Supplementary Information

Early maternal loss affects social integration of chimpanzees throughout their lifetime

Elfriede Kalcher-Sommersguter, Signe Preuschoft, Cornelia Franz-Schaider, Charlotte K. Hemelrijk, Karl Crailsheim & Jorg J. M. Massen

Supplementary Table 1. Biographic information on the subjects

Name	Sex	Est. Age at Onset of Deprivation	Years Spent Single Housed	Age at Onset of Observation	Deprivation Class
ALL–MALE GROUP (EX–LAB)					
Gogo	M	2	27	29	ELD
Max	M	1	24	25	ELD
Isidor	M	1	24	25	ELD
Johannes	M	1	21	22	ELD
Michi	M	1	21	22	ELD
Blacky	M	1	17	18	ELD
Jakob	M	3	16	20	LLD
MIXED–SEX GROUP 1 (EX–LAB)					
Clyde	M	4	16	21	LLD
Pünktchen	F	3	16	20	LLD
Martha	F	1	24	25	ELD
Ingrid	F	1	23	24	ELD
Gabi	F	1	23	24	ELD
MIXED–SEX GROUP 2 (EX–LAB)					
Moritz	M	3	16	20	LLD
Anton	M	4	16	21	LLD
Schuscha	F	4	15	21	LLD
Helene	F	4	15	21	LLD
Bonnie	F	4	15	21	LLD
Susi	F	2	27	29	ELD
ARNHEM GROUP (ZOO)					
Fons	M	-	-	35	ND
Gaby	F	-	-	26	ND
Giambo	M	-	-	21	ND
Geisha	F	-	-	17	ND
Mama	F	1	0	53	EMD
Moniek	F	-	-	33	ND
Morami	F	-	-	23	ND
Marka	F	-	-	26	ND
Tepel	F	5	0	51	LMD*
Teshua	F	-	-	24	ND
Tushi	F	-	-	18	ND
Jimmy	F	1	1[b]	50	EMD

Jing	M	-	-	29	ND
Roos[a]	F	-	-	31	ND
AMERSFOORT GROUP (ZOO)					
Mike	M	2	1[c]	45	EMD
Sonja	F	2	0	46	EMD
Belle	F	-	-	33	ND
Willy	F	-	-	19	ND
Sjors	F	1	0	44	EMD
Kokkie	F	2	0	44	EMD
Jet	F	3	3[b]	40	LMD*
Silvia	F	2	0	36	EMD
Sanne	F	-	-	21	ND
Bibi	F	-	-	14	ND
Chura	F	-	-	13	ND

Notes: Estimated age of maternally deprived zoo chimpanzees is based on Carlsen[44]. Tom de Jongh (EEP vice-coordinator) and Raymond van der Meer (curator Dierenpark Amersfoort) provided information regarding early rearing conditions of founder chimpanzees.
[a]adopted and reared by Mama, [b]Private Owner, [c]Circus; ELD = early and long-term deprived, LLD = late and long-term deprived, EMD = early maternally (and short-term) deprived, LMD = late maternally (and short-term) deprived, ND = non-deprived.
*Not considered in statistical analysis due to small sample size.

Supplementary Table 2. Medians (and range) of vertex strength centrality and deviation from edge weight disparity of close proximity and grooming given, respectively, for the different predictors

