

Supplementary Materials for

Locomotor play drives motor skill acquisition at the expense of growth: A life history trade-off

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Supplementary Materials

Supplementary figures

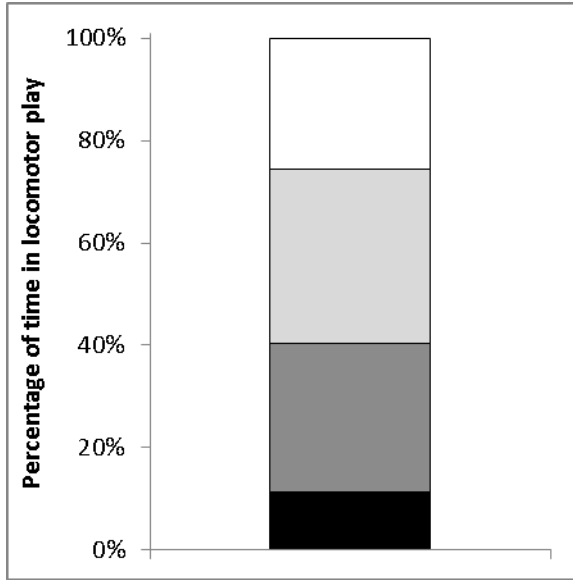


Fig. S1: Percentage of time in locomotor play at different tree heights. Black: on ground, dark grey: 0-5m, light grey: 5-10m, white: >10m

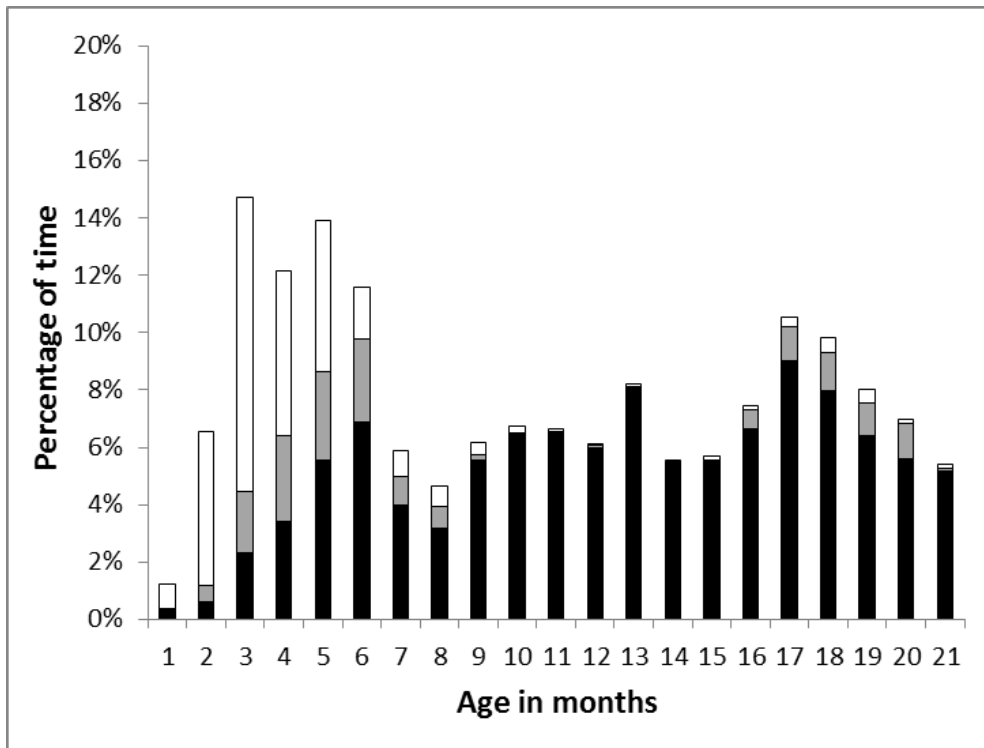


Fig. S2: Percentage of different play patterns at different ages. Black: rough & tumble social locomotor play (i.e. chasing, wrestling, fighting), grey: other social locomotor play (like sexual play or the clumsy interactions at the advent of social play), white: solitary locomotor play

