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Supplemental Information

Wild Chimpanzees Inform Ignorant Group Members of Danger

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Supplemental Inventory

Figure S1. Sketch of the experimental design, showing the spatial relationship between the subject, the snake model and a receiver (related to Experimental Procedures).

Figure S2. Snake model used to elicit “alert hoos” (a), with actual rhinoceros viper from Sonso home range for comparison (b) (related to Experimental Procedures).

Table S1. Variables tested to determine their influence on alert hoo production: variable definitions, predictions and distributions (related to Tables 1 and 2).

Table S2. The effect of predictor variables on calling behavior upon seeing the snake model, with reduced data set including Receiver Approach (related to Table 1).

Supplemental Experimental Procedures. Includes relevant supporting information for the paper, with indications in the main text stating where to find relevant sections of supporting information.

Supplemental References

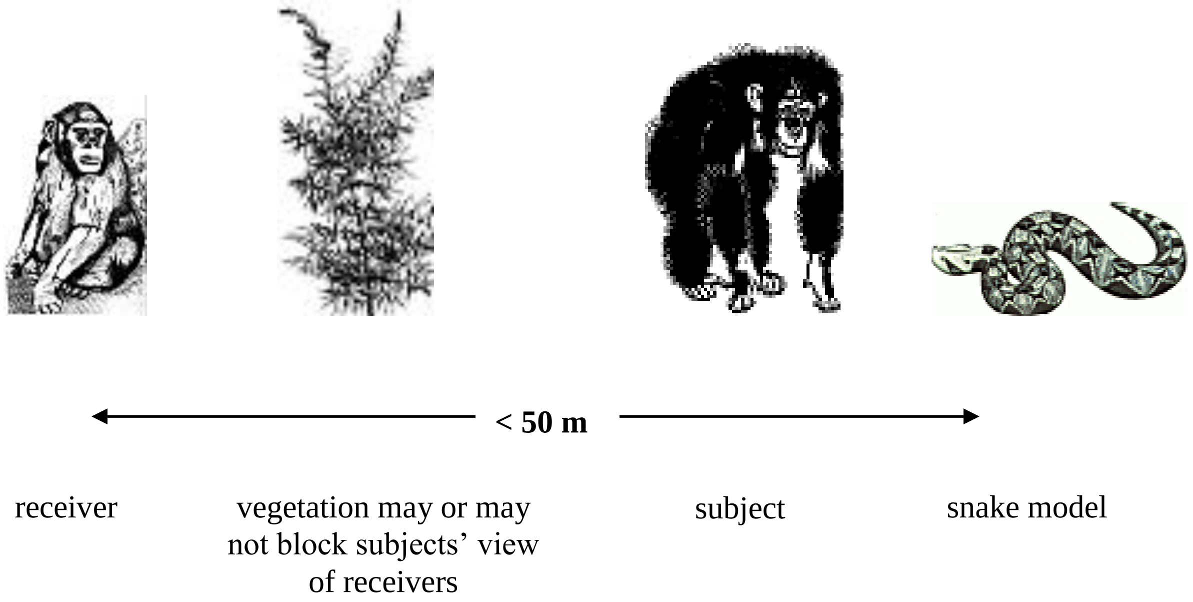

Figure S1. Sketch of the Experimental Design, Showing the Spatial Relationship between the Subject, the Snake Model, and a Receiver (Related to Experimental Procedures)
(Drawings courtesy of Arthur’s Clipart.)

