Supplementary material

Orientation toward humans predicts cognitive performance in orang-utans

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Supplementary Table S1: Parameter estimates from a binomial GLMM, predicting the probability of an animal solving the task when excluding independent variables for the novelty response tests.

Generalized Linear Mixed Model of overall performance in the honey tool-task.

Parameter estimates from a binomial GLMM, predicting the probability of an animal solving the task.

	B	*SE*	*Z*	*p value*
Human Orientation Index	0.243	0.09	2.679	**0.007 ****
Age	-0.018	0.03	-0.582	0.561
SEX (male)	-0.619	0.53	-1.158	0.247
Species (Sumatra)	0.295	0.60	0.484	0.628
Background				
Wild vs. Rest	-0.212	0.24	-0.890	0.373
Rehab vs. Zoo	-0.131	0.30	-0.436	0.663
Unknown vs. Rehab.Rest	0.160	0.22	0.730	0.466
Human vs. Station (within rehabilitation station)	-0.489	0.52	-0.933	0.351
Mother vs. Hand (within zoo)	0.383	0.52	0.573	0.465
Accessibility (trend analysis)				
Linear	1.211	0.87	1.395	0.163
Quadratic	1.209	0.97	1.249	0.212
Cubic	0.099	0.97	0.103	0.918
Sub-task (trend analysis)				
Linear	-5.046	0.72	-6.981	**<0.001*****
Quadratic	1.512	0.42	3.567	**<0.001*****
Cubic	-0.149	0.33	-0.457	0.648

Note: Analysis included 94 individuals in 10 different zoos/rehab stations, totalling 376 observations, χ^2_{ML}= 220.60, P< 0.001

Supplementary Table S2: Parameter estimates from a binomial GLMM, predicting the probability of an animal solving the task. Analysis without the HOI.

General Linear Mixed Model of overall performance in the honey tool-task.

Parameter estimates from a binomial GLMM, predicting the probability of an animal solving the task.

	B	***SE***	***Z***	***p value***
(Intercept)	-0.609	0.91	-0.670	0.503
Age	0.001	0.03	0.023	0.981
SEX (male)	-0.638	0.51	-1.252	0.210
Species (Sumatra)	0.186	0.56	0.332	0.740
Background				
Wild vs. Rest	-0.360	0.22	-1.604	0.109
Rehab vs. Zoo	-0.115	0.26	-0.447	0.655
Unknown vs. Rehab.Rest	0.221	0.21	1.041	0.298
Human vs. Station (within rehabilitation station)	-0.613	0.51	-1.201	0.230
Mother vs. Hand (within zoo)	0.157	0.41	0.381	0.704
Accessibility (trend analysis)				
Linear	0.910	0.81	1.118	0.263
Quadratic	1.499	0.83	1.803	0.071 .
Cubic	0.120	0.82	0.146	0.884
Sub-task (trend analysis)				
Linear	-4.905	0.66	-7.478	**<0.001 *****
Quadratic	1.509	0.39	3.830	**<0.001 *****
Cubic	0.036	0.31	0.118	0.906

Note: The model is controlling for repeated observations on each facility and individual. The performance in the honey tool-task was binary measured. The Analysis included 103 individuals in 12 different zoos/rehab stations, totalling 412 observations, χ^2= 236.43, *P*< 0.001

Supplementary Table S3: Detailed list of all different exploration actions coded as relevant and irrelevant exploration during the time an individual engaged with the honey tool-task.

