S1 Text. Statistical Analysis.

This file contains Tables A-G listing mean values and correlation coefficients of evaluated quantities, as well as the results of our Mann-Whitney-U Tests.

**Table A.** Mean 〈…〉 and SEM values of the evolved fitness EF, reliability across group sizes in the original setup R, and brain complexity ΦMax of the final evolved animats grouped by conditions. Roman numbers indicated the rank of the corresponding mean through all conditions. The results of brain complexity calculations for Gbigbrain are not available (NA) due to the computational complexity of the calculations.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | | SEM |  | SEM |  | SEM |
| 0.50 | (VIII) 3.1267 | 0.0727 | | (III) 2.9315 | 0.0845 | (III) 2.4921 | 0.2673 |
| random | (VI) 3.3051 | 0.0492 | | (II) 3.0257 | 0.0491 | (II) 2.6472 | 0.4319 |
| 1.00 | 2.4271 | 0.0822 | | (VIII) 2.3580 | 0.1415 | (VII) 1.8157 | 0.2595 |
| 0.75 | 2.6732 | 0.0891 | | (VII) 2.6239 | 0.1039 | (VI) 1.9209 | 0.3467 |
| 0.25 | (V) 3.3099 | 0.1188 | | (VI) 2.7311 | 0.0945 | (V) 2.1980 | 0.3278 |
| single | (II) 3.7356 | 0.0588 | | -2.2667 | 0.6666 | (X) 1.2476 | 0.1697 |
| bigbrain | (VII) 3.1847 | 0.1017 | | (IV) 2.7725 | 0.1047 | NA | NA |
| smallbrain | (X) 2.7296 | 0.0617 | | (IX) 2.3343 | 0.0809 | (IX) 1.1600 | 0.1906 |
| no-feedback | 1.9696 | 0.1131 | | (X) 1.7839 | 0.1165 | 0.3389 | 0.0824 |
| no-agent | 0.1788 | 0.1474 | | 0.3168 | 0.1865 | (VIII) 1.5529 | 0.3064 |
| 3sides | (III) 3.6092 | 0.1281 | | (I) 3.3808 | 0.1227 | 0.2483 | 0.0960 |
| w=a | 0.1793 | 0.0881 | | 0.2632 | 0.0868 | 0.6721 | 0.1025 |
| no-penalty | (I) 3.7867 | 0.0447 | | -2.8575 | 0.2115 | 0.9356 | 0.1348 |
| blocked/no-penalty | (IV) 3.3367 | 0.0532 | | 0.5958 | 0.2988 | (IV) 2.2055 | 0.2271 |
| blocked | (IX) 3.0994 | 0.0924 | | (V) 2.7442 | 0.0806 | (I) 3.0634 | 0.5598 |

**Table B**. The *p-values* of the Mann-Whitney-U Tests for the average mean of the evolved fitness score 〈EF〉 per condition. The p-value for the preceded Kruskal-Wallis-Test is 0.000.

| ***/*** | ***0.50*** | ***random*** | ***1.00*** | ***0.75*** | ***0.25*** | ***Single*** | ***bigbrain*** | ***smallbrain*** | ***no-feedback*** | ***no-agent*** | ***3sides*** | ***w=a*** | ***no-penalty*** | ***blocked/***  ***no-penalty*** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***random*** | 0.017 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ***1.00*** | 0.000 | 0.000 |  |  |  |  |  |  |  |  |  |  |  |  |
| ***0.75*** | 0.000 | 0.000 | 0.000 |  |  |  |  |  |  |  |  |  |  |  |
| ***0.25*** | 0.000 | 0.012 | 0.000 | 0.000 |  |  |  |  |  |  |  |  |  |  |
| ***single*** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |  |  |  |  |  |  |  |  |  |
| ***bigbrain*** | 0.453 | 0.204 | 0.000 | 0.000 | 0.071 | 0.000 |  |  |  |  |  |  |  |  |
| ***smallbrain*** | 0.000 | 0.000 | 0.009 | 0.334 | 0.000 | 0.000 | 0.001 |  |  |  |  |  |  |  |
| ***no-feedback*** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |  |  |  |  |  |  |
| ***no-agent*** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |  |  |  |  |  |
| ***3sides*** | 0.000 | 0.001 | 0.000 | 0.000 | 0.007 | 0.087 | 0.001 | 0.000 | 0.000 | 0.000 |  |  |  |  |
| ***w=a*** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.112 | 0.000 |  |  |  |
| ***no-penalty*** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.344 | 0.000 | 0.000 | 0.000 | 0.000 | 0.017 | 0.000 |  |  |
| ***blocked/no-penalty*** | 0.004 | 0.208 | 0.000 | 0.000 | 0.068 | 0.000 | 0.098 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |  |
| ***blocked*** | 0.435 | 0.048 | 0.000 | 0.000 | 0.001 | 0.000 | 0.372 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.012 |

**Table C**. The *p-values* of the Mann-Whitney-U Tests for the average brain complexity 〈ΦMax〉 per evolutionary setup. The results of brain complexity calculations for Gbigbrain are not available (NA) due to the computational complexity of the calculations. The p-value for the preceded Kruskal-Wallis-Test is 0.000.