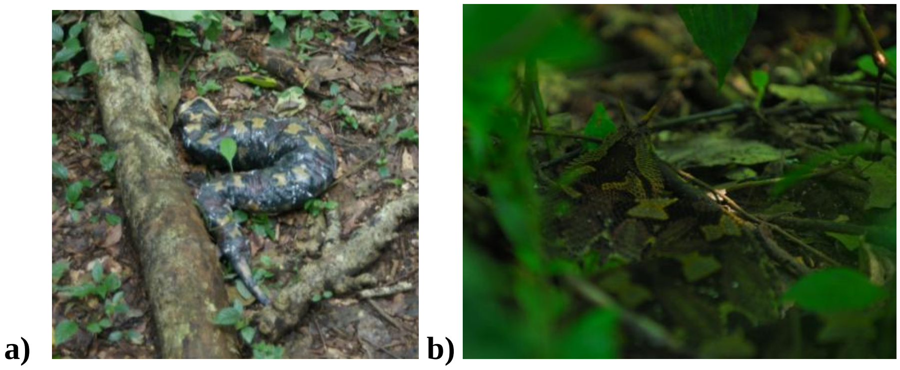

Figure S2. Snake Model used to Elicit “Alert Hoos” (a), with Actual Rhinoceros Viper from Sonso Home Range for Comparison (b) (Related to Experimental Procedures)

Table S1. Variables Tested to Determine Their Influence on Alert Hoo Production: Variable Definitions, Predictions, and Distributions (Related to Tables 1 and 2)

Variables, predictions and hypotheses in brackets () where relevant	**Yes, No, or Mean ± SD, or median (quartiles)**
Response Variables	
Call or not call (y/n): chimpanzees who could see the snake (subjects) either produced one or more "alert hoos", or produced no "alert hoos".	Y = 46 N = 65
Number of calls: the number of "alert hoos" subjects produced.	0 (0, 3) range = 0-70
Predictor variables	
(i) Receiver information (defining receiver ignorance or knowledge of the snake): 0 = "ignorant receivers": no receivers had seen snake nor could have heard – i.e. were within 50 m of - an "alert hoo"; 1 = "heard": *all* receivers had been within 50 m of an "alert hoo" but not all had seen the snake; 2 = "seen": all receivers had seen the snake and in most cases subjects had also heard "alert hoos" (subjects calling behavior is influenced by the degree of receivers' awareness of the snake: the more information receivers have about the nature of the current danger, the less likely they are to alarm call).	0 = 36 1 = 54 2 = 21 (Table 2: 1 = 16 2 = 14)
(ii) Subject information (defining subject's level of exposure and therefore habituation to snake-related stimuli): 0 = subject had no prior exposure to the snake; 1 = subject had prior exposure to the snake, either having heard an "alert hoo" or seen the snake (subjects calling behavior is related to their level of habituation to the snake: 0 = unhabituated to the snake and therefore more likely to alarm call compared with 1 = subjects who were already aware of the presence of a danger before seeing the snake and thus were partially habituated to the snake and thus less likely to alarm call).	0 = 31 1 = 80
(a) Subject distance (m): closest distance of the subject to the snake model (arousal – and alarm calling – increase with proximity to the snake).	5.85 ± 4.4
(b) Subject startled: subject startles upon seeing snake model, i.e., jumps aside or pilo-erects (alarm calling increases with arousal).	Y = 17 N = 94
(c) Subject total model encounters: number of previous exposures of subject to any snake model ever [with the exception of two pilot exposures in 2006 and 2007 no other object presentations had previously been made at Budongo] (habituation to snake models is likely to occur with increasing exposures, leading to less alarm calling).	3 (2, 4)
(d) Strong social bond partner (SBP) present: subjects' SBP(s) were amongst receivers – i. e., < 50 m from snake model (subjects call more when valuable partners, i. e., SBP are present).	Y = 70 N = 41
(e) Number of dominant receivers: number of receivers dominant to subject, i.e., within 50m (subjects call more when dominants are present).	3.1 ± 3.6
(f) Number of receivers: number of receivers (calling increases with increasing group size).	8.2 ± 5.2
(g) Receiver distance to snake (m): closest distance of the receiver closest to the snake model (calling increases with increasing risk or closer distance of the closest receiver).	13.6 ± 10.2
(h) Subject closer than receivers to snake: subject was closest to the snake when alarm calling or at any point in absence of calling (alarm calling results from a form of "sentinel duty" by the one closest to the snake: subjects call more when they are closer to the snake than any other chimpanzee).	Y = 67 N = 44
(i) Receiver Approach: at least one receiver was directly approaching the snake on a trajectory to pass < 1m from the snake, irrespective of receiver's actual distance to the snake (subject observes receiver's intention to pass within biting range of the snake: calling increases if receiver directly approaches the snake).	Y = 43 N = 57
(j) Latency since last call (min): latency between last alarm call produced by anyone and subject's alarm call (Recent alarm calling may incite arousal and thus increase alarm calling, or act as an habituator, decreasing alarm calling).	2 (0.05, 18)

