**Supplementary Materials**

# 1. Description of the data

Figure S1 plots the correct values of the inbound responses in triangle completion of Qi et al. (2021).

Chart, histogram

Description automatically generated

**Figure S1.** The distributions of the correct inbound path lengths (A) and turn angles (B).

# 2. Cross-validation without considering participant variable

## 2.1 Cross-validation results of individual folds

All ten folds’ cross-validation results based on two different algorithms using participants’ responses are summarized separately (model fitting performance in Table S1 and model validation performance in Table S2).

**Table S1**

*Model fitting performance using multiple response locations or only home response locations.* *Parameters are estimated slopes and intercepts of encoding functions ( and for length, and for angle) and execution functions ( and for length, and for angle) for three models in the model fitting. The RMSE, maximum log-likelihood, and partial r-squared are goodness-of-fit measures.*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | | Multiple response locations (1st round, subsample 1) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Fitting | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.378 | | | -6121.00 | 0.000 | |
| M1 | | 0.96 | | | 0.64 | 0.81 | 15.49 | 1 | 0 | 1 | 0 | | | 3.269 | | | -6042.04 | 0.063 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.75 | 1.22 | 0.77 | 44.16 | | | 3.242 | | | -6023.67 | 0.079 | |
| M3 | | 0.70 | | | 0.93 | 0.85 | 19.41 | 0.73 | 1.08 | 0.80 | 39.17 | | | 3.208 | | | -5994.13 | 0.098 | |
| Model | | Home response locations only (1st round, subsample 1) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Fitting | | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.922 | | | -1904.77 | 0.000 | |
| M1 | | 0.53 | | | 0.94 | 0.54 | 12.72 | 1 | 0 | 1 | 0 | | | 2.727 | | | -1854.58 | 0.129 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.48 | 1.98 | 0.45 | 87.29 | | | 2.735 | | | -1856.25 | 0.124 | |
| M3 | | 0.28 | | | 0.68 | 0.58 | -10.00 | 1.96 | -1.0 | 0.90 | 6.56 | | | 2.725 | | | -1854.30 | 0.130 | |
| Model | | Multiple response locations (1st round, subsample 2) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Fitting | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.976 | | | -5799.43 | 0.000 | |
| M1 | | 1.12 | | | 0.31 | 0.77 | 21.45 | 1 | 0 | 1 | 0 | | | 2.884 | | | -5722.36 | 0.061 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.66 | 1.34 | 0.80 | 38.07 | | | 2.865 | | | -5704.63 | 0.073 | |
| M3 | | 0.86 | | | 0.73 | 0.83 | 21.21 | 0.66 | 1.12 | 0.83 | 32.42 | | | 2.830 | | | -5671.87 | 0.096 | |
| Model | | Home response locations only (1st round, subsample 2) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Fitting | | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.693 | | | -1830.55 | 0.000 | |
| M1 | | 0.87 | | | 0.36 | 0.36 | 34.38 | 1 | 0 | 1 | 0 | | | 2.517 | | | -1778.07 | 0.126 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.36 | 2.20 | 0.47 | 83.69 | | | 2.522 | | | -1779.29 | 0.123 | |
| M3 | | 0.89 | | | 0.55 | 0.32 | 55.32 | 0.81 | 0.59 | 1.13 | -9.98 | | | 2.514 | | | -1776.50 | 0.128 | |
| Model | | Multiple response locations (2nd round, subsample 1) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Fitting | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.343 | | | -6074.95 | 0.000 | |
| M1 | | 1.26 | | | 0.16 | 0.73 | 26.60 | 1 | 0 | 1 | 0 | | | 3.229 | | | -5995.91 | 0.067 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.69 | 1.38 | 0.80 | 40.16 | | | 3.212 | | | -5987.98 | 0.077 | |
| M3 | | 1.18 | | | 0.26 | 0.74 | 31.17 | 0.75 | 0.94 | 0.82 | 34.20 | | | 3.175 | | | -5953.92 | 0.098 | |
| Model | | Home response locations only (2nd round, subsample 1) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Fitting | | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.969 | | | -1901.85 | 0.000 | |
| M1 | | 0.91 | | | 0.32 | 0.38 | 29.54 | 1 | 0 | 1 | 0 | | | 2.760 | | | -1855.84 | 0.136 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.38 | 2.25 | 0.44 | 88.46 | | | 2.772 | | | -1858.12 | 0.128 | |
| M3 | | 0.69 | | | 0.14 | 0.35 | 27.26 | 1.33 | 0.11 | 1.05 | -10.0 | | | 2.759 | | | -1855.72 | 0.136 | |
| Model | | Multiple response locations (2nd round, subsample 2) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Fitting | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.015 | | | -5838.87 | 0.000 | |
| M1 | | 0.80 | | | 0.83 | 0.84 | 12.70 | 1 | 0 | 1 | 0 | | | 2.925 | | | -5763.77 | 0.059 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.71 | 1.20 | 0.77 | 41.93 | | | 2.900 | | | -5735.84 | 0.075 | |
| M3 | | 0.55 | | | 1.18 | 0.89 | 14.64 | 0.67 | 1.10 | 0.84 | 32.75 | | | 2.861 | | | -5701.30 | 0.099 | |
| Model | | Home response locations only (2nd round, subsample 2) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Fitting | | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | 1 | | | 0 | | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.642 | | | -1824.93 | 0.000 | |
| M1  M2  M3 | 0.44  1  9.10 | | | 1.05  0  17.87 | | 0.51 | 17.71 | 1 | 0 | 1 | 0 | | | 2.482 | | | -1768.70 | 0.117 | |
| 1 | 0 | 0.46 | 1.93 | 0.48 | 82.97 | | | 2.482 | | | -1768.79 | 0.117 | |
| 0.84 | 27.26 | 0.03 | 1.97 | 0.63 | 66.94 | | | 2.479 | | | -1767.48 | 0.120 | |
| Model | | Multiple response locations (3rd round, subsample 1) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Fitting | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.320 | | | -6083.85 | 0.000 | |
| M1 | | 1.05 | | | 0.42 | 0.81 | 14.42 | 1 | 0 | 1 | 0 | | | 3.227 | | | -6015.45 | 0.055 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.70 | 1.31 | 0.83 | 35.29 | | | 3.206 | | | -6001.36 | 0.067 | |
| M3 | | 0.76 | | | 0.83 | 0.86 | 15.29 | 0.68 | 1.16 | 0.87 | 26.89 | | | 3.179 | | | -5977.51 | 0.083 | |
| Model | | Home response locations only (3rd round, subsample 1) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Fit | | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.937 | | | -1908.71 | 0.000 | |
| M1 | | 0.83 | | | 0.44 | 0.57 | 12.96 | 1 | 0 | 1 | 0 | | | 2.777 | | | -1871.03 | 0.106 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.52 | 1.84 | 0.58 | 68.69 | | | 2.782 | | | -1871.64 | 0.103 | |
| M3 | | 0.70 | | | 0.26 | 0.62 | 6.09 | 1.11 | 0.37 | 0.97 | 2.39 | | | 2.777 | | | -1870.90 | 0.106 | |
| Model | | Multiple response locations (3rd round, subsample 2) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Fitting | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.041 | | | -5854.76 | 0.000 | |
| M1 | | 1.03 | | | 0.52 | 0.77 | 22.35 | 1 | 0 | 1 | 0 | | | 2.931 | | | -5763.24 | 0.071 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.70 | 1.27 | 0.74 | 47.14 | | | 2.906 | | | -5743.56 | 0.087 | |
| M3 | | 0.65 | | | 1.07 | 0.79 | 27.14 | 0.68 | 1.13 | 0.77 | 42.32 | | | 2.857 | | | -5697.42 | 0.117 | |
| Model | | Home response locations only (3rd round, subsample 2) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Fitting | | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.677 | | | -1831.85 | 0.000 | |
| M1 | | 0.54 | | | 0.90 | 0.33 | 32.72 | 1 | 0 | 1 | 0 | | | 2.461 | | | -1764.61 | 0.154 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.31 | 2.36 | 0.43 | 90.00 | | | 2.468 | | | -1766.52 | 0.149 | |
| M3 | | 0.70 | | | 1.23 | 0.29 | 53.94 | 0.65 | 0.67 | 1.13 | -10.00 | | | 2.460 | | | -1763.85 | 0.155 | |
| Model | | Multiple response locations (4th round, subsample 1) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Fitting | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.443 | | | -6172.66 | 0.000 | |
| M1 | | 1.28 | | | 0.08 | 0.81 | 18.80 | 1 | 0 | 1 | 0 | | | 3.352 | | | -6111.46 | 0.052 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.67 | 1.34 | 0.78 | 42.48 | | | 3.328 | | | -6096.82 | 0.066 | |
| M3 | | 1.27 | | | 0.08 | 0.83 | 24.01 | 0.68 | 1.10 | 0.82 | 35.14 | | | 3.295 | | | -6069.04 | 0.084 | |
| Model | | Home response locations only (4th round, subsample 1) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Fitting | | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.056 | | | -1945.06 | 0.000 | |
| M1 | | 0.73 | | | 0.56 | 0.38 | 26.93 | 1 | 0 | 1 | 0 | | | 2.869 | | | -1899.73 | 0.119 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.37 | 2.23 | 0.44 | 90.00 | | | 2.872 | | | -1899.84 | 0.117 | |
| M3 | | 1.52 | | | 7.13 | 0.12 | 64.78 | 0.40 | -3.0 | 3.19 | 55.65 | | | 2.868 | | | -1899.11 | 0.119 | |
| Model | | Multiple response locations (4th round, subsample 2) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Fitting | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.900 | | | -5730.81 | 0.000 | |
| M1 | | 0.80 | | | 0.86 | 0.78 | 17.69 | 1 | 0 | 1 | 0 | | | 2.785 | | | -5628.82 | 0.078 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.73 | 1.23 | 0.79 | 39.90 | | | 2.767 | | | -5610.79 | 0.090 | |
| M3 | | 0.49 | | | 1.27 | 0.85 | 15.96 | 0.70 | 1.09 | 0.84 | 31.88 | | | 2.725 | | | -5570.60 | 0.117 | |
| Model | | Home response locations only (4th round, subsample 2) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Fitting | | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.540 | | | -1784.59 | 0.000 | |
| M1 | | 0.60 | | | 0.81 | 0.51 | 19.78 | 1 | 0 | 1 | 0 | | | 2.357 | | | -1726.92 | 0.139 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.47 | 1.96 | 0.49 | 80.44 | | | 2.366 | | | -1729.52 | 0.133 | |
| M3 | | 0.82 | | | 0.79 | 0.69 | -10.00 | 0.70 | 0.37 | 0.82 | 21.36 | | | 2.356 | | | -1726.83 | 0.140 | |
| Model | | Multiple response locations (5th round, subsample 1) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Fitting | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.108 | | | -5919.57 | 0.000 | |
| M1 | | 1.11 | | | 0.24 | 0.80 | 16.70 | 1 | 0 | 1 | 0 | | | 3.041 | | | -5866.22 | 0.043 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.70 | 1.14 | 0.80 | 39.54 | | | 3.009 | | | -5839.97 | 0.063 | |
| M3 | | 1.07 | | | 0.24 | 0.85 | 17.29 | 0.71 | 0.94 | 0.85 | 31.47 | | | 2.988 | | | -5820.31 | 0.076 | |
| Model | | Home response locations only (5th round, subsample 1) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Fitting | | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.732 | | | -1849.03 | 0.000 | |
| M1 | | 0.74 | | | 0.48 | 0.45 | 23.28 | 1 | 0 | 1 | 0 | | | 2.582 | | | -1803.53 | 0.107 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.41 | 1.97 | 0.49 | 80.60 | | | 2.586 | | | -1804.16 | 0.104 | |
| M3 | | 2.57 | | | 0.88 | 0.52 | 23.01 | 0.25 | 0.80 | 0.93 | 12.41 | | | 2.581 | | | -1803.11 | 0.107 | |
| Model | | Multiple response locations (5th round, subsample 2) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Fitting | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.257 | | | -6023.06 | 0.000 | |
| M1 | | 0.98 | | | 0.70 | 0.79 | 19.58 | 1 | 0 | 1 | 0 | | | 3.118 | | | -5913.01 | 0.084 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.70 | 1.43 | 0.77 | 42.46 | | | 3.104 | | | -5907.36 | 0.092 | |
| M3 | | 0.64 | | | 1.18 | 0.88 | 18.05 | 0.66 | 1.30 | 0.81 | 35.89 | | | 3.052 | | | -5858.41 | 0.122 | |
| Model | | Home response locations only (5th round, subsample 2) | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Fitting | | | |  |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | MaxLogL | Partial R2 | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.886 | | | -1889.97 | 0.000 | |
| M1 | | 0.62 | | | 0.86 | 0.43 | 24.32 | 1 | 0 | 1 | 0 | | | 2.663 | | | -1832.26 | 0.149 | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.41 | 2.25 | 0.43 | 90.00 | | | 2.669 | | | -1833.68 | 0.144 | |
| M3 | | 8.07 | | | 9.90 | 0.42 | 24.32 | 0.08 | 0.21 | 1.06 | -9.83 | | | 2.663 | | | -1832.31 | 0.149 | |

