# Supplementary Materials

**Supplementary Materials 1 – Predictors information and analysis details**

***Supplementary Figure 1 – Distribution of the frequency measures***

Density distribution of the frequency values for our set of stimuli.

Shape

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***Supplementary Figure 2 – Distribution of concept variability across participants for the rating measures***

Density distribution of concepts’ standard deviation across participants for the collected ratings (scale 1-6)

A picture containing chart

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**PCA procedure for visual and visuo-orthographic predictors**

measures with multidimensional output were averaged to obtain a single value for every image. As a rule of thumb, we selected the Principal Components (PCs) that, alone, explained more variance than what a variable would explain if they all explained the same amount of variance.

**Image visual PCs**

7 variables -> threshold: 100 / 7 = 14.29 %. We extracted three orthogonal PCs, explaining more than 84 % of the variance. We labeled the first PC *Image visual PC1*(about 50 % of variance explained, strong positive correlation with convolutional layer 1 of AlexNet, and strong negative correlation with SNR, GIST, Entropy, Saliency and AlexNet layer 4). The second PC was named *Image visual PC2*(about 18 % of variance explained, strong positive correlation with AlexNet layer 7, strong negative correlation with AlexNet layer 4). The third PC was named *Image visual PC3*(about 15 % of variance explained, medium positive correlation with AlexNet layers and Saliency, medium negative correlation with Entropy). We interpret the PC1 as an estimate of low-to-mid-level visual features of the images (stronger weights from AlexNet early layer, SNR, saliency, but also from AlexNet mid layer and GIST), while the PC2 seems to capture more complex mid-to-high-level visual features (stronger weights from AlexNet mid layer and entropy, but also from AlexNet late layer). PC3, however, has a less clear interpretation, capturing part of variance from both low-level and high-level visual features estimates (higher weights for all the three AlexNet layers).

***Supplementary Figure 3 – Correlations of visual predictors and extracted PCs***

Product-Moment Correlation Coefficients for each pair of visual predictors of objects and the Principal Components (PCs) extracted from the PCA on those predictors.

Chart

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|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Variables** | **PC1 loadings** | **PC2 loadings** | | **PC3 loadings** |
| AlexNet conv1 | **0.459** | 0.005 | | **0.413** |
| AlexNet conv4 | **-0.305** | **-0.505** | | **0.436** |
| AlexNet fc7 | -0.062 | **0.735** | | **0.352** |
| Saliency | **-0.366** | 0.154 | | **0.477** |
| GIST | **-0.486** | 0.080 | | 0.194 |
| Entropy | **-0.366** | **0.337** | | **-0.482** |
| SNR | **-0.434** | -0.249 | -0.134 | |

***Supplementary Table 1.*** Object image PCA loadings for every variable in every extracted principal component (PCs). They represent the weights of every variable on the extracted PCs.

**Visuo-orthographic PC**

4 variables -> threshold: 100 / 4 = 25 %; one principal component (PC) was extracted and was labeled *Visuo-orthographic PC* (variance explained circa 92 %; strong positive correlation with all the original variables). Being all the variables highly correlated between them and with the PC, interpretation seems straightforward and difficult at the same time. The rationale for including many variables that were expected to be highly correlated was to acknowledge the different levels (visual and orthographical) from which we wanted to extract a covariate able to control for perceptual aspects of a word.

***Supplementary Figure 4 – Correlations between visuo-orthographic predictors and the extracted PC***

Product-Moment Correlation Coefficients for each pair of visuo-orthographic predictors of words and the Principal Component (PC) extracted from the PCA on those predictors.

Chart

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***Supplementary Table 2.*** Word image PCA loadings for every variable in the extracted principal component (PC). They represent the weights that every variable has on the extract PC.

|  |  |
| --- | --- |
| **Variables** | **PC1 loadings** |
| OLD20 | **0.487** |
| Word length | **0.512** |
| Entropy | **0.515** |
| SNR | **0.485** |

***Supplementary Figure 5 – Correlations between continuous predictors measured for the study***

Product-Moment Correlation Coefficients for each pair of predictors used in the experiment.

***Chart

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**Model specifications**

We fitted Linear Mixed-effects Models (LMMs) via maximum likelihood estimation, and Satterthwaite’s method was used to obtain p-values (package lmerTest, Kuznetsova et al., 2017). Using the *scale()* function in R, we transformed each continuous predictor variable onto a common scale which improves model fitting procedures. These continuous predictors are the four frequency measures (SUBTLEX, dlexDB, Greene, ADE20K) and the covariates (Concept familiarity [different in Exp 1-2 and Exp 3], Image typicality [different in Exp 1-2 and Exp 3], Image visual PC1, Image visual PC2, Image visual PC3, Visual-orthographic PC, Target repetition [different in Exp 1-2 and Exp 3]).

For the coding of contrasts in categorical predictors (*Exp 1:* Concept modality: Words – Objects; Concept category: Natural – Man-made; Trial accuracy: Correct – Incorrect*; Exp 2 and Exp 3:* Target modality: Words - Objects; Priming condition: Cross-modal – Uni-modal; Matching condition: Mismatching – Matching; Trial accuracy: Correct - Incorrect), we used sum contrast coding, which in our case gave us an estimate of the difference between the two levels of each of our categorical variables, like main effects in a multi-way repeated measures ANOVA (Schad et al., 2020; Brehm & Alday, 2020).

Including trial response accuracy as a categorical covariate in the LMMs allows us to consider the variance explained by the output of the task (i.e., correct or incorrect trial), but at the same time to estimate the impact of the other variables independently from the output of the task itself. Besides, this way, we did not have to exclude further trials from the analysis, and we could exploit the flexibility offered by LMMs.

To account for the multiple repetitions of the same object concepts within participants and a potential carry-over effect that could confound frequency effects, we included in the models a numeric covariate Target repetition that represents the number of times that the current target concept has been presented (as either a word or an object image, as either target or prime).

To prevent misinterpretation of the effects and confounds due to high correlation of the predictors, we assessed potential multicollinearity of the models by computing the variance inflation factors (VIFs) for each term in each model, using the *check\_collinearity()* function in R (package performance; Lüdecke et al., 2021). When variance inflation factors are below 5, there are low correlations between predictors and therefore no predictors need to be excluded to avoid confounds in the interpretation of the results. When the variance inflation factors are higher than 5, those predictors should be excluded from the model and the analysis should be repeated.

**Analysis details**

1) We implement a model comparison based on the Akaike Information Criterion (AIC, Akaike, 1981). This step allowed us to compare our four frequency measures and select the frequency measures with the best fit. To implement this, we first fit one model per frequency measure (i.e., SUBTLEX, dlexDB, ADE20K, and Greene frequency) separately for the word and the object recognition trials (four frequency measures times two modalities: eight models in total). All models implemented the same covariates and random-effects structure. Then we compared the four models of each modality to a “baseline” model that did not include the frequency measure, but that was estimated on the same subset of data and implemented the same structure of covariates and random effects (2 baseline models in total, one for words and one for objects data). With this procedure, we could estimate the singular fit of each frequency measure in each stimulus modality. From that, we selected the frequency measures that explained a considerable amount of variance in both modalities for further analysis. A better fit was determined by a significant decrease in the AIC, which was tested by implementing the *anova()* function in R. Given the different sources from which word and object frequencies are estimated, they might provide a distinct contribution in representing the occurrence of objects/words in the world. Therefore, we operated the AIC-based selection following these criteria: in the best case, we would have selected two measures, i.e., the best fitting OF and the best fitting WF measure. In the worst-case, none of the frequency measures would have explained variance in both object and word trials. While, in between, we would have selected either only an OF or a WF measure.

2) After selecting the best frequency measures, we ran a LMM estimating the effects of those selected frequencies on the entire dataset (word trials + object trials), and including all categorical factors and continuous covariates, as well as random factors for participants and concepts.

3) When we detected significant interactions between frequency measures and categorical predictors, we also ran post-hoc LMMs in order to understand the different effects of frequency between different conditions (e.g., SUBTLEX in Cross-modal trials vs. SUBTLEX in Uni-modal trials) and within each condition (e.g., the simple effect of SUBTLEX in Cross-modal trials and simple effect of SUBTLEX in Uni-modal trials). Note that the estimation of frequency effects, given the structure of linear models, was independent (i.e., controlled for) from the effect of the several continuous covariates included in the models.

## Supplementary Materials 2 – Model selection in Experiment 1

Formula of the models computed in the selection process (1 model x 4 frequency measures x 2 modalities + baseline model without frequency measures x 2 modalities = 10 models):

*Exp1\_logRT ~ FREQUENCY MEASURE +*

*Concept category + Concept familiarity + Image typicality +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition + Trial accuracy +*

*(1|Participants) + (1/Concepts)*

***Supplementary Table 3.*** Summary table of the models included in the selection process. “Frequency” indicates the frequency measure included in the model, where ‘Baseline’ means no measures included. “AIC” is the criterion used to evaluate the fit of the model. “Modality” indicates which subset of data was considered. “AIC difference” is the difference in AIC between every model and the baseline model of the same modality. More negative differences indicate a better fit of the model including the frequency measure; significant improvements of fit are highlighted in bold.

|  |  |  |  |
| --- | --- | --- | --- |
| **Frequency** | **AIC** | **Modality** | **AIC difference** |
| Baseline | -1214.816 | Objects | 0 |
| SUBTLEX WF | -1218.978 | Objects | **-4.163** |
| ADE20K OF | -1212.867 | Objects | 1.949 |
| Greene OF | -1213.126 | Objects | 1.690 |
| dlexDB WF | -1214.462 | Objects | 0.354 |
| Baseline | -1442.289 | Words | 0 |
| SUBTLEX WF | -1469.443 | Words | **-27.153** |
| ADE20K OF | -1443.517 | Words | -1.228 |
| dlexDB WF | -1455.736 | Words | **-13.447** |
| Greene OF | -1441.156 | Words | 1.133 |

## Supplementary Materials 3 – Results of the selected model in Experiment 1

*Exp1\_logRT ~ SUBTLEX WF \* Concept modality +*

*Concept category + Concept familiarity + Image typicality +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition +*

*Trial accuracy + (1|Participants) + (1/Concepts)*

***Supplementary Table 4.*** Variance Inflation Factors for the estimated effects of the main model of Experiment 1

|  |  |
| --- | --- |
| **Term** | **VIF** |
| Concept modality (Words – Objects) | 1.012 |
| SUBTLEX WF | 1.535 |
| Visuo-orthographic PC | 1.698 |
| Concept familiarity | 1.043 |
| Image typicality | 1.015 |
| Image visual PC1 | 1.032 |
| Image visual PC2 | 1.027 |
| Image visual PC3 | 1.063 |
| Trial accuracy (Correct – Incorrect) | 1.017 |
| Concept category (Natural – Man-made) | 1.180 |
| Concept modality x SUBTLEX | 1.000 |
| Target repetition | 1.010 |

The measured SUBTLEX WF effect was independent of visual and visuo-orthographic information of the stimuli, as well as of image typicality, subjective familiarity, concept repetition, concept category and accuracy of categorization.