(k) Subject already called (y/n): subject has or has not already produced "alert hoos" to the snake model. (subjects habituate with exposure to snake-related stimuli: calling is less likely if subjects have already called upon seeing the snake model). In the 9 cases when subjects had already called, the latency since subjects' last call was, median [quartiles]: 15 [2, 81] min.	Y = 9 N = 21
(l) Duration subject exposure (min): time since subjects' first exposure to snake-related stimuli - i.e., seeing the snake or hearing alarm calls - until subject sees the snake model in this case (subjects habituate with exposure to snake-related stimuli: calling is reduced if subjects have prior exposure to snake-related stimuli).	8.0 (1.44, 64.25)

Variable names are written in italics. Subject: chimpanzee that could currently see the snake model. Receivers: all other chimpanzees within 50 m of the snake model (for more information see Supplemental Experimental Procedures). All predictors coded as yes or no were included into the models with yes represented by a 1 and no indicated by a 0.

Table S2. The Effect of Predictor Variables on Calling Behavior upon Seeing the Snake Model, with Reduced Data Set Including *Receiver Approach*

Response variable: Call or Not Call

Predictor variable	**Estimate**	**SE**	**z**	**p**
Intercept	-1.71	1.20	-1.42	0.154
Receiver information	-0.74	0.42	-1.78	0.076*
Subject startled	0.47	0.80	0.59	0.553
Subject distance to snake	-0.06	0.36	-0.16	0.869
Latency since last call	0.39	0.81	0.48	0.629
Subject closer than receivers	1.74	0.73	2.39	0.017**
Receiver approach	0.78	0.53	1.48	0.139

Response variable: Number of Calls

Predictor variable	**Estimate**	**SE**	**z**	**p**
Intercept	0.43	0.36	1.19	0.234
Receiver information	-0.39	0.13	-3.00	0.003**
Subject startled	0.60	0.19	3.21	0.001**
Subject distance to snake	-0.09	0.09	-0.98	0.328
Latency since last call	-0.59	0.25	-2.37	0.018**
Strong bond partner present	0.71	0.15	4.79	0.000**
Subject closer than receivers	0.51	0.23	2.20	0.028**
Receiver approach	0.51	0.16	3.13	0.002**

Models include 100/111 cases and Receiver Approach. Response variables are Call or Not Call (Top) and Number of Calls (Bottom). *p < 0.1, **p < 0.05. Three random factors were included in each model: Subject's Identity, Snake Model used (model 1, 2, or 3) and Model Presentation Event (with each event lasting for one day) (Supplemental Experimental Procedures 8). We included a reduced set of predictor variables to prevent model instability, which were variables significant in the full models (Table 1) or in the univariate models (Supplemental Experimental Procedures 7).

Supplemental Experimental Procedures

1. Chimpanzee Usage of Loud Alarm Calls versus Quiet Warning Calls

In alarm situations, chimpanzees produce either loud alarm calls or quiet warning calls. Loud alarm calls - “SOS” screams, “wraa” barks [20] and “alarm” barks [21] - can be heard well over 300 m and are typically produced when a deadly ambush threat has been identified, such as in response to a seeing or hearing a leopard [40], when caught in a snare, or predatory pythons [21]. Even more dangerous are neighboring communities, which can invade unexpectedly and cause significant mortality, a pattern regularly observed in wild chimpanzees [41]. There is good evidence that chimpanzees take these risks into account, for example by vocalizing less when traveling in small parties, when in the periphery of their own territory, or when entering human settlements with the intent of crop raiding [23].