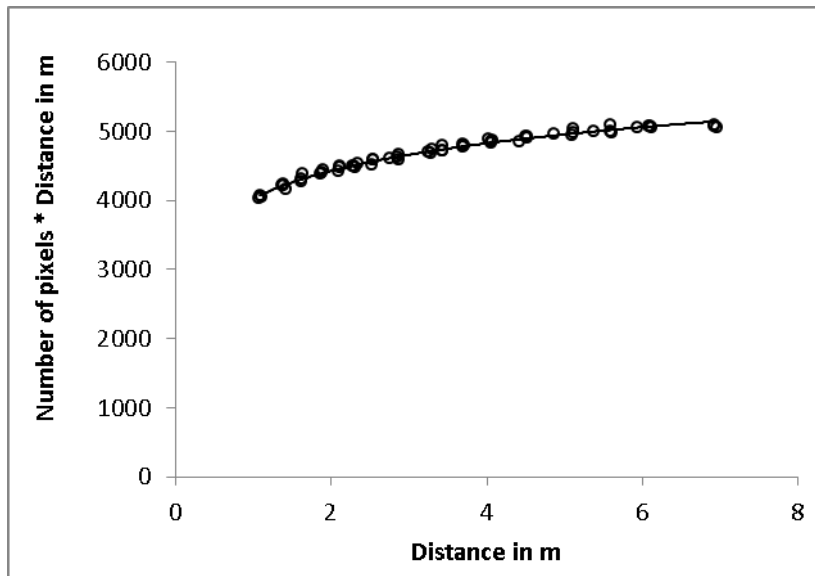


Fig. S3: Validation of photogrammetric measurement. 59 pictures and distance records of a sharp-edged object of known size (165.0mm) were taken from 1-7m distance. The relationship between distance and the product of the number of pixels in the picture and the distance should be a constant, but we found a systematic logarithmic deviation (see figure, $R^2 = 0.987$), probably due to changes in relative lens positions caused by autofocus. Correction of the calculated values for this relationship and transformation into relevant measures resulted in a constant value (Mean \pm SD: 165.00 \pm 1.35mm) and was thus applied to all values in the study.

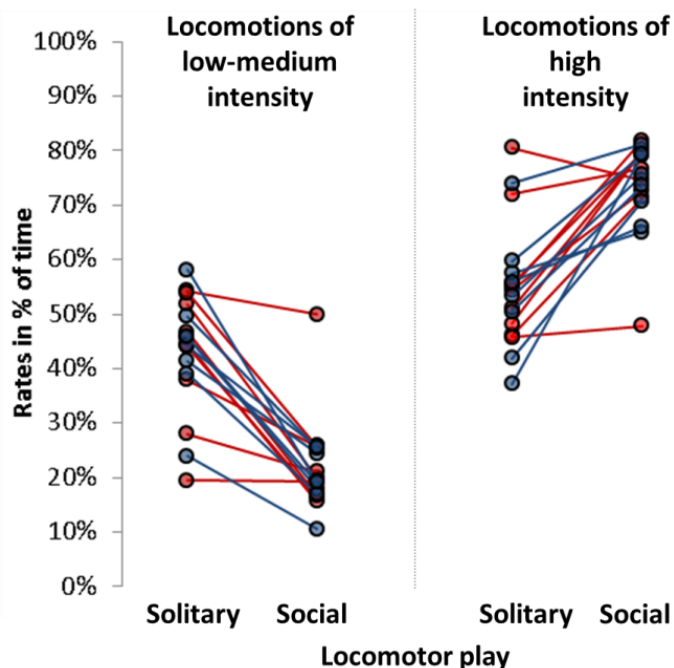


Fig. S4: Differences between solitary and social locomotor play in locomotion intensity. Rates of locomotions of low and medium intensity (i.e. standing and walking) strongly decreased from solitary to social locomotor play ($t = -8.12$, $p < 0.0001$), while rates of high intensive locomotions (i.e. running, climbing, jumping, hanging and pendulously travelling) strongly increased ($t = 6.13$, $p < 0.0001$, both pairwise two-sided t-tests). Blue: males, red: females.

