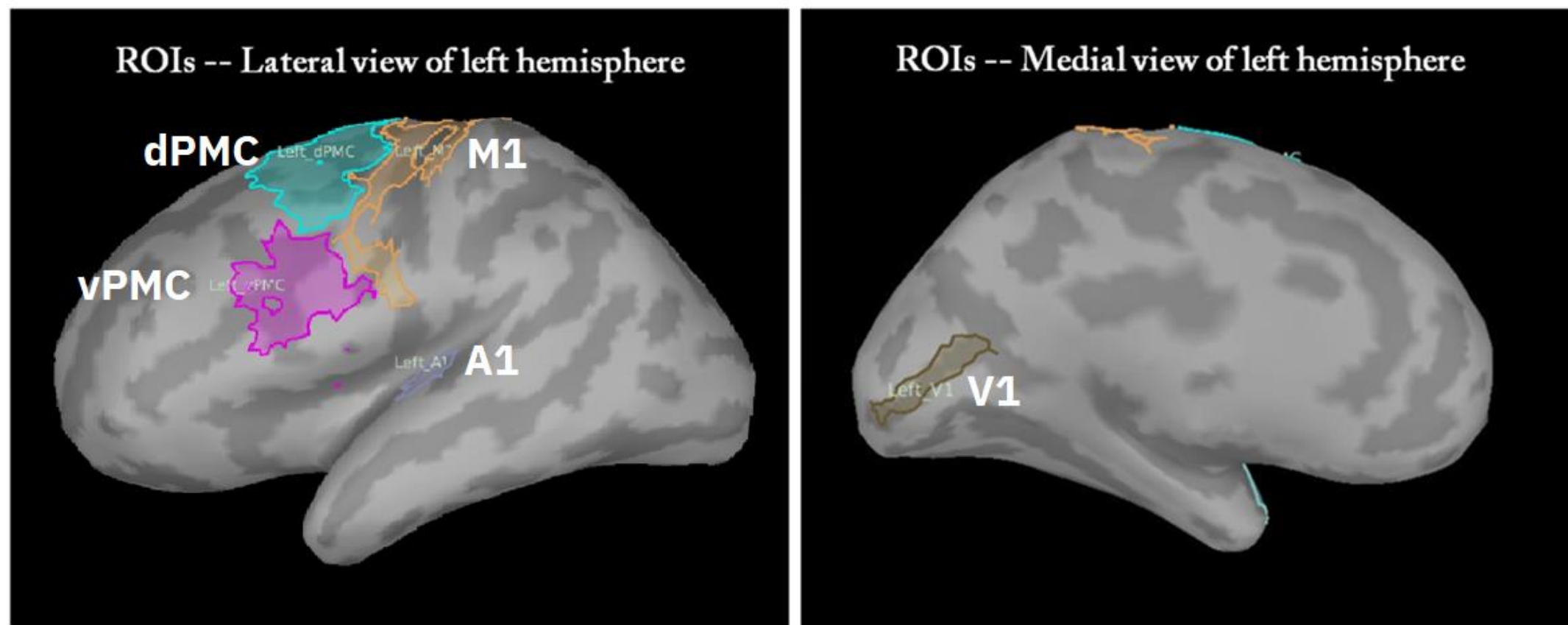**Figure 1.** Example of the five bilateral ROIs displayed over an inflated brain (right hemisphere not shown)


Two bilateral ROIs extracted from the **Desikan-Killiany** atlas: **A1** (violet; left panel), **V1** (ocre; right panel). Three bilateral ROIs extracted from the **Human Motor Atlas Template** (HMAT): **M1** (orange; left panel), **dPMC** (cyan; left panel), **vPMC** (purple; left panel).

