Identifying Differences Between Expert and Novice Meditator Brain Scans via Multiview Embedding

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Poster Video Link

Summary: We used a scalable, generalized canonical correlation analysis (GCCA) to construct low dimensional representations (gradients) [1] of fMRI data of experienced and novice meditators (traits) in different meditative states (states) and found statistically significant differences. Comparisons of mean gradients between groups revealed regions of potential future interest.

Data: Was collected at *CRNL* and consists of fMRI measurement of 18715 cortical vertices in 29 experienced meditators (>10000 hours of practice) and 47 novice meditators (1 weekend of training). Each took part in three, ten-minute sessions (300 time steps): a resting state, open monitoring meditative state, and compassion meditative state. Data was processed using the standard *fmriprep* [2] pipeline.

Methods: GCCA [3] (Fig 1) learned gradients (Fig 2) and multiscale graph correlation [4], a generalized distance correlation method [5], tested for statistically significant differences [6] between 24 pairs of state-by-trait combinations and across all combinations of their top 3 gradients. The Bonferroni correction was applied to all p-values. Differences of state-by-trait gradient means gave linearly optimal separating projections to visualize [7].

Results: At a 0.05 alpha level, *Experts* and *Novices* were significantly different for all gradient combinations (p=0.0168) and the distance covariance matrix revealed intra-expert relations (Fig 3). *Meditating Experts* and *Resting Novices* were also different across each of the second and third gradients (p=0.0168). Differences of means separated traits well (Fig 4) and reveal extreme regions on the gradients (Fig 5), finer ROIs potentially indicative of the differences between traits.

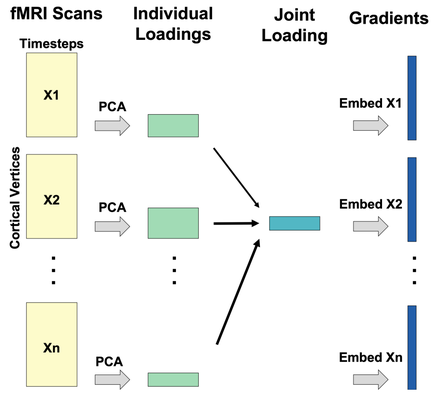


Fig 1: GCCA learns linear projections onto a joint subspace from individual PCA loadings. Each scan is projected to three gradients.

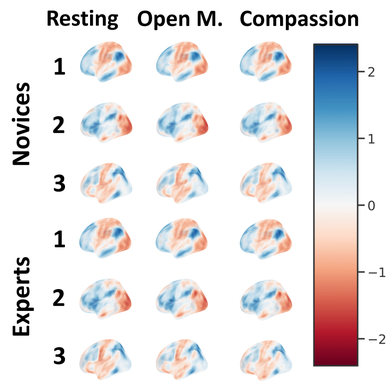


Fig 2: Mean state-by-trait gradients (1,2,3) from GCCA visualized on left hemisphere cortical vertices, lateral side.

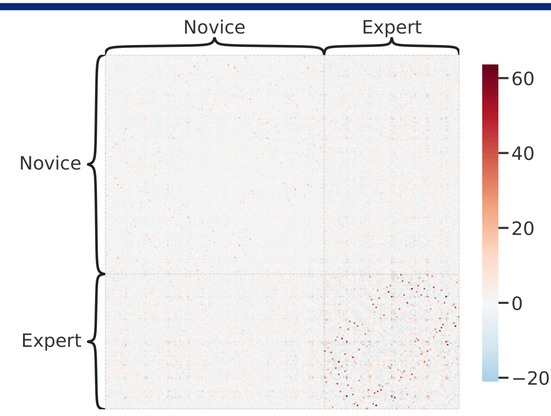


Fig 3: The distance covariance matrix (product of centered Euclidean distances between gradients and labels) reveals relatively strong intra-expert relations.

