**Supplementary Material**

**Orang-utans' use of multicomponent versus multisensory communicative acts**

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**Additional information**

**Results**

*Use of specific modalities.*We used GLMMs to test sources of variation (i.e. species, setting, kinship) in the use of communicative acts involving specific modalities. The full model was a better fit than the null model for visual and tactile acts only (LRT for visual acts: *χ*25 = 69.229, *P* < 0.001; tactile acts: *χ*25 = 106.53, *P* < 0.001; *N* = 7587). More specifically, communicative acts were more likely to contain visual acts in the wild, in the Sumatran orang-utans, and in interaction dyads other than mother-offspring or maternal kin (Tab. S5). For tactile acts, there was a significant interaction between species and setting: wild Bornean orang-utans employed more tactile acts than any other species-setting combination (Tab. S5, Fig. S2). Tactile acts were significantly more common in mother-infant interactions compared to other dyads (Fig. S2; Tab. S5). For effects of the control variables see Table S5.

*Use of specific articulators.*Next,we used GLMMs to test sources of variation (i.e. species, setting, kinship) in the use of communicative acts involving specific articulators. The full model was a better fit than the null model for the response variables manual, bodily, vocal and recipient-directed gaze acts (LRT for manual: *χ*25 = 45.191, *P* < 0.001; bodily: *χ*25 = 74.46, *P* < 0.001; gaze: *χ*25 =174.296, *P* < 0.001, vocal acts: *χ*25 = 15.166, *P* = 0.01). More specifically, we found a significant interaction between species and setting for the use of bodily acts and gaze: bodily acts played a larger role in captive Sumatrans compared to the other species-setting classes (Tab. S5, Fig. S3), whereas recipient-directed gaze accompanied interactions significantly less often in captive compared to wild orang-utans (Tab. S5, Fig. S4). We also found a significant impact of kinship: manual acts were significantly more common in interactions among mother-infant dyads (Tab. S5) and other maternal kin, whereas communicative acts among mother-infant dyads were less likely to involve recipient-directed gaze (Tab. S5, Fig. S4) than those among other interaction dyads. Moreover, vocal acts were more commonly used in interactions beyond the mother-offspring dyad. For effects of non-significant key predictors and those of control variables see Table S5.