**Figure 2.** PLV results obtained in GLMM 1 (n=90) in the beta frequency band
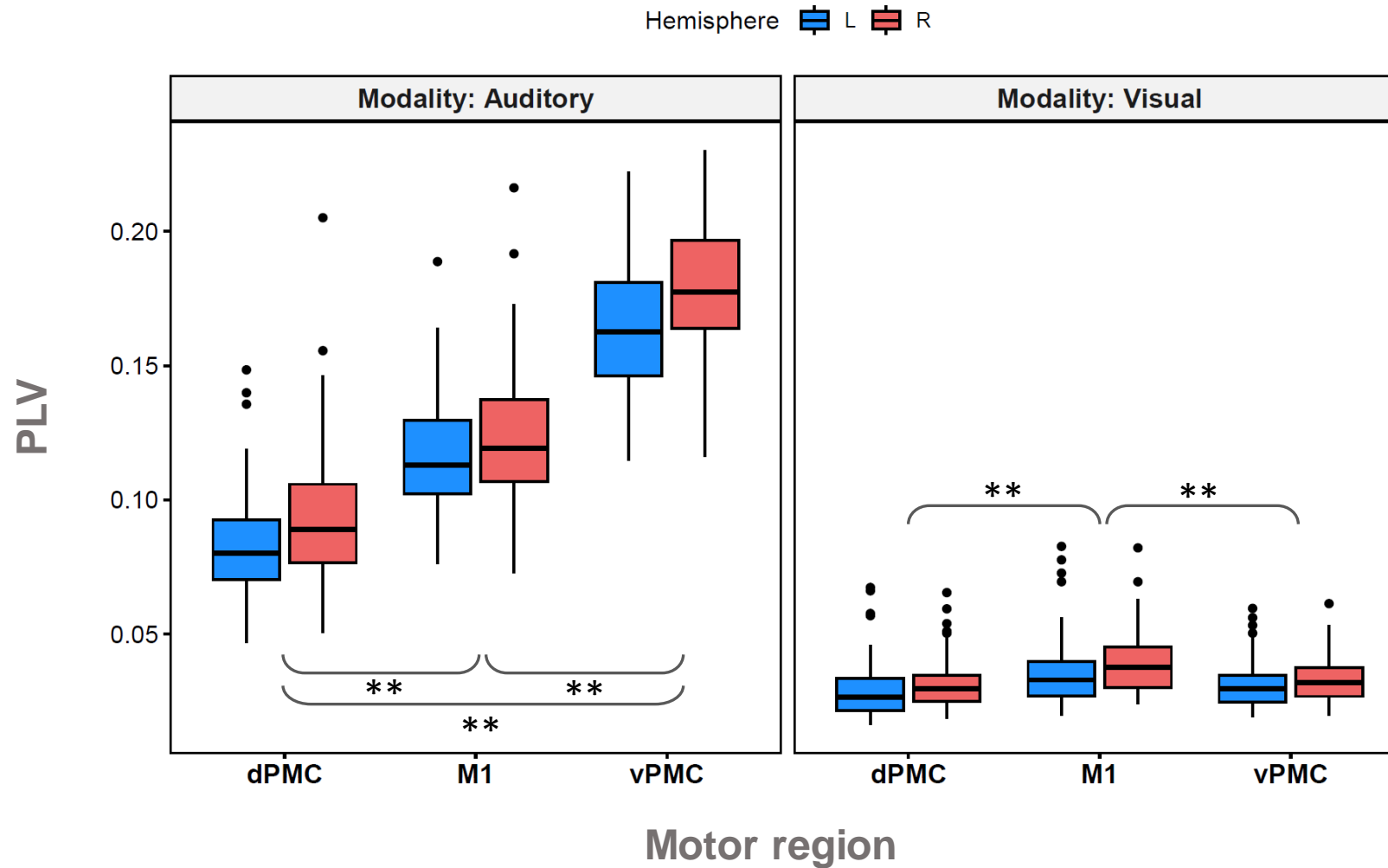
Interaction between 'Modality' and 'Motor region': Tighter phase coupling for auditory-motor connections, and different coupling strengths for all three motor targets only in the auditory modality. *Main effect of 'Hemisphere'*: Tighter phase coupling in right hemisphere across both modalities.