Relevant Exploration Actions	Irrelevant Exploration Actions
Insert stick into L-shaped channel	Hit (with any body parts) test apparatus or board
Insert finger into L-shaped channel	Hit (with any body parts) table on which apparatus is presented
Insert finger into I-shaped channel	Pull/ Push test apparatus, plexiglas, screws
Insert rope into I-shaped channel	Pull/ Push table or board on which apparatus is presented
Trace/ Poke finger outside glass of either I- or L-shaped channel	Touch test apparatus, plexiglas, screws (elsewhere but channels)
Trace/ Poke stick outside glass of either I- or L-shaped channel	Touch table or board on which apparatus is presented
Tool modification/ manufacture	Poke stick at apparatus, plexiglas, screws (elsewhere but channels)
Insert any other tool than stick or rope into L-shaped channel	Poke stick at board/table on which apparatus is presented
Insert any other tool than stick or rope into I-shaped channel	Touch sticks on the floor or besides test apparatus
Poke or push stick at opening of L-shaped channel	Touch ropes on the floor or besides test apparatus
Poke or push stick at opening of I-shaped channel	
Poke or push finger at opening of L-shaped channel	
Poke or push finger at opening of I-shaped channel	

Supplementary Table S4: Linear Mixed-Effects Model of relevant exploration variety controlling for repeated observations on each facility.

	B	*SE*	*df*	*t value*	*p value*
(Intercept)	1.209	1.41	48.66	0.857	0.396
HOI	0.221	0.05	80.07	4.049	**<0.001 *****
Age	0.014	0.03	80.84	0.414	0.680
SEX (male)	-0.059	0.55	79.52	-0.106	0.916
Species (Sumatra)	0.946	0.87	6.31	1.084	0.318
Background					
Wild vs. Rest	0.162	0.25	75.37	0.652	0.517
Rehab vs. Zoo	0.356	0.33	42.06	1.063	0.294
Unknown vs. Rehab.Rest	0.408	0.23	80.76	1.746	0.085 .
Human vs. Station (within rehabilitation station)	-0.257	0.53	79.81	-0.483	0.630
Mother vs. Hand (within zoo)	0.314	0.58	65.78	0.544	0.589
Accessibility (trend analysis)					
Linear	0.316	1.11	12.64	0.285	0.780
Quadratic	0.467	1.13	23.52	0.411	0.685
Cubic	1.540	1.04	77.21	1.486	0.141

Note: The model is controlling for repeated observations on each facility. The analysis was totalling 94 observations in 10 different zoos/rehab stations, $\chi^2 = 30.91$, $p < .0005$

Supplementary Table S5: Pairwise comparisons of the Human Orientation Index (HOI) between the different background and rearing categories.

Pairwise comparisons of HOI between different background categories, controlling for age, sex, island and repeated observations from each zoo and rehabilitation station.				
	B	***SE***	***Z***	***p value***
Hand-reared zoo - Station	1.649	2.03	0.814	0.960
Human - Station	-1.452	1.35	-1.078	0.877
Mother-reared zoo - Station	-0.605	1.62	-0.372	0.999
Unknown - Station	-0.279	1.28	-0.217	1.000
Wild - Station	-3.568	2.46	-1.450	0.670
Human – Hand-reared zoo	-3.102	1.82	-1.707	0.497
Mother-reared zoo – Hand-reared zoo	-2.254	1.50	-1.499	0.637
Unknown – Hand-reared zoo	-1.928	1.74	-1.106	0.864
Wild – Hand-reared zoo	-5.217	2.70	-1.931	0.354
Mother-reared zoo - Human	0.847	1.35	0.626	0.987
Unknown - Human	1.174	0.94	1.249	0.792
Wild - Human	-2.116	2.25	-0.941	0.927
Unknown – Mother-reared zoo	0.326	1.25	0.260	1.000
Wild – Mother-reared zoo	-2.963	2.41	-1.227	0.805
Wild - Unknown	-3.289	2.41	-1.468	0.658
P-values corrected for multiple comparisons using Tukey.				

Supplementary Table S6 study subjects.