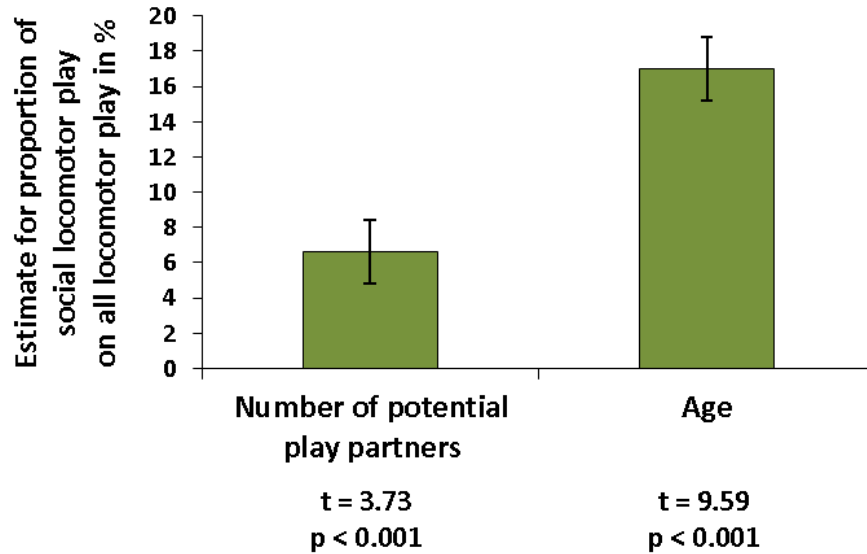


Fig. S5: The proportion of social on all locomotor play was positively related to age and the number of potential play partners around. In addition to age, the proportion of social on all locomotor play (i.e. intensity of locomotor play) was also predicted by the number of same-aged individuals, and thus potential play partners, in the group (GLMM with values from the first year of life and individuals as random factors; model significance: $p < 0.001$; Intercept: estimate 83.8 ± 1.6)

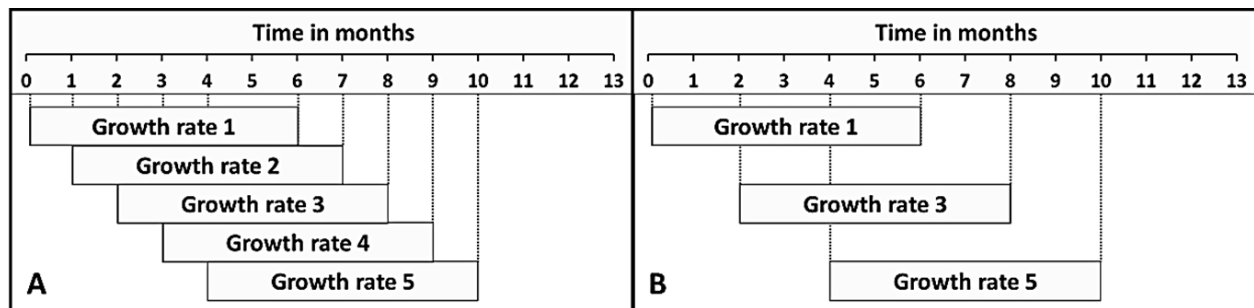


Fig. S6: Period overlap for monthly growth rate calculation. Growth rate indices were calculated for six-month periods. (A) Growth rate indices for consecutive months showed strong temporal overlap and were thus highly correlated to each other ($r = 0.586$, $p < 0.001$). (B) Growth rate indices calculated every other month did not show strong auto-correlation anymore ($r = 0.179$, $p = 0.104$) and were used in our analyses.