**Tables**

**Tab. S1** Information on study subjects (i.e. signallers and recipients) and sample size. Individuals with zero communicative acts were only recipients, those marked with an asterisk (\*) never acted as recipients (Bor = Bornean orang-utan, Sum = Sumatran orang-utan, Ad = adult, Oi = older immature, Yi = young immature).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **No subject** | **Setting** | **Species** | **Group** | **ID** | **Age group** | **Sex** | **N Comm. acts** |
| 1 | captive | Bor | Apenheul | WAT | Ad | F | 67 |
| 2 | captive | Bor | Apenheul | KAW | Oi | M | 59 |
| 3 | captive | Bor | Apenheul | BAJ | Yi | M | 65 |
| 4 | captive | Bor | Cologne | CAJ | Ad | F | 42 |
| 5 | captive | Bor | Cologne | COR | Ad | F | 31 |
| 6 | captive | Bor | Cologne | CIT | Oi | F | 60 |
| 7 | captive | Bor | Cologne | BUD | Oi | M | 25 |
| 8 | captive | Bor | Cologne | CIR | Yi | F | 86 |
| 9 | captive | Bor | Munster | MAN | Ad | F | 34 |
| 10 | captive | Bor | Munster | SAR | Ad | F | 17 |
| 11 | captive | Bor | Munster | NIA | Yi | F | 12 |
| 12 | captive | Bor | Munster | MIY | Yi | M | 79 |
| 13 | captive | Sum | Munich | JAH | Ad | F | 58 |
| 14 | captive | Sum | Munich | MAT | Ad | F | 70 |
| 15 | captive | Sum | Munich | SIT | Ad | F | 129 |
| 16 | captive | Sum | Munich | BRU | Ad | M | 11 |
| 17 | captive | Sum | Munich | ISO | Oi | F | 132 |
| 18 | captive | Sum | Munich | JOL | Oi | F | 70 |
| 19 | captive | Sum | Munich | RON | Yi | F | 197 |
| 20 | captive | Sum | Munich | QUE | Yi | M | 287 |
| 21 | captive | Sum | Munich | QUI | Yi | M | 102 |
| 22 | captive | Sum | Zurich | CAH | Ad | F | 82 |
| 23 | captive | Sum | Zurich | TIM | Ad | F | 50 |
| 24 | captive | Sum | Zurich | XIR | Ad | F | 52 |
| 25 | captive | Sum | Zurich | DJA | Ad | M | 22 |
| 26 | captive | Sum | Zurich | MIM | Oi | F | 208 |
| 27 | captive | Sum | Zurich | HAD | Oi | M | 103 |
| 28 | captive | Sum | Zurich | MAL | Oi | M | 342 |
| 29 | captive | Sum | Zurich | PAN | Yi | F | 199 |
| 30 | captive | Sum | Zurich | RIA | Yi | F | 99 |
| 31 | wild | Bor | Tuanan | CIA | Ad | F | 45 |
| 32 | wild | Bor | Tuanan | DES | Ad | F | 144 |
| 33 | wild | Bor | Tuanan | JUN | Ad | F | 96 |
| 34 | wild | Bor | Tuanan | KER | Ad | F | 223 |
| 35 | wild | Bor | Tuanan | KON | Ad | F | 69 |
| 36 | wild | Bor | Tuanan | MIL | Ad | F | 119 |
| 37 | wild | Bor | Tuanan | MIN | Ad | F | 100 |
| 38 | wild | Bor | Tuanan | TIN | Ad | F | 59 |
| 39 | wild | Bor | Tuanan | ZOL | Ad | F | 1 |
| 40 | wild | Bor | Tuanan | UNF | Ad | M | 67 |
| 41 | wild | Bor | Tuanan | MAW | Oi | F | 46 |
| 42 | wild | Bor | Tuanan | DAN | Oi | M | 17 |
| 43 | wild | Bor | Tuanan | TUK | Oi | M | 125 |
| 44 | wild | Bor | Tuanan | JAN | Yi | F | 320 |
| 45 | wild | Bor | Tuanan | MOB | Yi | F | 390 |
| 46 | wild | Bor | Tuanan | ZAK | Yi | F | 16 |
| 47 | wild | Bor | Tuanan | CAK | Yi | M | 124 |
| 48 | wild | Bor | Tuanan | DAR | Yi | M | 330 |
| 49 | wild | Bor | Tuanan | KEC | Yi | M | 54 |
| 50 | wild | Bor | Tuanan | KET | Yi | M | 467 |
| 51 | wild | Bor | Tuanan | MER | Yi | M | 418 |
| 52 | wild | Sum | Suaq | ALI | Ad | F | 0 |  |
| 53 | wild | Sum | Suaq | CIS | Ad | F | 41 |
| 54 | wild | Sum | Suaq | DOD | Ad | F | 0 |  |
| 55 | wild | Sum | Suaq | ELL | Ad | F | 113 |
| 56 | wild | Sum | Suaq | FRI | Ad | F | 44 |
| 57 | wild | Sum | Suaq | LIL | Ad | F | 43 |
| 58 | wild | Sum | Suaq | LIS | Ad | F | 34 |
| 59 | wild | Sum | Suaq | PIN | Ad | F | 13 |
| 60 | wild | Sum | Suaq | TIA | Ad | F | 22 |
| 61 | wild | Sum | Suaq | BEO | Ad | M | 6 |
| 62 | wild | Sum | Suaq | CRA | Ad | M | 0 |  |
| 63 | wild | Sum | Suaq | DRU | Ad | M | 0 |  |
| 64 | wild | Sum | Suaq | FLG | Ad | M | 0 |  |
| 65 | wild | Sum | Suaq | GUR | Ad | M | 0 |  |
| 66 | wild | Sum | Suaq | JAR | Ad | M | 0 |  |
| 67 | wild | Sum | Suaq | MAR | Ad | M | 0 |  |
| 68 | wild | Sum | Suaq | NIB | Ad | M | 6 |
| 69 | wild | Sum | Suaq | REE | Ad | M | 0 |  |
| 70 | wild | Sum | Suaq | ROB | Ad | M | 0 |  |
| 71 | wild | Sum | Suaq | UNF | Ad | M | 6 |
| 72 | wild | Sum | Suaq | CIN | Oi | F | 225 |
| 73 | wild | Sum | Suaq | TRI | Oi | F | 0 |
| 74 | wild | Sum | Suaq | YUL | Oi | F | 8 |
| 75 | wild | Sum | Suaq | FRA | Oi | M | 371 |
| 76 | wild | Sum | Suaq | KRO | Oi | M | 45 |
| 77 | wild | Sum | Suaq | LOI | Oi | M | 164 |
| 78 | wild | Sum | Suaq | EDE | Yi | F | 391 |
| 79 | wild | Sum | Suaq | AMO\* | Yi | M | 5 |
| 80 | wild | Sum | Suaq | LUT | Yi | M | 313 |
| 81 | wild | Sum | Suaq | PEP | Yi | M | 38 |
| 82 | wild | Sum | Suaq | TOR | Yi | M | 92 |  |

