Modelling results

Are there unconscious visual images in aphantasia? Development of an implicit priming paradigm

Maël Delem1,✉, Rudy Purkart1,2, Eddy Cavalli1, Virginie Ranson1, Charlotte Andrey1, Rémy Versace1, and Gaën Plancher1,3

1 Study of Cognitive Mechanisms (EMC) Laboratory  
2 Research Center of the Institut Universitaire de Gériatrie de Montréal (CRIUGM)  
3 Institut Universitaire de France (IUF)

✉ Correspondence: [Maël Delem <mael.delem@univ-lyon2.fr>](mailto:mael.delem@univ-lyon2.fr)

# 1. Questionnaires analyses

## 1.1 Group differences

### 1.1.1 Table

| Questionnaire | Aphantasics | Controls | df | t | p |
| --- | --- | --- | --- | --- | --- |
| VVIQ | 19.045 ± 0.911 | 54.242 ± 1.092 | 149 | -21.35 | 3.49e-47 |
| OSIQ\_Object | 23.91 ± 0.99 | 46.581 ± 1.186 | 149 | -13.35 | 3.08e-27 |
| OSIQ\_Spatial | 40.955 ± 0.866 | 45.532 ± 1.038 | 149 | -3.51 | 5.94e-04 |
| SUIS | 17.292 ± 0.749 | 37.194 ± 0.898 | 149 | -15.63 | 3.24e-33 |

