Multimodal Face and Object-related Signals Using Simultaneous fNIRS and EEG

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Introduction

Background: The human face constitutes a salient stimulus as it generates consistent neural effects. Functional neuroimaging studies have documented effects in the fusiform gyrus and other higher order visual areas in response to faces[1] and electroencephalography (EEG) studies have shown face-specific effects in the form of the N170, a negative amplitude response generated approximately 170 milliseconds after the presentation of the face[2]. Simultaneous acquisitions of early neural responses and later localized hemodynamic signals could provide a comprehensive account of face processing and serve as the basis for future directions relating the two data domains.

Aim: Here we present data from an experiment examining neural responses to faces to validate the multimodal approach of simultaneous EEG and functional near-infrared spectroscopy (fNIRS). We test the hypothesis that the location of the source generating the N170 event-related response to faces corresponds spatially to areas of increased hemodynamic activity.

Methods

Subjects: Fifteen adults (29.4 +/- 7 years old, 10 females, 93.3% right-handed[3] participated in the study. All subjects had shown detectable fNIRS signals in the contralateral motor cortex in a previous finger-thumb tapping localizer study.

Task: Face (F) and object (O) pictures were presented in a blocked oddball design, consisting of 7 non-oddball and 2 oddball stimuli per block (Figure 1). Two runs were presented for a total of 12 blocks.

Figure 1. An example diagram of one run of the concurrent fNIRS/EEG experiment. One run consisted of 6 blocks. Each block contained two stimuli which were a different category from the rest. F = Faces; O = Objects.

EEG Acquisition: EEG recordings were obtained at 256 Hz using a g.Tec bioamplifier from 32 electrodes according to a standard 10-10 layout.

fNIRS Acquisition: Recordings were obtained at 27 Hz using a Shimadzu LABNIRS system. Forty emitter and detectors pairs were placed on the head comprising a 134-channel layout. A Patriot Polhemus digitizer was used to record the position of EEG electrodes and fNIRS optodes for each subject.

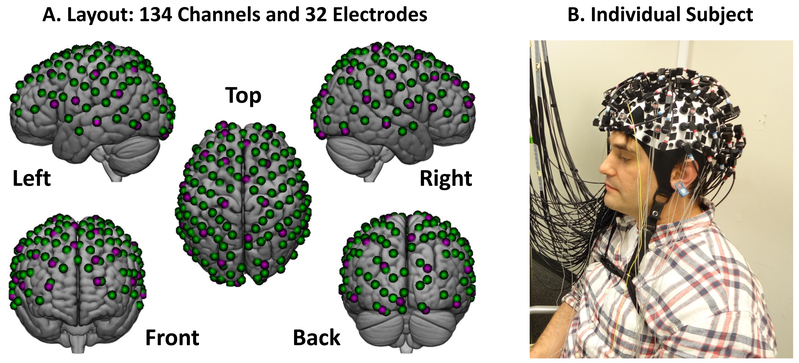

Figure 2A. Channel layout for one representative subject. Green dots represent 134 fNIRS channels; purple dots represent 32 EEG electrodes. **B.** Picture of one subject.

EEG Results

ERP analysis: EEG data were preprocessed using EEGLAB and SPM8. Data were high-pass filtered (1 Hz) and channels showing high frequency artifacts and noise were removed and interpolated. Data were epoched from -100 to 500 ms relative to stimulus onset and averaged.

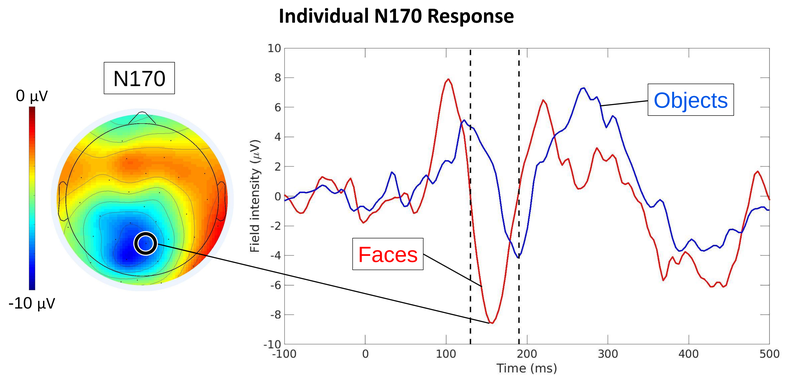

Figure 3. Single subject topographic plot during N170 peak and event-triggered average trace in one electrode, Pz (circled). Black dashed lines indicate time range used for source localization for this subject. Red line = faces, Blue line = objects.