Individual	Age in years at testing	years in captivity	species	current housing	Category
Amin	6	0.5	*Pongo abelii*	Reha-Station	unknown background
Amos	13	13.0	*Pongo pygmaeus*	Zoo	Mother reared
Andalas	3	0.5	*Pongo abelii*	Reha-Station	unknown background
Anette	30	30.0	*Pongo abelii*	Zoo	Mother reared
Ari	10	8.0	*Pongo pygmaeus*	Reha-Station	Background with humans
Ayu	6	0.5	*Pongo abelii*	Reha-Station	unknown background
Bahruni	10	0.5	*Pongo abelii*	Reha-Station	wild/ translocated
Bambang	10.5	5.0	*Pongo pygmaeus*	Reha-Station	Background with humans
Batu	14	14.0	*Pongo pygmaeus*	Zoo	Mother reared
Bella	14.5	10.0	*Pongo pygmaeus*	Reha-Station	unknown background
Binti	13	13.0	*Pongo pygmaeus*	Zoo	Human hand reared
Budi	8	8.0	*Pongo abelii*	Zoo	Mother reared
Cane	10	0.0	*Pongo abelii*	Reha-Station	wild/ translocated
Cantik	10	8.0	*Pongo pygmaeus*	Reha-Station	unknown background
Ceky Chan	6	0.0	*Pongo abelii*	Reha-Station	Background with humans
Cherie	18	18.0	*Pongo pygmaeus*	Zoo	Mother reared
Cici	15	10.0	*Pongo pygmaeus*	Reha-Station	unknown background
Dagu	28	28.0	*Pongo abelii*	Zoo	Mother reared
Dana	25	25.0	*Pongo abelii*	Zoo	Mother reared
Dandim	12	7.0	*Pongo pygmaeus*	Reha-Station	unknown background
Dewa	12	10.0	*Pongo pygmaeus*	Reha-Station	unknown background
Djamuna	13	13.0	*Pongo abelii*	Zoo	Mother reared
Dokana	25	25.0	*Pongo abelii*	Zoo	Mother reared
Dora	3.5	2.0	*Pongo abelii*	Reha-Station	Background with humans
Duanne	10	8.0	*Pongo pygmaeus*	Reha-Station	unknown background
Edwin	11.5	7.0	*Pongo pygmaeus*	Reha-Station	unknown background
Embrie	10	8.0	*Pongo pygmaeus*	Reha-Station	unknown background
Franky	7	0.5	*Pongo abelii*	Reha-Station	unknown background
Friend	5.5	3.5	*Pongo abelii*	Reha-Station	unknown background
Gagak	9.5	8.0	*Pongo pygmaeus*	Reha-Station	Reha-Station reared