**Table S2**

*Model validation performance using multiple response locations or only home response locations. Parameters are the same as in Table S1 from model fitting. The RMSE, maximum log-likelihood, and partial r-squared are generalizability measures, which were calculated by applying the parameters to the test subsamples.*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | | Multiple response locations (1st round, subsample 1) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Validation | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.378 | | | | -6121.00 | | 0.000 | | |
| M1 | | 1.12 | | | 0.31 | 0.77 | 21.45 | 1 | 0 | 1 | 0 | | | 3.274 | | | | -6044.00 | | 0.061 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.66 | 1.34 | 0.80 | 38.07 | | | 3.247 | | | | -6023.54 | | 0.076 | | |
| M3 | | 0.86 | | | 0.73 | 0.83 | 21.21 | 0.66 | 1.12 | 0.83 | 32.42 | | | 3.213 | | | | -5995.38 | | 0.095 | | |
| Model | | Home response locations only (1st round, subsample 1) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Validation | | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.922 | | | | -1904.77 | | 0.000 | | |
| M1 | | 0.87 | | | 0.36 | 0.36 | 34.38 | 1 | 0 | 1 | 0 | | | 2.739 | | | | -1857.78 | | 0.122 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.36 | 2.20 | 0.47 | 83.69 | | | 2.739 | | | | -1856.74 | | 0.121 | | |
| M3 | | 0.89 | | | 0.55 | 0.32 | 55.32 | 0.81 | 0.59 | 1.13 | -9.98 | | | 2.742 | | | | -1858.34 | | 0.119 | | |
| Model | | Multiple response locations (1st round, subsample 2) | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Validation | | | | |  |
|  | | |  |  |  |  |  |  |  | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.976 | | | | -5799.43 | 0.000 | | |
| M1 | | 0.96 | | | 0.64 | 0.81 | 15.49 | 1 | 0 | 1 | 0 | | | 2.889 | | | | -5727.83 | 0.058 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.75 | 1.22 | 0.77 | 44.16 | | | 2.872 | | | | -5710.81 | 0.069 | | |
| M3 | | 0.70 | | | 0.93 | 0.85 | 19.41 | 0.73 | 1.08 | 0.80 | 39.17 | | | 2.835 | | | | -5677.57 | 0.092 | | |
| Model | | Home response locations only (1st round, subsample 2) | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Validation | | | | | |  |
|  | | |  |  |  |  |  |  |  | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.693 | | | | -1830.55 | 0.000 | | |
| M1 | | 0.53 | | | 0.94 | 0.54 | 12.72 | 1 | 0 | 1 | 0 | | | 2.530 | | | | -1782.19 | 0.118 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.48 | 1.98 | 0.45 | 87.29 | | | 2.527 | | | | -1780.98 | 0.119 | | |
| M3 | | 0.28 | | | 0.68 | 0.58 | -10.00 | 1.96 | -1.0 | 0.90 | 6.56 | | | 2.533 | | | | -1783.70 | 0.115 | | |
| Model | | Multiple response locations (2nd round, subsample 1) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Validation | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.343 | | | | -6074.95 | | 0.000 | | |
| M1 | | 0.80 | | | 0.83 | 0.84 | 12.70 | 1 | 0 | 1 | 0 | | | 3.247 | | | | -6001.53 | | 0.061 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.71 | 1.20 | 0.77 | 41.93 | | | 3.215 | | | | -5986.01 | | 0.075 | | |
| M3 | | 0.55 | | | 1.18 | 0.89 | 14.64 | 0.67 | 1.10 | 0.84 | 32.75 | | | 3.186 | | | | -5961.14 | | 0.092 | | |
| Model | | Home response locations only (2nd round, subsample 1) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Validation | | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0  M1  M2  M3 | 1  0.44  1  9.10 | | | 0  1.05  0  17.87 | | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.969 | | | | -1901.85 | | 0.000 | | |
| 0.51 | 17.71 | 1 | 0 | 1 | 0 | | | 2.771 | | | | -1856.74 | | 0.129 | | |
| 1 | 0 | 0.46 | 1.93 | 0.48 | 82.97 | | | 2.776 | | | | -1857.42 | | 0.126 | | |
| 0.84 | 27.26 | 0.03 | 1.97 | 0.63 | 66.94 | | | 2.779 | | | | -1858.43 | | 0.124 | | |
| Model | | Multiple response locations (2nd round, subsample 2) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Validation | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.015 | | | | -5838.87 | | 0.000 | | |
| M1 | | 1.26 | | | 0.16 | 0.73 | 26.60 | 1 | 0 | 1 | 0 | | | 2.937 | | | | -5776.22 | | 0.051 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.69 | 1.38 | 0.80 | 40.16 | | | 2.904 | | | | -5738.89 | | 0.073 | | |
| M3 | | 1.18 | | | 0.26 | 0.74 | 31.17 | 0.75 | 0.94 | 0.82 | 34.20 | | | 2.883 | | | | -5723.42 | | 0.086 | | |
| Model | | Home response locations only (2nd round, subsample 2) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Validation | | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | 1 | | | 0 | | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.642 | | | | -1824.93 | | 0.000 | | |
| M1  M2  M3 | 0.91  1  0.69 | | | 0.32  0  0.14 | | 0.38 | 29.54 | 1 | 0 | 1 | 0 | | | 2.494 | | | | -1772.74 | | 0.109 | | |
| 1 | 0 | 0.38 | 2.25 | 0.44 | 88.46 | | | 2.486 | | | | -1770.31 | | 0.115 | | |
| 0.35 | 27.26 | 1.33 | 0.11 | 1.05 | -10.0 | | | 2.497 | | | | -1774.01 | | 0.106 | | |
| Model | | Multiple response locations (3rd round, subsample 1) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Validation | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.320 | | | | -6083.85 | | 0.000 | | |
| M1 | | 1.03 | | | 0.52 | 0.77 | 22.35 | 1 | 0 | 1 | 0 | | | 3.232 | | | | -6017.62 | | 0.052 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.70 | 1.27 | 0.74 | 47.14 | | | 3.211 | | | | -6005.37 | | 0.064 | | |
| M3 | | 0.65 | | | 1.07 | 0.79 | 27.14 | 0.68 | 1.13 | 0.77 | 42.32 | | | 3.190 | | | | -5985.37 | | 0.077 | | |
| Model | | Home response locations only (3rd round, subsample 1) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Validation | | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.937 | | | | -1908.71 | | 0.000 | | |
| M1 | | 0.54 | | | 0.90 | 0.33 | 32.72 | 1 | 0 | 1 | 0 | | | 2.789 | | | | -1874.63 | | 0.099 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.31 | 2.36 | 0.43 | 90.00 | | | 2.788 | | | | -1874.16 | | 0.099 | | |