Figure 3. PLV differences across modalities in GLMM 2 (n=90)
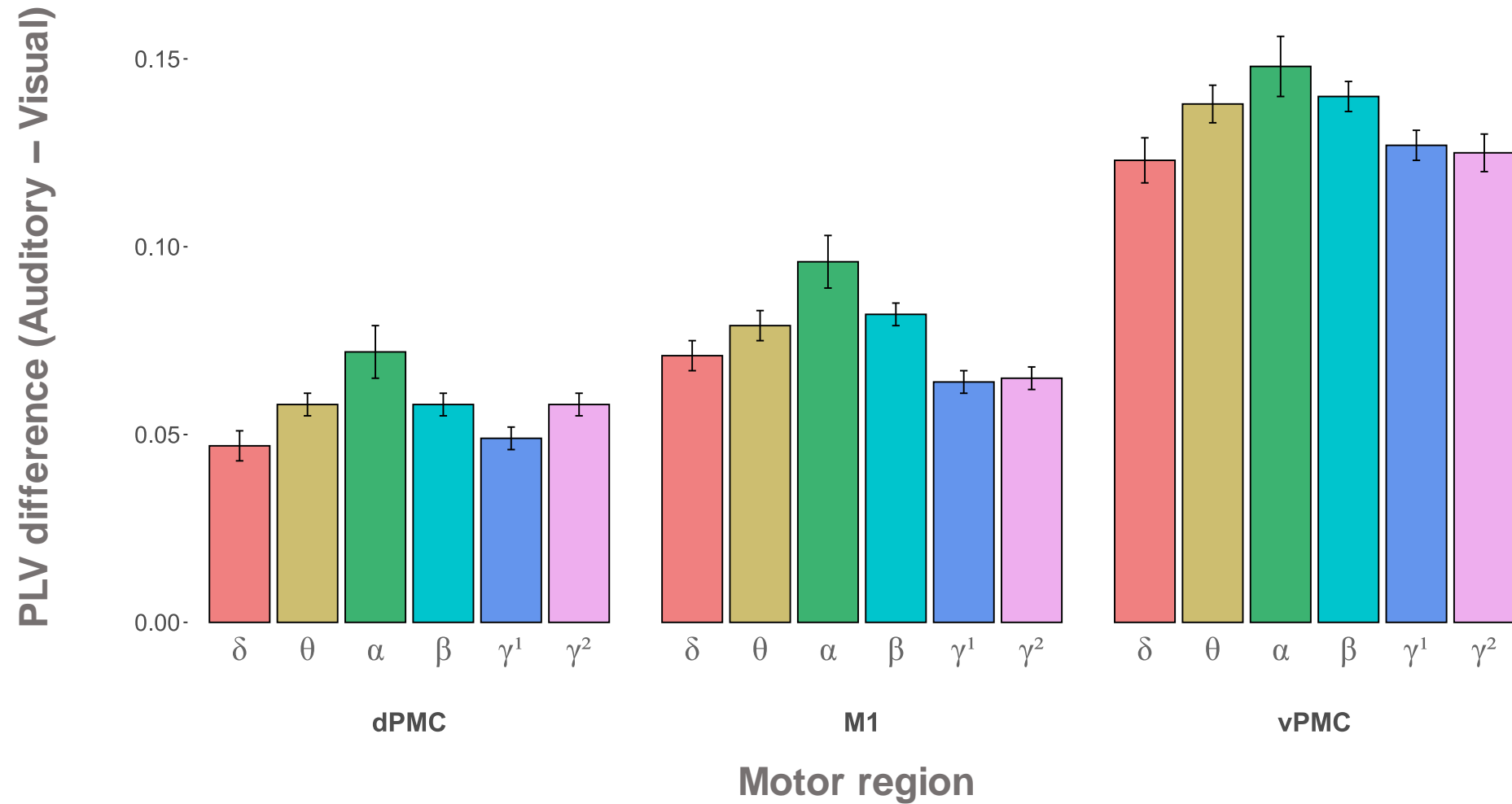
Interaction between 'Frequency band' and 'Motor region': All differences are positive, indicating larger PLVs in the auditory modality. Among these, the alpha, beta and theta frequency bands exhibit the largest PLV magnitude differences across all three motor targets.