Acoustically distinct low-amplitude warning calls – or alert hoos consistently elicit cryptic cautious approach or avoidance behavior in out-of sight receivers [Crockford, Wittig, and Zuberbühler, unpublished data] and are produced in less dangerous, but ambush-like situations, such as upon seeing vipers which are highly poisonous, camouflaged and sedentary snakes, fresh leopard scat, snares or fresh feces and chewed food from neighboring chimpanzee communities [Crockford, Wittig, and Zuberbühler, unpublished data]. These calls are comparatively quiet and are audible over distances of 50 - 100 m through the forest. Based on these facts we find it plausible to assume that the production of vocal signals, including warning calls, is costly for chimpanzees.

2. Snake Model Presentations

As gaboon and rhinoceros vipers can remain in a 2-5m^2 area of up to six weeks at a time digesting prey items [Crockford, Wittig, and Zuberbühler, unpublished data], it was relevant to continue to present the same snake model in a particular area. To ensure that snake model presentations remained below natural snake encounter rates, once any chimpanzees had seen a snake model five times in the same 50m^2 area, presentations in that area were terminated for 6 months.

3. Coding

All human observers were highly experienced and undergo a yearly inter-observer reliability test which results consistently of Spearman’s r > 0.85. Measures recorded for this study were relatively unambiguous, such as chimpanzee identities within 50 m of the snake, distance estimates which could be verified afterwards, whether a chimpanzee is stationary or moving, which chimpanzees could or could not see the snake (see next section below), and vocalization type produced. Video coding was conducted by CC.

CC coded chimpanzees’ behavior from videos using Adobe Premiere software and combined this with observational data and audio-recordings to obtain the target variables. Given that chimpanzees moved often, data points were taken at the time when the subject started vocalizing. For example, the distance of the closest receiver at this time point would be used as a data point. In cases when the subject did not vocalize, information was taken across the whole period that the subject could see the snake and the most extreme measure that should precipitate calling was used. For example, the closest distance of any receiver to the snake was taken as a data point. Although we tried to place the snake model in open areas, visibility was nonetheless usually restricted to some degree in some directions. If more than one variable was not clearly observable the data point was excluded. Also, as we were interested in the effects of receivers on signaling we excluded data points of chimpanzees who were "alone" when seeing the snake - i. e., when no other chimpanzees were within 100 m of the snake model - from the main analysis (subjects produced alarm calls on 1/6 of such occasions).

4. Classification of Predictor Variable *Receiver Information* (Related to Table S1)

Subjects were deemed "no longer able to see the snake" when the researcher moving within 5 m of the snake could no longer see the head or chest of the subject. For cases when chimpanzees vocalized, we used a latency of 3 min after the last alert hoo to differentiate chimpanzees that could and could not have heard the alarm call. 3 min marks the time a chimpanzee needs to travel the 50 – 100 m over which alert hoos can typically be heard. Thus, if a chimpanzee arrived in the snake model area 5 min after the last alert hoo was produced it is likely that it had not heard the last alert hoo and therefore was ignorant of the presence of the snake. This was generally corroborated by satellite human observers. When observing chimpanzees >100 m from the snake model, humans were unable to hear alert hoos produced at the snake model and chimpanzees showed no visible sign of having heard the call (for example, no interruption in current activity and no head-turning in the direction of the snake model). Using similar logic, when the louder alarm barks were elicited (N = 3/111), we assumed all chimpanzees arriving within the following 30 min had heard an alarm bark.