| M3 | | 0.70 | | | 1.23 | 0.29 | 53.94 | 0.65 | 0.67 | 1.13 | -10.00 | | | 2.790 | | | | -1874.82 | | 0.098 | | |
| Model | | Multiple response locations (3rd round, subsample 2) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Validation | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.041 | | | | -5854.76 | | 0.000 | | |
| M1 | | 1.05 | | | 0.42 | 0.81 | 14.42 | 1 | 0 | 1 | 0 | | | 2.935 | | | | -5768.42 | | 0.068 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.70 | 1.31 | 0.83 | 35.29 | | | 2.911 | | | | -5747.98 | | 0.084 | | |
| M3 | | 0.76 | | | 0.83 | 0.86 | 15.29 | 0.68 | 1.16 | 0.87 | 26.89 | | | 2.869 | | | | -5708.85 | | 0.110 | | |
| Model | | Home response locations only (3rd round, subsample 2) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Validation | | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.677 | | | | -1831.85 | | 0.000 | | |
| M1 | | 0.83 | | | 0.44 | 0.57 | 12.96 | 1 | 0 | 1 | 0 | | | 2.475 | | | | -1769.70 | | 0.145 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.52 | 1.84 | 0.58 | 68.69 | | | 2.479 | | | | -1770.26 | | 0.142 | | |
| M3 | | 0.70 | | | 0.26 | 0.62 | 6.09 | 1.11 | 0.37 | 0.97 | 2.39 | | | 2.475 | | | | -1769.72 | | 0.145 | | |
| Model | | Multiple response locations (4th round, subsample 1) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Validation | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.443 | | | | -6172.66 | | 0.000 | | |
| M1 | | 0.80 | | | 0.86 | 0.78 | 17.69 | 1 | 0 | 1 | 0 | | | 3.359 | | | | -6118.21 | | 0.048 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.73 | 1.23 | 0.79 | 39.90 | | | 3.329 | | | | -6096.64 | | 0.065 | | |
| M3 | | 0.49 | | | 1.27 | 0.85 | 15.96 | 0.70 | 1.09 | 0.84 | 31.88 | | | 3.302 | | | | -6075.20 | | 0.080 | | |
| Model | | Home response locations only (4th round, subsample 1) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Validation | | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.056 | | | | -1945.06 | | 0.000 | | |
| M1 | | 0.60 | | | 0.81 | 0.51 | 19.78 | 1 | 0 | 1 | 0 | | | 2.876 | | | | -1900.73 | | 0.115 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.47 | 1.96 | 0.49 | 80.44 | | | 2.876 | | | | -1900.38 | | 0.114 | | |
| M3 | | 0.82 | | | 0.79 | 0.69 | -10.00 | 0.70 | 0.37 | 0.82 | 21.36 | | | 2.878 | | | | -1901.72 | | 0.113 | | |
| Model | | Multiple response locations (4th round, subsample 2) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Validation | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.900 | | | | -5730.81 | | 0.000 | | |
| M1 | | 1.28 | | | 0.08 | 0.81 | 18.80 | 1 | 0 | 1 | 0 | | | 2.794 | | | | -5636.87 | | 0.072 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.67 | 1.34 | 0.78 | 42.48 | | | 2.768 | | | | -5611.56 | | 0.090 | | |
| M3 | | 1.27 | | | 0.08 | 0.83 | 24.01 | 0.68 | 1.10 | 0.82 | 35.14 | | | 2.743 | | | | -5587.92 | | 0.105 | | |
| Model | | Home response locations only (4th round, subsample 2) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Validation | | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.540 | | | | -1784.59 | | 0.000 | | |
| M1 | | 0.73 | | | 0.56 | 0.38 | 26.93 | 1 | 0 | 1 | 0 | | | 2.364 | | | | -1730.65 | | 0.134 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.37 | 2.23 | 0.44 | 90.00 | | | 2.371 | | | | -1732.53 | | 0.129 | | |
| M3 | | 1.52 | | | 7.13 | 0.12 | 64.78 | 0.40 | -3.0 | 3.19 | 55.65 | | | 2.365 | | | | -1730.73 | | 0.133 | | |
| Model | | Multiple response locations (5th round, subsample 1) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Validation | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.108 | | | | -5919.57 | | 0.000 | | |
| M1 | | 0.98 | | | 0.70 | 0.79 | 19.58 | 1 | 0 | 1 | 0 | | | 3.057 | | | | -5882.08 | | 0.032 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.70 | 1.43 | 0.77 | 42.46 | | | 3.024 | | | | -5855.21 | | 0.053 | | |
| M3 | | 0.64 | | | 1.18 | 0.88 | 18.05 | 0.66 | 1.30 | 0.81 | 35.89 | | | 3.010 | | | | -5842.31 | | 0.062 | | |
| Model | | Home response locations only (5th round, subsample 1) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Validation | | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.732 | | | | -1849.03 | | 0.000 | | |
| M1 | | 0.62 | | | 0.86 | 0.43 | 24.32 | 1 | 0 | 1 | 0 | | | 2.600 | | | | -1810.65 | | 0.095 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.41 | 2.25 | 0.43 | 90.00 | | | 2.602 | | | | -1811.29 | | 0.093 | | |
| M3 | | 8.07 | | | 9.90 | 0.42 | 24.32 | 0.08 | 0.21 | 1.06 | -9.83 | | | 2.599 | | | | -1810.56 | | 0.095 | | |
| Model | | Multiple response locations (5th round, subsample 2) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | | 5×2 Validation | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 3.257 | | | | -6023.06 | | 0.000 | | |
| M1 | | 1.11 | | | 0.24 | 0.80 | 16.70 | 1 | 0 | 1 | 0 | | | 3.134 | | | | -5926.20 | | 0.074 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.70 | 1.14 | 0.80 | 39.54 | | | 3.118 | | | | -5913.54 | | 0.083 | | |
| M3 | | 1.07 | | | 0.24 | 0.85 | 17.29 | 0.71 | 0.94 | 0.85 | 31.47 | | | 3.079 | | | | -5878.83 | | 0.106 | | |
| Model | | Home response locations only (5th round, subsample 2) | | | | | | | | | | | | | | | | | | | | |
|  | Parameters | | | | | | | | |  | |  | 5×2 Validation | | | | | |  | |
|  | | |  |  |  |  |  |  |  | | RMSE | | | | | MaxLogL | | Partial R2 | | |
| M0 | | 1 | | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | | 2.886 | | | | -1889.97 | | 0.000 | | |
| M1 | | 0.74 | | | 0.48 | 0.45 | 23.28 | 1 | 0 | 1 | 0 | | | 2.680 | | | | -1835.94 | | 0.138 | | |
| M2 | | 1 | | | 0 | 1 | 0 | 0.41 | 1.97 | 0.49 | 80.60 | | | 2.686 | | | | -1836.49 | | 0.134 | | |
| M3 | | 2.57 | | | 0.88 | 0.52 | 23.01 | 0.25 | 0.80 | 0.93 | 12.41 | | | 2.681 | | | | -1835.76 | | 0.137 | | |