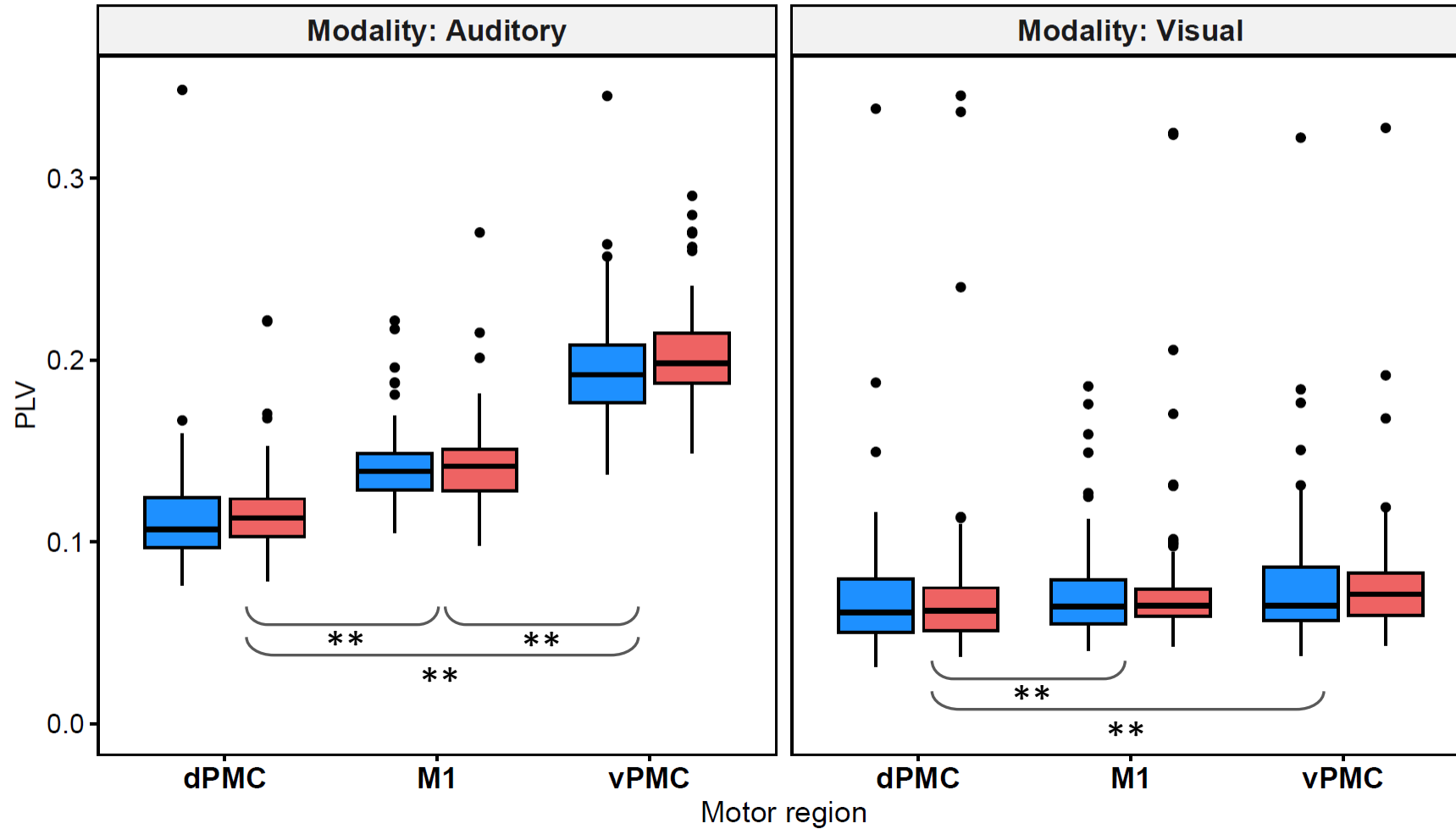**Figure 4.** Predominant auditory-motor PTE values across the frequency spectrum in GLMM 3 (n=90)
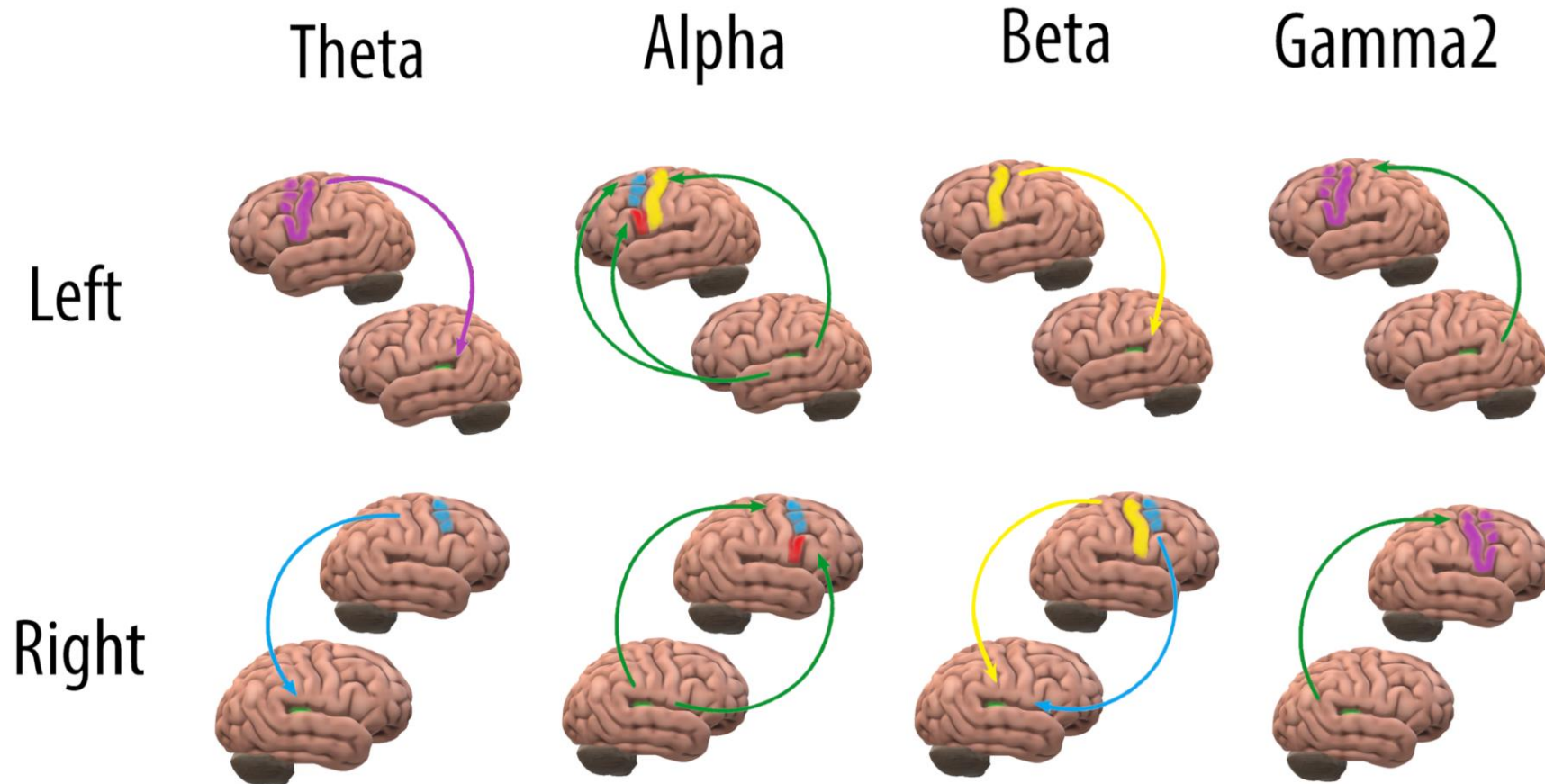
Interaction between 'Direction' and 'Motor region': In the right theta frequency band, the direction of phase information is strongest from dPMC to A1. In the