**Spatial Integration**

Eight subjects participated in a 3-Part visual oddball task recorded using a high-density EEG array (Compumedics Neuroscan Synamp™ 2 amplifier, 64 electrodes, 1kHz sampling). Subjects sat comfortably in a sound attenuating chamber, and performed 4 runs in which they were asked to identify a target stimulus (oddball/target) under conditions where there either was or was not a distractor stimulus. EEG data were band-pass filtered (0.1-100Hz), artifact reduced (UP2 filter, averaged -100 to -200 microV), and averaged according to stimulus type (standard, oddball, and distractor). These data were submitted to two analyses: one (Figure 1) in which CSD maps of task-related EEG activity were calculated and a second in which network dynamics based on continuous data were analyzed (Figure 2).

**FIGURE 1** Each EEG sensor (electrode) is located relative to the brain atlas. Sensor fields are projected to the underlying cortical region. Each sensor field projects to a 6 mm × 6 mm × 6 mm region of cortex. At far left, SWARM current source density localization techniques was used to overcome the coarse spherical splines (see Perrin et al., 1987). Data was resampled to 250 Hz and then band-pass filtered, around 6 common bands: θ (2.4 – 3.4 Hz), δ (1.4 – 6.5 Hz), low α (4 – 8 Hz), high α (9.5 – 10.5 Hz), β (19.5 – 22.5 Hz), and γ (37 – 41 Hz). The Hilbert transform of the data was taken, with signal magnitude and phase extracted prior to division of the data into epochs based on task type (standard, oddball, and distractor). Taking the Hilbert transform before dividing the data into epochs helps to avoid edge effects produced by the transform. For each stimulus type, epochs containing very-high-amplitude fluctuations or residual blink artifact were discarded. 10 regions of interest were identified for power waveform analysis based on both fMRI and EEG studies of oddball task activation, including DLPFC, FEF, M1/PMA, MT+ ,TPJ, and lateral visual association cortices. For each ROI, the summed squared voltage for each time t and frequency band b, \( S_{nb}(t) = \sum_{n} s_{n}(t) \), was normalized for each subject and region of interest to the value \( \frac{S_{nb}(t)}{\text{max}(S_{nb})} \) where \( N_{s} \) is the number of subjects included in the comparison. \( N_{s} \) = 6 for standard stimuli, \( N_{d} \) = 5 for oddball stimuli, and \( N_{d} \) = 3 for distractor stimuli. The mean normalized magnitude of the Hilbert transform is plotted for each bandwidth. This waveform represents an envelope of the filtered data, and can be an interpretation of power density (Doeburg et al. 2006). For synchrony analysis, a seed region was chosen on the scalp at the right TPJ, near EEG electrode C3.

Using the epoched phase values for the different bandwidths, a phase-locking value (PLV) (Lachaux et al. 1999) was calculated between the phase at this frequency band and a second frequency band for each subject. A phase-locking value (PLV) is defined as the correlation coefficient between the phase at one frequency band and the phase at another frequency band. The PLV is calculated as:

\[
\text{PLV}(f_1, f_2) = \frac{1}{N_{s} N_{t}} \sum_{n=1}^{N_{s}} \sum_{t=1}^{N_{t}} \left( \cos(\phi(n,t,f_1) - \phi(n,t,f_2)) \right)
\]

where \( \phi(n,t,f) \) is the phase of the signal at time \( t \) and frequency \( f \) for subject \( n \). The PLV ranges between 0 (no synchrony) and 1 (perfect synchrony), and was plotted as a topographic map for the theta, alpha, beta, and gamma bands at the exact time of the peak P300 waveform for each subject.

**FIGURE 2** Relative amplitudes of the envelopes of band-limited data following standard (left, 6 subjects), oddball (center, 5 subjects), and distractor (right, 3 subjects) stimuli. Stimulus presentation is noted at time = 0. Plots note the multi-frequency fluctuations in all bands throughout the recording epoch.

**CONCLUSIONS**

Both EEG and fMRI have enhanced our understanding of the brain networks involved in the complex behaviors associated with oddball (change detection) tasks. To date, however, a functional integration of the information available from these two important techniques has not been fully accomplished. The development of fMRI based on the correlation structure of the BOLD time series, has indicated that persistent functional linkages exist between network elements of such important and commonly accessed systems as the attention system (dorsal and ventral, Corbetta et al., 2001). Based in part on these data, and firmly based in the literature -3 -2 1. Van Essen DC, et al. (2001)

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