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Evidence for Joint & Complementary Hemispheric Lateralization, Within Subjects, Across Tasks & Dependent Measures: Evidence from Visual Half-Field Paradigm

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Abstract

Previous studies link the right hemisphere (RH) to visuo-spatial/configural processing and the left hemisphere (LH) to language, although evidence shows variability across tasks, measures, and individuals, with RH also contributing to verbal processing (Whitehouse & Bishop, 2012). The current study tested for hemispheric specialization using a visual half-field paradigm (face-matching, symmetry-judgment, and word-categorization tasks), analyzing accuracy, sensitivity (d′), RT, and decision bias (c). Mixed-effects modeling revealed a clear LVF/RH advantage for face-matching and symmetry-judgment, with higher sensitivity, faster RTs, greater accuracy, and a liberal bias for faces but a slightly conservative bias for symmetry. Word-categorization showed a subtle RVF/LH advantage in RT, both at task level and for abstract words, but no reliable visual field differences in accuracy. These findings demonstrate joint and complementary hemispheric asymmetries across tasks and measures for RH and LH functions, respectively, challenging the statistical independence view (Bryden, 1982; Harms & Elias, 2014).

Keywords: complementary hemispheric lateralization; visual half-field; symmetry; language; face-matching; mixed-effects models, visuo-spatial

Introduction

The human brain shows anatomical assymetries not only in structure but functional as well (De Schotten & Beckmann, 2021). Hemispheric lateralization is the specialization of the left and right cerebral hemispheres. For instance, left hemisphere (LH) has been found to be dominant for verbal functions, language production & arithmetics (Dehaene & Cohen, 1997; Knecht et al., 2000), whereas the right hemisphere (RH) has been found to be more adept at handling visuospatial functions, music and configural processing. Research has (Kosslyn et al., 1998; Zatorre et al., 2002) demonstrated that in right-handed individuals, the RH performs well on verbal tasks requiring pictorial or imagery-based encoding, but it shows little aptitude for purely linguistic analysis. Similarly, Lindell (2006) has reviewed evidence that the RH supports pragmatic, affective, and figurative aspects of language processing and production, highlighting its complementary role alongside the LH. Jung-Beeman (2005) further emphasized that although propositional language processing is left-lateralized, the RH contributes to contextual and semantic integration, underscoring bilateral participation in complex communication.

Two competing views have been offered to theoreticially account for hemispheric specializations, i.e., the causal complementarity view, according to which certain functions may depict joint lateralization and might be positively correlated within an individual (such as face & symmetry processing) whereas other functions such as a LH function (word recognition/naming) & a RH function (face/symmetry processing) may depict complementary lateralization and be negatively correlated within an individual. On the other hand, the statistical independence view (Whitehouse & Bishop, 2009; 2012) suggests that cognitive functions are lateralized independent of one another as their probabilities of lateralization stem from different independent sources and hence no correlation should be observed between them (Andresen & Marsolek, 2005; Harms & Elias, 2014).

Other examples would include, for instance, in terms of language, the LH efficiently handles abstract, symbolic language and the RH has been found to be more sensitive to concrete, imagery-rich, or emotionally grounded concepts (Wang et al. , 2010). These findings converge with the complementarity hypothesis (Badzakova-Trajkov, Corballis, & Häberling, 2016). Also, evidence from face (Kanwisher et al., 1997) and visual symmetry perception (Bertamini et al., 2011), illustrates this principle, i.e., the RH dominates holistic and configural processing whereas the LH supports local feature analysis and verbal processing (Chen et al., 2006; Cai et al., 2013). Building on this framework, the current study aimed to test for the joint hemispheric lateralization for faces and symmetry (i.e., RH dominance), and their complementary lateralization with word processing (i.e., LH dominance). Within word stimuli, we included both concrete and abstract categories, to test for their complementary lateralization as abstract word processing is expected to show greater left lateralization than concrete words (Ulanov et al., 2024). More specifically, using the VHF paradigm, we hypothesized that the hemispheric asymmetry for face-matching and symmetry-judgment will be in the same direction (LVF/RH) for most participants, whereas the asymmetry will be complementary for word processing (RVF/LH). The dependent measures we chose to test with are reaction times, accuracy, sensitivity (d’) and criterion. The findings are also expected to contrast the causal view of the complementarity view of hemispheric lateralization against the statistical independence view.