5. Habituation Hypothesis

The predictor variable Receiver Information (receivers' prior exposure to snake-related stimuli - seeing the snake or being within 50 m of an alert hoo) was highly correlated with Subject Information (Spearmans' r = 0.6) and thus could not be tested in the same GLMM. Subjects could have (i) no prior knowledge of the snake ("detectors"; 31/111 cases) or (ii) prior knowledge of the snake (heard alert hoos or seen snake; 80/111 cases). There was considerable overlap between receiver information and subject information, given that the cases when subjects had no prior exposure to the snake were generally those when receivers were ignorant. Consequently, when we re-ran the four GLMMs, substituting Subject Information for Receiver Information, we achieved very similar results such that estimates and P values of all predictor variables were similar. No changes to predictor variable significance were observed between models, except for Subject Information itself, which showed a trend in one model where Receiver Information had been significant (Table 1: estimate ± SE: -1.45 ± 0.79, z = -0.84, P = 0.066). In the remaining three models, Subject Information was significant (Table 1: -0.83 ± 0.24, z = -3.53, P = 0.000; Table S2: -1.62 ± 0.74, z = -2.18, P = 0.03; Table S2: -0.65 ± 0.23, z = -2.87, P = 0.004).

Thus, we ran an additional set of GLMMs to distinguish whether our key result was caused by hypothesis A) that subjects are more likely to call when receivers have less information about the snake, or by hypothesis B) that subjects are less likely to call as they habituate to snake-related stimuli. We took the following subset of the data: cases where both subject and receiver had prior exposure to snake-related stimuli (that is, cases when subjects were not "detectors", and no new receivers arrived), and in an attempt to standardize other main influencing variables, we used a time point when subjects were closer than receivers to the snake and a receiver was approaching in the direction of the snake model, giving N = 30 cases.

By removing data points when subjects had no prior exposure to the snake and retaining only those data points where subjects had prior exposure to the snake, we removed potential variation in subjects' calling behavior relating to a total lack of exposure - or habituation – to the snake.

However, within these 30 cases where subjects had some prior exposure to the snake model, we could not rule out that there was variation in subjects' level of exposure to snake-related stimuli and therefore variation in the extent they may be habituated to the stimuli. Thus, we extracted two additional variables to measure variation in subjects' exposure to snake-related stimuli. One variable, Subject Already Called, detailed whether or not subjects had already emitted a bout of alert hoos to the snake model, and the other variable, Duration Subject Exposure, detailed the latency from subjects first being exposed to snake-related stimuli to when subjects saw the receiver approaching [median (quartiles): 8 (1.3, 64.3) min].

In addition, we included the key variable, Receiver Information. In this subset of data, as stated above, subjects and receivers all had prior exposure to snake-related stimuli and subjects could currently see the snake (this being the definition of a "subject"). Nonetheless, Receiver Information varied. Some receivers had seen the snake and therefore had precise information about the danger, whilst others had only heard alert hoos, indicating they knew there was a danger but not exactly what it was nor where it was. We predicted that if subjects' calling behavior was driven by habituation to the snake-related stimuli, they would be less likely to call, and to emit fewer calls, the longer they had been aware of the snake and if they had already called. If, however, subjects' calling behavior was principally influenced by receivers' knowledge state, they would call less if receivers had seen the snake (and its location), compared with if receivers had only heard an alert hoo (and not seen its location).

With this subset of data, we conducted two GLMMs, one with each response variable (Call or Not Call and Number of Calls), to determine whether habituation-related variables and/or Receiver Information influenced subjects' calling behavior. We found that in both GLMMs only Receiver Information influenced calling behavior (Table 2), indicating that subjects' calling behavior was primarily influenced by the knowledge state of receivers and *not* by subjects' own level of habituation.

6. Alternative Explanations for Subjects' Calling Behavior

There are alternative explanations for the influence of Receiver Information on calling behavior. First, habituation to the snake stimuli could have been occurring, where the more exposure subjects had to a stimulus, the less likely they were to alarm call [25], or to look in the alarm call direction [24]. Additional analyses (Table 2) showed no support for habituation but provided support for the explanation that subjects were informing ignorant receivers. Moreover, irrespective of previous snake exposure, subjects produced more calls when strong social bond partners were present, when receivers demonstrated the intention to pass dangerously close to the snake by approaching it and when they themselves were closer to the snake than receivers (a relative assessment that did not correlate with absolute distances) (Tables 1 and S2), again suggesting that influences other than habituation were driving calling behavior.

