INTRODUCTION

As fMRI researchers increasingly tackle naturalistic, complex experimental paradigms, response reliability is often used in place of response amplitudes as a metric of each voxel’s responsiveness to a stimulus. A voxel’s response from one run is used as a model for the same voxel’s response in the other runs, a process that is repeated for each possible pairing of runs. Voxels with “reliable” responses are those that consistently show positive correlations across pairing (Hasson, 2004). This approach is especially useful in cases where the mapping from stimulus to response is not well characterized, such as the free viewing of a naturalistic movie. But the relatively unconstrained nature of these paradigms translates to a few contrast-to-noise ratios, so response reliability measures have much to gain from denoising techniques. To this end, we apply multi-echo independent component analysis (MEICA), a recently developed technique that has shown great promise in resting-state and task-based analyses (Hasson, 2012; Kuhl, 2013), to derive data from the free viewing of a naturalistic movie.

METHODS

Data Collection

GE 3T MR scanner; 110(40), 16187-16192.

RESULTS

Response Reliability is Greater with MEICA

Figure 1: Demonstration (with simulated data) of the intra-subject correlation (ISC) analysis used to assess response reliability in this study. The subject views the same video on N different runs (N=3 above). For each voxel, the time-course on each run is correlated with its time-course on each other run to get a correlation coefficient. The ISC is defined as the median of these correlation coefficients across all pairs of runs, a process that is repeated for each possible pairing of runs. Voxels with “reliable” responses are those that consistently show positive correlations across pairing (Hasson, 2004). This approach is especially useful in cases where the mapping from stimulus to response is not well characterized, such as the free viewing of a naturalistic movie. But the relatively unconstrained nature of these paradigms translates to a few contrast-to-noise ratios, so response reliability measures have much to gain from denoising techniques. To this end, we apply multi-echo independent component analysis (MEICA), a recently developed technique that has shown great promise in resting-state and task-based analyses (Hasson, 2012; Kuhl, 2013), to derive data from the free viewing of a naturalistic movie.

Figure 2: Preprocessing methodology. The Optimally Calibrated “OptiCore” time series is a weighted average of the three echos. The denoising process included removing a spatial ICA on the optimally combined time series, removing components that were deemed unlikely to be BOLD-weighted, and concatenating the remaining components into a denoised data set. This “MEICA” data was then corrected for time-of-flight and motion compensation, registration, and then finally applied to all three echos.

Figure 3: Average correlation coefficient across ISC analysis conducted on the Subject 1 video (top) and Subject 2 video (bottom), using Echo2 (left) or MEICA denoised (right) timeseries as input. (b) Reverse cumulative histogram of voxel-by-voxel Z scores across the whole brain for Subject 1 and Subject 2, with significantly more voxels above the threshold for MEICA than Echo2 preprocessing.

Figure 4: Percentage of voxels in each tissue type found to have significantly reliable activations (p<0.05) across all runs, using each preprocessing method. (a) (b) (c) (d) are based on AFNI’s 3D imaging segmentation into EPI space and thresholded at Z>3, P<0.01, and FDR<0.05.

Figure 5: Bar graphs showing newly reliable voxels in left fusiform gyrus (LFG) responding to the chimp video. These voxels are significantly more active in MEICA than Echo2 preprocessing.

Figure 6: (a) Echo2 data were spatially filtered with a 6mm Gaussian and used for the “Blurring” control analysis. In this condition, the voxel-by-voxel correlation coefficient between the two runs was used to identify the voxels with a significant correlation (p<0.05), and the results were corrected for multiple comparisons. (b) CompRem produces much less response reliability than MEICA. Blurring’s newly significant voxels are not as specific to GM.

Figure 7: A ‘time-lag’ spherical ROI whose response was significantly reliable with MEICA but not Echo2 preprocessing for Subject 1 was extracted for k-Space to the stimulus using the “reverse correlation” technique (Hasson, 2004). The time-lag command time across sessions) time-of-activity in the ROI is displayed in the main plot. The three times evoke the greatest activity in this area were mapped back onto the video frames that were most likely to have coincided with them (assuming an HRF delay of 5 s). These video frames are shown above the main plot, with the ROI’s connectivity and time associations from the NeuroSynth database.

CONCLUSIONS

The addition of Multi-Echo ICA denoising to intra-subject correlation analysis in a naturalistic paradigm results in a much greater spatial extent of reliable activation. This suggests that many areas of the brain are involved in processing naturalistic stimuli but are too obscured by noise to appear in standard ICA analysis. This result serves as a naturalistic-stimulus extension of recent findings that the low CNR of task-based fMRI studies generates numerous false negatives (Gonzalez-Castillo, 2012). These new observations may inspire new, more targeted studies using reverse correlation analysis (Hasson, 2004), which may generate testable hypotheses about the roles of these regions in the processing of dynamic visual stimuli.

REFERENCES


Supported by the NIMH Intramural Research Program

Contact: david.jangraw@nih.gov || http://fim.nimh.nih.gov