***Supplementary Table 5.*** Results from the selected model for Exp 1 including demographics of participants

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.403 | 0.071 | 89.871 | **<0.001** |
| Concept modality (Words – Objects) | 0.094 | 0.005 | 20.527 | **<0.001** |
| SUBTLEX WF | -0.031 | 0.007 | -4.404 | **<0.001** |
| Visuo-orthographic PC | -0.006 | 0.007 | -0.813 | 0.416 |
| Concept familiarity | -0.004 | 0.003 | -1.050 | 0.294 |
| Image typicality | -0.004 | 0.003 | -1.312 | 0.190 |
| Image visual PC1 | -0.002 | 0.006 | -0.314 | 0.754 |
| Image visual PC2 | 0.019 | 0.006 | 3.257 | **0.001** |
| Image visual PC3 | 0.008 | 0.006 | 1.403 | 0.161 |
| Target repetition | -0.011 | 0.002 | -4.933 | **<0.001** |
| Trial accuracy (Correct – Incorrect) | -0.017 | 0.009 | -1.943 | 0.052 |
| Concept category (Natural – Man-made) | 0.001 | 0.012 | 0.112 | 0.911 |
| Age | 0.030 | 0.032 | 0.950 | 0.342 |
| Gender (Men – Women) | -0.059 | 0.051 | -1.160 | 0.246 |
| Gender (No answer - Men and Women) | -0.265 | 0.147 | -1.807 | 0.071 |
| Education (University – Highschool) | -0.071 | 0.085 | -0.838 | 0.402 |
| Education (Highschool – Technical school) | -0.015 | 0.199 | -0.073 | 0.942 |
| Education (Technical school – No answer) | -0.179 | 0.201 | -0.890 | 0.373 |
| Language (Bi/multilingualism – Monolingualism) | -0.005 | 0.064 | -0.078 | 0.938 |
| SUBTLEX WF x (Words – Objects) | -0.019 | 0.005 | -4.161 | **<0.001** |

**Supplementary Materials 4 – Post-hoc of interaction in Experiment 1**

2 post-hoc models are estimated, with the same formula, but on 2 different subsest of the data (Object trials and Word trials):

*Exp1\_logRT ~ SUBTLEX WF +*

*Concept category + Concept familiarity + Image typicality +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition +*

*Trial accuracy + (1|Participants) + (1/Concepts)*

***Supplementary Table 6.*** Results from the post-hoc models for semantic categorization

**Objects Words**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.449 | 0.022 | 289.694 | **<0.001** | 6.520 | 0.024 | 266.828 | **<0.001** |
| SUBTLEX WF | -0.022 | 0.009 | -2.524 | **0.012** | -0.041 | 0.007 | -5.794 | **<0.001** |
| Concept category | 0.009 | 0.015 | 0.610 | 0.542 | -0.008 | 0.012 | -0.626 | 0.531 |
| Visuo-orthographic PC | -0.006 | 0.009 | -0.671 | 0.502 | -0.006 | 0.007 | -0.823 | 0.411 |
| Concept familiarity | -0.000 | 0.005 | -0.050 | 0.960 | -0.005 | 0.004 | -1.151 | 0.250 |
| Image typicality | -0.009 | 0.004 | -1.977 | **0.048** | -0.001 | 0.004 | -0.258 | 0.797 |
| Image visual PC1 | -0.004 | 0.007 | -0.598 | 0.550 | 0.000 | 0.006 | 0.069 | 0.945 |
| Image visual PC2 | 0.026 | 0.007 | 3.581 | **<0.001** | 0.011 | 0.006 | 1.949 | 0.051 |
| Image visual PC3 | 0.005 | 0.007 | 0.692 | 0.489 | 0.012 | 0.006 | 2.034 | **0.042** |
| Target repetition | 0.009 | 0.021 | 0.430 | 0.667 | -0.030 | 0.024 | -1.293 | 0.196 |
| Trial accuracy | -0.059 | 0.013 | -4.379 | **<0.001** | 0.005 | 0.011 | 0.483 | 0.629 |

***Supplementary Figure 6 – RTs estimated from post-hoc models of Experiment 1***

Estimated response times from individual post-hoc models for object (red) and word (blue) trials as a function of SUBTLEX frequency in Experiment 1. Points show concepts with different level of frequency, averaged across participants; lines represent linear fitting of points and shaded areas represent 95 % confidence interval

Chart, scatter chart

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## Supplementary Materials 5 – Results of new ratings on data of Exp 1

*Exp1\_logRT ~ SUBTLEX WF \* Concept modality +*

*Concept category + Concept familiarity (replication) +*

*Image typicality (replication) +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition +*

*Trial accuracy + (1|Participants) + (1/Concepts)*

***Supplementary Table 7****.* Results from main model of Exp 1 including ratings from replication study

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.479 | 0.021 | 303.428 | **<0.001** |
| Concept modality (Words – Objects) | 0.094 | 0.005 | 20.527 | **<0.001** |
| SUBTLEX WF | -0.035 | 0.008 | -4.690 | **<0.001** |
| Visuo-orthographic PC | -0.009 | 0.007 | -1.148 | 0.251 |
| Concept familiarity (replication) | 0.012 | 0.007 | 1.857 | 0.063 |
| Image typicality (replication) | -0.009 | 0.006 | -1.513 | 0.130 |
| Image visual PC1 | -0.001 | 0.006 | -0.233 | 0.816 |
| Image visual PC2 | 0.013 | 0.006 | 2.316 | **0.021** |
| Image visual PC3 | 0.010 | 0.006 | 1.741 | 0.082 |
| Target repetition | -0.011 | 0.002 | -4.933 | **<0.001** |
| Trial accuracy (Correct – Incorrect) | -0.017 | 0.009 | -1.905 | 0.057 |
| Concept category (Natural – Man-made) | 0.012 | 0.013 | 0.925 | 0.355 |
| SUBTLEX x (Words – Objects) | -0.019 | 0.005 | -4.157 | **<0.001** |

**Supplementary Materials 6 – Conceptual Distinctiveness effect in Exp 1**

*Exp1\_logRT ~ SUBTLEX WF \* Concept modality +*

*Concept category + Concept familiarity + Image typicality +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition + Conceptual Distinctiveness (CD) +*

*Trial accuracy + (1|Participants) + (1/Concepts)*

***Supplementary Table 8.***Results of Experiment 1 including CD as covariate

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.479 | 0.021 | 302.570 | **<0.001** |
| Concept modality (Words – Objects) | 0.094 | 0.005 | 20.529 | **<0.001** |
| SUBTLEX WF | -0.032 | 0.008 | -4.150 | **<0.001** |
| Visuo-orthographic PC | -0.006 | 0.007 | -0.805 | 0.421 |
| Concept familiarity | -0.003 | 0.003 | -0.980 | 0.327 |
| Image typicality | -0.004 | 0.003 | -1.279 | 0.201 |
| Image visual PC1 | -0.002 | 0.006 | -0.263 | 0.792 |
| Image visual PC2 | 0.019 | 0.006 | 3.259 | **0.001** |
| Image visual PC3 | 0.008 | 0.006 | 1.295 | 0.195 |
| Target repetition | -0.011 | 0.002 | -4.932 | **<0.001** |
| Conceptual Distinctiveness (CD) | 0.002 | 0.007 | 0.295 | 0.768 |
| Trial accuracy (Correct – Incorrect) | -0.017 | 0.009 | -1.940 | 0.052 |
| Concept category (Natural – Man-made) | 0.003 | 0.013 | 0.206 | 0.837 |
| SUBTLEX WF x (Words – Objects) | -0.019 | 0.005 | -4.160 | **<0.001** |

**Supplementary Materials 7 – Model selection in Experiment 2**

Formula of the models computed in the selection process (1 model x 4 frequency measures x 2 modalities + baseline model without frequency measures x 2 modalities = 10 models):

*Exp2\_logRT ~ FREQUENCY MEASURE \* Priming condition \* Matching condition +*

*Concept familiarity + Image typicality +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition + Trial accuracy +*

*(1|Participants) + (1/Concepts)*

***Supplementary Table 9****.* Summary table of the models included in the selection process. “Frequency” indicates the frequency measure included in the model, where ‘Baseline’ means no measures included. “AIC” is the criterion used to evaluate the fit of the model. “Modality” indicates which subset of data was considered. “AIC difference” is the difference in AIC between every model and the baseline model of the same modality. More negative differences indicate a better fit of the model including the frequency measure; significant improvements of fit are highlighted in bold.

|  |  |  |  |
| --- | --- | --- | --- |
| **Frequency** | **AIC** | **Modality** | **AIC difference** |
| Baseline | -5150.153 | Objects | 0 |
| SUBTLEX WF | -5194.848 | Objects | **-44.695** |
| ADE20K OF | -5152.258 | Objects | **-2.105** |
| DlexDB WF | -5175.167 | Objects | **-25.013** |
| Greene OF | -5169.700 | Objects | **-19.547** |
| Baseline | -6366.279 | Words | 0 |
| SUBTLEX WF | -6401.687 | Words | **-35.409** |
| ADE20K OF | -6385.581 | Words | **-19.302** |
| DlexDB WF | -6377.383 | Words | **-11.105** |
| Greene OF | -6401.694 | Words | **-35.415** |