## 2.2 AIC and BIC analyses for adjusting the number of free parameters in model fitting

We used the Akaike information criterion (AIC; Akaike, 1973), Bayesian Information Criterion (BIC; Schwarz, 1978), and the adjustment of the likelihood ratio approach (Glover & Dixon, 2004) to qualify these results, correcting the effect of model complexity (i.e., M3 has more parameters than M1 and M2). The AIC and BIC for a model *Mi* can be defined as:

= -2 + 2 . (S1)

= -2 + log(N) . (S2)

Where the L*i* is the maximum likelihood of M*i* and is the number of free parameters in M*i*. In particular, - = 4, - = 4. N is the number of data, N = 498 for multiple response locations and N = 498 for home response locations only.

The adjusted maximum likelihood ratio (aLR) indicates the relative likelihood of data under two models, and the aLR in favor of M*i* over M*j* (i.e., aLR*ij*)with AIC and BIC values can be written as:

= exp (). (S3)

= exp (). (S4)

**Table S3**

*Adjusted maximum likelihood ratio ( and) between models (row model over column model) in model fitting using multiple locations (left) or only home response locations (right).*

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Multiple response locations | | | |  | Home response locations only | | | | | |
|  |
|  | M0 | | M1 | M2 | M3 |  | | M0 | M1 | M2 | M3 |
| M1 | 7.30 × 1032\*\* | | |  |  |  | | 4.70 × 1020\*\* |  |  |  |
| M2 | 1.82 × 1040\*\* | | 2.49 × 107\*\* | |  |  | | 1.35 × 1020\*\* | 0.29\* |  |  |
| M3 | 1.51 × 1053\*\* | | 2.11 × 1020\*\* | 8.32 × 1012\*\* | |  | | 1.45 × 1019\*\* | 0.03\*\* | 0.003\*\* |  |
|  | M0 | | M1 | M2 | M3 |  | | M0 | M1 | M2 | M3 |
| M1 | 6.95 × 1031\*\* | | |  |  |  | | 1.17 × 1020\*\* | |  |  |
| M2 | 1.73 × 1039\*\* | | 2.49 × 107\*\* |  |  |  | | 3.33 × 1019\*\* | 0.29\* |  |  |
| M3 | 1.45 × 1051\*\* | | 2.02 × 1019\*\* | 8.10 × 1011\*\* | |  | | 8.89 × 1017\*\* | 0.008\*\* | 0.03\*\* |  |

*Note*: \* indicates clear evidence, i.e., LR > 3 or LR <1/3, and \*\* indicates strong evidence, i.e., LR > 10 or LR <1/10 (Glover & Dixon, 2004).

