Variability in Distribution of fMRI BOLD Response Linked to Prestimulus Alpha Power in Simultaneously-Acquired EEG

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Purpose

Nearly all cognitive processing is affected by attention. Even for identical sensory stimuli, the blood-oxygen-level-dependent (BOLD) response varies depending on the subject's internal brain state prior to each stimulus, and this state is unobservable using traditional fMRI analysis methods. EEG power in the alpha band (8-12 Hz) is commonly associated with endogenous attention, with high power known to correlate with decreased task-engagement. While a few studies have explored the correlates of the EEG alpha rhythm and the visually-evoked fMRI response[1,2], the role of prestimulus alpha oscillations on auditory perception has not been explored. Here we investigate the effects of endogenous attention on the evoked BOLD response to auditory stimuli, and hypothesize that the distribution of recruited brain regions depends on the prestimulus brain state. We use prestimulus EEG alpha to represent the subjects' task-engagement on each trial, and contrast the BOLD response for the high and low attention conditions.

Methods

Fifteen subjects participated in a standard auditory oddball paradigm, with eyes closed and responding only to targets, during which we acquired data using our custom-built 43-channel EEG system[3] in a 3T scanner. We performed gradient artifact removal, standard EEG preprocessing, and then independent components analysis to extract the projections of the EEG sensor data containing most of the alpha power. For each resulting component time series, we determined the ratio of alpha power to power in adjacent frequency bands, and we selected the top five as the "alpha components." We computed the Hilbert transform of each of the alpha-band-passed components and took the mean magnitude to obtain a single envelope of alpha activity across the run of the experiment. For each trial we computed the mean alpha power in the half second prior to stimulus onset, and within each of the two stimulus classes we grouped trials according to high, medium, or low prestimulus alpha power.

We performed bias field correction on all fMRI images to adjust for artifacts caused by the EEG wires, and performed slice timing correction, motion correction, and standard filtering on the 3x3x4 mm functional data. We constructed six regressors for our general linear model: high, medium, and low alpha targets, and high, medium, and low alpha standards. Each regressor was comprised of boxcars of unit amplitude, with onset and offset matching that of the stimuli, and all were convolved with the canonical hemodynamic response function. For each stimulus class, we computed a high vs. low alpha contrast, and we thresholded group-level statistical images at p=0.05 (multiple-comparison corrected).

Results

The mean event-related BOLD response to target stimuli was consistent with previous findings[4], showing the largest activations in thalamus, auditory cortex, insular cortex, and supplementary and primary motor areas. For these target stimuli, our high vs. low alpha contrasts revealed significant negative correlations bilaterally in precuneus, lateral occipital cortex (LOC), fusiform cortex, posterior cingulate, and lingual gyrus (Figure 1). The largest of these clusters (3755 voxels) spread across precuneus into LOC, and had max z score 3.78 at MNI coordinates (-6, -66, 62).

We detected no significant differences in brain regions that are of primary importance for auditory stimulus processing, but our contrast revealed multiple activations in areas that play only a supplementary role. These regions are likely responsible for enhancing perception by providing more detail about the incoming sensory information. The precuneus and posterior cingulate together are crucial for conscious information processing[5], and their recruitment during periods of high task-engagement may represent a heightened self-awareness of target identification and behavioral performance. Our results imply that during periods of low attention, only brain regions necessary for basic processing of the stimuli are engaged.

Conclusion

We have shown that the specific brain regions involved in auditory target stimulus processing depend on the alpha power prior to stimulus onset, which represents the subject's internal attentional state. When task-engagement wanes, recruitment of brain areas becomes limited, involving only the minimum areas required for the task.

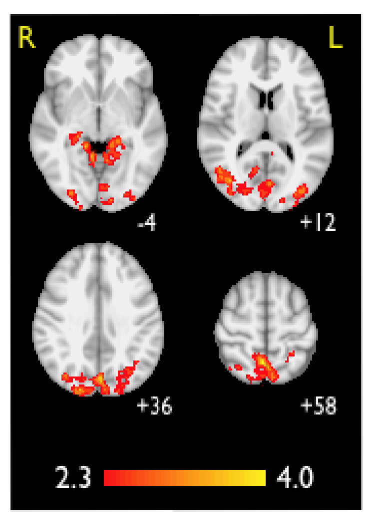

Figure 1: Brain regions that are significantly more activated by auditory target stimuli when the subject is in a high attentional state (low alpha power) compared to a low attentional state (high alpha power) prior to stimulus onset. Group-level z-score maps are shown overlaid on the average structural image. Slice is specified in MNI coordinates beside each image.

References
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