## Supplementary Materials 8 – Results selected model in Experiment 2

*Exp2\_logRT ~ SUBTLEX WF \* Priming condition \* Matching condition \* Target modality +*

*Greene OF \* Priming condition \* Matching condition \* Target modality +*

*Concept familiarity + Image typicality +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition + Trial accuracy +*

*(1|Participants) + (1/Concepts)*

***Supplementary Table 10.*** Variance Inflation Factors for the estimated effects of the main model of Experiment 2

|  |  |
| --- | --- |
| **Term** | **VIF** |
| Greene OF | 1.190 |
| Matching condition (Mismatch – Match) | 1.022 |
| Target modality (Words – Objects) | 1.032 |
| Priming condition (Cross-modal – Uni-modal) | 5.799 |
| SUBTLEX WF | 1.673 |
| Visuo-orthographic PC | 1.583 |
| Concept familiarity | 1.168 |
| Image typicality | 1.037 |
| Image visual PC1 | 1.026 |
| Image visual PC2 | 1.026 |
| Image visual PC3 | 1.069 |
| Trial accuracy (Correct – Incorrect) | 1.007 |
| Greene x Matching condition | 1.078 |
| Greene x Target modality | 1.077 |
| Matching condition x Target modality | 1.000 |
| Greene x Priming condition | 1.077 |
| Matching condition x Priming condition | 1.000 |
| Priming condition x Target modality | 1.004 |
| SUBTLEX x Matching condition | 1.078 |
| SUBTLEX x Target modality | 1.077 |
| SUBTLEX x Priming condition | 1.077 |
| Greene x Matching condition x Target modality | 1.077 |
| Greene x Matching condition x Priming condition | 1.078 |
| Greene x Target modality x Priming condition | 1.077 |
| Matching condition x Priming condition x Target modality | 1.000 |
| SUBTLEX x Matching condition x Target modality | 1.077 |
| SUBTLEX x Matching condition x Priming condition | 1.077 |
| SUBTLEX x Target modality x Priming condition | 1.077 |
| Greene x Matching condition x Priming condition x Target modality | 1.077 |
| SUBTLEX x Matching condition x Priming condition x Target modality | 1.077 |
| Target repetition | 5.857 |

The model showed moderate collinearity (VIFs = 5.8 and 5.9) between the Priming condition and Target repetition. This was expected because, despite counterbalancing block order for modalities (word-object or object-word) across participants, all participants performed the cross-modal blocks before the uni-modal blocks (and after Experiment 1). We kept the term for further analysis since collinearity was only just above the threshold for these terms, and because we deemed it important to account for potential carry-over effect.

The measured SUBTLEX WF and Greene OF effects were independent of visual and visuo-orthographic information of the stimuli, as well as of image typicality, subjective familiarity, target repetition, and accuracy of categorization.

***Supplementary Table 11.*** Results from the selected model for priming task including demographics

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.198 | 0.067 | 92.714 | **<0.001** |
| Greene OF | 0.008 | 0.002 | 4.478 | **<0.001** |
| Matching condition (Mismatch – Match) | 0.073 | 0.002 | 32.685 | **<0.001** |
| Target modality (Words – Objects) | -0.008 | 0.002 | -3.618 | **<0.001** |
| Priming condition (Cross-modal – Uni-modal) | 0.006 | 0.005 | 1.174 | 0.240 |
| SUBTLEX WF | -0.004 | 0.002 | -1.815 | 0.070 |
| Visuo-orthographic PC | 0.010 | 0.002 | 4.875 | **<0.001** |
| Concept familiarity | -0.001 | 0.002 | -0.851 | 0.395 |
| Image typicality | -0.004 | 0.002 | -2.524 | **0.012** |
| Image visual PC1 | 0.002 | 0.002 | 1.216 | 0.224 |
| Image visual PC2 | 0.004 | 0.002 | 2.788 | **0.005** |
| Image visual PC3 | -0.001 | 0.002 | -0.830 | 0.406 |
| Target repetition | -0.036 | 0.003 | -13.356 | **<0.001** |
| Trial accuracy (Correct – Incorrect) | 0.030 | 0.005 | 5.441 | **<0.001** |
| Age | 0.033 | 0.030 | 1.096 | 0.273 |
| Gender (Men – Women) | -0.073 | 0.048 | -1.522 | 0.128 |
| Gender (No answer – Men & Women) | -0.150 | 0.138 | -1.083 | 0.279 |
| Education (University – Highschool) | 0.042 | 0.080 | 0.524 | 0.600 |
| Education (Highschool – Technical school) | -0.082 | 0.187 | -0.436 | 0.663 |
| Education (Technical school – No answer) | -0.024 | 0.190 | -0.124 | 0.901 |
| Language (Bi/multilingualism – Monolingualism) | -0.001 | 0.061 | -0.023 | 0.982 |
| Greene OF x Matching condition | -0.017 | 0.002 | -7.454 | **<0.001** |
| Greene OF x Target modality | 0.003 | 0.002 | 1.396 | 0.163 |
| Matching condition x Target modality | -0.009 | 0.004 | -1.939 | 0.053 |
| Greene OF x Priming condition | 0.008 | 0.002 | 3.347 | **0.001** |
| Matching condition x Priming condition | 0.003 | 0.004 | 0.737 | 0.461 |
| Priming condition x Target modality | 0.013 | 0.004 | 2.872 | **0.004** |
| SUBTLEX WF x Matching condition | 0.021 | 0.002 | 9.074 | **<0.001** |
| SUBTLEX WF x Target modality | -0.005 | 0.002 | -2.378 | **0.017** |
| SUBTLEX WF x Priming condition | -0.015 | 0.002 | -6.334 | **<0.001** |
| Greene OF x Matching condition x Target modality | 0.003 | 0.005 | 0.668 | 0.504 |
| Greene OF x Matching condition x Priming condition | -0.020 | 0.005 | -4.256 | **<0.001** |
| Greene OF x Priming condition x Target modality | 0.007 | 0.005 | 1.416 | 0.157 |
| Matching condition x Priming condition x Target modality | 0.046 | 0.009 | 5.220 | **<0.001** |
| SUBTLEX WF x Matching condition x Target modality | -0.002 | 0.005 | -0.472 | 0.637 |
| SUBTLEX WF x Matching condition x Priming condition | 0.017 | 0.005 | 3.687 | **<0.001** |
| SUBTLEX WF x Priming condition x Target modality | 0.003 | 0.005 | 0.569 | 0.570 |
| Greene OF x Matching condition x Priming condition x Target modality | 0.002 | 0.009 | 0.227 | 0.821 |
| SUBTLEX WF x Matching condition x Priming condition x Target modality | 0.006 | 0.009 | 0.612 | 0.540 |

**Supplementary Materials 9 – Post-hoc of interactions in Experiment 2**

*Recoded factor* is a factor we obtained merging *Priming condition* and *Matching condition* to explore the interaction between frequency x Priming condition x Matching condition. This new factor has 4 levels (*Cross-modal Matching, Uni-modal Matching, Cross-modal Mismatching, Uni-modal Mismatching*) and 3 contrasts of interest are computed (*Cross-modal Matching – Uni-modal Matching, Cross-modal Mismatching – Uni-modal Mismatching, Cross-modal Matching – Uni-modal Mismatching*)

*Exp2\_logRT ~ SUBTLEX WF \* Recoded factor \* Target modality +*

*Greene OF \* Recoded factor \* Target modality +*

*Concept familiarity + Image typicality +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition + Trial accuracy +*

*(1|Participants) + (1/Concepts)*

***Supplementary Table 12****.* Results from the post-hoc model with re-coded contrasts

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.225 | 0.020 | 315.730 | **<0.001** |
| SUBTLEX WF | -0.004 | 0.002 | -1.812 | 0.070 |
| Cross-modal matching – Uni-modal matching | 0.005 | 0.006 | 0.805 | 0.421 |
| Cross-modal mismatching – Uni-modal mismatching | 0.008 | 0.006 | 1.360 | 0.174 |
| Cross-modal matching – Cross-modal mismatching | -0.075 | 0.003 | -23.733 | **<0.001** |
| Target modality (Words – Objects) | -0.008 | 0.002 | -3.618 | **<0.001** |
| Greene OF | 0.008 | 0.002 | 4.474 | **<0.001** |
| Visuo-orthographic PC | 0.010 | 0.002 | 4.877 | **<0.001** |
| Concept familiarity | -0.001 | 0.002 | -0.845 | 0.398 |
| Image typicality | -0.004 | 0.002 | -2.562 | **0.010** |
| Image visual PC1 | 0.002 | 0.002 | 1.217 | 0.224 |
| Image visual PC2 | 0.004 | 0.002 | 2.788 | **0.005** |
| Image visual PC3 | -0.001 | 0.002 | -0.832 | 0.405 |
| Target repetition | -0.036 | 0.003 | -13.357 | **<0.001** |
| Trial accuracy (Correct – Incorrect) | 0.030 | 0.005 | 5.444 | **<0.001** |
| SUBTLEX x (Cross-modal matching – Uni-modal matching) | -0.023 | 0.003 | -7.094 | **<0.001** |
| SUBTLEX x (Cross-modal mismatching – Uni-modal mismatching) | -0.006 | 0.003 | -1.870 | 0.062 |
| SUBTLEX x (Cross-modal matching – Cross-modal mismatching) | -0.029 | 0.003 | -9.027 | **<0.001** |
| SUBTLEX x Target modality | -0.005 | 0.002 | -2.378 | **0.017** |
| (Cross-modal matching – Uni-modal matching) x Target modality | -0.010 | 0.006 | -1.655 | 0.098 |
| (Cross-modal mismatching – Uni-modal mismatching) x Target modality | 0.036 | 0.006 | 5.717 | **<0.001** |
| (Cross-modal matching – Cross-modal mismatching) x Target modality | -0.015 | 0.006 | -2.320 | **0.020** |
| Greene x (Cross-modal matching – Uni-modal matching) | 0.018 | 0.003 | 5.379 | **<0.001** |
| Greene x (Cross-modal mismatching – Uni-modal mismatching) | -0.002 | 0.003 | -0.644 | 0.520 |
| Greene x (Cross-modal matching – Cross-modal mismatching) | 0.027 | 0.003 | 8.276 | **<0.001** |
| Greene x Target modality | 0.003 | 0.002 | 1.396 | 0.163 |
| SUBTLEX x (Cross-modal matching – Uni-modal matching) x Target modality | -0.000 | 0.007 | -0.031 | 0.975 |
| SUBTLEX x (Cross-modal mismatching – Uni-modal mismatching) x Target modality | 0.005 | 0.007 | 0.834 | 0.404 |
| SUBTLEX x (Cross-modal matching – Cross-modal mismatching) x Target modality | -0.001 | 0.007 | -0.099 | 0.921 |
| Greene x (Cross-modal matching – Uni-modal matching) x Target modality | 0.005 | 0.007 | 0.842 | 0.400 |
| Greene x (Cross-modal mismatching – Uni-modal mismatching) x Target modality | 0.008 | 0.007 | 1.161 | 0.246 |
| Greene x (Cross-modal matching – Cross-modal mismatching) x Target modality | -0.004 | 0.007 | -0.632 | 0.527 |