left alpha frequency band, the direction of information is strongest from A1 to all three motor nodes, and in the right alpha frequency band it is strongest from A1 to dPMC and vPMC. In the left beta frequency band, the direction of information is strongest from M1 to A1, and in the right beta frequency band it is strongest from M1 and dPMC to A1.

Main effect of 'Direction': In the left theta frequency band, the direction of phase information is strongest from the average activity across motor regions to A1. In bilateral gamma2, the direction of pase information is strongest from A1 to the average activity across motor regions.

Supplementary Figure 1. PLV results obtained in GLMM 1 (n=90) in the delta frequency band
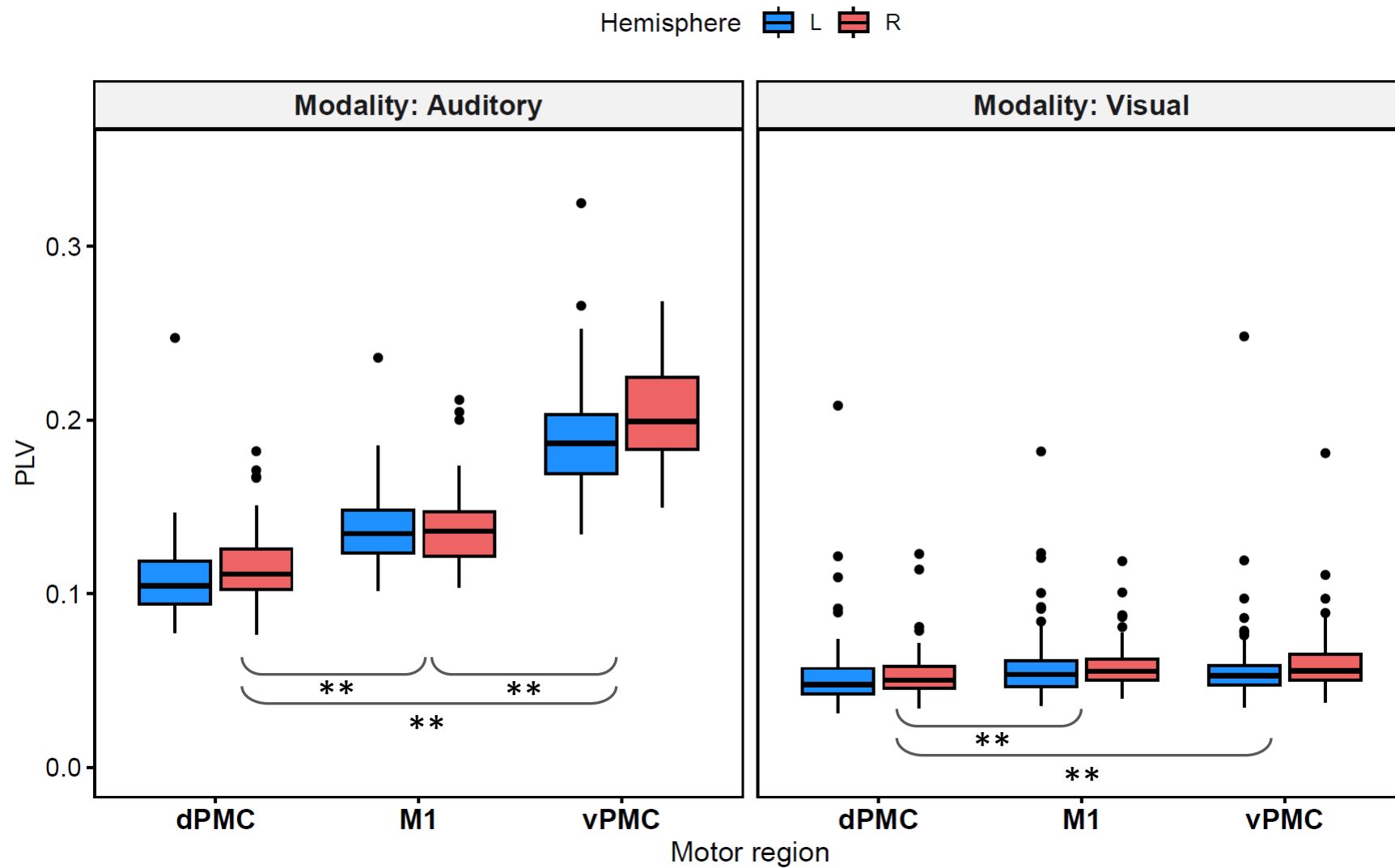
Supplementary Figure 2. PLV results obtained in GLMM 1 (n=90) in the theta frequency band

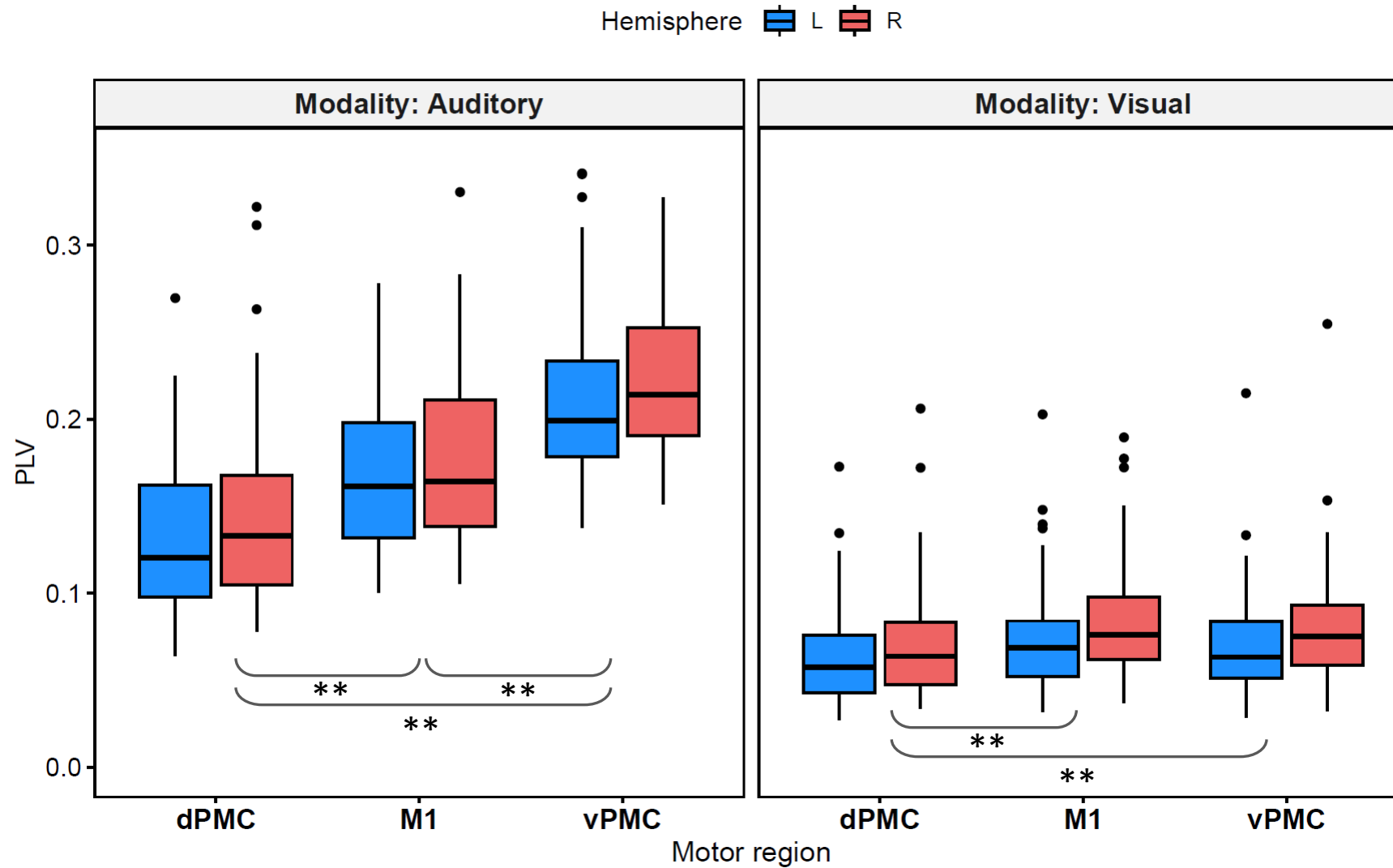**Supplementary Figure 3.** PLV results obtained in GLMM 1 (n=90) in the alpha frequency band

Supplementary Figure 4. PLV results obtained in GLMM 1 (n=90) in the beta frequency band