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Method

Participants 42 undergraduate students from Indian Institute of Technology Kanpur provided informed consent and participated voluntarily in this study. Handedness was assessed using a modified Edinburgh Handedness Inventory (Oldfield, 1971), and only right-handed participants were included. Data from 4 participants were excluded for all three tasks as their performance fell below 60% in at least one task, yielding a final sample of 38 participants (13 females; mean age 22.05 ± 3.18). All had normal or corrected-to-normal vision and LexTale scores above 60%.

Design All tasks were programmed in PsychoPy Coder (v2024.2.1post4; Peirce, 2007) and presented on a 24-inch monitor (1920 × 1200 px; 53.1 × 29.9 cm) with participants' heads stabilized on a chin rest ~60 cm from the screen. A repeated-measures design was used, with sessions separated by ≥4 hours. Linguistic proficiency was assessed with LexTale (Lemhöfer & Broersma, 2012). Each task began with a 40-trial practice session using five unique stimuli per type not used in the main experiment. Main tasks comprised four 100-trial blocks with self-paced breaks. Task order and response key assignments were counterbalanced. Participants responded bimanually to avoid right-hand advantage for RVF stimuli (Nicholls & Wood, 1998; Bourne, 2006; Verma et al., 2013), with responses recorded from the first keypress. For symmetric figures, match faces, or abstract words, participants pressed 'A' and 'K' with middle fingers; otherwise, they pressed 'Z' and 'M' with index fingers. Trials were valid only if both keys were pressed within 85 ms.

A divided visual half-field (VHF) paradigm was used for three tasks: face-matching, symmetry judgment, and word categorization (Hunter & Brysbaert, 2008).

Symmetry-judgment task (E1) followed Verma et al. (2013). Each trial began with a 1000 ms blank, followed by two 150 × 150 px (4 × 4°) stimuli presented 3° left and right of fixation for 200 ms to prevent saccades (Walker & McSorley, 2006). A central arrow (1 × 1°) randomly indicated left or right. Figures (50 symmetric, 50 asymmetric) consisted of horizontal rectangles of varying lengths. A 200 ms mask ("rectangular grid") preceded a 1500 ms blank during which participants responded. In compatible trials, both pointed and non-pointed stimuli were from the same category; otherwise, trials were incompatible. The 400-trial experiment fully counterbalanced all stimuli across VHFs, randomized within and across blocks. The design included three factors (2 × 2 × 2): visual half-field (LVF vs. RVF), stimulus type (symmetric vs. asymmetric), and compatibility.

Word-categorization task (E2) used the same design. Stimuli included 50 abstract and 50 concrete five-letter words selected from Brysbaert, Warriner, and Kuperman (2014) with concreteness ratings 1.5–3.0 (abstract) and 3.5–5.0 (concrete) and no high-frequency bigrams (>2000 in SUBTLEX). Words appeared in uppercase, 3° from fixation, subtending ~1° × 4° visual angle. Participants were instructed on abstract vs. concrete definitions (Brysbaert et al., 2014) and were asked to indicate the category of the pointed word after mask disappearance ("#####").

Face-matching task (E3): Each trial began with a 1000 ms blank and 300 ms fixation, followed by a central face (oval, cropped to exclude hair/ears) for 180 ms. Two face stimuli then appeared bilaterally for 200 ms, 3° left/right, each 4° × 5°. In match trials, the pointed-hemifield face matched the central face; in non-match trials, it differed. Compatible trials contained the same faces in both VHFs. Fifty neutral-expression Caucasian faces from the Radboud Faces Database (Langner et al., 2010) were used across eight conditions (50 × 8 trials). All faces were grayscale, luminance- and contrast-normalized in MATLAB R2024b via histogram matching to a reference image to control low-level visual differences.