The results of aLR in Table S3 clearly showed that the bi-component model (M3) is the best model when all three response locations were included in the model fitting. In contrast, although the encoding-error model, execution-error model, and the bi-component model (M1, M2, and M3) are better than the baseline model (M0), the bi-component model (M3) was even worse than the encoding-error and the execution-error models (M1 and M2) when only home response locations were included in the model fitting.

## 2.3 The frequency of the pairwise likelihood ratio in different categories in model recovery

Figure S2 plots the frequency of different categories of evidence for the true model in model validation on the 100 sets of simulated response locations. The results showed that the algorithm of using multiple response locations can successfully distinguish the true model from other models. Specifically, when the true model was M1, we got evidence favoring M1 over M2 and M3 with possibilities of 100% and 98% respectively. When the true model was M2, we got evidence favoring M2 over M1 and M3 with possibilities of 100% and 82% respectively. When the true model was M3, we got evidence favoring M3 over M1 and M2 with 100% for both. We never got evidence favoring the other two models over the true model.

In contrast, the algorithm of using home response locations only cannot clearly distinguish the true model from other models. When the true model was M1, we got evidence favoring M1 over M2 and M3 with possibilities of 40% and 52% respectively. When the true model was M2, we got evidence favoring M2 over M1 and M3 with possibilities of 93% and 51% respectively. When the true model was M3, we got evidence favoring M3 over M1 and M2 with possibilities of 37% and 26%. In addition to the relatively low chances to recover the true models, we also got evidence favoring the wrong models over the true model. There was evidence favoring M2 over the true model M1 with a possibility of 6%, evidence favoring M3 over the true model M2 with a possibility of 1%, and evidence favoring M1 and M2 over the true model M3 with possibilities of 9% and 17%.

A picture containing graphical user interface

Description automatically generated**Figure S2.** Frequency in each category of likelihood ratio in model validation using (A) multiple response locations or (B) home response locations only. These locations are simulated locations from different true models (M1, M2, or M3). *Mi/Mj* indicates the ratio of model *Mi* over model *Mj.* >10 indicates strong evidence supporting *Mi*, >3 indicates clear evidence supporting *Mi*, <10 indicates strong evidence supporting *Mj*, <3 indicates clear evidence supporting *Mj*.

## 2.4 Values of parameters estimated from real and simulated response locations

Table S4 lists the values of parameters estimated for the three models using real data (i.e., true parameters in the upper table) and using the simulated data generated from different models. The simulated data for each model were produced by fixed values of model parameters for all participants (Table 1).

**Table S4**

*The similarity between values of parameters based on real response locations (the upper panel) and simulated response locations from different models (the lower panel). S\_M1, S\_M2, and S\_M3 denote the simulated response locations from the true models of M1, M2, and M3 respectively.*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | Values of parameters based on real response locations | | | | | | | | | | | | | | | | | | | |
|  | | M1 | | | |  | | M2 | | | |  | M3 | | | | | | | | | | |
|  | |  |  |  |  | |  | |  |  |  |  | |  |  |  |  |  |  |  |
|  | | 1.04 | 0.48 | 0.79 | 18.38 | | 0.70 | | 1.29 | 0.78 | 41.11 | 0.82 | | 0.78 | 0.84 | 20.42 | 0.69 | 1.10 | 0.82 | 34.21 | | |
|  | Recovered parameters based on simulated locations from each true model | | | | | | | | | | | | | | | | | | | | | |
| S\_M1 | | 1.04 | 0.48 | 0.79 | 18.37 | | 1.10 | | 0.19 | 0.87 | 20.69 | 1.00 | | 0.53 | 0.80 | 17.99 | 0.98 | 0.08 | 0.98 | 2.54 | | |
| S\_M2 | | 1.39 | -.36 | 0.92 | 1.55 | | 0.69 | | 1.30 | 0.78 | 41.05 | 1.00 | | 0.00 | 1.00 | 0.21 | 0.69 | 1.31 | 0.79 | 41.06 | | |
| S\_M3 | | 1.06 | 0.41 | 0.82 | 14.91 | | 0.75 | | 1.29 | 0.78 | 41.11 | 0.82 | | 0.78 | 0.84 | 20.42 | 0.69 | 1.10 | 0.82 | 34.21 | | |

# 3. Effect of participant groups on model validation using the same parameters for all participants

Considering two different compression groups, we examined whether the compression group modulated the model performance. We conducted model validation for each group using the model parameters estimated in model fitting without considering the participant variable (see the parameters in Table 1). Tables S5-S8 show that model validation based on the parameters from the algorithm using home only still could not differentiate the three models in either compression group. However, model validation based on the parameters from the algorithm using multiple locations showed different results of model comparison in the strong and the weak compression groups. Specifically, for the strong compression group, the bi-component model (M3) was still the best model as indicated by the generalizability measures (RMSE, MaxLogL, and partialR2) in Table S5, RMSEs of individual folds in Table S6, the likelihood ratio in Table S7 and the results of *Alpaydin’s F-test* in Table S8. In contrast, for the weak compression group, all three models (M1-M3) even performed worse than the baseline model (M0) (e.g., partial R2 was negative in Table S5). Among the three models, the encoding-error model (M1) appeared to be the best one.

**Table S5**

*Mean validation performance across 10 folds for the group with strong (upper) and weak (lower) compression patterns using multiple locations (left) or only home response locations (right). The RMSE, maximum log-likelihood, and partial r-squared are generalizability measures, which were calculated by applying the same parameters for all participants (i.e., the parameters in Table 1 from model fitting).*

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | Strong compression group | | | | | | | | | | |
| Multiple response locations | | |  | | Home response locations only | | | | | |
| RMSE | MaxLogL | Partial R2 |  | RMSE | | MaxLogL | | Partial R2 | |
| M0 | 3.384 | -3768.8 | 0 | 3.043 | | | | -1191.6 | | 0 |
| M1 | 3.223 | -3691.3 | 0.094 | 2.765 | | | | -1143.2 | | 0.176 |
| M2 | 3.152 | -3651.6 | 0.133 | 2.767 | | | | -1143.2 | | 0.174 |
| M3 | 3.114 | -3632.7 | 0.154 | 2.767 | | | | -1143.5 | | 0.174 |
| Model | Weak compression group | | | | | | | | | | |
| Multiple response locations | | |  | | Home response locations only | | | | | |
| RMSE | MaxLogL | Partial R2 |  | RMSE | | MaxLogL | | Partial R2 | |
| M0 | 2.816 | -2168.7 | 0 | 2.375 | | | | -662.1 | | 0 |
| M1 | 2.849 | -2184.3 | -0.024 | 2.400 | | | | -668.6 | | -0.023 |
| M2 | 2.903 | -2205.2 | -0.063 | 2.400 | | | | -668.7 | | -0.022 |
| M3 | 2.890 | -2200.5 | -0.054 | 2.402 | | | | -668.9 | | -0.024 |