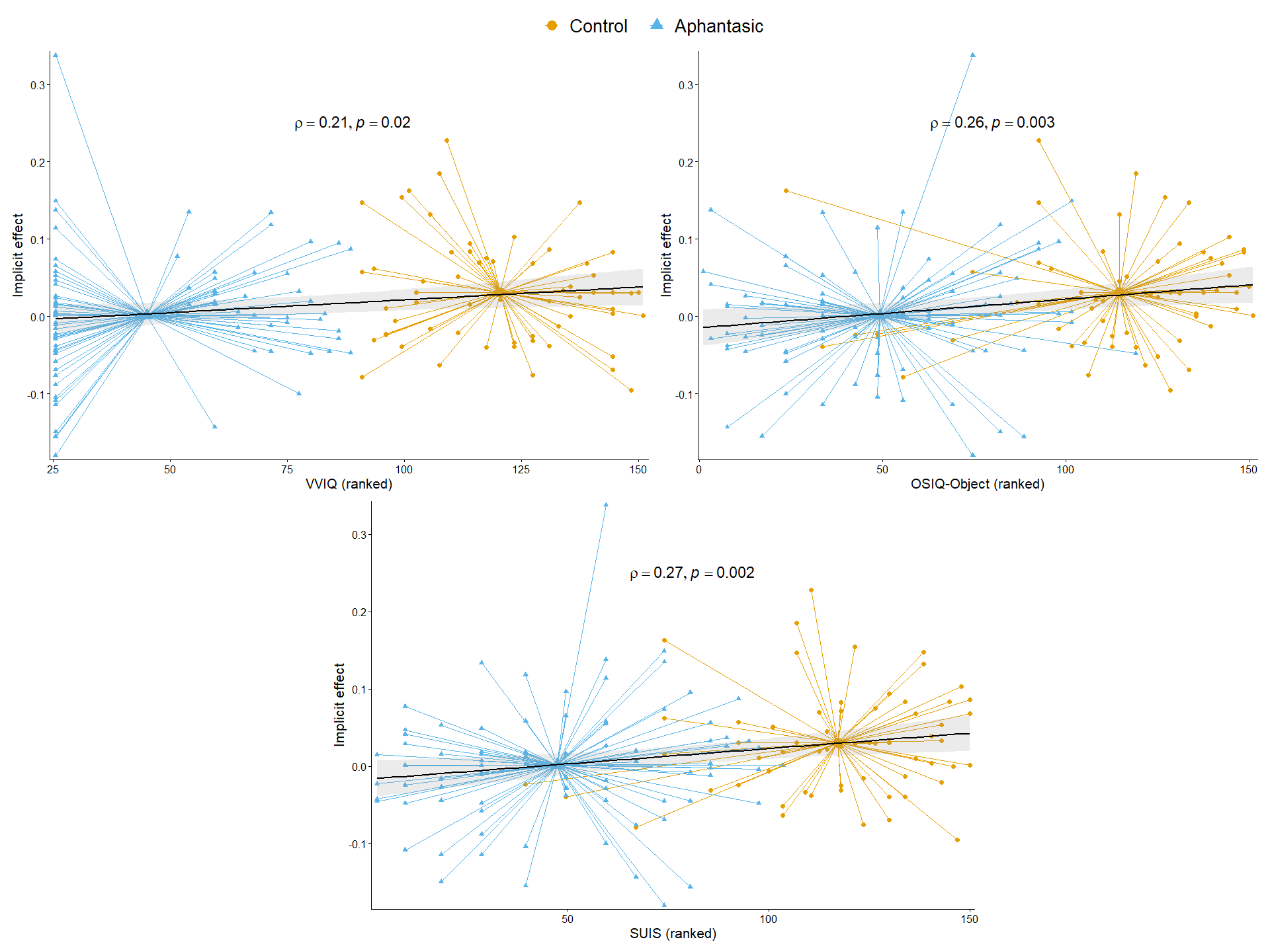
### 1.1.2 Plot

|  |
| --- |
| Figure 1.1 |

## 1.2 Congruence effects

### 1.2.1 Correlations

### 1.2.2 Plots



# 2. Accuracy analyses

We will quickly check for accuracy differences between groups with a logistic regression model.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table S2.1: Performance and estimates of the logistic GLMM fitted on accuracy in the implicit task.   | AIC | AICc | BIC | R2 (cond.) | R2 (marg.) | ICC | RMSE | Sigma | Log\_loss | Score\_log | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | 2614.99 | 2615.01 | 2679.02 | 0.17 | 9.48e-03 | 0.16 | 0.18 | 1.00 | 0.13 | -Inf |   # Fixed Effects   | Parameter | Log-Odds | SE | 95% CI | z | p | | --- | --- | --- | --- | --- | --- | | (Intercept) | 3.64 | 0.10 | (3.43, 3.84) | 34.70 | < .001 | | aphantasia1 | 0.19 | 0.19 | (-0.18, 0.56) | 1.01 | 0.312 | | congruence1 | 0.05 | 0.12 | (-0.18, 0.29) | 0.44 | 0.659 | | color1 | 0.32 | 0.12 | (0.08, 0.55) | 2.63 | 0.009 | | aphantasia1 × congruence1 | 0.15 | 0.24 | (-0.32, 0.63) | 0.64 | 0.519 | | aphantasia1 × color1 | -0.18 | 0.24 | (-0.65, 0.29) | -0.74 | 0.462 | | congruence1 × color1 | 8.71e-03 | 0.24 | (-0.46, 0.48) | 0.04 | 0.971 | | aphantasia1 × congruence1 × color1 | 0.34 | 0.48 | (-0.60, 1.29) | 0.72 | 0.473 |     # Random Effects   | Parameter | Coefficient | | --- | --- | | SD (Intercept: subjectid) | 0.79 | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table S2.2: Estimated probability of a correct answer and log-odds contrasts between groups for the accuracy in the implicit task.  Estimated Marginal Means   | aphantasia | Probability | SE | 95% CI | | --- | --- | --- | --- | | Control | 0.97 | 4.07e-03 | (0.96, 0.98) | | Aphantasia | 0.98 | 3.02e-03 | (0.97, 0.98) |   Marginal means estimated at aphantasia  Marginal Contrasts Analysis   | Level1 | Level2 | Odds ratio | 95% CI | SE | df | z | p | | --- | --- | --- | --- | --- | --- | --- | --- | | Control | Aphantasia | 0.83 | (0.57, 1.20) | 0.16 | Inf | -1.01 | 0.312 |   Marginal contrasts estimated at aphantasia p-values are uncorrected. |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table S2.3: Performance and estimates of the logistic GLMM fitted on accuracy in the explicit task.   | AIC | AICc | BIC | R2 (cond.) | R2 (marg.) | ICC | RMSE | Sigma | Log\_loss | Score\_log | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | 2020.26 | 2020.28 | 2084.03 | 0.18 | 0.03 | 0.16 | 0.15 | 1.00 | 0.11 | -Inf |   # Fixed Effects   | Parameter | Log-Odds | SE | 95% CI | z | p | | --- | --- | --- | --- | --- | --- | | (Intercept) | 3.98 | 0.12 | (3.74, 4.21) | 33.19 | < .001 | | aphantasia1 | 0.21 | 0.21 | (-0.19, 