Dependent Variable	Predictor Sample Size, Median, Range								Mann-Whitney U w/ Holm-Bonferroni
CLOSE PROXIMITY									
Subsequent to Re-socialisation	**Age Class**								
	Mature				Old				
	VSC: *n*=33, 1.9, 0.2-7.4 DEWD: *n*=33, 0.08, 0.01-0.80				VSC: *n*=8, 3.3, 1.2-4.1 DEWD: *n*=8, 0.02, 0.01-0.11				
	Sex								
	Male				Female				
	VSC: *n*=14, 1.2, 0.2-4.7 DEWD: *n*=14, 0.13, 0.02-0.34				VSC: *n*=27, 3.8, 0.2-7.4 DEWD: *n*=27, 0.04, 0.01-0.80				VSC: ***U*=65.0, *P*=0.001**
	Deprivation Class								
	ELD		LLD		EMD		ND		
	VSC: *n*=10, 1.2, 0.2-1.6 DEWD: *n*=10, 0.20, 0.05-0.80		VSC: *n*=8, 1.5, 0.2-7.4 DEWD: *n*=8, 0.20, 0.07-0.31		VSC: *n*=7, 3.4, 1.2-4.1 DEWD: *n*=7, 0.02, 0.01-0.11		VSC: *n*=16, 4.1, 1.9-5.7 DEWD: *n*=16, 0.02, 0.01-0.10		VSC: **ELD vs. EMD: *U*=4.0, *P*=0.001, ELD vs. ND: *U*=0.0, *P*<0.001** DEWD: **ELD vs. EMD: *U*=3.0, *P*=0.001, ELD vs. ND: *U*=3.0, *P*<0.001, LLD vs. EMD: *U*=1.0, *P*=0.001, LLD vs. ND: *U*=1.0, *P*<0.001**
	Sex*Deprivation Class								
	Male				Female				
	ELD	LLD	EMD	ND	ELD	LLD	EMD	ND	
	VSC: *n*=6, 0.8, 0.4-1.5 DEWD: *n*=6, 0.18, 0.05-0.34	VSC: *n*=4, 1.0, 0.2-1.8 DEWD: *n*=4, 0.23, 0.07-0.31	VSC: *n*=1, 1.2 DEWD: *n*=1, 0.02	VSC: *n*=3, 3.1, 3.1-4.7 DEWD: *n*=3, 0.02, 0.02-0.02	VSC: *n*=4, 1.3, 0.2-1.6 DEWD: *n*=4, 0.26, 0.09-0.80	VSC: *n*=4, 5.2, 1.2-7.4 DEWD: *n*=4, 0.20, 0.17-0.31	VSC: *n*=6, 3.6, 2.5-4.1 DEWD: *n*=6, 0.03, 0.01-0.11	VSC: *n*=13, 4.1, 1.9-5.7 DEWD: *n*=13, 0.02, 0.01-0.10	VSC: **ELD_f vs. EMD_f: *U*=0.0, *P*=0.010, ELD_f vs. ND_f: *U*=0.0, *P*=0.001**

Supplementary Table 2 cont.

2nd Year of Group-life

Age Class							
Mature				Old			
VSC: n=33, 3.5, 0.0-5.9 DEWD: n=32, 0.09, 0.01-0.83				VSC: n=8, 3.3, 1.2-4.1 DEWD: n=8, 0.02, 0.01-0.11			
Sex							
Male				Female			
VSC: n=14, 1.8, 0.0-4.7 DEWD: n=13, 0.17, 0.02-0.83				VSC: n=27, 3.8, 0.2-5.9 DEWD: n=27, 0.04, 0.01-0.36			
Deprivation Class							
ELD		LLD		EMD		ND	
VSC: n=10, 0.3, 0.0-3.6 DEWD: n=9, 0.36, 0.10-0.83		VSC: n=8, 4.3, 0.1-5.9 DEWD: n=8, 0.15, 0.04-0.83		VSC: n=7, 3.4, 1.2-4.1 DEWD: n=7, 0.02, 0.01-0.11		VSC: n=16, 4.1, 1.9-5.7 DEWD: n=16, 0.02, 0.01-0.10	
Sex*Deprivation Class							
Male				Female			
ELD	LLD	EMD	ND	ELD	LLD	EMD	ND
VSC: n=6, 0.7, 0.0-3.6 DEWD: n=5, 0.83, 0.33-0.83	VSC: n=4, 2.4, 0.1-4.6 DEWD: n=4, 0.16, 0.04-0.83	VSC: n=1, 1.2 DEWD: n=1, 0.02	VSC: n=3, 3.1,3.1-4.7 DEWD: n=3, 0.02, 0.02-0.02	VSC: n=4, 0.3, 0.2-0.6 DEWD: n=4, 0.21, 0.10-0.36	VSC: n=4, 4.8, 0.3-5.9 DEWD: n=4, 0.13, 0.09-0.32	VSC: n=6, 3.6, 2.5-4.1 DEWD: n=6, 0.03, 0.01-0.11:	VSC: n=13, 4.1,1.9-5.7 DEWD: n=13, 0.02, 0.01-0.10

Supplementary Table 2 cont.