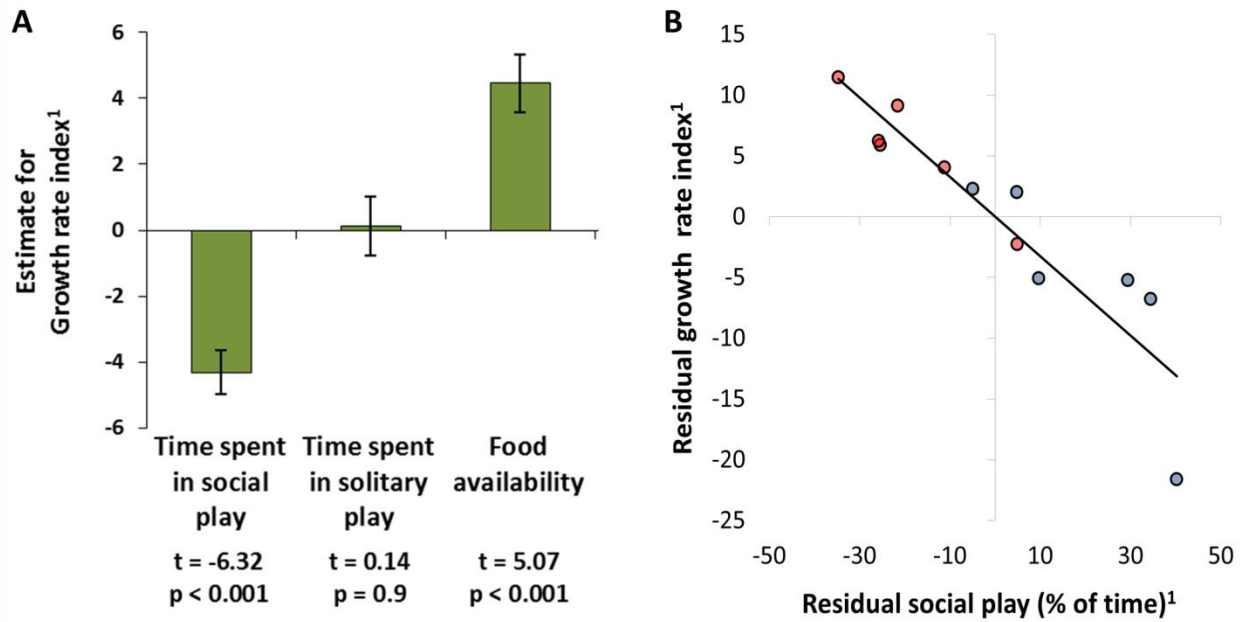


Fig. S7: Energy trade-off between social locomotor play and growth. Red: female, blue: male. ¹Residuals are translated into deviations from average in %. **(A)** Splitting locomotor play into social and solitary locomotor play, growth was traded-off against social but not solitary locomotor play (GLM, model significance $p < 0.001$ compared to null model, $R^2 = 0.845$, $N = 12$), **(B)** Growth rate over social locomotor play ($r = -0.916$, $p = 0.001$); additionally controlled for sex (no figure): $r = -0.835$, $p = 0.005$ (Residual plot of the individual values for the whole study period; Pearson partial correlation controlled for average food availability and lactation category; $N = 12$).