**Tab. S2** Information on variables coded using BORIS

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Variable and levels** | **Coding type** | **Description** |  |  |
| **Presumed goal** | single-select | Apparent aim of the signaller (S) as determined by observer, based on the individuals involved and the signaller`s behaviour before and after the communicative act |  |  |
| Food/object share |  | Recipient (R) shares/hands over food item or object with signaller |  |  |
| Groom |  | R grooms S |  |  |
| Move away |  | R moves away from S |  |  |
| Play/affiliate |  | R plays or physically affiliates with |  |  |
| Sexual contact |  | R engages in sexual contact with S |  |  |
| Stop action |  | R stops a certain behaviour (e.g. begging) from S |  |  |
| Joint travel |  | R starts joint travel/co-locomotion with S |  |  |
| **Body part** | multi-select | Body part(s) used by the signaller to execute behaviour/gesture/etc. |  |  |
| Arm-R |  | Right arm |  |  |
| Arm-L |  | Left arm |  |  |
| Hand-R |  | Right hand |  |  |
| Hand-L |  | Left hand |  |  |
| Leg-R |  | Right leg |  |  |
| Leg-L |  | Left leg |  |  |
| Foot-R |  | Right foot |  |  |
| Foot-L |  | Left foot |  |  |
| Head |  | Head and eyes |  |  |
| Front |  | Front |  |  |
| Torso |  | Torso |  |  |
| Mouth/lips |  | Mouth/lips |  |  |
| Other |  | Other |  |  |
| NA |  | Na |  |  |
| **Modality** | multi-select | Sensory modaility in which the signal is perceived by the recipient |  |  |
| Auditory |  | S's behaviour produces a sound and is perceived through hearing |  |  |
| Visual |  | S's behaviour is perceived via eye sight |  |  |
| Seismic |  | S's behaviour is perceived through substrate movement *(like vibration = indirect mechanic modality)* |
| Tactile |  | S's behaviour is perceived through body contact |  |  |
| **Distance** | single-select | Physical distance between S and R BEFORE signal/behaviour is executed (e.g. before R is touched) |
| Body contact |  | S and R are in body contact |  |  |
| Within arm's reach |  | No body contact, but S could (theoretically) touch R if he stretches out arm/leg | |  |
| Same tree/substrate |  | S and R sit on/are attached to same substrate (e.g. Branch, liana, tree log) | |  |
| Different tree/substrate |  | S and R sit on/are attached to different substrate (e.g. Branch, liana, tree log) | |  |
| NA |  | Not clearly visible, unknown |  |  |
| **Objects** | single-select | Objects involved by signaller in behaviour/interaction |  |  |
| None |  | No object involved |  |  |
| Immobile |  | Immobile object involved, e.g. tree branch that is still attached to tree |  |  |
| Mobile |  | Mobile object involved, e.g. loose branch, stone, stick, leaf…. |  |  |
| NA |  | Not clearly visible, unknown |  |  |
| **Gaze direction** | single-select | Visual orientation of signaller as determined by head/eye direction |  |  |
|  |  |  |  |  |
| At recipient |  | S’s head directed towards R |  |  |
| Mutual gaze |  | S’s head directed towards R and vice versa |  |  |
| At object |  | S’s head directed towards object (e.g. food item, toy) held/eaten by R |  |  |
| Alt between obj and rec | | S alternates head direction between R and object |  |  |
| Other |  | S’s head directed neither towards R nor towards object held/eaten by R |  |  |
| NA |  | Not clearly visible, unknown |  |  |
| **Attentional state** | single-select | Visual orientation of recipient (R) during S's behaviour |  |  |
| In visual field |  | S is in the R’s visual field, i.e. The R can see the S without moving his or her head | |  |
| 90 degrees |  | S is in the periphery of the R’s visual field (ca. 90 degrees), i.e. R can see the S from the corner of his/her eye. |
| Rec turned away |  | S is not in the R’s visual field, that is the R would have to make a major turn with his/her head or body to see the S |
| NA |  | Not clearly visible, unknown |  |  |
| **Interaction outcome** | single-select | Response of recipient in reaction to S's behaviour |  |  |
| No reaction |  | No discernible response by R |  |  |
| ASO |  | "Apparently Satisfactory Outcome": R responds in a way that seems to satisfy S, in that no more communicative acts are produced |
| Responds w/ signal |  | R responds with a signal - "negotiation" |  |  |
| Visual attention | | R’s head directed towards S, but no other response |  |  |
| Move away |  | R moves away from S |  |  |
| Agonistic |  | R reacts in an aggressive or agonistic way to S's behaviour |  |  |
| NA |  | Not clearly visible, unknown |  |  |