**Table S6**

*RMSEs of individual folds in validation for strong and weak compression groups using two algorithms.*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Strong compression group | | | | | | | | | |
|  | Multiple response locations | | |  | Home response locations only | | | | |  | |
| RMSE | M1 | M2 | M3 |  | M1 | M2 | | M3 | |
| 1st round | 2.951 | 2.889 | 2.842 |  | 2.598 | 2.598 | | 2.603 | |
|  | 3.473 | 3.405 | 3.360 |  | 2.928 | 2.929 | | 2.931 | |
| 2nd round | 3.031 | 2.955 | 2.923 |  | 2.630 | 2.620 | | 2.635 | |
|  | 3.427 | 3.355 | 3.321 |  | 2.912 | 2.916 | | 2.923 | |
| 3rd round | 2.957 | 2.890 | 2.836 |  | 2.559 | 2.567 | | 2.559 | |
|  | 3.494 | 3.428 | 3.392 |  | 2.982 | 2.980 | | 2.982 | |
| 4th round | 2.793 | 2.705 | 2.678 |  | 2.369 | 2.380 | | 2.370 | |
|  | 3.644 | 3.577 | 3.540 |  | 3.131 | 3.131 | | 3.135 | |
| 5th round | 3.350 | 3.299 | 3.252 |  | 2.888 | 2.892 | | 2.886 | |
|  | 3.111 | 3.020 | 2.997 |  | 2.649 | 2.658 | | 2.648 | |
| Weak compression group | | | | | | | | | |
|  | Multiple response locations | | |  | Home response locations only | | | |  | |
| RMSE | M1 | M2 | M3 |  | M1 | | M2 | M3 | |
| 1st round | 2.791 | 2.845 | 2.824 |  | 2.420 | | 2.414 | 2.422 | |
|  | 2.915 | 2.968 | 2.955 |  | 2.394 | | 2.393 | 2.399 | |
| 2nd round | 2.778 | 2.818 | 2.817 |  | 2.253 | | 2.248 | 2.254 | |
|  | 2.921 | 2.982 | 2.961 |  | 2.532 | | 2.539 | 2.536 | |
| 3rd round | 2.897 | 2.948 | 2.926 |  | 2.317 | | 2.312 | 2.316 | |
|  | 2.813 | 2.870 | 2.876 |  | 2.485 | | 2.488 | 2.487 | |
| 4th round | 2.796 | 2.875 | 2.852 |  | 2.356 | | 2.357 | 2.356 | |
|  | 2.889 | 2.926 | 2.916 |  | 2.451 | | 2.453 | 2.452 | |
| 5th round | 2.713 | 2.772 | 2.747 |  | 2.267 | | 2.277 | 2.272 | |
|  | 2.978 | 3.029 | 3.030 |  | 2.526 | | 2.520 | 2.525 | |

**Table S7**

*Maximum likelihood ratio (LR) between models (row model over column model) in model validation for the strong (upper) and weak (lower) compression groups using multiple locations (left) or only home response locations (right).*

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Strong compression group | | | | | | | | |  | |
|  | Multiple response locations | | | |  | Home response locations only | | | |
| LR | M0 | M1 | M2 | M3 |  | M0 | M1 | M2 | M3 | |
| M1 | 1.93 × 1033\*\* |  |  |  |  | 1.06 × 1021\*\* |  |  |  | |
| M2 | 3.40 × 1050\*\* | 1.76 × 1017\*\* |  |  |  | 1.01 × 1021\*\* | 0.95— |  |  | |
| M3 | 5.52 × 1058\*\* | 2.86 × 1025\*\* | 1.63 × 108\*\* |  |  | 8.16 × 1020\*\* | 0.77— | 0.81— |  | |
|  | Weak compression group | | | | | | | | |  | |
|  | Multiple response locations | | | |  | Home response locations only | | | |
| LR | M0 | M1 | M2 | M3 |  | M0 | M1 | M2 | M3 | |
| M1 | 1.63 × 10-7\*\* |  |  |  |  | 0.0014\*\* |  |  |  | |
| M2 | 1.39 × 10-16\*\* | 8.56 × 10-10\*\* |  |  |  | 0.0013\*\* | 0.89— |  |  | |
| M3 | 1.60 × 10-14\*\* | 9.82 × 10-8\*\* | 114.94\*\* |  |  | 0.0011\*\* | 0.76— | 0.86— |  | |

*Note*: \* indicates clear evidence, i.e., LR > 3 or LR <1/3, and \*\* indicates strong evidence, i.e., LR > 10 or LR <1/10. — indicates no evidence (Glover & Dixon, 2004).

**Table S8**

*Alpaydin’s F-test examining the differences in RMSE (dRMSE) between models (the row model minus the column model) for the strong (upper) and weak (lower) compression groups when using multiple locations (left) or only home response locations (right).*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Strong compression group | | | | | | | | | | | | | | | |
|  | Multiple response locations | | | | | |  | Home response locations only | | | | | | |  |
| dRMSE | | M0 | | M1 | M2 | M3 |  | dRMSE | | M0 | M1 | M2 | M3 | | |
| M1 | -.161∗∗∗ | | |  |  |  |  | M1 | -.278∗∗∗ | |  |  |  | | |
| M2 | -.187∗∗∗ | | | -.071∗∗ |  |  |  | M2 | -.276∗∗∗ | | .002— |  |  | | |
| M3 | -.270∗∗ | | | -.109∗∗∗ | -.038∗∗ |  |  | M3 | -.275∗∗∗ | | .003— | .000— |  | | |
| Weak compression group | | | | | | | | | | | | | | | |
|  | Multiple response locations | | | | | |  | Home response locations only | | | | | |  | |
| dRMSE | | | M0 | M1 | M2 | M3 |  | dRMSE | | M0 | M1 | M2 | M3 | | |
| M1 | .033— | | |  |  |  |  | M1 | .025— | |  |  |  | | |
| M2 | .087∗ | | | .054∗∗ |  |  |  | M2 | .025— | | -.000— |  |  | | |
| M3 | .074— | | | .042∗ | -.013— |  |  | M3 | .027— | | .002— | .002— |  | | |

# 4. Cross-validation considering participant variable (model recovery using varied values of parameters)

## 4.1 Model fitting for different groups

Table S9 summarizes the results of model fitting in two different compression groups using two algorithms. The difference in fitting performance (goodness-of-fit measures) between models is most distinct numerically in the strong compression group when multiple response locations were included, and the results suggest that the bi-component model (M3) was the best model.