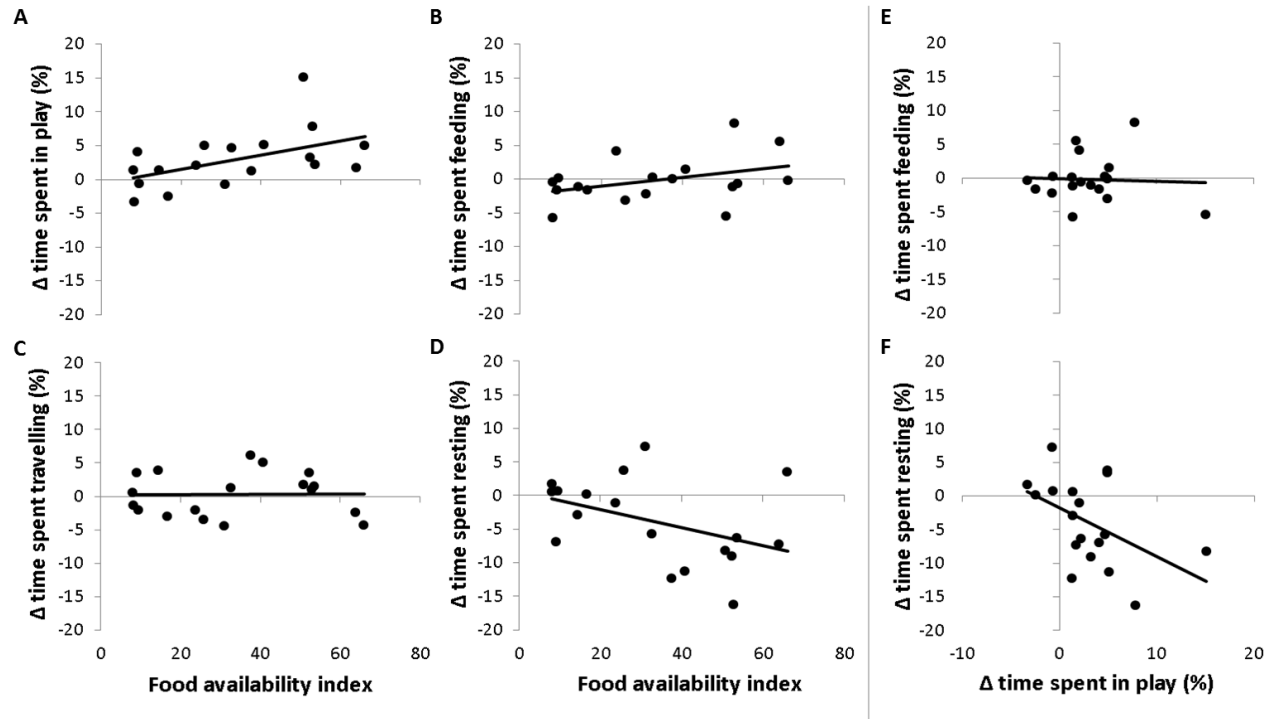


Fig. S8. Time budget analysis: Sex differences (Δ) in time spent in locomotor play were due to sex differences in resting time, not feeding time. Two-tailed Pearson correlations; $\Delta = \text{mean}_{\text{males}} - \text{mean}_{\text{females}}$ per month; $N = 18$. (A) Locomotor play over food availability ($r = 0.667$, $p = 0.003$), (B) feeding over food availability ($r = 0.372$, $p = 0.128$), (C) travelling over food availability ($r = -0.014$, $p = 0.957$), (D) resting over food availability ($r = -0.419$, $p = 0.083$), (E) feeding over locomotor play ($r = 0.101$, $p = 0.690$), (F) resting over locomotor play ($r = -0.753$, $p < 0.001$).

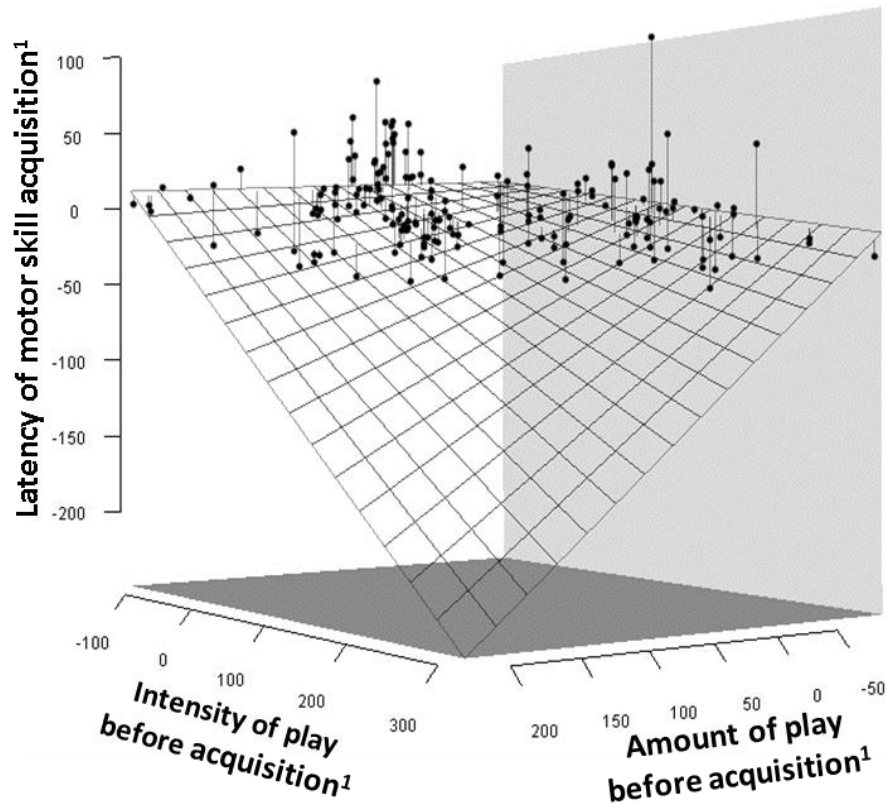


Fig. S9: Latencies of motor skill acquisition as a function of average intensity and time spent in locomotor play before acquisition. ¹Plotted are deviations from the respective motor skill specific averages in % (N = 184)