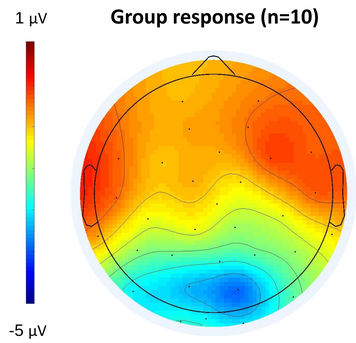

Figure 4. Topographic plot for face trials from average of ten selected subjects during the peak N170 response shows negative activity in the parieto-occipital electrodes.

EEG Subject Selection: The averaged ERP response was manually inspected based on the criteria of N170 response showing negative deflection with duration from 100 to 200 ms for face trials in the parieto-occipital electrodes. Ten subjects met this criteria and were further included in EEG source localization analysis. The topographic maps of the selected subjects at individual N170 peak response time were averaged to determine group-response N170 topographic map. The topographic map suggests the bilateral cortical sources in the inferior parietal area that correspond to face-dependent N170 response.

EEG Source Localization: The ten selected subjects who showed the expected N170 response for face trials were included in the analysis. For each subject, the time range of the N170 peak for faces was identified. A mesh model was generated using an MNI template, assuming 8,196 current sources in the cortical layer. A boundary element method was used to generate the forward model. The Multiple Sparse Priors algorithm implemented in SPM8 was used in the inversion to identify the time course and spatial localization of the sources of the ERP response, generating an image for each subject for faces and for objects. Group-level analysis was performed with one-tailed t-tests on the images generated by the difference between the face and object responses.

Spatial Localization Results

fNIRS analysis: Raw deOxyHb signals were converted to concentrations, and wavelet detrending was applied to these values prior to hemodynamic modeling using the general linear model (GLM). A Gaussian spatial filter[4] was applied to remove global artifact, and face and object events were convolved with the hemodynamic response function and modeled to fit the data. Group-level data were generated with one-tailed t-tests in SPM8.

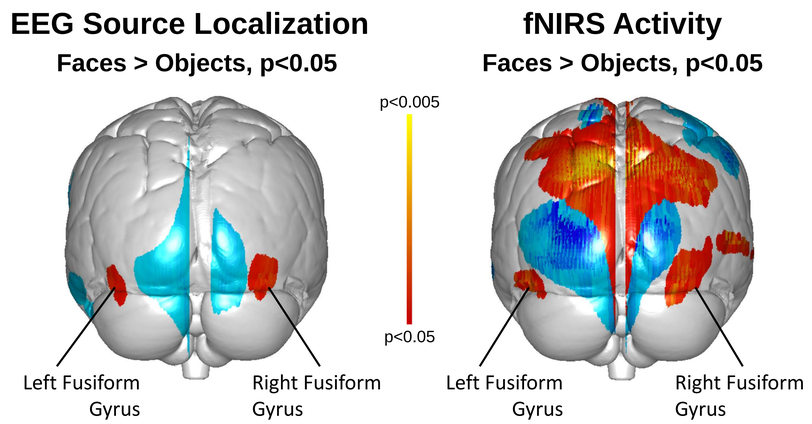

Figure 5. Posterior view of localized EEG source (left) and fNIRS deoxyhemoglobin activity (right) with contrast Faces > Objects, rendered at p<0.05. Red shows areas of positive activity, blue shows negative activity.

Results and Discussion:

- The Faces > Objects contrast showed activity in bilateral fusiform gyrus, consistent with prior fMRI studies of face processing. Source localization of the EEG N170 activity in the face versus object trials also showed positive activity in bilateral fusiform gyrus.
- Negative activity in primary visual cortex also corresponded for both EEG and fNIRS measures.
- The dorsal activity observed in the parietal lobe during task-related fNIRS activity is not observed with EEG source localization.

Conclusions

1. Functional NIRS can detect and differentiate between face-specific and object-specific hemodynamic signals in the outer portion of the fusiform gyrus.
2. Thirty-two electrodes can be used to localize the spatial source of the EEG signal underlying event-related responses to faces.
3. Simultaneous fNIRS/EEG data showed good spatial concordance between hemodynamic and electrophysiological signals in fusiform areas.
4. This validation of simultaneous EEG and fNIRS advances technical approaches to investigate unexplored relationships between early and specialized social processes.

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