Dependent Variable	Predictor Sample Size, Median, Range								Mann-Whitney U w/ Holm-Bonferroni
GROOMING GIVEN									
----Subsequent to Re-socialisation----	**Age Class**								
	Mature				Old				
	VSC: *n*=33, 0.5, 0.0-4.4 DEWD: *n*=23, 0.18, 0.05-0.83				VSC: *n*=8, 0.2, 0.1-0.6 DEWD: *n*=8, 0.35, 0.08-0.90				
	Sex								
	Male				Female				
	VSC: *n*=14, 0.1, 0.0-1.1 DEWD: *n*=8, 0.75, 0.10-0.90				VSC: *n*=27, 0.6, 0.0-4.4 DEWD: *n*=23, 0.18, 0.05-0.90				DEWD: *U*=50.5, *P*=0.064
	Deprivation Class								
	ELD		LLD		EMD		ND		
	VSC: *n*=10, 0.0, 0.0-0.1 DEWD: *n*=2, 0.83, 0.83-0.84		VSC: *n*=8, 0.7, 0.0-4.4 DEWD: *n*=6, 0.34, 0.23-0.80		VSC: *n*=7, 0.1, 0.1-0.6 DEWD: *n*=7, 0.40, 0.08-0.90		VSC: *n*=16, 1.1, 0.1-1.5 DEWD: *n*=16, 0.13, 0.05-0.35		VSC: **ELD vs. LLD: *U*=12.0, *P*=0.014, ELD vs. EMD: *U*=4.0, *P*=0.003, ELD vs. ND: *U*=1.0, *P*<0.001, EMD vs. ND: *U*=8.5, *P*=0.002** DEWD: **ELD vs. ND: *U*=0.0, *P*=0.013, ELD vs. ND: *U*=6.0, *P*=0.001, EMD vs. ND: *U*=18.0, *P*=0.010**
	Sex*Deprivation Class								
	Male				Female				
	ELD	LLD	EMD	ND	ELD	LLD	EMD	ND	
	VSC: *n*=6, 0.0, 0.0-0.1 DEWD: *n*=6, 0.83, 0.83-0.84	VSC: *n*=4, 0.3, 0.0-1.1 DEWD: *n*=4, 0.75, 0.69-0.80	VSC: *n*=1, 0.1 DEWD: *n*=1, 0.90	VSC: *n*=3, 0.7, 0.6-1.1 DEWD: *n*=3, 0.11, 0.10-0.19	VSC: *n*=4, 0.0, 0.0-0.0 DEWD: *n*=0	VSC: *n*=4, 1.5, 0.4-4.4 DEWD: *n*=4, 0.31, 0.23-0.35	VSC: *n*=6, 0.2, 0.1-0.6 DEWD: *n*=6, 0.35, 0.08-0.90	VSC: *n*=13, 1.1, 0.1-1.5 DEWD: *n*=13, 0.14, 0.05-0.35	DEWD: LLD_f vs. ND_f: *U*=6.0, *P*=0.023, EMD_f vs. ND_f: *U*=15.0, *P*=0.037

Supplementary Table 2 cont.