0.62) | 1.03 | 0.304 | | congruence1 | 0.12 | 0.15 | (-0.16, 0.41) | 0.84 | 0.401 | | color1 | 0.65 | 0.15 | (0.37, 0.94) | 4.49 | < .001 | | aphantasia1 × congruence1 | -8.30e-03 | 0.29 | (-0.58, 0.56) | -0.03 | 0.977 | | aphantasia1 × color1 | -0.24 | 0.29 | (-0.81, 0.33) | -0.83 | 0.407 | | congruence1 × color1 | 0.32 | 0.29 | (-0.25, 0.89) | 1.11 | 0.265 | | aphantasia1 × congruence1 × color1 | -0.31 | 0.58 | (-1.45, 0.83) | -0.53 | 0.595 |     # Random Effects   | Parameter | Coefficient | | --- | --- | | SD (Intercept: subjectid) | 0.78 | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table S2.4: Estimated probability of a correct answer and log-odds contrasts between groups for the accuracy in the explicit task.  Estimated Marginal Means   | aphantasia | Probability | SE | 95% CI | | --- | --- | --- | --- | | Control | 0.98 | 3.37e-03 | (0.97, 0.99) | | Aphantasia | 0.98 | 2.40e-03 | (0.98, 0.99) |   Marginal means estimated at aphantasia  Marginal Contrasts Analysis   | Level1 | Level2 | Odds ratio | 95% CI | SE | df | z | p | | --- | --- | --- | --- | --- | --- | --- | --- | | Control | Aphantasia | 0.81 | (0.54, 1.21) | 0.17 | Inf | -1.03 | 0.304 |   Marginal contrasts estimated at aphantasia p-values are uncorrected. |

# 3. Response Times analyses

## 3.1 Rationale

To account for the non-normal, positively skewed distributions of the RTs, we fitted Generalized Linear Mixed Models (GLMMs) with inverse Gaussian distributions. The models were implemented in the lme4 R package and integrated in tidymodels workflows using the package multilevelmod. Models with Gamma and Gaussian distributions were also fitted and compared with the AIC and BIC to ensure that we chose the best distribution available.

The models included the ***Group*** (aphantasic, control), ***Congruence*** condition (congruent or incongruent) and ***Color*** condition (color or uncolored) along with all their two and three way interactions as fixed categorical predictors, while ***participants*** have been included as grouping factors (i.e. “random effects”). The random effect structure was chosen by fitting and comparing models with every possible combination of distribution and structure (intercept by participant, congruence or color, slope by participant on congruence and/or color) aiming for the best balance between goodness of fit and parsimony. Complex random-effects structures including various slopes on the factors failed to converge to stable and reliable estimates, hence the optimal models chosen included a single by-participant random intercept.

## 3.2 Model fitting

The formula of the model fitted is . See the HTML version for the code and details.