Supplementary tables

Table S1 provides a list of 18 motor skills scored for their first occurrence in an infant in this study. We calculated a sequence of occurrence by applying a method established for dominance hierarchy analyses (50). After constructing a matrix of all skills over all skills we entered for every combination how often (across infants) skill A was observed before skill B. The sequence of items in the matrix was reshuffled 10,000 times in order to identify the sequence with the highest linearity or maximal transitivity of relations between skills (Corrected Linearity index $h' = 0.998$ ($p < 0.001$), Directional Consistency Index (DCI) = 0.716). This sequence was used to control our analyses of determinants of skill acquisition latencies for auto-correlation effects between the latencies of sequential skills.

Acknowledging that the nature of a skill relates to the predictability of the interacting environment (45), we treated several motor patterns as two different skills depending on whether they occurred as closed skills (45) in a solitary locomotor play context or as open skills in the much more unpredictable social locomotor play context. Hanging on all extremities, one or two arms or one or two legs when involved in social locomotor play involved play partners that jump on, cling to or pull the subject and was typically performed on moving substrates (branches). These skills all developed in a social context long after they were observed in a solitary context (27.3 ± 2.6 days later (mean \pm SE), $t = 10.51$, $p < 0.0001$, pairwise two-sided t-test). * jumping from branch to branch

Table S1: List of the 18 motor skills used in this study.

Sequence	Motor skill	Average age of acquisition (Mean \pm SD)
1	Hanging on all extremities in solitary context	33.8 \pm 15
2	Hanging on two arms in solitary context	36.2 \pm 14.6
3	Jumping on ground	47.7 \pm 15.2
4	Hanging on one arm in solitary context	50.7 \pm 20.7
5	Jumping in tree	51.1 \pm 15.8
6	Running on ground	54.8 \pm 14.5
7	Hanging on two legs in solitary context	59.4 \pm 15.3
8	Running in tree	63.9 \pm 18.3
9	Hanging on all extremities in social play context	59.8 \pm 16.8
10	Jumping a distance of <1m in less than 5m height*	67.6 \pm 20.5
11	Hanging on two arms in social play context	62.2 \pm 15.7
12	Jumping a distance of <1m in more than 5m height*	67.7 \pm 13.3
13	Hanging on one leg in solitary context	71.6 \pm 27.3
14	Hanging on two legs in social play context	79.9 \pm 19.5
15	Hanging on one arm in social play context	77.8 \pm 21.7
16	Jumping a distance of 1-2m in less than 5m height*	105.6 \pm 28.7
17	Jumping a distance of 1-2m in more than 5m height*	116.8 \pm 27.5
18	Hanging on one leg in social play context	108.4 \pm 21.3

Table S2: Percentage of time spent in locomotor play (mean \pm SD) for each sex and age.