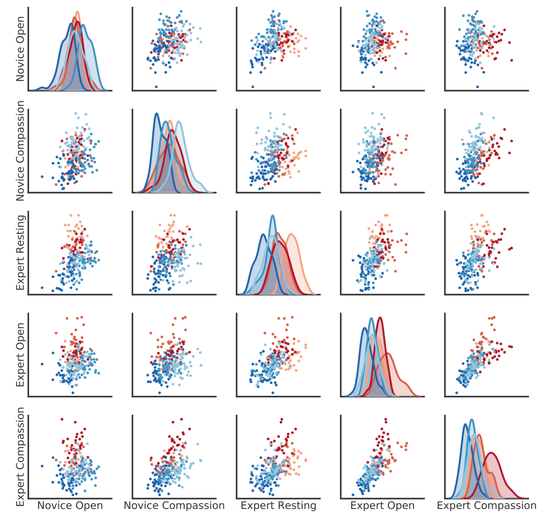
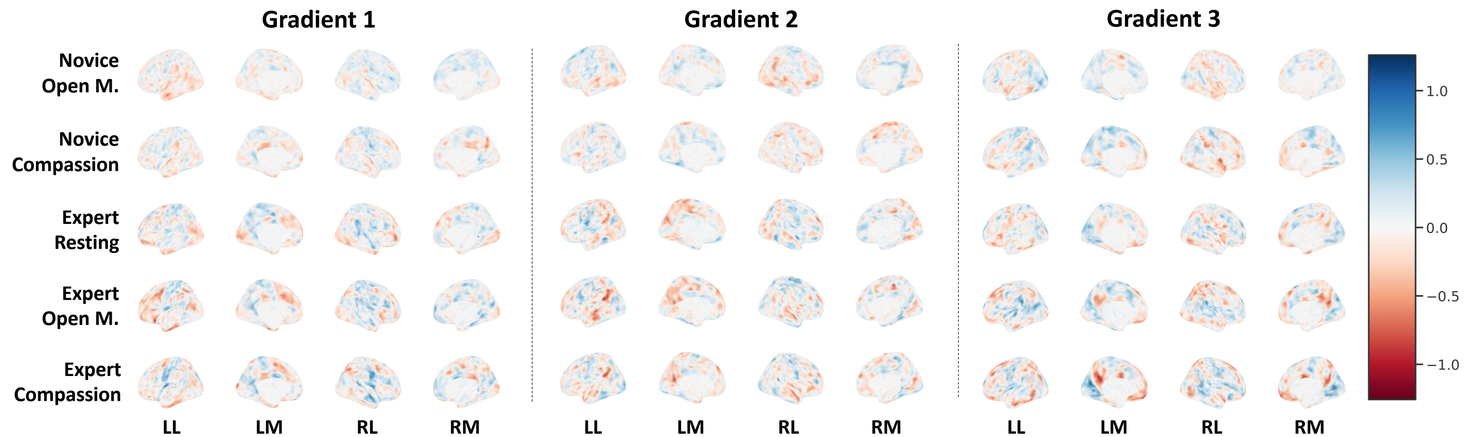


Fig 4: Concatenated gradients projected onto the differences of mean *Resting Novice* gradient with other state-by-trait means. Experts (red) separate well from novices (blue).

- Expert Resting
- Expert Open
- Expert Compassion
- Novice Resting
- Novice Open
- Novice Compassion

Fig 5: In each gradient (column), the *Resting Novice* mean was subtracted from other state-by-trait means and the result was normalized by the pooled sample variance (rows). Resulting vectors are visualized on their respective cortical vertices from left lateral (LL), left medial (LM), right lateral (RL), and right medial (RM) perspectives. Certain regions show extreme values across expert states in some gradients (See the left lateral view in the second gradient and the left medial view in the third gradient).



References:

[1] Margulies et al. PNAS, 2016.
[2] Esteban et al. Nat Meth, 2018.
[3] Perry et al. arxiv, 2020.
[4] Shen et al. JASA, 2020.
[5] Szekely et al. Ann. Statist., 2007.
[6] Shen et al. arxiv, 2018.
[7] Vogelstein et al. arxiv 2018.

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