## 3.3 Model diagnostics

The quality checks of the models are displayed in [Figure S3.1](#suppfig-implicit-checks-2) and [Figure S3.2](#suppfig-explicit-checks-2).

|  |
| --- |
| Figure S3.1: Model assumption checks for the Generalized Linear Mixed Model fit on the RTs in the implicit task. |

|  |
| --- |
| Figure S3.2: Model assumption checks for the Generalized Linear Mixed Model fit on the RTs in the explicit task. |

## 3.4 Model summaries

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table S3.1: Performance and estimates of the GLMM fitted on the implicit task data.   | AIC | AICc | BIC | R2 (cond.) | R2 (marg.) | ICC | RMSE | Sigma | | --- | --- | --- | --- | --- | --- | --- | --- | | -4619.06 | -4619.03 | -4548.26 | 0.01 | 3.47e-04 | 0.01 | 0.26 | 0.48 |   # Fixed Effects   | Parameter | Coefficient | SE | 95% CI | t(8767) | p | | --- | --- | --- | --- | --- | --- | | (Intercept) | 0.67 | 0.01 | (0.64, 0.69) | 53.99 | < .001 | | aphantasia1 | 0.02 | 0.02 | (-0.03, 0.07) | 0.77 | 0.442 | | congruence1 | -0.01 | 4.03e-03 | (-0.02, -5.69e-03) | -3.37 | < .001 | | color1 | -2.57e-03 | 4.02e-03 | (-0.01, 5.32e-03) | -0.64 | 0.523 | | aphantasia1 × congruence1 | 0.02 | 8.05e-03 | (7.70e-03, 0.04) | 2.92 | 0.004 | | aphantasia1 × color1 | -7.96e-04 | 8.04e-03 | (-0.02, 0.01) | -0.10 | 0.921 | | congruence1 × color1 | 0.01 | 8.03e-03 | (-5.65e-03, 0.03) | 1.26 | 0.209 | | aphantasia1 × congruence1 × color1 | 0.02 | 0.02 | (-0.01, 0.05) | 1.20 | 0.229 |     # Random Effects   | Parameter | Coefficient | | --- | --- | | SD (Intercept: subjectid) | 0.08 | | SD (Residual) | 0.48 | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table S3.2: Performance and estimates of the GLMM fitted on the explicit task data.   | AIC | AICc | BIC | R2 (cond.) | R2 (marg.) | ICC | RMSE | Sigma | | --- | --- | --- | --- | --- | --- | --- | --- | | -2673.61 | -2673.58 | -2603.01 | 0.03 | 7.96e-04 | 0.03 | 0.28 | 0.41 |   # Fixed Effects   | Parameter | Coefficient | SE | 95% CI | t(8593) | p | | --- | --- | --- | --- | --- | --- | | (Intercept) | 0.79 | 0.02 | (0.75, 0.83) | 37.14 | < .001 | | aphantasia1 | 0.01 | 0.04 | (-0.07, 0.09) | 0.25 | 0.799 | | congruence1 | -0.02 | 4.21e-03 | (-0.03, -9.82e-03) | -4.29 | < .001 | | color1 | -0.03 | 4.20e-03 | (-0.04, -0.02) | -6.93 | < .001 | | aphantasia1 × congruence1 | 0.03 | 8.42e-03 | (0.01, 0.04) | 3.19 | 0.001 | | aphantasia1 × color1 | 7.19e-03 | 8.39e-03 | (-9.26e-03, 0.02) | 0.86 | 0.392 | | congruence1 × color1 | 2.74e-03 | 8.39e-03 | (-0.01, 0.02) | 0.33 | 0.744 | | aphantasia1 × congruence1 × color1 | 0.01 | 0.02 | (-0.02, 0.05) | 0.84 | 0.402 |     # Random Effects   | Parameter | Coefficient | | --- | --- | | SD (Intercept: subjectid) | 0.12 | | SD (Residual) | 0.41 | |