**Supplementary Figure 7 *- RTs estimated from post-hoc of interaction effects of Experiment 2 (between condition)***

Response times as a function of logarithmic SUBTLEX frequency (top plots, dark green) and Greene frequency (bottom plots, light green) in the 3-way significant interaction with Matching condition and Priming condition (Cross-modal matching vs. Uni-modal matching; Cross-modal mismatching vs Uni-modal mismatching; Cross-modal matching vs. Cross-modal mismatching). RTs were estimated based on the selected model. Points present participant-based mean response times for concepts in the different frequency levels. Lines represent linear fitting of points (solid: cross-modal; dashed: uni-modal), and shaded areas represent 95 % confidence interval. Bottom-left and top-left plots represent the effects in prime-target matching condition, while bottom-right and top-right plots represent the effects in prime-target mismatching condition

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4 post-hoc models are additionally computed, one for every level of the re-coded factor (Cross-modal Matching, Uni-modal Matching, Cross-modal Mismatching, Uni-modal Mismatching)

*Exp2\_logRT ~ SUBTLEX WF \* Target modality + Greene OF \* Target modality +*

*Concept familiarity + Image typicality +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition + Trial accuracy +*

*(1|Participants) + (1/Concepts)*

***Supplementary Table 13****.* Results from the post-hoc individual models for conditions of interest

**Uni-modal Matching Cross-modal Matching**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.139 | 0.020 | 309.972 | **<0.001** | 6.238 | 0.021 | 290.842 | **<0.001** |
| SUBTLEX WF | -0.001 | 0.003 | -0.245 | 0.807 | -0.019 | 0.006 | -3.230 | **0.001** |
| Target modality (Words – Objects) | 0.008 | 0.004 | 1.790 | 0.073 | -0.012 | 0.005 | -2.620 | **0.009** |
| Greene OF | 0.007 | 0.003 | 2.725 | **0.006** | 0.023 | 0.005 | 4.710 | **<0.001** |
| Visuo-orthographic PC | 0.013 | 0.003 | 4.418 | **<0.001** | 0.018 | 0.006 | 3.077 | **0.002** |
| Concept familiarity | -0.000 | 0.003 | -0.150 | 0.881 | -0.003 | 0.003 | -0.858 | 0.391 |
| Image typicality | -0.005 | 0.003 | -1.835 | 0.067 | -0.013 | 0.003 | -3.825 | **<0.001** |
| Image visual PC1 | 0.003 | 0.002 | 1.289 | 0.197 | 0.003 | 0.005 | 0.593 | 0.553 |
| Image visual PC2 | 0.004 | 0.002 | 1.758 | 0.079 | 0.001 | 0.005 | 0.254 | 0.799 |
| Image visual PC3 | -0.003 | 0.002 | -1.173 | 0.241 | 0.001 | 0.005 | 0.178 | 0.859 |
| Target repetition | -0.002 | 0.002 | -0.792 | 0.428 | -0.028 | 0.002 | -12.095 | **<0.001** |
| Trial accuracy (Correct – Incorrect) | 0.058 | 0.010 | 6.001 | **<0.001** | -0.008 | 0.010 | -0.760 | 0.448 |
| SUBTLEX x (Words – Objects) | -0.004 | 0.004 | -0.982 | 0.326 | -0.005 | 0.005 | -0.948 | 0.343 |
| Greene x (Words – Objects) | -0.001 | 0.004 | -0.304 | 0.761 | 0.005 | 0.005 | 1.012 | 0.311 |

**Uni-modal Mismatching Cross-modal Mismatching**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.202 | 0.020 | 312.978 | **<0.001** | 6.286 | 0.022 | 279.822 | **<0.001** |
| SUBTLEX WF | 0.005 | 0.003 | 1.535 | 0.125 | 0.000 | 0.003 | 0.108 | 0.914 |
| Target modality (Words – Objects) | -0.026 | 0.004 | -5.943 | **<0.001** | 0.004 | 0.004 | 0.863 | 0.388 |
| Greene OF | 0.001 | 0.003 | 0.543 | 0.587 | -0.002 | 0.002 | -0.733 | 0.463 |
| Visuo-orthographic PC | 0.001 | 0.003 | 0.407 | 0.684 | 0.005 | 0.003 | 1.978 | **0.048** |
| Concept familiarity | -0.003 | 0.003 | -1.225 | 0.221 | 0.002 | 0.003 | 0.586 | 0.558 |
| Image typicality | 0.001 | 0.003 | 0.221 | 0.825 | 0.003 | 0.003 | 1.109 | 0.268 |
| Image visual PC1 | 0.000 | 0.002 | 0.024 | 0.981 | 0.002 | 0.002 | 0.751 | 0.452 |
| Image visual PC2 | 0.008 | 0.002 | 3.082 | **0.002** | 0.005 | 0.002 | 2.194 | **0.028** |
| Image visual PC3 | -0.001 | 0.003 | -0.322 | 0.748 | -0.003 | 0.002 | -1.172 | 0.241 |
| Target repetition | -0.007 | 0.002 | -3.341 | **0.001** | -0.023 | 0.002 | -10.344 | **<0.001** |
| Trial accuracy (Correct – Incorrect) | 0.083 | 0.012 | 6.712 | **<0.001** | 0.063 | 0.012 | 5.361 | **<0.001** |
| SUBTLEX x (Words – Objects) | -0.009 | 0.004 | -2.113 | **0.035** | -0.004 | 0.005 | -0.951 | 0.342 |
| Greene x (Words – Objects) | 0.001 | 0.004 | 0.226 | 0.821 | 0.009 | 0.005 | 2.027 | **0.043** |

***Supplementary Figure 8 - RTs estimated from post-hoc models of Experiment 2 (within conditions)***

Effects of SUBTLEX WF (dark green, top) and Greene OF (light green, bottom) on reaction times estimated from the post-hoc models separately for each Priming condition (continuous and dashed-dotted line types) and Matching condition (left and right plots). Points show concepts with different level of frequency, averaged across participants; lines represent linear fitting of points and shaded areas represent 95 % confidence interval.

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**Supplementary Materials 10 – Results of new ratings on data of Exp 2**

*Exp2\_logRT ~ SUBTLEX WF \* Priming condition \* Matching condition \* Target modality +*

*Greene OF \* Priming condition \* Matching condition \* Target modality +*

*Concept familiarity (replication) + Image typicality (replication) +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition + Trial accuracy +*

*(1|Participants) + (1/Concepts)*

***Supplementary Table 14****.* Results from main model of Exp 2 including ratings from replication study

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** |  | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.225 |  | 0.020 | 315.766 | **<0.001** |
| Greene OF | 0.005 |  | 0.002 | 2.978 | **0.003** |
| Matching condition (Mismatch – Match) | 0.073 |  | 0.002 | 32.683 | **<0.001** |
| Target modality (Words – Objects) | -0.008 |  | 0.002 | -3.613 | **<0.001** |
| Priming condition (Cross-modal – Uni-modal) | 0.006 |  | 0.005 | 1.175 | 0.240 |
| SUBTLEX WF | -0.001 |  | 0.002 | -0.576 | 0.565 |
| Visuo-orthographic PC | 0.010 |  | 0.002 | 5.485 | **<0.001** |
| Concept familiarity (replication) | -0.002 |  | 0.002 | -0.795 | 0.427 |
| Image typicality (replication) | -0.008 |  | 0.002 | -4.829 | **<0.001** |
| Image visual PC1 | 0.003 |  | 0.002 | 2.077 | **0.038** |
| Image visual PC2 | 0.003 |  | 0.002 | 2.173 | **0.030** |
| Image visual PC3 | -0.002 |  | 0.002 | -1.518 | 0.129 |
| Target repetition | -0.036 |  | 0.003 | -13.355 | **<0.001** |
| Trial accuracy (Correct – Incorrect) | 0.030 |  | 0.005 | 5.453 | **<0.001** |
| Greene x Matching condition | -0.017 |  | 0.002 | -7.458 | **<0.001** |
| Greene x Target modality | 0.003 |  | 0.002 | 1.396 | 0.163 |
| Matching condition x Target modality | -0.009 |  | 0.004 | -1.938 | 0.053 |
| Greene x Priming condition | 0.008 |  | 0.002 | 3.347 | **0.001** |
| Matching condition x Priming condition | 0.003 |  | 0.004 | 0.736 | 0.462 |
| Priming condition x Target modality | 0.013 |  | 0.004 | 2.874 | **0.004** |
| SUBTLEX x Matching condition | 0.021 |  | 0.002 | 9.075 | **<0.001** |
| SUBTLEX x Target modality | -0.005 |  | 0.002 | -2.376 | **0.018** |
| SUBTLEX x Priming condition | -0.015 |  | 0.002 | -6.335 | **<0.001** |
| Greene x Matching condition x Target modality | 0.003 |  | 0.005 | 0.666 | 0.505 |
| Greene x Matching condition x Priming condition | -0.020 |  | 0.005 | -4.257 | **<0.001** |
| Greene x Priming condition x Target modality | 0.007 |  | 0.005 | 1.412 | 0.158 |
| Matching condition x Priming condition x Target modality | 0.046 |  | 0.009 | 5.216 | **<0.001** |
| SUBTLEX x Matching condition x Target modality | -0.002 |  | 0.005 | -0.473 | 0.636 |
| SUBTLEX x Matching condition x Priming condition | 0.017 |  | 0.005 | 3.687 | **<0.001** |
| SUBTLEX x Priming condition x Target modality | 0.003 |  | 0.005 | 0.569 | 0.569 |
| Greene x Matching condition x Priming condition x Target modality | 0.002 |  | 0.009 | 0.228 | 0.819 |
| SUBTLEX x Matching condition x Priming condition x Target modality | 0.006 |  | 0.009 | 0.612 | 0.540 |

## Supplementary Materials 11 – Exploratory analysis in Experiment 2

**Description exploratory analysis**

Since we detected similar frequency effects in both word and object modalities (i.e., no significant interaction including target modality), as well as the presence of these effects only when semantic processing is required (cross-modal trials), we decided to further explore whether the frequency effects found in Experiment 2 represented common semantic processing of objects and words. Thus, we restricted this exploratory analysis to the *Cross-modal matching trials*. Response times from this subset showed substantial word and object frequency effects and, at the same time, included predictive semantic processing to a high degree.