| ***/*** | ***0.50*** | ***random*** | ***1.00*** | ***0.75*** | ***0.25*** | ***single*** | ***bigbrain*** | ***smallbrain*** | ***no-feedback*** | ***no-agent*** | ***3sides*** | ***w=a*** | ***no-penalty*** | ***blocked/***  ***no-penalty*** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***random*** | 0.409 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ***1.00*** | 0.037 | 0.099 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ***0.75*** | 0.023 | 0.041 | 0.370 |  |  |  |  |  |  |  |  |  |  |  |  |
| ***0.25*** | 0.111 | 0.162 | 0.289 | 0.177 |  |  |  |  |  |  |  |  |  |  |  |
| ***single*** | 0.000 | 0.000 | 0.062 | 0.177 | 0.010 |  |  |  |  |  |  |  |  |  |  |
| ***bigbrain*** | NA | NA | NA | NA | NA | NA |  |  |  |  |  |  |  |  |  |
| ***smallbrain*** | 0.000 | 0.002 | 0.080 | 0.191 | 0.029 | 0.496 | NA |  |  |  |  |  |  |  |  |
| ***no-feedback*** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | NA | 0.000 |  |  |  |  |  |  |  |
| ***no-agent*** | 0.002 | 0.007 | 0.124 | 0.259 | 0.049 | 0.389 | NA | 0.421 | 0.000 |  |  |  |  |  |  |
| ***3sides*** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | NA | 0.000 | 0.092 | 0.000 |  |  |  |  |  |
| ***w=a*** | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 | NA | 0.008 | 0.009 | 0.008 | 0.000 |  |  |  |  |
| ***no-penalty*** | 0.000 | 0.000 | 0.008 | 0.023 | 0.001 | 0.105 | NA | 0.154 | 0.000 | 0.138 | 0.000 | 0.057 |  |  |  |
| ***blocked/no-penalty*** | 0.196 | 0.375 | 0.134 | 0.063 | 0.331 | 0.001 | NA | 0.003 | 0.000 | 0.011 | 0.000 | 0.000 | 0.000 |  |  |
| ***blocked*** | 0.395 | 0.494 | 0.079 | 0.026 | 0.145 | 0.000 | NA | 0.002 | 0.000 | 0.006 | 0.000 | 0.000 | 0.000 | 0.337 |  |

**Table D.** The *p-values* of the Mann-Whitney-U Tests for the average number of concepts in the set of elements with ΦMax, according to IIT, per evolutionary setup. The results of brain complexity calculations for Gbigbrain are not available (NA) due to the computational complexity of the calculations. The p-value for the preceded Kruskal-Wallis-Test is 0.000.

| / | 0.50 | random | 1.00 | 0.75 | 0.25 | single | bigbrain | smallbrain | no-feedback | no-agent | 3sides | w=a | no-penalty | blocked/  no-penalty |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| random | 0.372 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1.00 | 0.246 | 0.381 |  |  |  |  |  |  |  |  |  |  |  |  |
| 0.75 | 0.070 | 0.120 | 0.272 |  |  |  |  |  |  |  |  |  |  |  |
| 0.25 | 0.265 | 0.339 | 0.465 | 0.239 |  |  |  |  |  |  |  |  |  |  |
| single | 0.007 | 0.014 | 0.083 | 0.221 | 0.051 |  |  |  |  |  |  |  |  |  |
| bigbrain | NA | NA | NA | NA | NA | NA |  |  |  |  |  |  |  |  |
| smallbrain | 0.000 | 0.000 | 0.010 | 0.019 | 0.002 | 0.044 | NA |  |  |  |  |  |  |  |
| no-feedback | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | NA | 0.000 |  |  |  |  |  |  |
| no-agent | 0.004 | 0.007 | 0.040 | 0.116 | 0.022 | 0.249 | NA | 0.187 | 0.000 |  |  |  |  |  |
| 3sides | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | NA | 0.000 | 0.059 | 0.000 |  |  |  |  |
| w=a | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | NA | 0.044 | 0.001 | 0.019 | 0.000 |  |  |  |
| no-penalty | 0.000 | 0.000 | 0.002 | 0.011 | 0.001 | 0.042 | NA | 0.462 | 0.000 | 0.193 | 0.000 | 0.038 |  |  |
| blocked/  no-penalty | 0.185 | 0.164 | 0.084 | 0.015 | 0.093 | 0.000 | NA | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |  |
| blocked | 0.418 | 0.430 | 0.300 | 0.142 | 0.350 | 0.025 | NA | 0.001 | 0.000 | 0.013 | 0.000 | 0.000 | 0.000 | 0.204 |

**Table E**. The *p-values* of the Mann-Whitney-U Tests for the average reliability score 〈R〉 per condition. The p-value for the preceded Kruskal-Wallis-Test is 0.000.