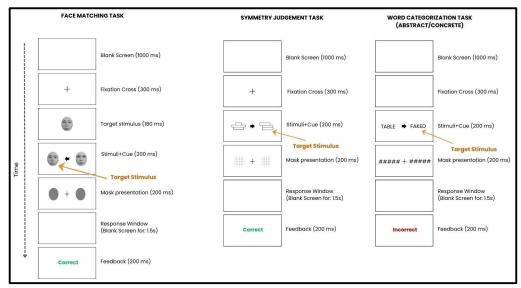

Figure 1: Design of all tasks.

Data Analysis

Trials with missing RTs were excluded, retaining only responses between 200–1000 ms. RTs ±3 SD from each participant's mean were also removed. Filtered data were used to compute all dependent variables (DVs). Mixed-effects models accounted for repeated measures and individual differences in baseline performance and sensitivity to task, visual hemifield, and stimulus manipulations (Baayen et al., 2008; Barr et al., 2013), improving power, handling unequal trial counts, and controlling for non-independence. Continuous DVs (d′, criterion, log-RT) were analyzed using linear mixed-effects models (LMMs) in R 4.4.1 with lme4 and REML, while accuracy, a binary outcome, was analyzed with a generalized linear mixed-effects model (GLMM) using a binomial distribution and logit link. Models included participant-specific random intercepts and, where appropriate, random slopes. Compatibility was included as a factor but not reported as it was not directly relevant to the study hypotheses.

Model Diagnostics

Residual diagnostics were assessed using the DHARMa package for R (Hartig, 2023). For the accuracy GLMM, no overdispersion was detected (Dispersion $p = 0.926$). LMMs for criterion, d′, and log RT showed approximate normality for criterion (KS $p = 0.868$) and d′ (KS $p = 0.777$), while log RT exhibited expected skew (KS $p < 0.001$). Dispersion tests indicated no over- or under-dispersion, and outlier detection showed 0% extreme residuals across models. All models converged with properly estimated random effects and no singular fits.

Statistical Models

Reaction Time (RT) Log-transformed RTs were modeled as a function of task, VHF (LVF/RVF), stimulus type (abstract/concrete words, match/non-match faces and symmteric/asymmetric figures), and compatibility (compatible/incompatible), including their interactions, with participant-specific random intercepts and random slopes for VHF and task. Following is the model equation:

$$log\ (RT)_{ij} = \beta_0 + \beta_1\, Task_i + \beta_2\, VHF_i + \beta_3\, Pointed\_stimulus_i + \beta_4\, Compatibility_i + \beta_5\, (Task \times VHF)_i + \beta_6\, (VHF \times Pointed\_stimulus)_i + \beta_7\, (VHF \times Pointed\_stimulus \times Compatibility)_i + b_{0j} + b_{1j}\, VHF_i + b_{2j}\, Task_i + \varepsilon_{ij}$$

Accuracy The following model estimated the effects of task, VHF: LVF/RVF, stimulus type, and compatibility as fixed effects, with participant-specific random intercepts and random slopes for VHF and task, on the log-odds of a correct response:

$$logit[P(correct_{ij})] = \beta_0 + \beta_1\, Task_i + \beta_2\, VHF_i + \beta_3\, Pointed\_stimulus_i + \beta_4\, Compatibility_i + \beta_5\, (Task \times VHF)_i + \beta_6\, (VHF \times Pointed\_stimulus)_i + \beta_7\, (Pointed\_stimulus \times Compatibility)_i + \beta_8\, (VHF \times Pointed\_stimulus \times Compatibility)_i + b_{0j} + b_{1j}\, VHF_i + b_{2j}\, Task_i$$

Signal Detection Measures (d′ and Criterion) Perceptual sensitivity (d′) and response bias (criterion, c) were calculated using signal detection theory for each participant, task, and VHF condition. In E1, symmetric figures were treated as signal trials and asymmetric figures as noise trials, in E2, abstract words were treated as signal trials and concrete words as noise trials and in E3, match-face trials were treated as signal and non-match trials as noise. Hit rates were defined as the proportion of correct responses on signal trials, and false alarm rates as the proportion of incorrect responses on noise trials. A log-linear correction was applied to avoid infinite z-scores, after which d′ was calculated as the difference and criterion as the negative half-sum of the z-transformed hit and false alarm rates.