Second, it is unlikely that this result was due to subjects responding to specific receiver behaviors indicative of ignorance. First, trials included a wide variety of different receiver behaviors performed by 1 – 23 simultaneously present receivers (mean ± SD: 7.2 ± 5.2), including resting, feeding, approaching, observing or bypassing the snake from 2 - 50 m. Also, in 43% (39/90) of cases, receivers did not produce alarm-associated vocalizations and, crucially, at least some receivers remained out of the subject's sight (e. g. up in a tree) throughout the observation period making it unlikely that subjects reacted to any receiver non-vocal behavior.

We also noted that, when new ignorant group members arrived, subjects resumed calling as they came into view (N = 3 of 5), independent of the latency since the last call produced (range: 5 – 45 min).

In sum, we found no explicit behavior, or sets of behaviors, that could have served as a proxy for subjects to assess the ignorance or knowledge of others. More likely, subjects kept track of what others could have seen or heard over time. Whether or not this was done through an abstract mental concept of "knowledge of danger" cannot be decided by this study although it is consistent with our findings. Our data was not collected under standardized laboratory conditions. However, the study was conducted under evolutionarily relevant conditions, and in testing multiple predictor variables, we have been able to control for key potential confounds.

7. GLMM Analysis (Related to Tables 1 and 2)

We ran all GLMMs [42] in R (version 2.11.1, R Development Core Team 2010) using the function lmer provided by the R package lme4 [43]. To control for pseudo-replication, we included three random factors in each model: Subject's Identity, Snake Model (which of the three snake models was presented) and Snake Presentation (all cases arising from a single presentation of the snake model). For the binomial response variable Call or Not Call, we fitted the models using binomial error structure and logit link function. For the ranked response variable Number of Calls (see below for this and other variable transformations), we used a Poisson error structure and log link function. For the Poisson model, we additionally checked for absence of over-dispersion, an essential prerequisite for the validity of models with Poisson error structure, and found no severe deviation from this assumption (range of dispersion parameters: 0.81-1.2). As a check of the overall significance of all predictor variables, we ran likelihood ratio tests comparing the full model with the respective null model (comprising only the random effects). We only considered the effect of the individual predictors if the full model reached significance. Likelihood ratio tests comparing full and null models, including Receiver Information and excluding Receiver Approach (Table 1): Call or Not Call: $\chi^2 = 29.99$, df = 10, N = 111, P = 0.0009; Number of Calls: $\chi^2 = 66.26$, N = 111, df = 10, $p < 0.0001$; including Receiver Information and Receiver Approach (table S2): Call or Not Call: $\chi^2 = 32.50$, df = 9, N = 100, P = 0.0002; Number of Calls: $\chi^2 = 82.65$, df = 9, N = 100, $p < 0.0001$; including data subset of 30 cases (Table 2): Call or Not Call: $\chi^2 = 9.29$, df = 3, P = 0.026; Number of Calls: $\chi^2 = 17.93$, df = 3, $p < 0.0005$.

We transformed the dependent variable Call Number to achieve a distribution that could be modeled using a standard error structure. We ranked the values according to the following rule: the smallest number of vocalizations (zero) was turned into zero, the second smallest into one, the third smallest into two and so on, until the largest number of vocalizations which was turned into a value equal to the total number of different numbers of vocalizations observed.

Prior to running the models, we log-transformed Subject Distance to Snake, Receiver Distance to Snake, Number of Dominant Receivers (after adding 1 to it) and Number of Receivers to achieve more symmetrical distributions of these variables. For the first individual encountering the snake model Latency Since Last Call could not be defined. Rather than omit these data points we set them to 200 min (5 min longer than the largest value) and then transformed the variable to latency = 1-1/(latency+1), to limit the impact of this arbitrarily chosen default value on the distribution of the variable.

Colinearity

We also checked for colinearity by inspecting Variance Inflation Factors (VIF) derived from a multiple regression with the random effects excluded (using the function vif of the R package car [43]). Except for highly correlated variables Receiver Information and Subject Information, this did not indicate any colinearity problem with the largest VIF = 2.57 in any model.