**Table S9**

*Model fitting performance for the strong and weak compression groups. Parameters are estimated from model fitting for each corresponding group. The RMSE, maximum log-likelihood, and partial r-squared are mean goodness-of-fit measures across 10 folds in model fitting.*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Strong compression group | | | | | | | | | | | | | | | | | |
| Model | Multiple response locations | | | | | | | | | | | | | | | |  | |
|  | Parameters | | | | | | | |  |  | | 5×2 Fitting | | | | |  |
|  | |  |  |  |  |  |  |  | RMSE | | | | MaxLogL | | Partial R2 | | |
| M0 | 1 | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | 3.382 | | | | -3770.4 | 0 | | |
| M1 | 1.14 | | 0.49 | 0.79 | 15.45 | 1 | 0 | 1 | 0 | | 3.191 | | | | -3681.1 | 0.110 | | |
| M2 | 1 | | 0 | 1 | 0 | 0.60 | 1.86 | 0.68 | 58.50 | | 3.113 | | | | -3640.8 | 0.153 | | |
| M3 | 0.64 | | 1.19 | 0.88 | 18.69 | 0.57 | 1.76 | 0.72 | 52.07 | | 3.063 | | | | -3613.1 | 0.180 | | |
| Model | Home response locations only | | | | | | | | | | | | | | | |  | |
| Parameters | | | | | | | | |  |  | 5×2 Fitting | | | | | |  |
|  | |  |  |  |  |  |  |  | RMSE | | | | MaxLogL | | Partial R2 | | |
| M0 | 1 | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | 3.037 | | | | -1190.9 | 0 | | |
| M1 | 0.84 | | 0.58 | 0.46 | 18.64 | 1 | 0 | 1 | 0 | | 2.716 | | | | -1136.4 | 0.200 | | |
| M2 | 1 | | 0 | 1 | 0 | 0.44 | 2.42 | 0.50 | 81.24 | | 2.725 | | | | -1137.7 | 0.195 | | |
| M3 | 2.88 | | 0.84 | 0.43 | 12.46 | 0.72 | 0.86 | 1.51 | 12.50 | | 2.713 | | | | -1135.9 | 0.202 | | |
|  | Weak compression group | | | | | | | | | | | | | | | | |  |
| Model | Multiple response locations | | | | | | | | | | | | | | | | |  |
|  | Parameters | | | | | | | |  |  | | 5×2 Fitting | | | | |  |
|  | |  |  |  |  |  |  |  | RMSE | | | | MaxLogL | | Partial R2 | | |
| M0 | 1 | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | 2.817 | | | | -2169.2 | 0 | | |
| M1 | 0.86 | | 0.46 | 0.80 | 21.2 | 1 | 0 | 1 | 0 | | 2.787 | | | | -2158.9 | 0.021 | | |
| M2 | 1 | | 0 | 1 | 0 | 0.85 | 0.46 | 1.00 | 2.96 | | 2.807 | | | | -2166.7 | 0.007 | | |
| M3 | 0.81 | | 0.56 | 0.80 | 21.9 | 0.92 | 0.17 | 1.04 | -1.73 | | 2.778 | | | | -2155.8 | 0.028 | | |
| Model | Home response locations only | | | | | | | | | | | | | | | | |  |
|  | Parameters | | | | | | | |  |  | 5×2 Fitting | | | | | |  |
|  | |  |  |  |  |  |  |  | RMSE | | | | MaxLogL | | Partial R2 | | |
| M0 | 1 | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | 2.379 | | | | -662.8 | 0 | | |
| M1 | 0.51 | | 0.69 | 0.44 | 33.0 | 1 | 0 | 1 | 0 | | 2.300 | | | | -653.0 | 0.067 | | |
| M2 | 1 | | 0 | 1 | 0 | 0.44 | 1.43 | 0.44 | 84.44 | | 2.304 | | | | -653.6 | 0.062 | | |
| M3 | 1.54 | | 11.7 | 2.25 | 17.8 | 0.58 | 0.06 | 2.24 | 17.13 | | 2.293 | | | | -652.2 | 0.071 | | |

## 4.2 Model validation for different groups

Table S10 summarizes the validation performance of RMSEs in all ten folds for two different compression groups using two algorithms.