We considered three sources of data: 1) the actual response times from cross-modal matching trials of words and objects; 2) response times estimated from the effect of SUBTLEX WF in cross-modal matching trials of words and objects; 3) response times estimated from the effect of Greene OF in cross-modal matching trials of words and objects. 2) and 3) were estimated using two models (one for word trials and one for object trials) that included SUBTLEX WF, Greene OF, and all the covariates and random effects of the main model of Experiment 2 introduced before. The comparison between word and object processing was made for each of the three datasets considering response times for every participant and for every concept in both modalities. To test the similarity between frequency effects in words and objects, we implemented *paired-samples equivalence tests* and *product-moment correlation tests* between response times from word and object trials.

With the equivalence test, we can check if two samples/conditions come from the same distribution (i.e., they are equivalent). Thus, we computed test statistics for which low probability values allow us to reject the null hypothesis of statistical difference (instead of rejecting the null hypothesis of statistical equivalence of commonly used t-test). For the equivalence test, we needed to set an epsilon parameter, i.e., the maximally allowed difference to consider two conditions non-different; in our case, we used 50 % of the standard deviation of the difference between object and word trials (Robinson & Froese, 2004). The correlation of word-based vs. object-based reaction times could additionally prove whether associated entries show similar behavior.

For actual response time data, we found a significant equivalence (mean of differences = 0.005 log(ms), ε=0.045 log(ms), CI = [-0.018 0.028], *p*=0.003) and correlation (r=0.804, *t*(40)=8.554, *p*<0.001), between *participants’ performance* in object and word trials; also, we found a significant equivalence (mean of differences = 0.006 log(ms), ε=0.028 log(ms), CI = [-0.004 0.015], *p*<0.001) and correlation (r=0.652, *t*(98)=8.503, *p*<0.001) between *processing of concepts* in the two different modalities (*Supplementary* *Figure 9A-B*). That implies high interrelation between the processing objects and words which becomes evident when comparing participants and comparing stimuli with the same semantics.

***Supplementary Figure 9 - Linear relationship between object trials and word trials in Cross-modal matching trials***

**Chart, scatter chart

Description automatically generated**Correlations among unique participants (dark blue: A, C, and E) and unique concepts (orange: B, D and F). A, B) Actual response times for Cross-modal matching trials (solid lines). C, D) Response times estimated from SUBTLEX WF effect in Cross-modal matching trials (dashed lines); E, F) Response times estimated from Greene OF effect in Cross-modal matching trials (dashed-dotted lines). Points represent performance of individual participants or concepts in the two tasks. Lines represent linear fitting of points, and shaded areas represent 95 % confidence interval.

To get an estimate to which degree the interrelation was driven by the WF effect, we predicted RTs that were influenced by the SUBTLEX WF effect without confounds based on the estimated models (one for cross-modal matching trials of objects, one for cross-modal matching trials for words). For *participants’ performance*, we could not reject statistical difference (mean of differences = 0.0049 log(ms), ε=0.0009 log(ms), CI = [0.0044 0.0053], *p*=1), but we found a significant correlation (r=0.860, *t*(40)=10.667, *p*<0.001) between object trials and word trials; similarly, but *considering single concepts*, we could reject statistical difference (mean of differences = 0.005 log(ms), ε=0.010 log(ms), CI = [0.001 0.008], *p*=0.004), and we found also a significant correlation (r=0.717, *t*(98)=10.186, *p*<0.001) (*Supplementary* *Figure 9C-D*).

We repeated the same procedure for the Greene OF effect and found the same pattern: statistical difference could not be reject for individual participants (mean of differences = 0.0048 log(ms), ε=0.0009 log(ms), CI = [0.0044 0.0053], *p*=1), but it was rejected for individual concepts performance (mean of differences = 0.005 log(ms), ε=0.010 log(ms), CI = [0.001 0.008], *p*<0.001), while both showed a strong correlation between object and word trials (participants: r=0.868, *t*(40)=11.067, *p*<0.001; concepts: r=0.779, *t*(98)=12.29, *p*<0.001) (*Supplementary* *Figure 9E-F*). Overall, these exploratory analyses show that even if the WF and OF do not affect object and word processing completely identically, the individual participant’s frequency effects for words and object and the frequency effects for single semantic concepts are strongly associated to each other across modalities.

**Supplementary Materials 12 – Interaction of Greene OF with Conceptual Distinctiveness in Experiment 2**

**Object frequency and interference**

We can draw parallels between the experimental visual experience created and tested by Konkle and colleagues (2010) (i.e., manipulating the frequency of visually presented objects in the lab) and what the Greene OF used in our study aims to represent (i.e., the frequency of visually encountered objects in the real world). This comparison might raise some concerns since the two studies seem relatively different at first sight: First, Konkle et al. artificially induced memory interference and second, they specifically measured visual LTM. That said, we believe that Konkle et al. (2010) of course aimed at measuring a phenomenon of memory interference that they think is happening intrinsically when encountering objects in the world. While Konkle's task required retrieving specific exemplars, our task required retrieving a concept (i.e., the prime meaning) from memory. For both tasks, however, interferences from other exemplars are similarly possible. In addition, to correctly perform the Cross-modal priming task in our study, participants in our study had to access representations in semantic long-term memory (LTM), which was also the locus of the memory interferences as highlighted by Konkle et al. (2010). This is in line with the observation that the Greene OF effect in our study only came into play in Cross-modal Matching trials, where semantic processing and LTM involvement was particularly high.

*Recoded factor* is a factor we obtained merging *Priming condition* and *Matching condition* to explore interaction between frequency x Priming condition x Matching condition. This new factor has 4 levels (*Cross-modal Matching, Uni-modal Matching, Cross-modal Mismatching, Uni-modal Mismatching*) and 3 contrasts of interest are computed (*Cross-modal Matching – Uni-modal Matching, Cross-modal Mismatching – Uni-modal Mismatching, Cross-modal Matching – Uni-modal Mismatching*)

*Exp2\_logRT ~ SUBTLEX WF \* Recoded factor \* Target modality +*

*Greene OF \* Conceptual Distinctiveness \* Recoded factor \* Target modality +*

*Concept familiarity + Image typicality +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition + Trial accuracy +*