Univariate GLMMs

Since the models investigated included many fixed effects relative to the number of cases (N = 111) reduced power may have lead to false negatives (i.e., erroneously non-significant effects), as well as some risk of instability in the derived estimates. Hence, we ran an additional set of univariate GLMMs with each including only one of the fixed effects at a time (and the same random effects as the full model). The aim of the univariate GLMMs was to reveal effects that potentially might reveal significance with a larger sample and to assess potential issues of instability. In the model with vocalization occurrence (Call or Not Call) as a response variable, additional predictors with significant effects ($p < 0.05$) in the GLMM, were Latency Since Last Call (estimate ± SE = 1.9 ± 0.59, $z = 3.21$, $P = 0.001$), Subject Distance to Snake (-0.73 ± 0.28, $z = -2.57$, $P = 0.010$) and Subject Startled (1.63 ± 0.66, $z = 2.481$, $P = 0.013$). In the model with Number of Calls as the response variable, significant predictor variables were Subject Total Model Encounters (-0.62 ± 0.21, $z = -2.99$, $P = 0.003$), Latency Since Last Call (0.39 ± 0.20, $z = 1.48$, $P = 0.048$), Subject Distance to Snake (-0.31 ± 0.09, $z = -3.29$, $P = 0.001$), Receiver Approach (-0.95 ± 0.3, $z = -3.18$, $P = 0.001$), Strong Bond Partner Present (0.62 ± 0.17, $z = 3.68$, $p < 0.001$), Subject Startle (0.92 ± 0.16, $z = 5.69$, $p < 0.001$).

Effect of Sex and Age Class on Alarm Calling Behavior (Related to Section: Factors Influencing the Likelihood of Alarm Calling)

To compare between sex-age classes, we ran a two-way ANOVA into which we initially included the two-way interaction between the two predictor variables. As the responses we used the proportion of experiments in which the subjects responded (determined separately for each subject) as well as the mean number of calls uttered per experiment and subject. Inspection of residuals plotted against fitted values did not suggest that the assumptions of normally distributed and homogeneous error variances were violated. However, mean numbers of calls were highly skewed (also after the log transformation, which we applied) due to many zeroes, and hence the results for this response should be treated with some caution. We tested significance based on Type III sum of squares. Prior to testing the significance of the two main effects we removed their interaction from the model. F-tests based on Type III sum of squares were derived using the function Anova from the R-package car.

8. Calculation for Defining Strong Social Bond Partners (Related to Section: Subjects, Vocal and Behavioral Observations)

Strong social bond relationships were deemed more likely to determine alarm-calling behavior in chimpanzees than the narrower category of kin relationships, given that in chimpanzees, highly affiliative and cooperative dyads are as likely to be non-kin as kin [44, 45]. We assessed the quality of relationships by calculating “all occurrence” rates of the following behaviors over the current and preceding annual quarters: coalitionary support, food sharing, grooming, staying in proximity and aggression [46, 47]. From the resulting rates, we calculated a Composite Relationship Index. According to this measure, 1.9% of kin dyads and 1.6% of non-kin dyads reached bond partner status. To differentiate bond from non-bond partners, we used the Composite Relationship Index (CRI), a measure derived from the Composite Sociality Index [46], but which included socionegative, as well as sociopositive, behaviors [44, 47]. The CRI gives sociopositive and socionegative behaviors equal weight: CRI = $(SP1_{ij}/SP1_{ave} + SP2_{ij}/SP2_{ave})/2 - NP_{ij}/NP_{ave}$, where SP1 = rate of grooming bouts plus rate of resting in 1m proximity; SP2 = rate of food sharing plus rate of coalitionary support; NP = rate of aggression, i = individual and j = dyad partner. “Bond partners” were defined as dyads having a net sociopositive relationship lasting ≥ 6 months. This can occur through either a mutual sociopositive relationship (CRI > 0) during the annual quarter of the experiment and the preceding quarter, or a large mutual sociopositive (CRI > 10) during one of the quarters and a socioneutral or positive relationship (CRI ≥ 0) during the other quarter.