Criterion The following model estimated the effect of task, VHF, and their interaction on response bias while accounting for participant-level variability:

$$Criterion_{ij} = \beta_0 + \beta_1 Task_i + \beta_2 VHF_i + \beta_3 (Task \times VHF)_i + b_{0j} + \varepsilon_{ij}.$$

Perceptual Sensitivity (d′) The model included tasks, VHF, and their interaction as fixed effects, with participant-specific random intercepts and slopes for VHF to account for individual differences in VHF sensitivity. The model equation is as follows:

$$d'_{ij} = \beta_0 + \beta_1 Task_i + \beta_2 VHF_i + \beta_3 (Task \times VHF)_i + b_{0j} + b_{1j} VHF_i + \varepsilon_{ij}$$

Results

Accuracy

Random effects indicated substantial variability in baseline accuracy (SD = 0.45), as well as in sensitivity to visual half-field (SD = 0.46) and task (SD ≈ 0.42). Symmetry judgments were most accurate (β = 1.30, OR ≈ 3.67), while face-matching (β = −0.46, OR ≈ 0.63, $p < .001$) and word categorization (β = −0.26, OR ≈ 0.77, p = .013) showed lower accuracy. Accuracy was higher for left visual field (LVF) than right visual field (RVF) presentations (β = 0.38, OR ≈ 1.48, $p < .001$), with stronger effects for asymmetric (β = 0.44, OR ≈ 1.55, $p < .001$) and match stimuli (β = 0.36, OR ≈ 1.43, p = .002).

Post hoc estimated marginal means (emmeans) comparisons showed lower accuracy in the RVF than the LVF for symmetry judgments (OR = 0.53, $p < .001$) and face-matching (OR = 0.53, $p < .001$), but no reliable visual field difference for word categorization (OR = 1.16, p = .092), with a non-significant trend toward an RVF advantage. Within the LVF, symmetry judgments were more accurate than face-matching (OR = 1.35, p = .004) and word categorization (OR = 2.09, $p < .001$), and face-matching also exceeded word categorization (OR = 1.55, $p < .001$). In contrast, within the RVF, face-matching was less accurate than word categorization (OR = 0.72, $p < .001$). Predicted probabilities (Figure 2) were computed by inverse-logit transformation of emmeans estimates:

$$Probability = e\hat{\ }estimate\ /\ (1 + e\hat{\ }estimate)$$

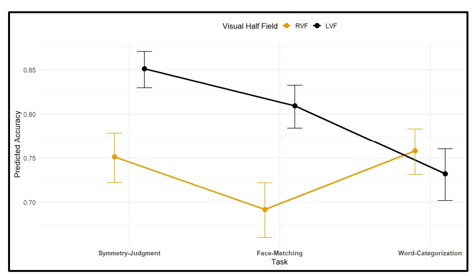

Figure 2: Predicted Accuracy (Probability Scale) by Task & VHF (Estimated Marginal Means).

Within-task comparisons revealed stimulus-specific effects that varied by visual field. In the face task, accuracy was higher for match than non-match stimuli in the LVF (OR = 1.32, p = .003), with no corresponding difference in the RVF (OR = 0.97, p = 1.00). In the symmetry task, asymmetric stimuli were less accurate than symmetric stimuli in the RVF (OR = 0.57, $p < .001$), whereas no reliable difference was observed in the LVF (OR = 0.93, p = .999). In the word-categorization task, abstract stimuli showed higher accuracy in the RVF than LVF (OR = 1.31, p = .003), whereas concrete stimuli showed no reliable visual field difference (OR = 0.995, p = .953). Comparisons between abstract and concrete stimuli were non-significant in both the RVF (OR = 1.12, p = .845) and LVF (OR = 0.85, p = .188).