2nd Year of Group-life	**Age Class**							
	Mature				Old			
	VSC: *n*=33, 0.7, 0.0-2.9 DEWD: *n*=24, 0.17, 0.05-0.83				VSC: *n*=8, 0.2, 0.1-0.6 DEWD: *n*=8, 0.35, 0.08-0.90			
	Sex							
	Male				Female			DEWD: ***U*=55.5, *P*=0.047**
	VSC: *n*=14, 0.3, 0.0-1.6 DEWD: *n*=9, 0.35, 0.10-0.90				VSC: *n*=27, 0.7, 0.0-2.9 DEWD: *n*=23, 0.17, 0.05-0.90			
	Deprivation Class							
	ELD		LLD		EMD		ND	†
	VSC: *n*=10, 0.0, 0.0-0.6 DEWD: *n*=2, 0.59, 0.35-0.83		VSC: *n*=8, 0.8, 0.0-2.9 DEWD: *n*=7, 0.28, 0.06-0.83		VSC: *n*=7, 0.1, 0.1-0.6 DEWD: *n*=7, 0.40, 0.08-0.90		VSC: *n*=16, 1.1, 0.1-1.5 DEWD: *n*=16, 0.13, 0.05-0.35	VSC: **ELD vs. LLD: *U*=8.0, *P*=0.005, ELD vs. ND: *U*=6.5, *P*<0.001**
	Sex*Deprivation Class							
	Male				Female			
	ELD	LLD	EMD	ND	ELD	LLD	EMD	ND
	VSC: *n*=6, 0.0, 0.0-0.6 DEWD: *n*=2, 0.59, 0.35-0.83	VSC: *n*=4, 0.5, 0.0-1.6 DEWD: *n*=3, 0.63, 0.28-0.83	VSC: *n*=1, 0.1 DEWD: *n*=1, 0.90	VSC: *n*=3, 0.7, 0.6-1.1 DEWD: *n*=3, 0.11, 0.10-0.19	VSC: *n*=4, 0.0, 0.0-0.0 DEWD: *n*=0	VSC: *n*=4, 1.2, 0.8-2.9 DEWD: *n*=4, 0.17, 0.06-0.52	VSC: *n*=6, 0.2, 0.1-0.6 DEWD: *n*=6, 0.40, 0.08-0.90	VSC: *n*=13, 1.1, 0.1-1.5 DEWD: *n*=13, 0.14, 0.05-0.35

Abbr.: ELD = early and long-term deprived, LLD = late and long-term deprived, EMD = early maternally (and short-term) deprived, ND = non-deprived, VSC = vertex strength centrality, DEWD = deviation from edge weight disparity.
Significant outcomes of post-hoc Mann-Whitney U tests after Holm-Bonferroni correction are shown in bold.
† Note that values for the zoo chimpanzees did not change and thus for comparisons between EMD and ND we refer to the earlier analyses (subsequent to re-socialisation) above.

Supplementary Table 3. Medians (and range) of vertex strength centrality and deviation from edge weight disparity of grooming given for *mature* early maternally deprived (EMD_M), *old* early maternally deprived (EMD_O) and non-deprived (ND) chimpanzees in comparison

Dependent Variable	Predictor Sample Size, Median, Range		Mann-Whitney U w/ Holm-Bonferroni
GROOMING GIVEN			
	Age Class		
EMD_M*	EMD_O	ND	
VSC: *n*=7, 0.1, 0.0-0.5 DEWD: *n*=7, 0.33, 0.12-0.50	VSC: *n*=7, 0.1, 0.1-0.6 DEWD: *n*=7, 0.40, 0.08-0.90	VSC: *n*=16, 1.1, 0.1-1.5 DEWD: *n*=16, 0.13, 0.05-0.35	VSC: EMD_M vs. EMD_o: *U* = 22.0, *P*=0.805, **EMD_M vs. ND: *U*=7.0, *P*<0.001,** **EMD_O vs. ND: *U*=8.5, *P*=0.002** DEWD: EMD_M vs. EMD_o: *U* = 17.0, *P*=0.383, **EMD_M vs. ND: *U*=17.0, *P*=0.008,** **EMD_O vs. ND: *U*=18.0, *P*=0.010**

Note: *EMD_M comprises seven adult females (for details see Table below) from Arnhem zoo. Vertex strength centrality and deviation from edge weight disparity were calculated out of individual medians for every groomer-groomee dyad over a 10-year period (1976-1985). Charlotte Hemelrijk provided scan data.