**Tab. S3** Overview of communicative acts for which dominant outcomes could be identified (Ad = adult, Im = old immature, Dp = young immature, FS = Share food/object, GR = Groom, JT = Co-locomote, PL = Play/affiliate, SX = Sexual contact, ST = stop action)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Comm. act** | **Type** | **No. subjects** | **Dominant outcome** | **Total** |
| beg hand-hand | manual | 36 | FS | 306 |
| beg hand-mouth | manual | 33 | FS | 223 |
| beg mouth-hand | bodily | 27 | FS | 173 |
| beg mouth-mouth | bodily | 30 | FS | 202 |
| bite | bodily | 47 | PL | 348 |
| bite attempt | bodily | 50 | PL | 237 |
| dangle | bodily | 33 | PL | 168 |
| embrace | manual | 23 | PL | 50 |
| flapped lip | facial | 6 | ST | 11 |
| fling | manual | 19 | PL | 72 |
| grab/hold | manual | 65 | PL | 1417 |
| hand on | manual | 47 | PL, FS, GR | 418 |
| head-butt | bodily | 10 | PL | 32 |
| head-stand | bodily | 3 | PL | 5 |
| hit | manual | 20 | PL | 91 |
| kiss | bodily | 37 | PL | 126 |
| look at | bodily | 53 | PL | 348 |
| look back at | bodily | 11 | PL | 27 |
| loud scratch | manual | 11 | JT | 34 |
| peer | bodily | 38 | FS | 361 |
| play face | facial | 26 | PL | 83 |
| poke | manual | 23 | PL | 126 |
| pout face | facial | 7 | PL | 16 |
| present body part | manual | 36 | PL, GR | 148 |
| present object | manual | 16 | PL | 27 |
| pull | manual | 61 | PL, FS | 548 |
| push | manual | 50 | ST, PL | 278 |
| raise limb | manual | 28 | PL | 52 |
| reach | manual | 53 | PL, FS | 236 |
| rise up | bodily | 7 | PL | 3 |
| roll on back | bodily | 7 | PL | 5 |
| rub body | bodily | 12 | SX | 87 |
| shake object | manual | 1 | PL | 5 |
| somersault | bodily | 6 | PL | 10 |
| spin | bodily | 3 | PL | 3 |
| spit | bodily | 1 | PL | 5 |
| stroke | manual | 11 | PL | 19 |
| throw object | manual | 7 | PL | 11 |
| throw self | bodily | 19 | PL | 72 |
| touch | manual | 66 | PL | 1045 |
| Total |  | 70 |  | 7428 |

**Tab. S4** Distribution of coded interactions across settings, species and interaction dyads (mother-offspring: interactions among mothers and their dependent unweaned offspring; interactions among maternal kin other than mother-dependent offspring, other: all other interaction dyads).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Captive | | | Wild | | Total |
| Interaction dyad | | Bornean | Sumatran | Bornean | Sumatran |  |
| mother-offspring | 330 | | 465 | 2208 | 1263 | 4266 |
| maternal kin | 131 | | 933 | 517 | 226 | 1807 |
| Other | 116 | | 788 | 187 | 423 | 1514 |
| **Total** | **577** | | **2186** | **2912** | **1912** | **7587** |