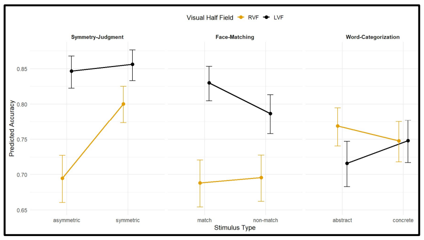

Figure 3: Predicted Accuracy (Probability Scale) by Stimulus Type & VHF (Estimated Marginal Means).

Task-specific slopes further confirmed these patterns (Figure 4). For face matching, the mean slope (LVF − RVF) was 0.156 (SD = 0.091), with 37 of 38 participants showing higher accuracy in the LVF, t(37) = 10.5, p < .001. For symmetry judgments, the mean slope was 0.117 (SD = 0.078), with 37 of 38 participants (97.4%) showing LVF superiority, t(37) = 9.26, p < .001. In contrast, word-categorization showed no consistent hemispheric bias across participants (mean slope = −0.030, SD = 0.091), t(37) = −1.99, p = .054.

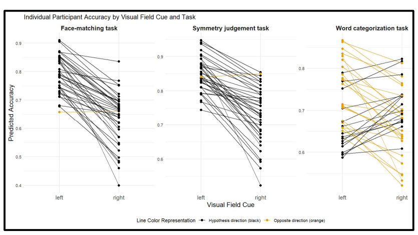

Figure 4: Predicted Accuracy (Probability Scale) Per Participant by Stimulus Type & VHF

Overall, 15 of 38 participants (~39.5%) followed the complementarity hypothesis. 92.1% of participants showed LVF superiority in both the face-matching and symmetry-judgment tasks, indicating high concordance across tasks, which was further supported by a strong positive correlation between participant-specific VHF slopes (r(36) = .95, p < .001, 95% CI [.91, .98]).

Reaction Time

Participants varied in baseline log RT (random intercept SD = 0.202) and in their sensitivity to VHF (SD = 0.055) and task (SD = 0.143–0.174), with residual variability of 0.285, indicating substantial trial-to-trial variation. At baseline, responses in the reference condition were estimated at 6.051 (SE = 0.034, p < .001). Asymmetric stimuli were associated with slower responses (β = 0.039, p < .001), whereas non-match relational trials were associated with faster responses (β = −0.020, p = .04). A robust VHF effect indicated faster responses in the LVF compared with the RVF (RVF; β = −0.075, p < .001). This effect was modulated by task and stimulus context, being reduced in the word-categorization task (β = 0.112, p < .001) and smaller for asymmetric stimuli (β = −0.033, p < .05). Emmeans further showed task-dependent visual field effects. In the face-matching task, responses were significantly slower in the RVF than the LVF (right − left = 0.056, SE = 0.010, z = 5.39, p < .001), as was also observed in the symmetry-judgment task (right − left = 0.086, SE = 0.010, z = 8.45, p < .001). In contrast, the word-categorization task showed the opposite pattern, with faster responses in the RVF than the LVF (right − left = −0.023, SE = 0.010, z = −2.25, p = .025) indicating complementary hemispheric specialization across perceptual domains.

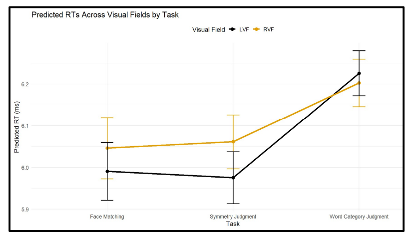

Figure 4: Predicted RT in milliseconds by Task & VHF (Estimated Marginal Means).

Stimulus-specific contrasts revealed task-dependent VHF effects in RT. In the face-categorization task, responses were slower in the RVF than LVF for both match (estimate = 0.084, p < .001) and non-match trials (estimate = 0.027, p = .016), indicating a consistent LVF advantage. A similar pattern was observed in the symmetry-judgement task, with slower RVF responses for asymmetric (estimate = 0.099, p < .001) and symmetric stimuli (estimate = 0.073, p < .001), with a stronger effect for asymmetric stimuli. In the word-categorization task, abstract stimuli showed a significant RVF advantage (right − left = −0.028, p = .012), whereas concrete stimuli did not differ reliably between visual fields (p = .12). Within visual fields, no significant differences were observed between abstract and concrete stimuli in either the LVF (p = .129) or RVF (p = .985).

