatial biases or changes in motivation, we normalized our data by subtracting the mean successful reaction time for each monkey and target direction across a 15-minute moving window within each dataset.

All monkeys had extensive experience with nonsocial visual orienting tasks. However, to investigate the effects of experience in this specific paradigm, we parameterised the training history at every data point by noting the log chronological order in which each data point was gathered from a given subject. Neither training history nor the local (±2.5-minute) success rate interacted with gaze-following or the temporal dynamics thereof as continuous predictors of normalized reaction time in a homogeneity-of-slopes general linear model (training history on congruence, p=0.3, training history on cue duration by congruence, p=0.09; local success rate on congruence, p=0.3, local success rate on cue duration by congruence, p=0.4). We found an identical pattern of subject status effects using only the first 500 correct trials from each monkey, confirming that training history was not responsible for the subject effects reported here.

Morphometric data was recorded in one day while monkeys were anaesthetized for a routine physical exam. To estimate circulating testosterone, we used callipers to measure the testicles of each subject across their longest axis: these measurements, cubed, estimate testicular volume and thus the rate of testosterone production[S6].

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S2. Fuchs, A.F., and Robinson, D.A. (1966). A method for measuring horizontal and vertical eye movement chronically in the monkey. J Appl Physiol *21*, 1068-1070.

S3. Judge, S.J., Richmond, B.J., and Chu, F.C. (1980). Implantation of magnetic search coils for measurement of eye position: an improved method. Vision Res *20*, 535-538.

S4. Deaner, R.O., and Platt, M.L. (2003). Reflexive social attention in monkeys and humans. Curr Biol *13*, 1609-1613.

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S6. Bercovitch, F.B., and Ziegler, T.E. (2002). Current topics in primate socioendocrinology. Annual Review of Anthropology *31*, 45-67.