**Tab. S5** Effects of research setting, orang-utan species, kinship and control predictors on the use of different sensory modalities (a-b) and articulators (c-f), derived using GLMMs with a binomial error structure (N = 7587). Significant effects (P < 0.05) are depicted in italics.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **(a) Visual** | Estimate | SE | *χ*21 | *P* |
| Intercept | -0.786 | 0.189 | — | — |
| *Setting [wild]* | *0.763* | *0.126* | *33.396* | *<0.001* |
| *Species [Sumatran]* | *0.583* | *0.13* | *18.065* | *<0.001* |
| Age group [young im.] | 0.179 | 0.139 | 1.599 | 0.206 |
| Age group [older im.] | 0.152 | 0.155 | 0.939 | 0.332 |
| Sex [male] | -0.176 | 0.117 | 2.241 | 0.134 |
| *Kinship [mother]* | *-0.794* | *0.147* | *28.780* | *<0.001* |
| *Kinship [mat. kin]* | *-0.636* | *0.141* | *19.755* | *<0.001* |
| *Context [share]* | *1.933* | *0.14* | *134.821* | *<0.001* |
| *Context [play]* | *0.23* | *0.095* | *5.725* | *0.017* |
| **(b) Tactile** |  |  |  |  |
| Intercept | 0.546 | 0.296 | — | — |
| Setting [wild] | 1.861 | 0.301 | — | — |
| Species [Sumatran] | 0.18 | 0.26 | — | — |
| Age group [young im.] | -0.008 | 0.193 | 0.002 | 0.969 |
| Age group [older im.] | 0.027 | 0.21 | 0.017 | 0.897 |
| *Sex [male]* | *0.366* | *0.163* | *4.925* | *0.026* |
| *Kinship [mother]* | *1.002* | *0.206* | *22.243* | *<0.001* |
| Kinship [mat. kin] | 0.368 | 0.188 | 3.834 | 0.050 |
| *Context [share]* | *-0.803* | *0.175* | *20.652* | *<0.001* |
| Context [play] | 0.067 | 0.125 | 0.287 | 0.592 |
| *Setting x species* | *-2.53* | *0.367* | *42.966* | *<0.001* |
| **(c) Manual** |  |  |  |  |
| Intercept | 0.669 | 0.251 | — | — |
| Setting [wild] | 0.42 | 0.173 | 5.710 | 0.017 |
| Species [Sumatran] | -0.233 | 0.184 | 1.581 | 0.209 |
| Age group [young im.] | -0.395 | 0.2 | 3.825 | 0.050 |
| Age group [older im.] | -0.269 | 0.213 | 1.560 | 0.212 |
| Sex [male] | 0.14 | 0.17 | 0.668 | 0.414 |
| *Kinship [mother]* | *1.003* | *0.207* | *22.414* | *<0.001* |
| *Kinship [mat. kin]* | *0.556* | *0.192* | *8.227* | *0.004* |
| *Context [share]* | *-1.102* | *0.143* | *49.474* | *<0.001* |
| Context [play] | -0.186 | 0.128 | 2.027 | 0.155 |
| **(d) Bodily** |  |  |  |  |
| Intercept | -2.168 | 0.282 | — | — |
| Setting [wild] | -0.691 | 0.271 | — | — |
| Species [Sumatran] | 0.584 | 0.246 | — | — |
| Age group [young im.] | 0.304 | 0.183 | 2.772 | 0.096 |
| Age group [older im.] | 0.172 | 0.199 | 0.747 | 0.388 |
| Sex [male] | 0.11 | 0.153 | 0.513 | 0.474 |
| Kinship [mother] | -0.09 | 0.192 | 0.221 | 0.638 |
| Kinship [mat. kin] | 0.017 | 0.179 | 0.009 | 0.922 |
| *Context [share]* | *1.645* | *0.158* | *73.177* | *<0.001* |
| *Context [play]* | *0.661* | *0.132* | *23.346* | *<0.001* |
| *Setting x species* | *-0.832* | *0.335* | *5.980* | *0.014* |
| **(e) Recipient-directed gaze** |  |  |  |  |
| Intercept | -2.114 | 0.308 | — | — |
| Setting [wild] | 4.022 | 0.307 | — | — |
| Species [Sumatran] | 2.781 | 0.278 | — | — |
| Age group [young im.] | -0.019 | 0.189 | 0.011 | 0.918 |
| Age group [older im.] | 0.307 | 0.208 | 2.181 | 0.140 |
| Sex [male] | 0.023 | 0.169 | 0.018 | 0.892 |
| *Kinship [mother]* | *-0.866* | *0.202* | *17.886* | *<0.001* |
| Kinship [mat. kin] | -0.093 | 0.193 | 0.236 | 0.627 |
| *Context [share]* | *-1.539* | *0.167* | *65.507* | *<0.001* |
| *Context [play]* | *0.478* | *0.124* | *14.903* | *<0.001* |
| *Setting x species* | *-2.589* | *0.365* | *45.187* | *<0.001* |
| **(f) Vocal** |  |  |  |  |
| Intercept | -9.041 | 2.075 | — | — |
| Setting [wild] | 0.352 | 1.483 | 0.055 | 0.815 |
| Species [Sumatran] | -2.505 | 1.583 | 2.223 | 0.136 |
| *Age group [young im.]* | *3.849* | *1.62* | *5.394* | *0.020* |
| Age group [older im.] | 1.999 | 1.741 | 1.203 | 0.273 |
| *Sex [male]* | *-3.083* | *1.416* | *4.874* | *0.027* |
| *Kinship [mother]* | *-6.441* | *2.041* | *11.130* | *0.001* |
| Kinship [mat. kin] | -2.494 | 1.829 | 1.960 | 0.161 |
| *Context [share]* | *-3.964* | *1.912* | *10.439* | *0.001* |
| *Context [play]* | *-5.846* | *1.535* | *22.286* | *<0.001* |