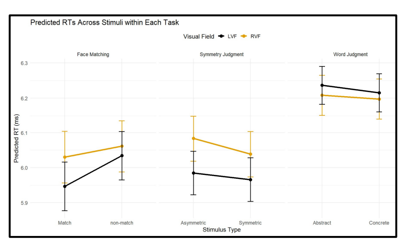

Figure 5: Predicted RT (ms) by Stimulus Type & VHF (Estimated Marginal Means).

Across tasks, in the RVF, words were faster than match faces (abstract: estimate = −0.178, SE = 0.027; concrete: −0.167, SE = 0.027) and asymmetric stimuli (estimate = −0.124, SE = 0.024; all $p < .0001$). In the LVF, match faces and symmetric stimuli were faster than words (match vs. abstract: 0.290, vs. concrete: 0.268; symmetric vs. abstract: 0.270, vs. concrete: 0.249; all SEs = 0.024–0.027, $p < .0001$).

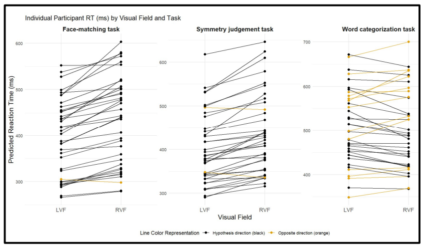

Figure 6: Individual Predicted RT (ms) by Task & VHF

Predicted individual RTs (ms) reflected the expected visual half-field advantages. For face-matching, mean slope = 37.6 ms (SD = 26.4), with 97.4% of participants following the LVF advantage, $t(37) = 8.76$, $p < 0.001$; for symmetry, mean slope = 32.0 ms (SD = 24.6), 94.7% followed LVF, $t(37) = 8.01$, $p < 0.001$; for words, mean slope = 5.11 ms (SD = 27.7), 65.8% followed RVF, $t(37) = 1.14$, $p = 0.263$. Across all tasks, 23/38 participants (60.5%) showed the full predicted pattern, which was not significantly above chance, $p = 0.128$. 89.5% participants showed the same LVF advantage in both tasks. RT lateralization was also highly consistent across tasks, with a very strong correlation participant-specific VHF slopes, $r(36) = .97$, $p < .001$.

Perceptual Sensitivity (d′)

Predicted sensitivity (d′; Figure 7) was derived using task-specific signal detection definitions (symmetry: symmetric = signal; asymmetry = noise; word: abstract = signal; concrete = noise; face-matching: match = signal; non-match = noise). Overall sensitivity was moderate (β = 1.763, 95% CI [1.510, 2.016], $p < .001$) and varied across tasks, being higher for symmetry judgments (β = 0.300, 95% CI [0.054, 0.546], $p = .009$) and lower for word categorization (β = −0.562, 95% CI [−0.808, −0.316], $p < .001$) relative to face-matching.

Random effects showed substantial between-participant variability in baseline sensitivity (SD = 0.383) and visual-field asymmetry (SD = 0.424), with moderate residual variability (SD = 0.494), indicating reliable individual differences in both overall performance and hemispheric bias. A robust visual-field effect emerged, with lower sensitivity in the RVF than LVF overall (β = −0.745, 95% CI [−0.991, −0.499], $p < .001$). This effect was significantly modulated by task, reversing in the word-categorization condition (β = 0.903, 95% CI [0.657, 1.149], $p < .001$), while no comparable modulation was observed for symmetry judgments. Follow-up emmeans confirmed higher LVF than RVF d′ for face-matching (estimate = 0.745, SE = 0.133, $t(115) = 5.621$, $p < .0001$) and symmetry-judgment (estimate = 0.723, SE = 0.133, $t(115) = 5.452$, $p < .0001$), with no difference for word-categorization (estimate = −0.158, SE = 0.133, $t(115) = −1.192$, $p = .236$).