Galih	10	7.0	*Pongo pygmaeus*	Reha-Station	Background with humans
Gambira	18	18.0	*Pongo pygmaeus*	Zoo	Mother reared
Gina	49	45.0	*Pongo abelii*	Zoo	Mother reared
Gober	25	5.0	*Pongo abelii*	Reha-Station	wild/ translocated
Harry	8.5	7.0	*Pongo pygmaeus*	Reha-Station	Reha-Station reared
Hulu	14	8.0	*Pongo pygmaeus*	Reha-Station	Background with humans
Imas	9.5	8.0	*Pongo pygmaeus*	Reha-Station	Background with humans
Inou	17	15.0	*Pongo pygmaeus*	Reha-Station	unknown background
Ito	6	6.0	*Pongo pygmaeus*	Zoo	Mother reared
Jack2	9	6.0	*Pongo pygmaeus*	Reha-Station	Background with humans
Jacky	5	1.0	*Pongo abelii*	Reha-Station	Background with humans
Janu	6	4.0	*Pongo pygmaeus*	Reha-Station	unknown background
Jarot	5	4.0	*Pongo abelii*	Reha-Station	Reha-Station reared
Jarwo	15	10.0	*Pongo pygmaeus*	Reha-Station	unknown background
Jaya	9	9.0	*Pongo abelii*	Zoo	Mother reared
Jill	8	7.0	*Pongo pygmaeus*	Reha-Station	Reha-Station reared
Jose	21	21.0	*Pongo pygmaeus*	Zoo	Mother reared
Julius	5	2.0	*Pongo abelii*	Reha-Station	Background with humans
Karan	10	8.0	*Pongo pygmaeus*	Reha-Station	unknown background
Karen	15	9.0	*Pongo pygmaeus*	Reha-Station	unknown background
Kasmin	10.5	9.0	*Pongo pygmaeus*	Reha-Station	Background with humans
Kevin	32	32.0	*Pongo pygmaeus*	Zoo	Human hand reared
Kibriah	36	36.0	*Pongo pygmaeus*	Zoo	Human hand reared
Kila	13	13.0	*Pongo abelii*	Zoo	Mother reared
King	17	10.0	*Pongo pygmaeus*	Reha-Station	unknown background
Kraba	12	10.0	*Pongo pygmaeus*	Reha-Station	unknown background
Lanang	11	10.0	*Pongo pygmaeus*	Reha-Station	Reha-Station reared
Mali	20	20.0	*Pongo pygmaeus*	Zoo	Mother reared
Mandi	14	14.0	*Pongo pygmaeus*	Zoo	Human hand reared
Mawoto	17	13.0	*Pongo pygmaeus*	Reha-Station	unknown background
Maya	5	5.0	*Pongo abelii*	Zoo	Mother reared
MercedeS	12	10.0	*Pongo pygmaeus*	Reha-Station	unknown background
Natalia	18	0.0	*Pongo abelii*	Reha-Station	wild/ translocated
Natalie	11	9.0	*Pongo pygmaeus*	Reha-Station	unknown background

Niken	16	14.0	*Pongo pygmaeus*	Reha-Station	unknown background
Nonja	36	36.0	*Pongo pygmaeus*	Zoo	Human hand reared
Oracle	8.5	7.0	*Pongo pygmaeus*	Reha-Station	Reha-Station reared
Otong	13	11.0	*Pongo pygmaeus*	Reha-Station	unknown background
Padana	16	16.0	*Pongo abelii*	Zoo	Mother reared
Pilar	11	9.0	*Pongo pygmaeus*	Reha-Station	Background with humans
Pini	25	25.0	*Pongo abelii*	Zoo	Mother reared
Pongo	15	15.0	*Pongo pygmaeus*	Zoo	Mother reared
Radja	52	51.0	*Pongo pygmaeus*	Zoo	Mother reared
Raja	13	13.0	*Pongo abelii*	Zoo	Mother reared
Ramon	18	18.0	*Pongo pygmaeus*	Zoo	Human hand reared
Roma	17	13.0	*Pongo pygmaeus*	Reha-Station	unknown background
Rowland	10	8.0	*Pongo pygmaeus*	Reha-Station	unknown background
Runtu	13	8.0	*Pongo pygmaeus*	Reha-Station	Background with humans
Sabin	9.5	9.0	*Pongo pygmaeus*	Reha-Station	Reha-Station reared
Sandakan	32	32.0	*Pongo pygmaeus*	Zoo	Mother reared
Sari	43	43.0	*Pongo pygmaeus*	Zoo	Human hand reared
Sarimin	11	9.0	*Pongo pygmaeus*	Reha-Station	unknown background
Silvia	49	48.0	*Pongo pygmaeus*	Zoo	Mother reared
Sony	16	12.0	*Pongo pygmaeus*	Reha-Station	unknown background
Suaq	5	5.0	*Pongo abelii*	Zoo	Mother reared
Sule	7	4.0	*Pongo pygmaeus*	Reha-Station	unknown background
Summer	13	13.0	*Pongo pygmaeus*	Zoo	Mother reared
Suri	5	3.0	*Pongo abelii*	Reha-Station	Background with humans
Tanah	5	5.0	*Pongo abelii*	Zoo	Mother reared
Tao	8	8.0	*Pongo abelii*	Zoo	Mother reared
Temmy	31	31.0	*Pongo pygmaeus*	Zoo	Human hand reared
Toba	18	18.0	*Pongo abelii*	Zoo	Mother reared
Trio	16	13.0	*Pongo pygmaeus*	Reha-Station	unknown background
Ulin	14	11.0	*Pongo pygmaeus*	Reha-Station	unknown background
Vendel	13	13.0	*Pongo abelii*	Zoo	Mother reared
Victor	10.5	9.0	*Pongo pygmaeus*	Reha-Station	Background with humans
Victoria	31	31.0	*Pongo pygmaeus*	Zoo	Human hand reared
Walter	23	23.0	*Pongo abelii*	Zoo	Mother reared