**Tab. S6** Effects of research setting, orang-utan species, kinship and control predictors on the composition of communicative acts, derived using GLMMs with a binomial error structure (a: *N* = 4954, b: *N* = 5239, c: *N* = 2633, d: *N* = 2348). Significant effects (P < 0.05) are depicted in italics.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **(a) Multisensory (UC)** | Estimate | SE | *χ*21 | *P* |
| Intercept | -4.584 | 0.388 | — | — |
| Setting [wild] | 3.129 | 0.336 | — | — |
| Species [Sumatran] | 1.342 | 0.334 | — | — |
| *Age group [young im.]* | *0.598* | *0.181* | *10.132* | *0.001* |
| Age group [older im.] | 0.306 | 0.223 | 1.900 | 0.168 |
| Sex [male] | 0.031 | 0.154 | 0.042 | 0.838 |
| Kinship [mother] | -0.046 | 0.2 | 0.052 | 0.819 |
| Kinship [mat. kin] | -0.13 | 0.208 | 0.394 | 0.530 |
| *Context [share]* | *1.548* | *0.184* | *45.124* | *<0.001* |
| Context [play] | 0.18 | 0.143 | 1.602 | 0.206 |
| *Setting x species* | *-1.306* | *0.391* | *12.041* | *0.001* |
| **(b) Multicomponent (US)** |  |  |  |  |
| Intercept | -2.537 | 0.326 | — | — |
| Setting [wild] | 2.359 | 0.314 | — | — |
| Species [Sumatran] | 1.99 | 0.291 | — | — |
| Age group [young im.] | -0.287 | 0.183 | 2.408 | 0.121 |
| Age group [older im.] | -0.11 | 0.193 | 0.324 | 0.569 |
| Sex [male] | -0.226 | 0.154 | 2.121 | 0.145 |
| *Kinship [mother]* | *-1.071* | *0.193* | *28.144* | *<0.001* |
| Kinship [mat. kin] | 0.035 | 0.18 | 0.038 | 0.845 |
| *Context [share]* | *-0.527* | *0.168* | *11.239* | *0.001* |
| Context [play] | 0.109 | 0.139 | 0.616 | 0.433 |
| *Setting x species* | *-1.08* | *0.356* | *9.456* | *0.002* |
| **(c) Multisensory (MC**) |  |  |  |  |
| Intercept | -2.988 | 0.701 | — | — |
| Setting [wild] | 1.461 | 0.68 | — | — |
| Species [Sumatran] | 1.225 | 0.669 | — | — |
| Age group [young im.] | 0.212 | 0.281 | 0.565 | 0.452 |
| Age group [older im.] | 0.26 | 0.309 | 0.705 | 0.401 |
| Sex [male] | 0.212 | 0.224 | 0.895 | 0.344 |
| *Kinship [mother]* | *0.558* | *0.279* | *3.933* | *0.047* |
| *Kinship [mat. kin]* | *-0.914* | *0.263* | *11.526* | *0.001* |
| Context [share] | 0.333 | 0.396 | 0.627 | 0.429 |
| *Context [play]* | *0.447* | *0.201* | *5.101* | *0.024* |
| *Setting x species* | *-1.916* | *0.726* | *7.664* | *0.006* |
| **(d) Multicomponent (MS)** |  |  |  |  |
| Intercept | -1.429 | 0.836 | — | — |
| Setting [wild] | 0.665 | 0.8 | — | — |
| Species [Sumatran] | 2.458 | 0.815 | — | — |
| Age group [young im.] | -0.387 | 0.304 | 1.620 | 0.203 |
| Age group [older im.] | -0.039 | 0.374 | 0.011 | 0.918 |
| Sex [male] | 0.012 | 0.257 | 0.002 | 0.964 |
| *Kinship [mother]* | *-0.627* | *0.314* | *3.987* | *0.046* |
| Kinship [mat. kin] | -0.589 | 0.329 | 3.210 | 0.073 |
| *Context [share]* | *-2.301* | *0.522* | *29.094* | *<0.001* |
| *Context [play]* | *0.703* | *0.239* | *9.309* | *0.002* |
| *Setting x species* | *-2.071* | *0.866* | *6.049* | *0.014* |