*(1|Participants) + (1/Concepts)*

***Supplementary Table 15****.* Results from model including Conceptual Distinctiveness in interaction with Greene frequency.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.225 | 0.020 | 315.564 | **<0.001** |
| Conceptual Distinctiveness (CD) | 0.002 | 0.002 | 0.799 | 0.424 |
| Greene OF | 0.008 | 0.002 | 3.709 | **<0.001** |
| Cross-modal matching – Uni-modal matching | 0.009 | 0.006 | 1.533 | 0.125 |
| Cross-modal mismatching – Uni-modal mismatching | 0.007 | 0.006 | 1.235 | 0.217 |
| Cross-modal matching – Cross-modal mismatching | -0.070 | 0.003 | -20.276 | **<0.001** |
| Target modality (Words – Objects) | -0.008 | 0.002 | -3.356 | **0.001** |
| SUBTLEX | -0.004 | 0.002 | -1.923 | 0.055 |
| Visuo-orthographic PC | 0.009 | 0.002 | 4.807 | **<0.001** |
| Concept familiarity | -0.001 | 0.002 | -0.762 | 0.446 |
| Image typicality | -0.004 | 0.002 | -2.440 | **0.015** |
| Image visual PC1 | 0.002 | 0.002 | 1.266 | 0.206 |
| Image visual PC2 | 0.005 | 0.002 | 2.776 | **0.006** |
| Image visual PC3 | -0.002 | 0.002 | -0.976 | 0.329 |
| Target repetition | -0.036 | 0.003 | -13.333 | **<0.001** |
| Trial accuracy (Correct – Incorrect) | 0.031 | 0.005 | 5.595 | **<0.001** |
| Conceptual Distinctiveness (CD)x Greene | -0.001 | 0.002 | -0.749 | 0.454 |
| CD x (Cross-modal matching – Uni-modal matching) | 0.004 | 0.004 | 1.051 | 0.293 |
| CD x (Cross-modal mismatching – Uni-modal mismatching) | 0.001 | 0.004 | 0.246 | 0.806 |
| CD x (Cross-modal matching – Cross-modal mismatching) | 0.007 | 0.004 | 1.937 | 0.053 |
| Greene x (Cross-modal matching – Uni-modal matching) | 0.021 | 0.004 | 5.364 | **<0.001** |
| Greene x (Cross-modal mismatching – Uni-modal mismatching) | -0.003 | 0.004 | -0.810 | 0.418 |
| Greene x (Cross-modal matching – Cross-modal mismatching) | 0.030 | 0.004 | 7.737 | **<0.001** |
| Conceptual Distinctiveness (CD)x Target modality | -0.000 | 0.003 | -0.065 | 0.948 |
| Greene x Target modality | 0.003 | 0.003 | 1.155 | 0.248 |
| Target modality x (Cross-modal matching – Uni-modal matching) | -0.009 | 0.007 | -1.252 | 0.211 |
| Target modality x (Cross-modal mismatching – Uni-modal mismatching) | 0.030 | 0.007 | 4.432 | **<0.001** |
| Target modality x (Cross-modal matching – Cross-modal mismatching) | -0.013 | 0.007 | -1.872 | 0.061 |
| SUBTLEX x (Cross-modal matching – Uni-modal matching) | -0.023 | 0.004 | -6.500 | **<0.001** |
| SUBTLEX x (Cross-modal mismatching – Uni-modal mismatching) | -0.007 | 0.004 | -1.873 | 0.061 |
| SUBTLEX x (Cross-modal matching – Cross-modal mismatching) | -0.030 | 0.004 | -8.512 | **<0.001** |
| SUBTLEX x Target modality | -0.005 | 0.003 | -2.181 | **0.029** |
| CD x Greene x (Cross-modal matching – Uni-modal matching) | -0.010 | 0.003 | -3.139 | **0.002** |
| CD x Greene x (Cross-modal mismatching – Uni-modal mismatching) | 0.002 | 0.003 | 0.495 | 0.621 |
| CD x Greene x (Cross-modal matching – Cross-modal mismatching) | -0.012 | 0.003 | -3.774 | **<0.001** |
| CD x Greene x Target modality | 0.000 | 0.002 | 0.086 | 0.932 |
| CD x (Cross-modal matching – Uni-modal matching) x Target modality | -0.001 | 0.008 | -0.072 | 0.942 |
| CD x (Cross-modal mismatching – Uni-modal mismatching) x Target modality | 0.001 | 0.008 | 0.129 | 0.898 |
| CD x (Cross-modal matching – Cross-modal mismatching) x Target modality | -0.002 | 0.008 | -0.275 | 0.784 |
| Greene x (Cross-modal matching – Uni-modal matching) x Target modality | 0.008 | 0.008 | 0.984 | 0.325 |
| Greene x (Cross-modal mismatching – Uni-modal mismatching) x Target modality | 0.001 | 0.008 | 0.143 | 0.886 |
| Greene x (Cross-modal matching – Cross-modal mismatching) x Target modality | -0.002 | 0.008 | -0.195 | 0.845 |
| SUBTLEX x (Cross-modal matching – Uni-modal matching) x Target modality | 0.001 | 0.007 | 0.078 | 0.938 |
| SUBTLEX x (Cross-modal mismatching – Uni-modal mismatching) x Target modality | 0.003 | 0.007 | 0.464 | 0.643 |
| SUBTLEX x (Cross-modal matching – Cross-modal mismatching) x Target modality | 0.001 | 0.007 | 0.083 | 0.934 |
| CD x Greene x (Cross-modal matching – Uni-modal matching) x Target modality | -0.004 | 0.006 | -0.666 | 0.506 |
| CD x Greene x (Cross-modal mismatching – Uni-modal mismatching) x Target modality | 0.013 | 0.006 | 2.031 | **0.042** |
| CD x Greene x (Cross-modal matching – Cross-modal mismatching) x Target modality | -0.004 | 0.006 | -0.631 | 0.528 |

## Supplementary Materials 13 – Results main model of Experiment 3

*Exp3\_logRT ~ SUBTLEX WF \* Priming condition \* Matching condition \* Target modality +*

*Greene OF \* Priming condition \* Matching condition \* Target modality +*

*Concept familiarity (replication) + Image typicality (replication) +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition + Trial accuracy +*

*(1|Participants) + (1/Concepts)*

***Supplementary Table 16.*** Variance Inflation Factors for the effects of the main model of Replication experiment.

|  |  |
| --- | --- |
| **Term** | **VIF** |
| Greene OF | 1.535 |
| Matching condition | 1.022 |
| Target modality | 1.003 |
| Priming condition | 1.000 |
| SUBTLEX WF | 1.974 |
| Visuo-orthographic PC | 1.725 |
| Concept familiarity (replication) | 1.705 |
| Image typicality (replication) | 1.337 |
| Image visual PC1 | 1.084 |
| Image visual PC2 | 1.093 |
| Image visual PC3 | 1.206 |
| Target repetition | 1.097 |
| Trial accuracy | 1.006 |
| Greene x Matching condition | 1.076 |
| Greene x Target modality | 1.076 |
| Matching condition x Priming condition | 1.000 |
| Greene x Priming condition | 1.076 |
| Matching condition x Target modality | 1.000 |
| Priming condition x Target modality | 1.077 |
| SUBTLEX x Matching condition | 1.077 |
| SUBTLEX x Target modality | 1.076 |
| SUBTLEX x Priming condition | 1.076 |
| Greene x Matching condition x Target modality | 1.076 |
| Greene x Matching condition x Priming condition | 1.076 |
| Greene x Priming condition x Target modality | 1.076 |
| Matching condition x Priming condition x Target modality | 1.000 |
| SUBTLEX x Matching condition x Target modality | 1.076 |
| SUBTLEX x Matching condition x Priming condition | 1.076 |
| SUBTLEX x Priming condition x Target modality | 1.076 |
| Greene x Matching condition x Priming condition x Target modality | 1.076 |
| SUBTLEX x Matching condition x Priming condition x Target modality | 1.076 |

The measured SUBTLEX WF and Greene OF effects were independent of visual and visuo-orthographic information of the stimuli, as well as of image typicality, subjective familiarity, target repetition and accuracy of categorization.

***Supplementary Table 17.*** Results from the main model of Exp 3 including demographics of participants

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.086 | 0.075 | 80.810 | **<0.001** |
| Greene OF | 0.003 | 0.002 | 1.661 | 0.097 |
| Matching condition (Mismatch – Match) | 0.062 | 0.002 | 27.488 | **<0.001** |
| Target modality (Words – Objects) | -0.002 | 0.002 | -0.896 | 0.370 |
| Priming condition (Cross-modal – Uni-modal) | -0.019 | 0.031 | -0.621 | 0.534 |
| SUBTLEX WF | -0.008 | 0.002 | -3.933 | **<0.001** |
| Visuo-orthographic PC | 0.005 | 0.002 | 2.489 | **0.013** |
| Concept familiarity | -0.001 | 0.002 | -0.346 | 0.729 |
| Image typicality | -0.009 | 0.002 | -5.229 | **<0.001** |
| Image visual PC1 | 0.001 | 0.002 | 0.633 | 0.527 |
| Image visual PC2 | 0.003 | 0.002 | 1.929 | 0.054 |
| Image visual PC3 | 0.001 | 0.002 | 0.593 | 0.553 |
| Target repetition | -0.036 | 0.001 | -31.063 | **<0.001** |
| Trial accuracy (Correct – Incorrect) | 0.013 | 0.007 | 1.959 | 0.050 |
| Age | 0.042 | 0.018 | 2.278 | **0.023** |
| Gender (Men – Women) | -0.076 | 0.036 | -2.077 | **0.038** |
| Gender (Others – Men & Women) | -0.322 | 0.117 | -2.747 | **0.006** |
| Language (Bi/multilingualism – Monolingualism) | 0.058 | 0.041 | 1.419 | 0.156 |
| Education (University – Highschool) | -0.003 | 0.061 | -0.050 | 0.960 |
| Education (Highschool – Technical school) | 0.249 | 0.167 | 1.486 | 0.137 |
| Education (Technical school – No answer) | 0.180 | 0.219 | 0.823 | 0.410 |
| Greene OF x Matching condition | -0.008 | 0.002 | -3.528 | **<0.001** |
| Greene OF x Target modality | 0.001 | 0.002 | 0.370 | 0.711 |
| Matching condition x Target modality | 0.001 | 0.004 | 0.195 | 0.845 |
| Greene OF x Priming condition | 0.012 | 0.002 | 5.159 | **<0.001** |
| Matching condition x Priming condition | -0.016 | 0.004 | -3.523 | **<0.001** |
| Priming condition x Target modality | -0.029 | 0.005 | -6.285 | **<0.001** |
| SUBTLEX WF x Matching condition | 0.013 | 0.002 | 5.638 | **<0.001** |
| SUBTLEX WF x Target modality | -0.011 | 0.002 | -4.830 | **<0.001** |
| SUBTLEX WF x Priming condition | -0.010 | 0.002 | -4.292 | **<0.001** |
| Greene OF x Matching condition x Target modality | -0.004 | 0.005 | -0.917 | 0.359 |
| Greene OF x Matching condition x Priming condition | -0.010 | 0.005 | -2.165 | **0.030** |
| Greene OF x Priming condition x Target modality | 0.000 | 0.005 | 0.019 | 0.985 |
| Priming condition x Matching condition x Target modality | 0.030 | 0.009 | 3.406 | **0.001** |
| SUBTLEX WF x Matching condition x Target modality | 0.016 | 0.005 | 3.399 | **0.001** |
| SUBTLEX WF x Matching condition x Priming condition | 0.009 | 0.005 | 1.880 | 0.060 |
| SUBTLEX x Priming condition x Target modality | -0.006 | 0.005 | -1.231 | 0.219 |
| Greene OF x Priming condition x Matching condition x Target modality | -0.011 | 0.009 | -1.169 | 0.242 |
| SUBTLEX WF x Priming condition x Matching condition x Target modality | 0.021 | 0.009 | 2.268 | **0.023** |

**Supplementary Materials 14 – Post-hoc of interactions in Experiment 3**

*Recoded factor* is a factor we obtained merging *Priming condition* and *Matching condition* to explore the interaction between frequency x Prining condition x Matching condition. This new factor has 4 levels (*Cross-modal Matching, Uni-modal Matching, Cross-modal Mismatching, Uni-modal Mismatching*) and 3 contrasts of interest are computed (*Cross-modal Matching – Uni-modal Matching, Cross-modal Mismatching – Uni-modal Mismatching, Cross-modal Matching – Uni-modal Mismatching*)