## 3.5 Estimated means and contrasts

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table S3.3: Estimated means for each group in each congruence condition and contrasts between groups and conditions in the implicit task.   | Group | Condition | Median (ms) | SE | df | asymp.LCL | asymp.UCL | | --- | --- | --- | --- | --- | --- | --- | | Control | Incongruent | 669.71 | 19.36 | Inf | 631.77 | 707.65 | | Aphantasia | Incongruent | 676.89 | 15.84 | Inf | 645.84 | 707.93 | | Control | Congruent | 644.38 | 19.31 | Inf | 606.53 | 682.22 | | Aphantasia | Congruent | 675.05 | 15.83 | Inf | 644.02 | 706.08 |   Marginal Contrasts Analysis   | Level1 | Level2 | Difference | 95% CI | SE | df | z | p | | --- | --- | --- | --- | --- | --- | --- | --- | | Aphantasia Incongruent | Aphantasia Congruent | 1.84e-03 | (-0.01, 0.01) | 5.23e-03 | Inf | 0.35 | 0.725 | | Aphantasia Incongruent | Control Congruent | 0.03 | (-0.02, 0.08) | 0.02 | Inf | 1.30 | 0.193 | | Control Congruent | Aphantasia Congruent | -0.03 | (-0.08, 0.02) | 0.02 | Inf | -1.23 | 0.219 | | Control Incongruent | Aphantasia Congruent | -5.34e-03 | (-0.05, 0.04) | 0.02 | Inf | -0.21 | 0.831 | | Control Incongruent | Aphantasia Incongruent | -7.18e-03 | (-0.06, 0.04) | 0.02 | Inf | -0.29 | 0.774 | | Control Incongruent | Control Congruent | 0.03 | ( 0.01, 0.04) | 6.13e-03 | Inf | 4.13 | < .001 |   Marginal contrasts estimated at aphantasia, congruence p-values are uncorrected. |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table S3.4: Estimated means for each group in each congruence condition and contrasts between groups and conditions in the explicit task.   | Group | Condition | Median (ms) | SE | df | asymp.LCL | asymp.UCL | | --- | --- | --- | --- | --- | --- | --- | | Control | Incongruent | 801.78 | 33.22 | Inf | 736.68 | 866.88 | | Aphantasia | Incongruent | 799.21 | 27.05 | Inf | 746.18 | 852.23 | | Control | Congruent | 770.29 | 33.17 | Inf | 705.28 | 835.30 | | Aphantasia | Congruent | 794.57 | 27.04 | Inf | 741.56 | 847.57 |   Marginal Contrasts Analysis   | Level1 | Level2 | Difference | 95% CI | SE | df | z | p | | --- | --- | --- | --- | --- | --- | --- | --- | | Aphantasia Incongruent | Aphantasia Congruent | 4.64e-03 | (-0.01, 0.02) | 5.45e-03 | Inf | 0.85 | 0.394 | | Aphantasia Incongruent | Control Congruent | 0.03 | (-0.05, 0.11) | 0.04 | Inf | 0.68 | 0.499 | | Control Congruent | Aphantasia Congruent | -0.02 | (-0.11, 0.06) | 0.04 | Inf | -0.57 | 0.570 | | Control Incongruent | Aphantasia Congruent | 7.21e-03 | (-0.08, 0.09) | 0.04 | Inf | 0.17 | 0.866 | | Control Incongruent | Aphantasia Incongruent | 2.57e-03 | (-0.08, 0.09) | 0.04 | Inf | 0.06 | 0.952 | | Control Incongruent | Control Congruent | 0.03 | ( 0.02, 0.04) | 6.42e-03 | Inf | 4.91 | < .001 |   Marginal contrasts estimated at aphantasia, congruence p-values are uncorrected. |

## 3.6 Visualisations

The figures below are also displayed in the main article. [See the HTML version for the code and details.] {.content-hidden when-format=“html”}

|  |
| --- |
| Figure 3.1: Subject means and model-estimated means per group and condition in the implicit task. |

|  |
| --- |
| Figure 3.2: Subject means and model-estimated means per group and condition in the explicit task. |

# 4. Correlational analyses