**Tab. S7** Effects of multisensory (MS; a: visual plus, b: tactile plus) or multicomponent use (MC; c: bodily plus, d: recipient-directed gaze plus) of communicative acts and control predictors on the probability of receiving an apparently satisfactory outcome (ASO), derived using GLMMs with a binomial error structure (a: *N* = 2301, b: *N* = 3743, c: *N* = 4513). Significant effects (P < 0.05) are depicted in italics.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **(a) ASO ~ Visual plus** | Estimate | SE | *χ*21 | *P* |
| Intercept | 0.724 | 0.563 | — | — |
| *MS use [visual plus]* | *0.89* | *0.211* | *14.458* | *<0.001* |
| Setting [wild] | -0.127 | 0.466 | 0.074 | 0.785 |
| *Species [Sumatran]* | *-1.372* | *0.496* | *4.395* | *0.036* |
| *Age group [young im.]* | *-0.842* | *0.31* | *7.510* | *0.006* |
| Age group [older im.] | -0.531 | 0.337 | 2.538 | 0.111 |
| Sex [male] | 0.483 | 0.257 | 3.528 | 0.060 |
| *Kinship [mother]* | *0.918* | *0.308* | *9.066* | *0.003* |
| Kinship [mat. kin] | 0.463 | 0.319 | 2.122 | 0.145 |
| *Context [share]* | *-0.949* | *0.277* | *10.523* | *0.001* |
| Context [play] | 0.242 | 0.287 | 0.721 | 0.396 |
| **(b) ASO ~ Tactile plus** |  |  |  |  |
| Intercept | -0.462 | 0.463 | — | — |
| *MS use [tactile plus]* | *0.549* | *0.161* | *9.692* | *0.002* |
| Setting [wild] | 0.616 | 0.413 | 2.397 | 0.122 |
| Species [Sumatran] | -0.454 | 0.424 | 1.330 | 0.249 |
| Age group [young im.] | -0.036 | 0.285 | 0.036 | 0.850 |
| Age group [older im.] | -0.148 | 0.312 | 0.007 | 0.935 |
| Sex [male] | 0.341 | 0.269 | 1.217 | 0.270 |
| *Kinship [mother]* | *0.778* | *0.275* | *10.661* | *0.001* |
| Kinship [mat. kin] | 0.295 | 0.272 | 0.156 | 0.693 |
| Context [share] | -0.243 | 0.192 | 1.361 | 0.243 |
| Context [play] | 0.377 | 0.229 | 1.900 | 0.168 |
| **(c) ASO ~ Gaze plus** |  |  |  |  |
| Intercept | 0.535 | 0.271 | — | — |
| *MC use [gaze plus]* | *0.492* | *0.117* | *15.810* | *<0.001* |
| Setting [wild] | 0.139 | 0.181 | 0.587 | 0.443 |
| *Species [Sumatran]* | *-0.995* | *0.191* | *25.631* | *<0.001* |
| Age group [dependent] | -0.289 | 0.206 | 1.960 | 0.161 |
| Age group [immature] | 0.056 | 0.226 | 0.061 | 0.806 |
| Sex [male] | 0.12 | 0.181 | 0.447 | 0.504 |
| *Kinship [mother]* | *0.632* | *0.22* | *8.384* | *0.004* |
| Kinship [mat. kin] | 0.037 | 0.206 | 0.033 | 0.856 |
| *Context [share]* | *-1.149* | *0.192* | *36.053* | *<0.001* |
| Context [play] | 0.233 | 0.151 | 2.426 | 0.119 |

**Tab. S8** Effects of multicomponent (MC) use of communicative acts (a: bodily plus, b: recipient-directed gaze plus) and control predictors on the probability of matching the dominant outcome (DOM) of a communicative act, derived using GLMMs with a binomial error structure (a: *N* = 1429, b: *N* = 3869). Significant effects (*P* < 0.05) are depicted in italics.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **(a) DOM ~ Bodily plus** | Estimate | SE | *χ*21 | *P* |
| Intercept | -1.82 | 0.727 | — | — |
| *MC use [bodily plus]* | *-0.907* | *0.414* | *4.690* | *0.030* |
| Setting [wild] | -0.483 | 0.541 | 0.785 | 0.376 |
| Species [Sumatran] | -0.59 | 0.564 | 1.115 | 0.291 |
| Age group [young im.] | 0.762 | 0.668 | 1.319 | 0.251 |
| Age group [older im.] | 0.679 | 0.71 | 0.910 | 0.340 |
| Sex [male] | 1.202 | 0.619 | 3.821 | 0.051 |
| Kinship [mother] | 0.483 | 0.365 | 1.754 | 0.185 |
| Kinship [mat. kin] | 0.582 | 0.387 | 2.261 | 0.133 |
| *Context [share]* | *5.797* | *0.518* | *162.881* | *<0.001* |
| *Context [play]* | *3.697* | *0.37* | *131.890* | *<0.001* |
| **(b) DOM ~ Gaze plus** |  |  |  |  |
| Intercept | -0.621 | 0.537 | — | — |
| *MC use [gaze plus]* | *-0.668* | *0.257* | *6.560* | *0.010* |
| Setting [wild] | -0.569 | 0.338 | 2.750 | 0.097 |
| Species [Sumatran] | -0.311 | 0.337 | 0.840 | 0.360 |
| Age group [young im.] | -0.221 | 0.366 | 0.360 | 0.547 |
| Age group [older im.] | -0.005 | 0.401 | 0.000 | 0.990 |
| Sex [male] | 0.653 | 0.335 | 3.740 | 0.053 |
| Kinship [mother] | 0.245 | 0.223 | 1.210 | 0.272 |
| *Kinship [mat. kin]* | *1.01* | *0.24* | *17.660* | *<0.001* |
| Context [share] | 0.436 | 0.244 | 3.130 | 0.077 |
| *Context [play]* | *5.049* | *0.194* | *1204.620* | *<0.001* |