*Exp3\_logRT ~ SUBTLEX WF \* Recoded factor \* Target modality +*

*Greene OF \* Recoded factor \* Target modality +*

*Concept familiarity (replication) + Image typicality (replication) +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition + Trial accuracy +*

*(1|Participants) + (1/Concepts)*

***Supplementary Table 18****.* Results from the post-hoc model with re-coded contrasts in the Replication exp

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.355 | 0.017 | 374.337 | **<0.001** |
| SUBTLEX WF | -0.008 | 0.002 | -3.865 | **<0.001** |
| Cross-modal matching – Uni-modal matching | 0.022 | 0.033 | 0.649 | 0.517 |
| Cross-modal mismatching – Uni-modal mismatching | 0.006 | 0.033 | 0.175 | 0.861 |
| Cross-modal matching – Cross-modal mismatching | -0.063 | 0.003 | -19.787 | **<0.001** |
| Target modality (Words – Objects) | 0.001 | 0.002 | 0.614 | 0.539 |
| Greene OF | 0.003 | 0.002 | 1.636 | 0.102 |
| Visuo-orthographic PC | 0.005 | 0.002 | 2.465 | **0.014** |
| Concept familiarity (replication) | -0.001 | 0.002 | -0.309 | 0.758 |
| Image typicality (replication) | -0.009 | 0.002 | -5.220 | **<0.001** |
| Image visual PC1 | 0.001 | 0.002 | 0.557 | 0.577 |
| Image visual PC2 | 0.003 | 0.002 | 1.881 | 0.060 |
| Image visual PC3 | 0.001 | 0.002 | 0.618 | 0.537 |
| Trial accuracy (Correct – Incorrect) | 0.009 | 0.007 | 1.317 | 0.188 |
| SUBTLEX x (Cross-modal matching – Uni-modal matching) | -0.014 | 0.003 | -4.324 | **<0.001** |
| SUBTLEX x (Cross-modal mismatching – Uni-modal mismatching) | -0.006 | 0.003 | -1.664 | 0.096 |
| SUBTLEX x (Cross-modal matching – Cross-modal mismatching) | -0.018 | 0.003 | -5.291 | **<0.001** |
| SUBTLEX x Target modality | -0.011 | 0.002 | -4.786 | **<0.001** |
| Target modality x (Cross-modal matching – Uni-modal matching) | -0.006 | 0.006 | -0.949 | 0.343 |
| Target modality x (Cross-modal mismatching – Uni-modal mismatching) | 0.025 | 0.006 | 3.872 | **<0.001** |
| Target modality x (Cross-modal matching – Cross-modal mismatching) | -0.017 | 0.006 | -2.591 | **0.010** |
| Greene x (Cross-modal matching – Uni-modal matching) | 0.017 | 0.003 | 5.165 | **<0.001** |
| Greene x (Cross-modal mismatching – Uni-modal mismatching) | 0.007 | 0.003 | 1.959 | 0.050 |
| Greene x (Cross-modal matching – Cross-modal mismatching) | 0.013 | 0.003 | 3.874 | **<0.001** |
| Greene x Target modality | 0.001 | 0.002 | 0.344 | 0.731 |
| SUBTLEX x (Cross-modal matching – Uni-modal matching) x Target modality | -0.016 | 0.007 | -2.401 | **0.016** |
| SUBTLEX x (Cross-modal mismatching – Uni-modal mismatching) x Target mod | 0.005 | 0.007 | 0.794 | 0.427 |
| SUBTLEX x (Cross-modal matching – Cross-modal mismatching) x Target mod | -0.027 | 0.007 | -4.008 | **<0.001** |
| Greene x (Cross-modal matching – Uni-modal matching) x Target modality | 0.005 | 0.007 | 0.818 | 0.414 |
| Greene x (Cross-modal misatching – Uni-modal mismatching) x Target modality | -0.006 | 0.007 | -0.871 | 0.384 |
| Greene x (Cross-modal matching – Cross-modal mismatching) x Target modality | 0.010 | 0.007 | 1.487 | 0.137 |

**Supplementary Figure 10 - RTs estimated from post-hoc of interaction effects of Experiment 3 (between conditions)**

A picture containing chart

Description automatically generatedResponse times as a function of logarithmic SUBTLEX frequency (top plots, dark green) and Greene frequency (bottom plots, light green) in the 3-way significant interaction with Matching condition and Priming condition (Cross-modal matching vs Uni-modal matching; Cross-modal mismatching vs Uni-modal mismatching; Cross-modal matching vs Cross-modal mismatching). RTs were estimated based on the selected model. Points present participant-based mean response times for concepts in the different frequency levels. Lines represent linear fitting of points (solid: cross-modal; dashed: uni-modal), and shaded areas represent 95 % confidence interval. Bottom-left and top-left plots represent the effects in prime-target matching condition, while bottom-right and top-right plots represent the effects in prime-target mismatching condition

4 post-hoc models are additionally computed, one for every level of the re-coded factor (Cross-modal Matching, Uni-modal Matching, Cross-modal Mismatching, Uni-modal Mismatching)

*Rep\_logRT ~ SUBTLEX WF \* Target modality + Greene OF \* Target modality +*

*Concept familiarity (replication) + Image typicality (replication) +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition + Trial accuracy +*

*(1|Participants) + (1/Concepts)*

***Supplementary Table 19****.* Results from the post-hoc individual models for conditions of interest in Exp 3.

**Uni-modal Matching Cross-modal Matching**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.304 | 0.022 | 289.192 | **<0.001** | 6.340 | 0.027 | 237.811 | **<0.001** |
| SUBTLEX WF | -0.011 | 0.003 | -3.470 | **0.001** | -0.013 | 0.006 | -2.253 | **0.024** |
| Target modality (Words – Objects) | 0.016 | 0.004 | 3.748 | **<0.001** | -0.036 | 0.005 | -7.115 | **<0.001** |
| Greene OF | 0.001 | 0.003 | 0.398 | 0.691 | 0.010 | 0.005 | 1.873 | 0.061 |
| Visuo-orthographic PC | 0.002 | 0.003 | 0.818 | 0.413 | 0.009 | 0.006 | 1.613 | 0.107 |
| Concept familiarity | -0.000 | 0.003 | -0.010 | 0.992 | -0.004 | 0.006 | -0.754 | 0.451 |
| Image typicality | -0.001 | 0.003 | -0.463 | 0.643 | -0.026 | 0.005 | -5.426 | **<0.001** |
| Image visual PC1 | 0.001 | 0.002 | 0.422 | 0.673 | 0.001 | 0.004 | 0.274 | 0.784 |
| Image visual PC2 | 0.006 | 0.002 | 2.379 | **0.017** | 0.002 | 0.004 | 0.499 | 0.618 |
| Image visual PC3 | 0.003 | 0.003 | 1.191 | 0.234 | -0.000 | 0.005 | -0.005 | 0.996 |
| Target repetition | -0.026 | 0.002 | -12.208 | **<0.001** | -0.051 | 0.003 | -20.200 | **<0.001** |
| Trial accuracy (Correct – Incorrect) | 0.019 | 0.011 | 1.781 | 0.075 | -0.012 | 0.012 | -1.051 | 0.293 |
| SUBTLEX x (Words – Objects) | -0.011 | 0.004 | -2.516 | **0.012** | -0.027 | 0.005 | -5.433 | **<0.001** |
| Greene x (Words – Objects) | 0.000 | 0.004 | 0.018 | 0.985 | 0.006 | 0.005 | 1.141 | 0.254 |

**Uni-modal Mismatching Cross-modal Mismatching**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.369 | 0.023 | 276.110 | **<0.001** | 6.367 | 0.027 | 233.415 | **<0.001** |
| SUBTLEX WF | -0.003 | 0.003 | -1.204 | 0.229 | -0.004 | 0.003 | -1.234 | 0.217 |
| Target modality (Words – Objects) | 0.001 | 0.004 | 0.337 | 0.736 | -0.010 | 0.005 | -2.018 | **0.044** |
| Greene OF | -0.002 | 0.003 | -0.699 | 0.484 | 0.003 | 0.003 | 1.044 | 0.297 |
| Visuo-orthographic PC | 0.002 | 0.003 | 0.565 | 0.572 | 0.006 | 0.003 | 2.018 | **0.044** |
| Concept familiarity | 0.002 | 0.003 | 0.692 | 0.489 | -0.000 | 0.003 | -0.094 | 0.925 |
| Image typicality | -0.000 | 0.002 | -0.205 | 0.838 | -0.007 | 0.003 | -2.695 | **0.007** |
| Image visual PC1 | 0.004 | 0.002 | 1.896 | 0.058 | -0.003 | 0.002 | -1.071 | 0.284 |
| Image visual PC2 | 0.003 | 0.002 | 1.489 | 0.137 | 0.001 | 0.002 | 0.221 | 0.825 |
| Target repetition | -0.028 | 0.002 | -13.127 | **<0.001** | -0.040 | 0.002 | -16.764 | **<0.001** |
| Image visual PC3 | -0.001 | 0.002 | -0.538 | 0.591 | 0.002 | 0.002 | 0.733 | 0.464 |
| Trial accuracy (Correct – Incorrect) | 0.048 | 0.017 | 2.920 | **0.004** | 0.065 | 0.015 | 4.251 | **<0.001** |
| SUBTLEX x (Words – Objects) | -0.006 | 0.004 | -1.340 | 0.180 | -0.000 | 0.005 | -0.072 | 0.943 |
| Greene x (Words – Objects) | 0.001 | 0.004 | 0.314 | 0.754 | -0.004 | 0.005 | -0.796 | 0.426 |

***Supplementary Figure 11 – RTs estimated from post-hoc models of Experiment 3 (within conditions)***

Effects of SUBTLEX WF (dark green, top) and Greene OF (light green, bottom) on reaction times estimated from the post-hoc models separately for each Priming condition (continuous and dashed-dotted line types) and Matching condition (left and right plots) in the Replication experiment. Points show concepts with different level of frequency, averaged across participants; lines represent linear fitting of points and shaded areas represent 95 % confidence interval.