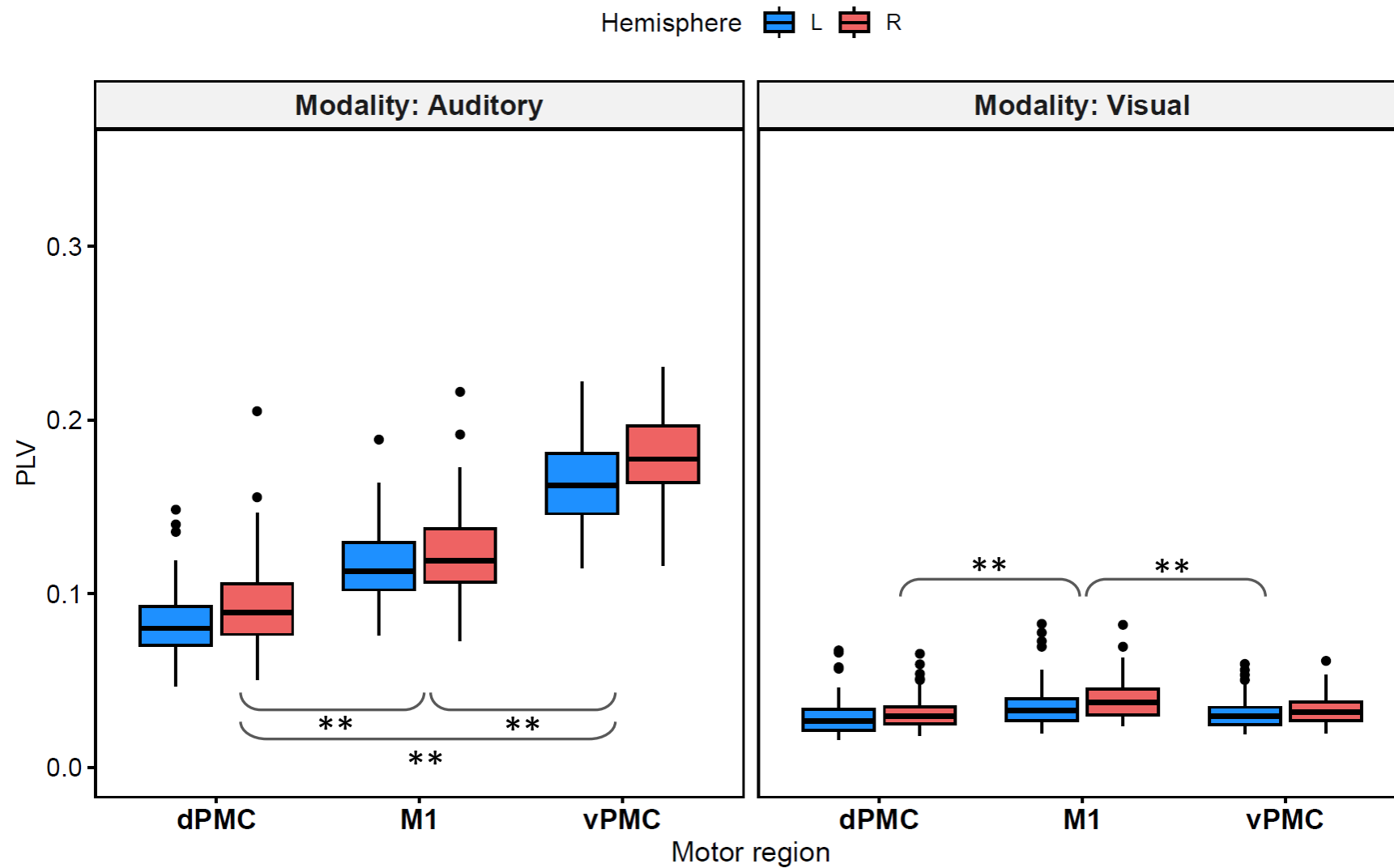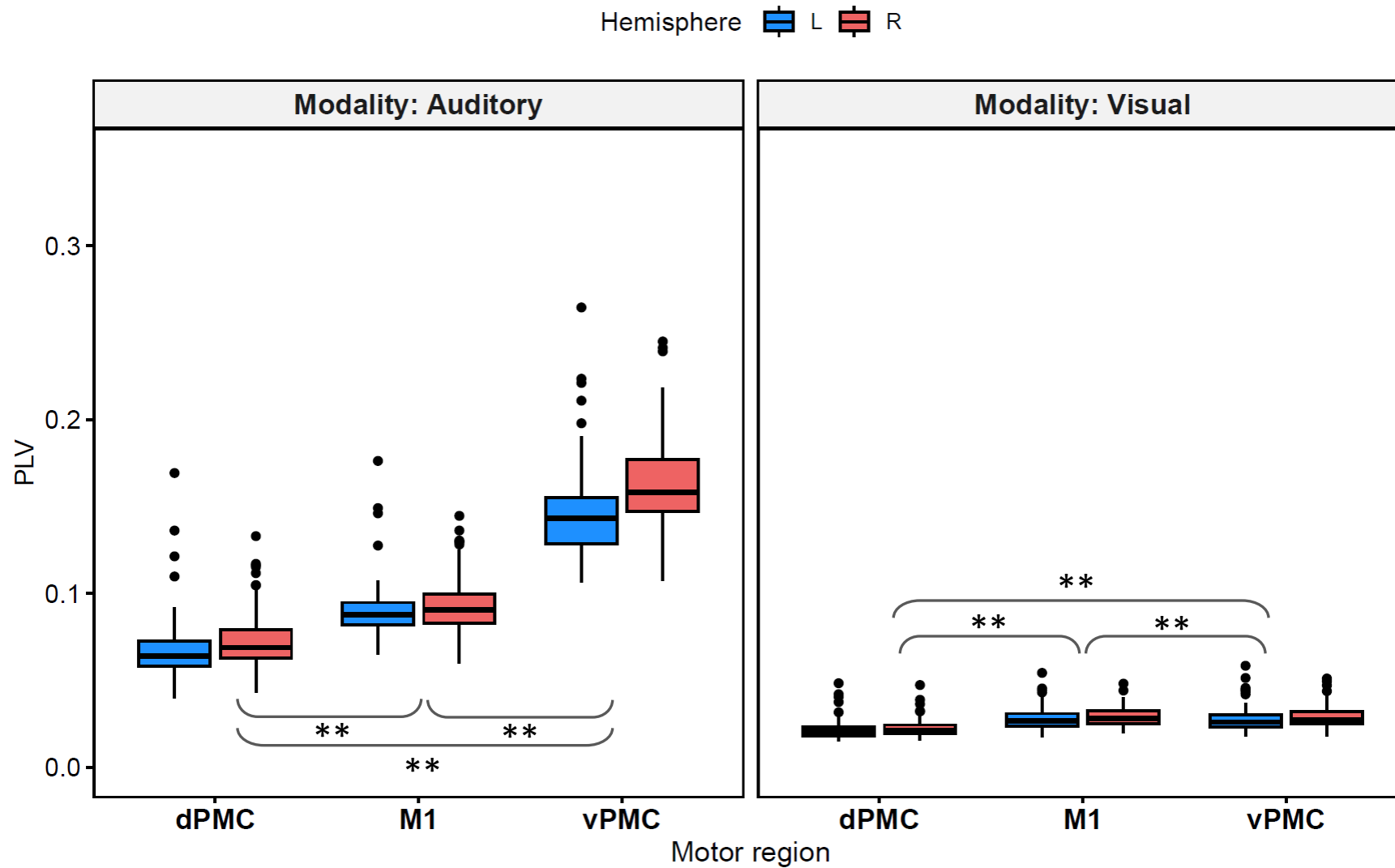Beta: Boxplot of 'Hemisphere' by 'Modality' by 'Motor region' (Re−scaled)

Supplementary Figure 5. PLV results obtained in GLMM 1 (n=90) in the gamma1 frequency band

Supplementary Figure 6. PLV results obtained in GLMM 1 (n=90) in the gamma2 frequency band