To construct the CRI, we created a matrix of all subjects counting the key behavioral events subjects had initiated towards recipients and assigning them to one of the three different behavioral categories (SP1, SP2, SN) for each quarter of the year during the experimental period. To control for differences in observation time across chimpanzees, we calculated an overall interaction rate for each subject by dividing the behavioral event count by each subject’s observation time. We then standardized the rate by dividing subjects’ interaction rates through the average rate of each interaction type for each dyadic sex class (male-male, male-female, female-female), as different sex classes engage in these interactions at substantially different rates:

Interaction rate ($A_i B_j$) = (# events $A_i B_j$ / observation time A_i) / average interaction rate (sex class of $A_i B_j$),

A is the actor and B is the receiver of the interaction. This produced three matrices, one for each interaction type. We added the three values for each interaction type and constructed the unidirectional Composite Relationship Index (uCRI) by weighing the two sociopositive interaction-types as being equivalent to the socionegative interaction type:

$$uCRI (A_i B_j) = (SP1 (A_i B_j) + SP2 (A_i B_j)) / 2 – SN (A_i B_j)$$

where SP1 = rate of grooming bouts plus rate of resting in 1m proximity; SP2 = rate of food sharing plus rate of coalitionary support; NP = rate of aggression, i = individual and j = dyad partner. Using the uCRI we created two measures: (A) we calculated a dyadic relationship quality index by creating a one-sided matrix by adding the uCRI of A_i B_j and B_j A_i into a bi-directional CRI (bCRI). Since the experimental trails were conducted over a long period of time (October 2008 – July 2010) and social relationships can be transient, we used the dyad’s average bCRI across the quarter of the experimental trail and the quarter preceding the trial:

$$bCRI_{2Q} (A_i B_j) = (k_{Q-1}\ bCRI_{Q-1} + k_Q\ bCRI_Q) / 2$$

k = 2, if services were bi-directional during the quarter Q; k = 1, if services were uni-directional. We used $bCRI_{2Q}$ as the relationship quality measure in the multivariate GLM.

We defined two individuals as being strong social bond partners when the dyad followed one of the two criteria. (A) Each individual showed an uCRI > 0 with the other individual (mutual sociopositive relationship) during the quarter of the experiment and also the preceding quarter. (B) A dyad had a mutual sociopositive relationship (both uCRI > 0) with a large bCRI (bCRI > 10) during one quarter and a non-socionegative relationship (bCRI ≥ 0) during the second quarter. The resulting mean ± s.d. for the bCRI for the different grooming conditions were as follows: Kin Bond Partners = 61.7 ± 35.1, Non-kin Bond Partners = 41.7 ± 23.9 and Non-Bond Partners = 4.3 ± 6.7. We assessed the bCRI for known maternal kin for reference purposes only. All kin dyads included in the analysis achieved bond partner status using the bCRI scores.

Behaviors Used to Calculate Composite Relationship Index

We used the following key behaviors to identify closely bonded social relations, namely food sharing, coalitionary support, social grooming, proximity and aggression. Food sharing and coalitionary support were not defined in the main text and are defined here. Food sharing is handing over food without aggression or jointly eating from a single food item within body contact range. Shared food was mammalian meat (black and white colobus monkey or blue duiker), rotting raffia wood, or large fruits, such as *Treculia africana*. Coalitionary support is when a third, previously uninvolved individual intervenes with an aggressive act (display or hit) or signal (bark, pant roars or drum) against either the victim or aggressor of a conflict between two others [20]. We always noted whether the action was given or received, to determine whether such events were symmetrical.

9. Subject Behavior without Visual Contact to Snake

When subjects had moved away from the snake so that they could no longer see it, the patterns of calling behavior changed. In 8/11 cases, individuals did not resume alarm calling if other group members approached. In the remaining 3 cases, observers resumed calling (0.5 – 90 min later) and interestingly this was in 3/4 encounters when social bond partners that had not yet seen the snake model were amongst receivers. Motivation to inform may require the visual stimulus of the snake.

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