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High-resolution spatiotemporal imaging of cortical phase-locking values using combin and fMRI

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Introduction

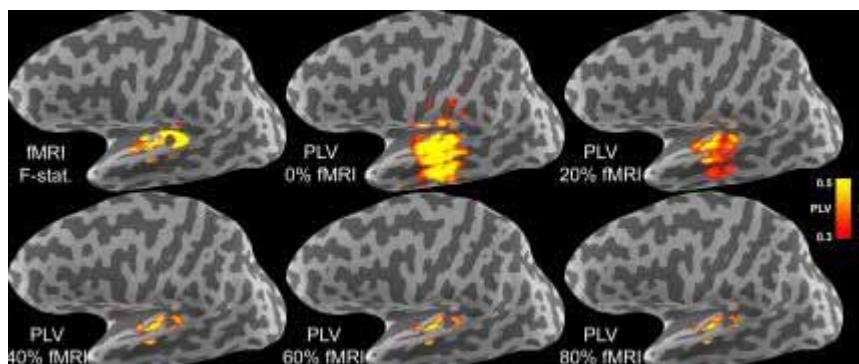
The high temporal resolution in MEG allows the characterization of cortical oscillatory activity using Phase-Locking Value (PLV) and associated statistics [1, 2]. Using minimum-norm estimation (MNE) algorithm, PLV can be estimated on the cortical surfaces. However, it renders spatially blurred results due to the L2-norm constraint [2]. Using fMRI as spatial priors, the spatial resolution can be improved [3]. In this study, we propose a modified MNE algorithm to combine fMRI and MEG to estimate cortical oscillatory activity with improved spatial resolution.

Method

The MNE of brain activity based on MEG and fMRI/MRI measurement was formulated as a point-by-time-point mapping of the MEG data $\mathbf{Y}(t)$ to cortical source estimates $\mathbf{X}(t)$ using an inverse operator \mathbf{W} , which was derived from the forward matrix \mathbf{A} , the source covariance matrix \mathbf{C} , and a regularization parameter λ : $\mathbf{X}(t) = \mathbf{W}\mathbf{Y}(t) = \mathbf{R}\mathbf{A}^T(\mathbf{A}\mathbf{R}\mathbf{A}^T + \lambda\mathbf{C})^{-1}\mathbf{Y}(t)$. In the PLV calculation, we first computed inverse estimates for the wavelet-filtered sensor data to obtain the band-filtered phase at each source location. Second, the phase difference with respect to the reference signal was accumulated with spatially varying radius depending on fMRI priors. We defined p as the value in the diagonal entries of \mathbf{R} at locations with fMRI prior, and $1-p$ at locations without fMRI prior. The fMRI weighting was varied parametrically from $p=0.5$ (corresponding to $2p-1 = 0\%$ fMRI weighting) to $p=1.0$ (100% fMRI weighting). MEG was measured with a 306-channel whole head system (Elekta Neuromag Ltd., Helsinki, Finland). Anatomical and functional MRI were acquired on a 3T scanner (Trio, Siemens Medical Solutions Erlangen, Germany). In MEG, the auditory stimuli were delivered from a PC by Earstone EF transducers (Etymotic, Elk Grove, IL, USA). Stimuli consisted of 90 repetitions of 1-second clicks. In fMRI, we employed a sparse imaging paradigm, where auditory clicks were presented during the 7 seconds silent period between consecutive EPI acquisitions. fMRI priors were calculated using the general linear model [4].

Results

The figure below shows the 40-Hz fMRI-weighted PLV on an inflated representation of the subject's cortical surface. The fMRI F-statistics map shows BOLD response at Heschl gyrus. Without fMRI weighting (0% fMRI), PLV suggested activation both in the Heschl gyrus and additionally, at the superior temporal gyrus (STG), medial temporal gyrus (MTG), superior sulcus (STC), and inferior part of central sulcus. With fMRI weighting, the PLV map was more focal, limited to STG and Heschl gyrus as would be expected.



Conclusion

An integrated fMRI/MEG algorithm to estimate cortical oscillatory activity was demonstrated and applied to human auditory data. This method has the potential of enhancing the spatial resolution of phase-locking analysis of oscillatory activity in cortical networks.

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References

1. Lachaux, J.P., et al., *Hum Brain Mapp*, 1999. 8(4): p. 194-208.
2. Lin, F.H., et al., *Neuroimage*, 2004. 23(2): p. 582-95.
3. Liu, A.K., et al., *Proc Natl Acad Sci U S A*, 1998. 95(15): p. 8945-50.
4. Friston, K.J., et al., *Neuroimage*, 1995. 2(1): p. 45-53.