Name	Est. Age at Onset of Deprivation[1]	Age in 1976[3]	Observation period	Number of Available Adult Grooming Partners 1976-1985
Mama	1	20	1976-1985	7-15
Puist	?	16	1976-1985	7-15
Gorilla	2[2]	19	1976-1985	7-15
Jimmy	1	16	1976-1985	7-15
Franje	2[2]	19	1976-1979	7-9
Krom	1	15	1976-1984	7-14
Spin	?	16	1976-1985	7-15

[1]Carlsen, F. European studbook for the chimpanzee *Pan troglodytes* (Copenhagen Zoo, 2009).
[2]Based on information and a picture provided by Tom de Jongh (EEP vice-coordinator).
[3]Adang, O. M. J., Wensing, J. A. B. & van Hooff, J. A. R. A. M. The Arnhem Zoo colony of chimpanzees *Pan troglodytes*: development and management techniques. *Int. Zoo Yb*. **26**, 236-248 (1987).

Supplementary Table 4. Model selection according to comparisons of the corrected Akaike Information Criteria (cAICs)

	Dependent Variable	Model	F	P	cAIC	Δ cAIC
CLOSE PROXIMITY a) subsequent to re-socialisation for ex-laboratory chimpanzees	Vertex strength centrality	**Full Model**	**4.514**	**0.001**	**112.444**	
		Full Model - Age class	5.176	0.000	115.144	-2.700
	Deviation from edge weight disparity	Full Model	3.662	0.004	-32.485	
		Reduction 1: Full Model - Age class	4.040	0.003	-34.629	2.144
		Reduction 2: Reduction 1 - Sex*Deprivation class	9.689	0.000	-40.034	5.405
		Reduction 3: Reduction 2 - Sex	**12.073**	**0.000**	**-42.859**	**2.825**
CLOSE PROXIMITY b) 2nd of group-life for ex-laboratory chimpanzees	Vertex strength centrality	Full Model	1.666	n.s.		
	Deviation from edge weight disparity	Full Model	0.807	n.s.		
GROOMING GIVEN a) subsequent to re-socialisation for ex-laboratory chimpanzees	Vertex strength centrality	**Full Model**	**3.408**	**0.006**	**76.720**	
		Full Model - Age class	3.956	0.003	78.114	-1.394
		Full Model - Sex	3.408	0.006	76.720	0.000
		Full Model - Sex*Deprivation class	3.328	0.015	87.614	-10.894
	Deviation from edge weight disparity	Full Model	8.623	0.000	-9.405	
		Full Model - Age class	**10.365**	**0.000**	**-10.972**	**1.567**
GROOMING GIVEN b) 2nd of group-life for ex-laboratory chimpanzees	Vertex strength centrality	**Full Model**	**3.758**	**0.003**	**57.115**	
		Full Model - Age class	4.338	0.002	57.998	-0.883
		Full Model - Sex	3.758	0.003	57.115	-0.000
		Full Model - Sex*Deprivation class	4.473	0.003	64.130	-7.015
	Deviation from edge weight disparity	Full Model	3.484	0.100	0.863	
		Reduction 1: Full Model - Age class	**4.213**	**0.005**	**-0.368**	**1.231**
		Reduction 2: Reduction 1 - Sex*Deprivation class	4.618	0.006	1.417	-1.785

Bold: Best-fitting models according to comparisons of cAICs; if Δ cAIC > 2, we chose the new model (Burnham and Anderson 2002), and if 0 < Δ cAIC < 2, we chose the most parsimonious model.

Supplemental references:

Burnham, K. P. & Anderson, D. R. *Model selection and multimodel inference: a practical information-theoretic approach* (Springer, 2002).