| ***/*** | ***0.50*** | ***random*** | ***1.00*** | ***0.75*** | ***0.25*** | ***Single*** | ***bigbrain*** | ***smallbrain*** | ***no-feedback*** | ***no-agent*** | ***3sides*** | ***w=a*** | ***no-penalty*** | ***blocked/***  ***no-penalty*** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***random*** | 0.023 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ***1.00*** | 0.000 | 0.000 |  |  |  |  |  |  |  |  |  |  |  |  |
| ***0.75*** | 0.001 | 0.000 | 0.260 |  |  |  |  |  |  |  |  |  |  |  |
| ***0.25*** | 0.198 | 0.002 | 0.003 | 0.008 |  |  |  |  |  |  |  |  |  |  |
| ***single*** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |  |  |  |  |  |  |  |  |  |
| ***bigbrain*** | 0.450 | 0.077 | 0.001 | 0.003 | 0.210 | 0.000 |  |  |  |  |  |  |  |  |
| ***smallbrain*** | 0.000 | 0.000 | 0.206 | 0.036 | 0.001 | 0.000 | 0.001 |  |  |  |  |  |  |  |
| ***no-feedback*** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |  |  |  |  |  |  |
| ***no-agent*** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.015 | 0.000 | 0.000 | 0.000 |  |  |  |  |  |
| ***3sides*** | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 |  |  |  |  |
| ***w=a*** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |  |  |  |
| ***no-penalty*** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.123 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |  |  |
| ***blocked/no-penalty*** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.041 | 0.000 |  |
| ***blocked*** | 0.438 | 0.031 | 0.000 | 0.000 | 0.156 | 0.000 | 0.473 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Table F**. Spearman’s correlation coefficient ρ between the evolved fitness ***EF*** and brain complexity ΦMax per condition (Gi). Note that weak or non-significant correlation coefficients may be due to small variance in the final evolved fitness values in some conditions.

|  |  | |  | |
| --- | --- | --- | --- | --- |
| ρ | p-value | ρ | p-value |
| 0.5 | 0.6318 | 0.0002 | 0.6597 | 0.0001 |
| random | 0.2300 | 0.2215 | 0.0360 | 0.8504 |  |
| 1.00 | 0.4588 | 0.0108 | 0.6178 | 0.0003 |  |
| 0.75 | 0.2024 | 0.2834 | 0.1585 | 0.4028 |  |
| 0.25 | 0.6045 | 0.0004 | 0.4908 | 0.0059 |  |
| single | 0.1532 | 0.4189 | 0.3471 | 0.0602 |  |
| bigbrain | NA | NA | NA | NA |  |
| smallbrain | -0.4112 | 0.1011 | -0.2983 | 0.2449 |  |
| no-feedback | -0.1034 | 0.5936 | -0.1034 | 0.5936 |  |
| no-agent | 0.0439 | 0.8212 | 0.0768 | 0.6921 |  |
| 3sides | 0.2847 | 0.1273 | 0.2804 | 0.1333 |  |
| w=a | -0.0985 | 0.6047 | 0.0430 | 0.8214 |  |
| no-penalty | -0.1293 | 0.4960 | -0.1067 | 0.5748 |  |
| blocked/no-penalty | 0.2598 | 0.1656 | 0.4160 | 0.0222 |  |
| blocked | 0.4626 | 0.0100 | 0.6275 | 0.0002 |  |

**Table G.** Task fitness values of all conditions ***Gi*** in the five evaluated environments.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Map *m =*** | | | | |
| *Original* | *Noisy Corners* | *Small Gate* | *4 Rooms* | *4 Messy Rooms* |
| ***0.25*** | 2.71 | 0.98 | 1.50 | 1.54 | 0.80 |
| ***random*** | 3.02 | 0.94 | 1.60 | 1.50 | 0.70 |
| ***0.50*** | 2.89 | 0.84 | 1.83 | 1.66 | 0.87 |
| ***0.75*** | 2.66 | 1.08 | 1.86 | 1.94 | 1.06 |
| ***1.00*** | 2.48 | 0.96 | 1.78 | 1.82 | 1.13 |
| ***single*** | -3.59 | -4.22 | -5.53 | -4.08 | -5.80 |
| ***bigbrain*** | 2.96 | 0.78 | 1.32 | 1.31 | 0.64 |
| ***smallbrain*** | 2.54 | 0.44 | 2.09 | 2.47 | 1.46 |
| ***no-feedback*** | 1.94 | 0.64 | 1.58 | 2.20 | 1.18 |
| ***no-agent*** | -1.61 | -2.18 | -2.75 | -2.68 | -4.29 |
| ***3sides*** | 3.33 | 0.64 | 2.56 | 3.13 | 1.59 |
| ***w=a*** | 0.13 | -0.11 | -0.45 | -0.85 | -2.36 |
| ***no-penalty\**** | 3.75 [-3.88] | 2.83 | 1.95 | 0.94 | 0.31 |
| ***blocked/no-penalty\**** | 3.08 [-0.11] | 0.61 | 1.44 | 1.74 | 0.75 |
| ***blocked\**** | 2.87 [2.88] | 0.75 | 1.83 | 1.61 | 0.93 |

\* The condition was tested in the environment with the interaction parameters they evolved in. The corresponding values of ***R*** (evaluated in the *Original* environment under standard settings: active penalty, blocking disabled) are added in parenthesis.