**Introduction:** When individual subjects are imaged with multiple modalities, biological information is present not only within each modality, but also between modalities – that is, in how modalities covary at the voxel level. Previous studies have shown that local covariance structures between modalities, or intermodal coupling (IMCo), can be summarized for two modalities, and that two-modality IMCo reveals otherwise undiscovered patterns in neurodevelopment and certain diseases. However, previous IMCo methods are based on the slopes of local weighted linear regression lines, which are inherently asymmetric and limited to the two-modality setting. We present a generalization of IMCo estimation which uses local covariance decompositions to define a symmetric, voxel-wise coupling coefficient that is valid for two or more modalities.

**Methods:** We included 803 subjects ages 8 through 22 from the Philadelphia Neurodevelopment Cohort who completed T1-weighted MR, arterial spin labeling MRI, and resting-state fMRI.

For each subject, we estimated voxel-wise IMCo between three images – cerebral blood flow, amplitude of low frequency fluctuation, and regional homogeneity. First, we applied a gray matter mask and normalized each image to a standard normal. Then, for each voxel, we extracted a local neighborhood from each modality, estimated a weighted covariance matrix, and used principal component analysis (PCA) to calculate the proportion of variance explained by the first eigenvalue. Then, we scaled these proportional first eigenvalues to range from 0 to 1 and performed a logit transformation to obtain the final PCA-based IMCo (pIMCo) coupling value. This pIMCo value represents the strength of the intermodal relationship at each voxel. An R package for estimating pIMCo is available at: <https://github.com/hufengling/pIMCo>.

We conducted voxel-wise analyses across subject-level pIMCo images to explore coupling associations with age and sex. Multiple comparisons were corrected for using false discovery rate (Q < 0.05). Additionally, enrichment of age and sex effects were studied across cortical networks using a permutation-inspired test.

**Results:** We demonstrate that coupling is spatially heterogeneous in cortical networks and subcortical structures. Associations between age and coupling were enriched in the frontoparietal (p = 0.0125) and default (p = 0.039) cortical networks and were highly prevalent throughout subcortical structures. Associations between sex and coupling were enriched in the frontoparietal network (p = 0.0115) and most prevalent in the hippocampus and thalamus.

**Conclusion:** pIMCo offers a novel method for studying voxel-level covariance structures between more than two modalities and a symmetric generalization of previous local IMCo approaches for two modalities. We use pIMCo to uncover that coupling between cerebral blood flow, resting state fluctuations, and local connectivity changes with age and sex in cortical networks known to evolve throughout neurodevelopment. These findings reveal patterns that are not present in individual modalities. As availability of multi-modal data continues to increase, pIMCo offers a powerful approach for summarizing relationships between multiple aspects of brain structure and function.