A picture containing chart

Description automatically generated

***Supplementary Table 20****.* Results from the post-hoc individual models for conditions of interest in Experiment 3.

**Cross-modal Matching Words Cross-modal Matching Object**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.341 | 0.027 | 239.179 | **<0.001** | 6.345 | 0.029 | 215.770 | **<0.001** |
| SUBTLEX WF | -0.027 | 0.007 | -3.699 | **<0.001** | 0.000 | 0.007 | 0.042 | 0.966 |
| Greene OF | 0.015 | 0.006 | 2.307 | **0.021** | 0.005 | 0.006 | 0.802 | 0.422 |
| Visuo-orthographic PC | 0.008 | 0.007 | 1.221 | 0.222 | 0.010 | 0.006 | 1.528 | 0.126 |
| Concept familiarity | -0.008 | 0.007 | -1.165 | 0.244 | -0.000 | 0.006 | -0.074 | 0.941 |
| Image typicality | -0.024 | 0.006 | -4.039 | **<0.001** | -0.028 | 0.005 | -5.162 | **<0.001** |
| Image visual PC1 | -0.001 | 0.005 | -0.195 | 0.846 | 0.003 | 0.005 | 0.669 | 0.503 |
| Image visual PC2 | 0.000 | 0.005 | 0.082 | 0.935 | 0.004 | 0.005 | 0.734 | 0.463 |
| Image visual PC3 | 0.004 | 0.006 | 0.726 | 0.468 | -0.004 | 0.005 | -0.751 | 0.453 |
| Targer repetition | -0.051 | 0.007 | -7.415 | **<0.001** | -0.055 | 0.007 | -8.106 | **<0.001** |
| Trial accuracy | -0.017 | 0.016 | -1.001 | 0.317 | -0.018 | 0.017 | -1.065 | 0.287 |

***Supplementary Figure 12 – RTs estimated from post-hoc models of Experiment 3 (within modalities)***

Effects of SUBTLEX WF (left) on reaction times estimated from the post-hoc models for Cross-modal matching trials of words (blue) and Cross-modal matching trials of objects (red) in the Replication experiment. Points show concepts with different level of frequency, averaged across participants; lines represent linear fitting of points and shaded areas represent 95 % confidence interval.

Chart, scatter chart

Description automatically generated

**Supplementary Materials 15 – Effect of dlexDB on Experiment 1**

*Exp1\_logRT ~ dlexDB WF \* Concept modality +*

*Concept category + Concept familiarity + Image typicality +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition +*

*Trial accuracy + (1|Participants) + (1/Concepts)*

***Supplementary Table 21****.* Results from main model of Exp 1 including dlexDB instead of SUBTLEX

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.480 | 0.021 | 301.419 | **<0.001** |
| Target modality (Words – Objects) | 0.094 | 0.005 | 20.523 | **<0.001** |
| dlexDB WF | -0.021 | 0.008 | -2.801 | **0.005** |
| Visuo-orthographic PC | -0.000 | 0.008 | -0.050 | 0.960 |
| Concept familiarity | -0.004 | 0.003 | -1.263 | 0.206 |
| Image typicality | -0.005 | 0.003 | -1.416 | 0.157 |
| Image visual PC1 | -0.002 | 0.006 | -0.261 | 0.794 |
| Image visual PC2 | 0.020 | 0.006 | 3.272 | **0.001** |
| Image visual PC3 | 0.009 | 0.006 | 1.481 | 0.139 |
| Target repetition | -0.011 | 0.002 | -4.926 | **<0.001** |
| Trial accuracy (Correct – Incorrect) | -0.018 | 0.009 | -2.032 | **0.042** |
| Concept category (Natural – Man-made) | 0.001 | 0.013 | 0.074 | 0.941 |
| dlexDB x (Words – Objects) | -0.020 | 0.005 | -4.394 | **<0.001** |

Results from 2 post-hoc models one for each stimulus modality.

*Exp1\_logRT ~ dlexDB WF +*

*Concept category + Concept familiarity + Image typicality +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition +*

*Trial accuracy + (1|Participants) + (1/Concepts)*

***Supplementary Table 22.***Results from post-hoc models of Exp 1 including dlexDB instead of SUBTLEX

**Objects trials Word trials**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.450 | 0.022 | 289.121 | **<0.001** | 6.520 | 0.025 | 265.635 | **<0.001** |
| dlexDB WF | -0.012 | 0.009 | -1.289 | 0.197 | -0.031 | 0.008 | -4.081 | **<0.001** |
| Concept category (Natural – Man-made) | 0.009 | 0.016 | 0.601 | 0.548 | -0.009 | 0.013 | -0.664 | 0.506 |
| Visuo-orthographic PC1 | -0.000 | 0.010 | -0.018 | 0.986 | -0.001 | 0.008 | -0.090 | 0.928 |
| Concept familiarity | -0.001 | 0.005 | -0.277 | 0.782 | -0.007 | 0.004 | -1.480 | 0.139 |
| Image typicality | -0.009 | 0.004 | -2.054 | **0.040** | -0.002 | 0.004 | -0.462 | 0.644 |
| Image visual PC1 | -0.004 | 0.007 | -0.597 | 0.551 | 0.001 | 0.006 | 0.179 | 0.858 |
| Image visual PC2 | 0.026 | 0.007 | 3.524 | **<0.001** | 0.013 | 0.006 | 2.172 | **0.030** |
| Image visual PC3 | 0.005 | 0.008 | 0.665 | 0.506 | 0.014 | 0.006 | 2.192 | **0.028** |
| Target repetition | 0.009 | 0.021 | 0.428 | 0.668 | -0.030 | 0.024 | -1.290 | 0.197 |
| Trial accuracy (Correct – Incorrect) | -0.059 | 0.013 | -4.403 | **<0.001** | 0.004 | 0.011 | 0.398 | 0.690 |

**Supplementary Materials 16 – Effect of ADE20K on Experiment 2**

*Exp2\_logRT ~ SUBTLEX WF \* Recoded factor \* Target modality +*

*ADE20K OF \* Recoded factor \* Target modality +*

*Concept familiarity + Image typicality +*

*Image visual PC1 + Image visual PC2 + Image visual PC3 +*

*Visuo-orthographic PC + Target repetition + Trial accuracy +*

*(1|Participants) + (1/Concepts)*

***Supplementary Table 23****.* Results from main model of Exp 2 including ADE20K instead of Greene

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Predictors*** | ***β*** | ***SE*** | ***t*** | ***p*** |
| (Intercept) | 6.225 | 0.020 | 315.721 | **<0.001** |
| SUBTLEX WF | -0.005 | 0.002 | -2.420 | **0.016** |
| Cross-modal matching – Uni-modal matching | 0.005 | 0.006 | 0.829 | 0.407 |
| Cross-modal mismatching – Uni-modal mismatching | 0.008 | 0.006 | 1.380 | 0.168 |
| Cross-modal matching – Cross-modal mismatching | -0.075 | 0.003 | -23.729 | **<0.001** |
| Target modality (Words – Objects) | -0.008 | 0.002 | -3.612 | **<0.001** |
| ADE20K OF | 0.008 | 0.002 | 4.391 | **<0.001** |
| Visuo-orthographic PC | 0.010 | 0.002 | 5.256 | **<0.001** |
| Concept familiarity | -0.001 | 0.002 | -0.739 | 0.460 |
| Image typicality | -0.004 | 0.002 | -2.638 | **0.008** |
| Image visual PC1 | 0.002 | 0.002 | 1.085 | 0.278 |
| Image visual PC2 | 0.005 | 0.002 | 3.463 | **0.001** |
| Image visual PC3 | -0.002 | 0.002 | -1.134 | 0.257 |
| Target repetition | -0.036 | 0.003 | -13.329 | **<0.001** |
| Trial accuracy (Correct – Incorrect) | 0.029 | 0.005 | 5.393 | **<0.001** |
| SUBTLEX x (Cross-modal matching – Uni-modal matching) | -0.027 | 0.004 | -7.622 | **<0.001** |
| SUBTLEX x (Cross-modal mismatching – Uni-modal mismatching) | -0.006 | 0.004 | -1.568 | 0.117 |
| SUBTLEX x (Cross-modal matching – Cross-modal mismatching) | -0.035 | 0.004 | -9.901 | **<0.001** |
| SUBTLEX x Target modality | -0.007 | 0.003 | -2.651 | **0.008** |
| Target modality x (Cross-modal matching – Uni-modal matching) | -0.010 | 0.006 | -1.657 | 0.098 |
| Target modality x (Cross-modal mismatching – Uni-modal mismatching) | 0.036 | 0.006 | 5.720 | **<0.001** |
| Target modality x (Cross-modal matching – Cross-modal mismatching) | -0.015 | 0.006 | -2.322 | **0.020** |
| ADE20K x (Cross-modal matching – Uni-modal matching) | 0.018 | 0.004 | 5.167 | **<0.001** |
| ADE20K x (Cross-modal mismatching – Uni-modal mismatching) | -0.002 | 0.004 | -0.617 | 0.537 |
| ADE20K x (Cross-modal matching – Cross-modal mismatching) | 0.028 | 0.004 | 7.731 | **<0.001** |
| ADE20K x Target modality | 0.004 | 0.003 | 1.726 | 0.084 |
| SUBTLEX x (Cross-modal matching – Uni-modal matching) x Target modality | -0.005 | 0.007 | -0.743 | 0.457 |
| SUBTLEX x (Cross-modal mismatching – Uni-modal mismatching) x Target modality | 0.005 | 0.007 | 0.762 | 0.446 |
| SUBTLEX x (Cross-modal matching – Cross-modal mismatching) x Target modality | -0.003 | 0.007 | -0.448 | 0.654 |
| ADE20K x (Cross-modal matching – Uni-modal matching) x Target modality | 0.014 | 0.007 | 1.937 | 0.053 |
| ADE20K x (Cross-modal mismatching – Uni-modal mismatching) x Target modality | 0.004 | 0.007 | 0.588 | 0.557 |
| ADE20K x (Cross-modal matching – Cross-modal mismatching) x Target modality | 0.003 | 0.007 | 0.441 | 0.660 |

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