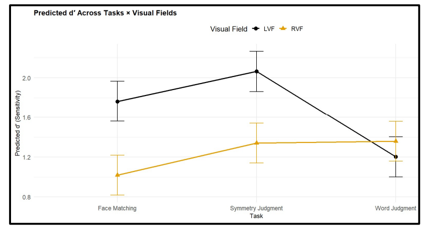

Figure 7: Predicted Sensitivity by Task & VHF (Estimated Marginal Means).

In the LVF, d′ was higher in symmetry-judgment than face-matching (estimate = 0.300, SE = 0.113, $t(148) = 2.649$, $p = .024$), and d′, in both face-matching (estimate = 0.562, SE = 0.113, $t(148) = 4.957$, $p < .0001$) and symmetry-judgment (estimate = 0.862, SE = 0.113, $t(148) = 7.606$, $p < .0001$) exceeded d′ in word-categorization. In the RVF, face-matching showed lower sensitivity than symmetry-judgment (estimate = −0.323, SE = 0.113, $t(148) = −2.847$, $p = .014$) and word-categorization (estimate = −0.341, SE = 0.113, $t(148) = −3.011$, $p = .009$), with no difference between symmetry-judgment and word-categorization (estimate = −0.019, SE = 0.113, $t(148) = −0.164$, $p = .985$).

Predicted d′ slopes were significantly positive for all tasks (face-matching: mean = 0.745, $t(37) = 15.0$, $p < .001$; symmetry-judgement: mean = 0.723, $t(37) = 14.5$, $p < .001$; word-categorization: mean = 0.158, $t(37) = 3.17$, $p = .003$). At the individual level (Figure 8), 28/38 (73.7%) participants showed the predicted LVF advantage for face-matching and symmetry-judgement, and the predicted RVF advantage for word-categorization, exceeding chance (binomial test, $p = .0025$). A significant positive correlation was observed between face-matching and symmetry-judgment participant-specific VHF slopes (d′; $r(36) = .45$, $p = .005$).

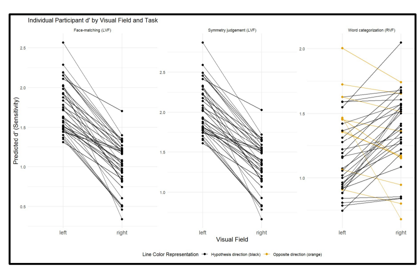

Figure 8: Individual Sensitivity (d′) Across Tasks & VHF

Criterion

Analyzed using the same SDT definitions as d′, overall response bias was slightly liberal (β = −0.134, 95% CI [−0.231, −0.037], $p < .05$) and more conservative for symmetry-judgment (β = 0.113, 95% CI [0.016, 0.210], $p < .05$) and word-categorization (β = 0.185, 95% CI [0.088, 0.282], $p < .05$). Responses were more conservative for RVF stimuli (β = 0.133, 95% CI [0.036, 0.230], $p < .05$), but this effect was reduced for symmetry-judgment (β = −0.280, 95% CI [−0.377, −0.183], $p < .05$) and word-categorization (β = −0.215, 95% CI [−0.312, −0.118], $p < .05$). Random effects: baseline criterion SD = 0.051, residual SD = 0.214.

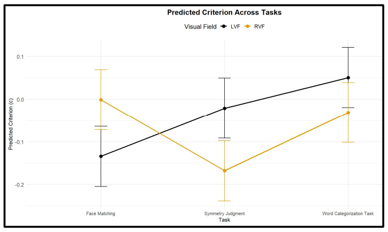

Figure 9: Predicted Bias by Task & VHF (Estimated Marginal Means).