Age in months	All locomotor play:		Solitary locomotor play:		Social locomotor play:		Social rough&tumble play:	
	males	females	males	females	males	females	males	females
1	0.5 \pm 0.8	0.9 \pm 2.1	0.5 \pm 0.8	0.9 \pm 2.1	0.9 \pm 2.3	0.0 \pm 0.1	0.0 \pm 0.0	0.0 \pm 0.0
2	5.3 \pm 6.1	4.7 \pm 8.3	5.0 \pm 5.9	4.7 \pm 8.3	1.4 \pm 1.9	1.0 \pm 1.5	0.2 \pm 0.5	0.0 \pm 0.0
3	9.5 \pm 8.9	12.7 \pm 12.1	7.1 \pm 6.0	12.2 \pm 11.8	6.1 \pm 3.4	3.0 \pm 2.5	2.5 \pm 3.6	0.5 \pm 0.9
4	7.5 \pm 4.3	9.6 \pm 5.7	4.6 \pm 2.1	7.0 \pm 5.5	6.5 \pm 3.8	6.4 \pm 4.6	2.9 \pm 3.1	2.7 \pm 1.9
5	11.3 \pm 8.3	8.5 \pm 6.0	5.6 \pm 3.5	4.5 \pm 3.3	9.2 \pm 6	7.3 \pm 5	5.7 \pm 6.6	4.0 \pm 3.7
6	11.8 \pm 8.5	5.6 \pm 3.8	1.7 \pm 1.4	2.0 \pm 1.9	13.3 \pm 7.7	7.3 \pm 4.7	10.1 \pm 7.7	3.7 \pm 2.7
7	3.9 \pm 3.3	5.3 \pm 4.4	0.6 \pm 0.8	2.0 \pm 4.3	4.7 \pm 3.8	3.9 \pm 3.2	3.3 \pm 2.8	3.2 \pm 2.9
8	1.8 \pm 2.3	4.5 \pm 3.1	0.2 \pm 0.2	1.0 \pm 1.0	1.6 \pm 2.2	4.6 \pm 3.7	1.6 \pm 2.2	3.5 \pm 2.7
9	5.5 \pm 5.2	5.6 \pm 6.7	0.2 \pm 0.3	1.4 \pm 2.0	5.7 \pm 5.2	4.6 \pm 5.9	5.3 \pm 5.3	4.2 \pm 5.2
10	8.1 \pm 2.3	5.4 \pm 2.0	0.4 \pm 0.6	0.2 \pm 0.5	7.7 \pm 2.1	5.2 \pm 2.2	7.7 \pm 2.1	5.2 \pm 2.1
11	9.2 \pm 3.0	3.9 \pm 2.2	0.1 \pm 0.1	0.2 \pm 0.2	9.3 \pm 3.1	3.8 \pm 2.2	9.2 \pm 3.1	3.7 \pm 2.1
12	5.8 \pm 2.6	6.4 \pm 3.2	0.0 \pm 0.1	0.0 \pm 0.1	6.0 \pm 2.7	6.4 \pm 3.2	5.8 \pm 2.6	6.3 \pm 3.2
13	11.7 \pm 8.1	3.9 \pm 1.1	0.1 \pm 0.3	0.0 \pm 0.0	11.7 \pm 7.9	3.9 \pm 1.2	11.6 \pm 7.9	3.9 \pm 1.1
14	8.4 \pm 7.6	3.8 \pm 2.5	0.0 \pm 0.0	0.0 \pm 0.1	8.5 \pm 7.7	3.8 \pm 2.5	8.4 \pm 7.6	3.8 \pm 2.5
15	8.2 \pm 5.5	2.4 \pm 3.2	0.3 \pm 0.4	0.0 \pm 0.0	8.0 \pm 5.5	2.6 \pm 3.2	7.9 \pm 5.5	2.4 \pm 3.2
16	9.8 \pm 3.6	5.5 \pm 3.7	0.0 \pm 0.0	0.2 \pm 0.2	10.7 \pm 4.4	5.7 \pm 3.7	9.8 \pm 3.6	5.2 \pm 3.5
17	11.6 \pm 4.3	6.8 \pm 2.3	0.3 \pm 0.5	0.3 \pm 0.4	12.7 \pm 5.8	7.2 \pm 3.2	11.2 \pm 3.9	6.4 \pm 2.0
18	12.6 \pm 8.5	5.1 \pm 3.0	0.6 \pm 0.7	0.4 \pm 0.5	13.9 \pm 8.7	5.3 \pm 3.4	12.0 \pm 7.9	4.7 \pm 2.7
19	7.7 \pm 5.3	5.2 \pm 3.4	0.3 \pm 0.4	0.4 \pm 0.5	8.3 \pm 5.6	5.7 \pm 3.5	7.4 \pm 5.2	4.7 \pm 3.5
20	10.2 \pm 7.9	3.4 \pm 1.1	0.1 \pm 0.3	0.1 \pm 0.2	11.6 \pm 9.5	4.1 \pm 2	10.0 \pm 8.0	3.3 \pm 1.1