**Table S10**

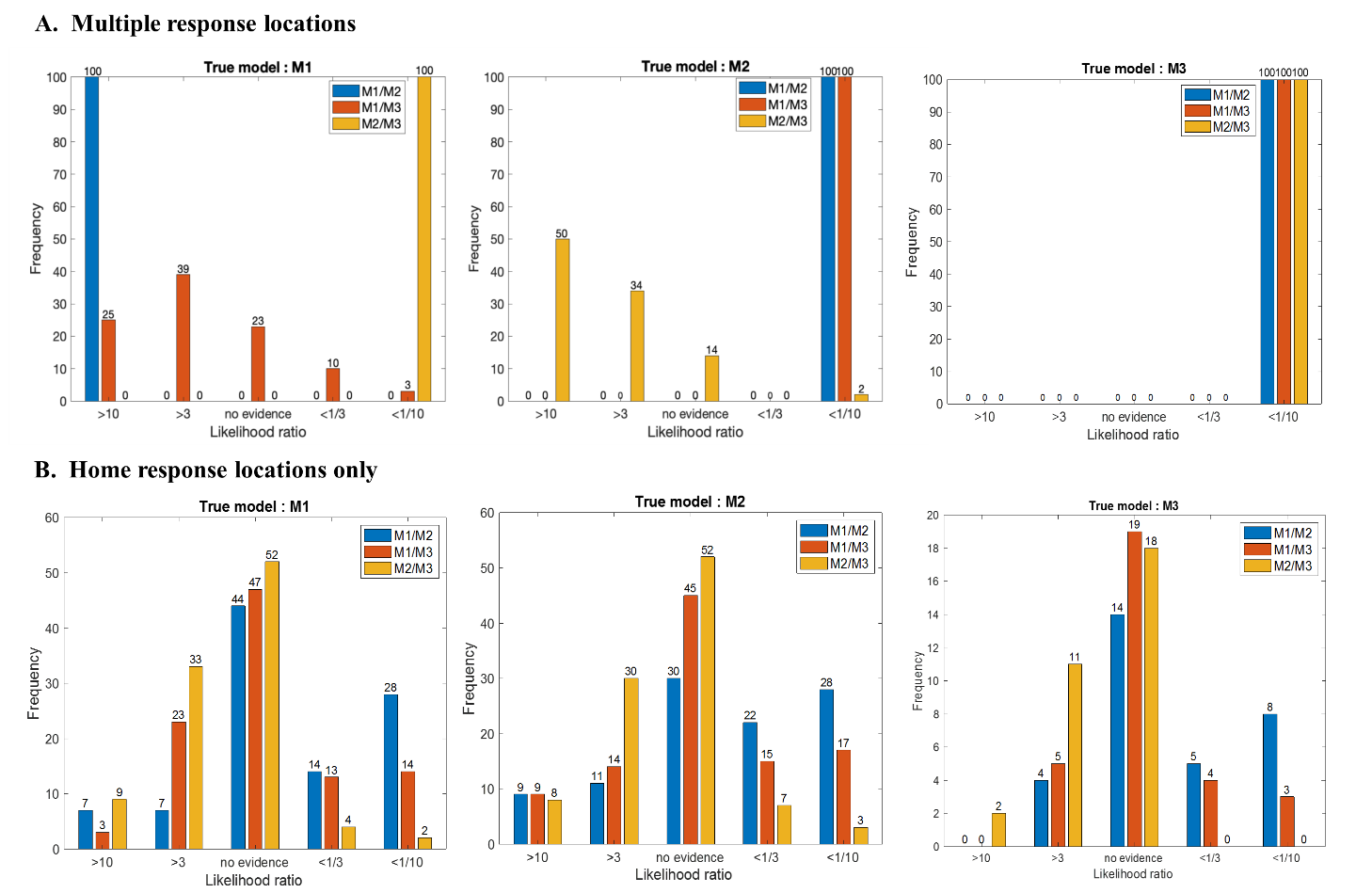
*RMSEs of individual folds in validation for strong and weak compression groups using two algorithms.*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Strong compression group | | | | | | | | | |
|  | Multiple response locations | | |  | Home response locations only | | | | |  | |
| RMSE | M1 | M2 | M3 |  | M1 | M2 | | M3 | |
| 1st round | 3.438 | 3.366 | 3.319 |  | 2.934 | 2.930 | | 2.934 | |
|  | 2.976 | 2.873 | 2.842 |  | 2.535 | 2.546 | | 2.536 | |
| 2nd round | 3.436 | 3.341 | 3.317 |  | 2.905 | 2.912 | | 2.907 | |
|  | 2.966 | 2.906 | 2.842 |  | 2.572 | 2.574 | | 2.572 | |
| 3rd round | 2.879 | 2.774 | 2.734 |  | 2.422 | 2.423 | | 2.423 | |
|  | 3.562 | 3.473 | 3.436 |  | 3.051 | 3.053 | | 3.050 | |
| 4th round | 3.350 | 3.272 | 3.234 |  | 2.920 | 2.931 | | 2.926 | |
|  | 3.119 | 2.990 | 2.956 |  | 2.576 | 2.595 | | 2.604 | |
| 5th round | 3.117 | 3.039 | 2.996 |  | 2.544 | 2.543 | | 2.544 | |
|  | 3.298 | 3.214 | 3.166 |  | 2.931 | 2.943 | | 2.932 | |
| Weak compression group | | | | | | | | | |
|  | Multiple response locations | | |  | Home response locations only | | | |  | |
| RMSE | M1 | M2 | M3 |  | M1 | | M2 | M3 | |
| 1st round | 2.788 | 2.803 | 2.777 |  | 2.334 | | 2.330 | 2.333 | |
|  | 2.842 | 2.819 | 2.836 |  | 2.322 | | 2.314 | 2.319 | |
| 2nd round | 2.681 | 2.695 | 2.672 |  | 2.360 | | 2.370 | 2.364 | |
|  | 2.925 | 2.934 | 2.927 |  | 2.281 | | 2.278 | 2.284 | |
| 3rd round | 2.790 | 2.737 | 2.785 |  | 2.390 | | 2.397 | 2.329 | |
|  | 2.907 | 2.890 | 2.915 |  | 2.329 | | 2.328 | 2.329 | |
| 4th round | 2.825 | 2.855 | 2.828 |  | 2.360 | | 2.359 | 2.359 | |
|  | 2.790 | 2.805 | 2.787 |  | 2.282 | | 2.276 | 2.338 | |
| 5th round | 2.862 | 2.867 | 2.850 |  | 2.474 | | 2.476 | 2.472 | |
|  | 2.732 | 2.756 | 2.726 |  | 2.155 | | 2.155 | 2.230 | |

## 4.3 The frequency of the pairwise likelihood ratio in different categories in model recovery

After producing 100 sets of simulated response locations using varied values of parameters, the frequency of different categories of evidence for the true model in model validation are represented in Figure S3. The results showed that the algorithm of using multiple response locations can successfully distinguish the true model from other models. Specifically, when the true model was M1, we got evidence favoring M1 over M2 and M3 with possibilities of 100% and 64% respectively. When the true model was M2, we got evidence favoring M2 over M1 and M3 with possibilities of 100% and 84% respectively. When the true model was M3, we got evidence favoring M3 over M1 and M2 with 100% for both. We never got evidence favoring the other two models over the true model.

In contrast, the algorithm of using home response locations only cannot clearly distinguish the true model from other models. When the true model was M1, we got evidence favoring M1 over M2 and M3 with possibilities of 14% and 26% respectively. When the true model was M2, we got evidence favoring M2 over M1 and M3 with possibilities of 50% and 38% respectively. When the true model was M3, we got evidence favoring M3 over M1 and M2 with possibilities of 7% and 0%. In addition to the relatively low chances to recover the true models, we also got evidence favoring the wrong models over the true model. There was evidence favoring M2 and M3 over the true model M1 with a possibility of 42% and 27% respectively, evidence favoring M1 and M3 over the true model M2 with a possibility of 20% and 10% respectively, and evidence favoring M1 and M2 over the true model M3 with possibilities of 5% and 13%.



**Figure S3.** Frequency in each category of likelihood ratio in model validation using (A) multiple response locations or (B) home response locations only. These locations are simulated locations from different true models (M1, M2, or M3). *Mi/Mj* indicates the ratio of model *Mi* over model *Mj.* >10 indicates strong evidence supporting *Mi*, >3 indicates clear evidence supporting *Mi*, <10 indicates strong evidence supporting *Mj*, <3 indicates clear evidence supporting *Mj*.

## 4.4 Values of parameters estimated from real and simulated response locations.

Table S11 lists the values of parameters estimated for the three models using real data (i.e., true parameters in the upper table) and using the simulated data generated from different models. The simulated data for each model were produced by varied values of model parameters considering the participants’ differences in compression patterns.

**Table S11**

*The similarity between values of parameters based on real response locations (the upper panel) and simulated response locations from different models (the lower panel). S\_M1, S\_M2, and S\_M3 denote the simulated response locations from the true models of M1, M2, and M3 respectively.*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | True parameters based on real data | | | | | | | | | | | | | | | | | | | |
| M1 | | | |  | | M2 | | | |  | M3 | | | | | | | | | | |
|  |  |  |  | |  | |  |  |  |  | |  |  |  |  |  |  |  |
|  | | 1.04 | 0.48 | 0.79 | 18.38 | | 0.70 | | 1.29 | 0.78 | 41.11 | 0.82 | | 0.78 | 0.84 | 20.42 | 0.69 | 1.10 | 0.82 | 34.21 | | |
|  | Recovered parameters based on simulated data | | | | | | | | | | | | | | | | | | | | | |
| S\_M1 | | 1.07 | 0.48 | 0.80 | 17.78 | | 1.07 | | 0.21 | 0.85 | 23.60 | 1.06 | | 0.45 | 0.79 | 18.44 | 0.96 | 0.06 | 0.97 | 4.76 | | |
| S\_M2 | | 1.25 | -.30 | 0.93 | 1.73 | | 0.59 | | 1.20 | 0.79 | 40.61 | 0.98 | | 0.01 | 1.00 | -.09 | 0.60 | 1.21 | 0.79 | 40.83 | | |
| S\_M3 | | 1.04 | 0.29 | 0.81 | 16.66 | | 0.67 | | 1.04 | 0.74 | 45.00 | 0.96 | | 0.50 | 0.84 | 19.09 | 0.64 | 0.93 | 0.81 | 34.86 | | |