Predicted criterion (Figure 9) showed more liberal bias in LVF than RVF for face-matching (estimate = −0.133, SE = 0.049, $t(185) = -2.713$, $p = .007$) and more liberal for symmetry judgment in RVF (estimate = 0.147, SE = 0.049, $t(185) = 3.000$, $p = .003$), with no difference for word task (estimate = 0.082, SE = 0.049, $t(185) = 1.673$, $p = .096$). Within LVF, symmetry-judgment was marginally more liberal than face-matching (estimate = −0.113, SE = 0.049, $t(185) = -2.312$, $p = .057$), face-matching more liberal than words (estimate = −0.185, SE = 0.049, $t(185) = -3.775$, $p = .001$), and symmetry vs. words was not significant (estimate = −0.072, SE = 0.049, $t(185) = -1.463$, $p = .311$). In RVF, face-matching was more conservative than symmetry (estimate = 0.167, SE = 0.049, $t(185) = 3.401$, $p = .002$), showed no difference from words (estimate = 0.030, SE = 0.049, $t(185) = 0.611$, $p = .815$), and symmetry was slightly more liberal than words (estimate = −0.137, SE = 0.049, $t(185) = -2.790$, $p = .016$). Individual participant plots (Figure 10) indicate that most participants had slightly lower criterion in the RVF for words, reflecting raw trends not statistically significant in the model-adjusted emmeans. No significant correlation between participant-specific VHF slopes of face matching and symmetry judgment tasks ($r = -0.04$, $p = 0.82$) was found.

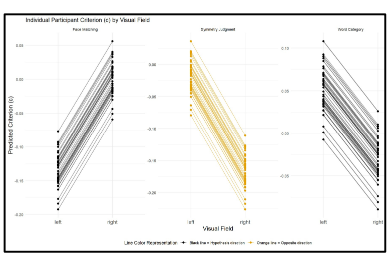

Figure 10: Individual decision bias Across Tasks & VHF

Discussion

The findings in the current study provide support for the causal and complementarity view of hemispheric lateralization. For nonverbal tasks, such as face-matching and symmetry-judgment, participants consistently exhibited LVF/RH advantage, reflected not only in faster responses and greater accuracy, but also in higher sensitivity across stimulus subtypes. This aligns with prior work emphasizing RH specialization for visuospatial, configural, and symmetry processing (Bryden, 1982; Bertamini et al., 2014; Verma et al., 2013). In particular, symmetry detection relies preferentially on RH mechanisms when judgments require global shape or pattern processing (Bertamini & Makin, 2014), consistent with our finding that LVF presentations enhanced performance on symmetric stimuli. In contrast, word-categorization revealed a more complex pattern. Word processing at the task level showed no reliable overall visual field effect in accuracy, but with faster RT in RVF. A selective RVF advantage emerged for abstract words in accuracy and RT, while concrete words showed no hemispheric difference, indicating a stimulus-specific and limited lateralization effect. Accuracy of word-categorization task was higher than face-matching in RVF; sensitivity and reaction time showed an RVF advantage, consistent with LH specialization for language (Ivry & Robertson, 1998; Kimura, 1967). Although the right hemisphere has occasionally been implicated in processing imagery-rich or concrete words, fMRI evidence indicates that such involvement is neither specific nor consistent (Fiebach & Friederici, 2004). Consistent with this, our data shows that LVF/RH advantage for concrete words are subtle, highlighting that hemispheric contributions to word processing are dynamic and task-dependent, rather than strictly divided by semantic type. Response bias (criterion) showed task-dependent patterns. Face-matching was more evident in the LVF, reflecting RH configural processing, whereas symmetry judgments were more subtle in the LVF despite higher sensitivity. For words, emmeans contrasts did not show a significant LVF–RVF difference; however, individual participant plots revealed consistently lower criterion in the RVF, indicating a subtle tendency for more liberal responding in the LH for verbal stimuli. This highlights that VHF advantages in sensitivity do not always align with shifts in response bias, consistent with prior research showing bias can reveal lateralized differences not evident in accuracy alone (Bryden, 1982). Across individuals, LVF advantages for non-verbal tasks were robust, while RVF advantages for verbal task emerged in most but not all participants, reflecting in a subtler RVF/LH advantage, primarily evident in d′, RT, and criterion rather than accuracy. Overall, hemispheric specialization appears partially shared across perceptual domains, reflecting both consistent (joint) and task-dependent (complementary) lateralization patterns. These findings also highlight the importance of integrating multiple measures to fully characterize individual lateralized cognitive profiles.

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