Wattana	18	18.0	*Pongo pygmaeus*	Zoo	Human hand reared
Willy	6	3.0	*Pongo abelii*	Reha-Station	Background with humans
Winda	12	7.0	*Pongo pygmaeus*	Reha-Station	wild/ translocated
Yogi	8	8.0	*Pongo pygmaeus*	Reha-Station	Reha-Station reared
Zatarra	10	8.0	*Pongo pygmaeus*	Reha-Station	unknown background

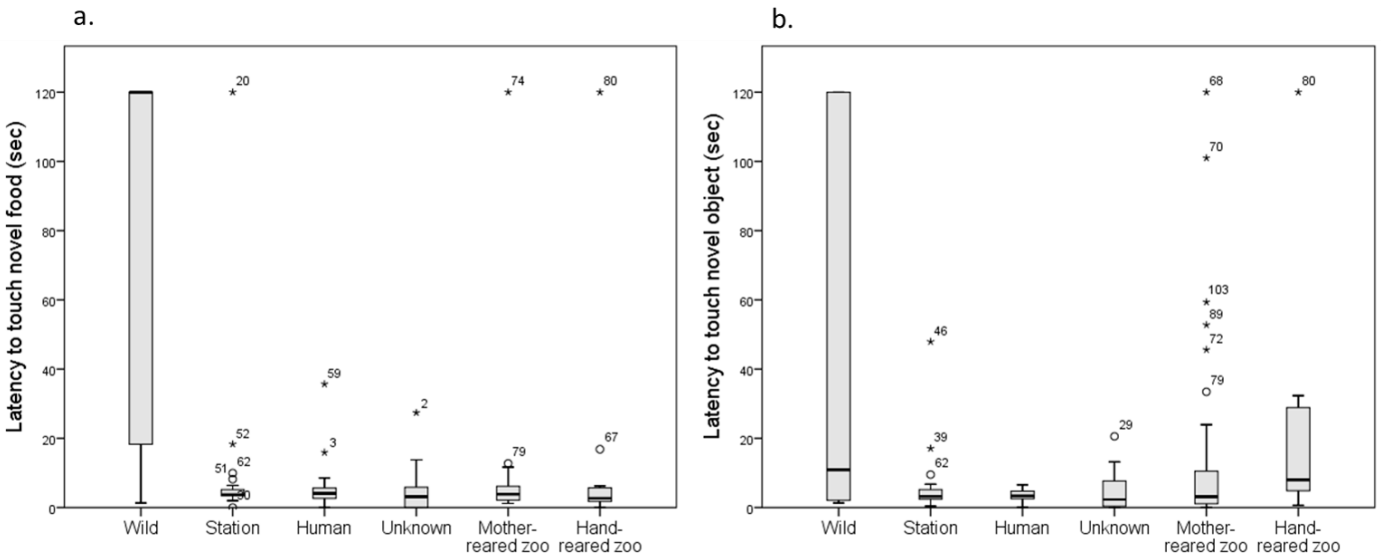

Figure S1: Novelty response across individuals of different background categories. (**a**) Latency to touch novel food and (**b**) Latency to touch a novel object.