**Tab. S9** Information on corresponding variable and level names in R script (ESM 3)

|  |  |
| --- | --- |
| **Variable** | **Names of binary variables in R script** |
| *Predictor variables* |  |
| Setting (captive, wild) | setting (captive, wild) |
| Species (Bornean, Sumatran) | species (Bor, Sum) |
| Age group: young immature | age.dep |
| Age group: older immature | age.imm |
| Sex: female, male | sex.code |
| Kinship: mother-offspring | kinship.mo |
| Kinship: maternal kin | kinship.mk |
| Presumed goal: share object/food | context\_fs |
| Presumed goal: share object/food | context\_pl |
| Constituent parts: visual plus, tactile plus, recipient-directed gaze plus, bodily plus, manual plus, | vis\_mm, tac\_mm, gaze\_mp, bodily\_mp, manual\_mp |
| *Response variables* |  |
| Articulators: bodily. manual, recipient-directed gaze, vocal, facial | artic\_bod, artic\_man, artic\_gaze, , artic\_voc, artic\_fac |
| Modalities: visual, tactile. audible, seismic | modality\_vis2, modality\_tac, modality\_aud, modality\_seis |
| Multicomponent (all unisensory) | mc\_us |
| Multisensory (all unicomponent) | ms\_uc |
| Multisensory (all multicomponent) | MC\_ms |
| Multicomponent (all multisensory) | MS\_mc |
| Effectiveness (ASO) | effect |
| Dominant outcome match (DOM) | match\_tight |

**Figures**



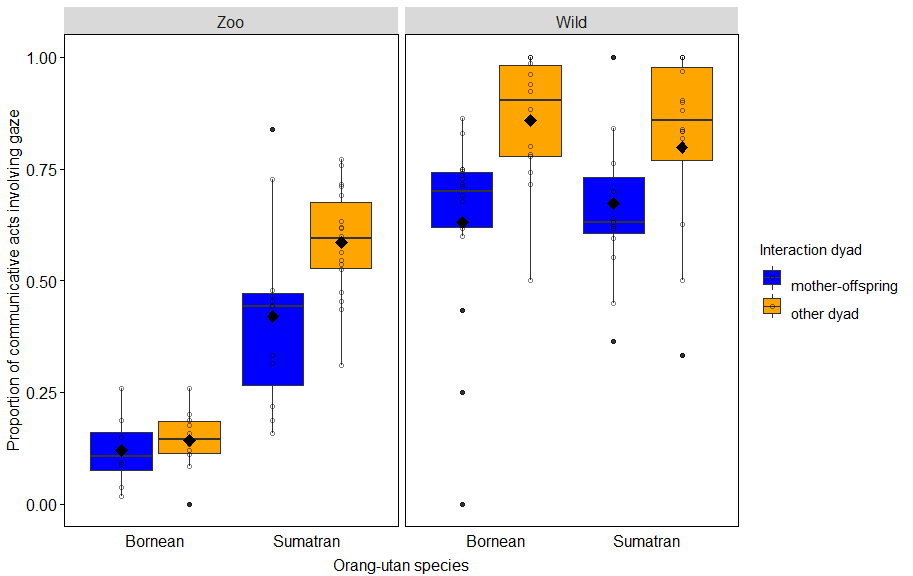
**Fig. S1** Proportion of unisensory communicative acts receiving an apparently satisfactory outcome (ASO) as a function of multicomponent use of communicative acts (without/plus recipient-directed gaze). Circles indicate individual means, with circle area representing sample size (range = 1–181). Red diamonds depict model estimates with 95% confidence intervals.



**Fig. S2** Proportion of tactile communicative acts as a function of research setting, species and interaction dyad. Indicated are individual means (circles), population means (filled diamonds), medians (horizontal lines), quartiles (boxes), percentiles (2.5% and 97.5%, vertical lines) and outliers (filled dots).

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**Fig. S3** Proportion of bodily acts as a function of research setting, species and interaction dyad. Indicated are individual means (circles), population means (filled diamonds), medians (horizontal lines), quartiles (boxes), percentiles (2.5% and 97.5%, vertical lines) and outliers (filled dots).



**Fig. S4** Proportion of communicative acts involving recipient-directed gaze as a function of research setting, species and interaction dyad. Indicated are individual means (circles), population means (filled diamonds), medians (horizontal lines), quartiles (boxes), percentiles (2.5% and 97.5%, vertical lines) and outliers (filled dots).