Abstract
Invasive electrode recordings currently are the most important source of information regarding the brain's neural activity. Noninvasive methods would offer numerous advantages, including access to a larger fraction of the brain. Furthermore, recent results demonstrate that functional near infrared spectroscopic (fNIRS) imaging can probe cortical function with spatial resolution sufficient to localize neural activation to the correct cortical locus, with fewer mobility constraints than are commonly associated with, e.g., functional magnetic resonance imaging (fMRI). We are developing a closed-loop system for optimizing the utility of fNIRS measurement, alone or in conjunction with EEG measurements, as a method for studying brain function. The essential components include solid-state, programmable, dynamic phantoms for fNIRS or simultaneous fNIRS/EEG measurements, in human or primate subjects. This hardware component allows users to directly evaluate the accuracy, robustness, speed, and other performance characteristics of data analysis strategies applied to noninvasive neuroimaging data. The complementary software component includes a set of anatomical atlases for human and primate functional neuroimaging. These are 3D representations of the heads of standardized human and primate subjects that improve the accuracy and spatial resolution of recovered images by taking the details of the irregularly, irregularly shaped anatomy, into account, and their use mimics the effects of inter-subject variability. Presented results demonstrate the utility of the tool in assessing the temporal and spatial accuracy of information in recovered images, and for characterizing algorithms that are used in studies on the effective connectivity among mutually interacting cortical regions.

Introduction
- Among the many applications proposed for functional near infrared spectroscopic (fNIRS) imaging, neuroimaging currently is the focus of a large fraction of research and development efforts.
- Reasons for the interest in fNIRS imaging include that it has the spatial resolution needed to localize activation in the somatosensory cortex (1), and it is more mobile than other non-invasive methods [2].
- As described in an accompanying paper, fNIRS imaging also readily lends itself to the consideration of simultaneous dual-mode neuroimaging methods. Of particular interest is combining fNIRS and EEG.
- As is the case for any functional imaging application, in fNIRS or fNIRS-EEG it is necessary to develop methods to assess the accuracy of recovered spatial and temporal information.
- Functional properties do not necessarily have obvious anatomical counterparts.
- Consequently, there would be considerable value in a tool that would allow researchers or practitioners to conduct tests of functional imaging hypotheses with a priori knowledge of the "ground truth".

Methods
- Solid-State Dynamic Phantom (Fig. 1)
  - Anthropomorphic (or other biological forms (see Fig. 5A)), air-tight, and resistant to biological degradation
  - Matrix consists of silicon and silicone-based biopolymers
  - Electrochrome cells (ECC) mimicking wavelength-dependent hemodynamic responses
  - Electrode-mimic microvascular connectivity
  - Connectors for user interface and controlling electronics are built into the base of the phantom (see Fig. 28C).
- Sensing and Headgear
  - NAVI (Near-Infrared, Acquisition, Visualization and Imaging) (7).
  - Extensive data-editing functionality
  - Fiberna image formation (Fig. 3).
- Methods (cont.)
  - Experimental study of DCM model selection accuracy, based on analysis of fNIRS time series imaging data
  - Bilateral mathematical model of temporally evolving neuronal activity (4).
  - In conjunction with EEG measurements, as a method for studying brain function. The essential
  - A, B and C matrices in Eq. (1) specify the effective connectivity, i.e., the effects that activity in concurrent with EEG measurements, as a method for studying brain function. The essential
  - For each cortical region, the hemodynamic response to a given value x of neuronal activity is estimated by means of a non-linear hemodynamic model (3).

Results
- Five sets of fNIRS measurements were carried out, using EEG driving functions for each of the models in Fig. 8.
- Analysis performed with NAVI-SPM, using GLM methods from Level-1 SPM, that allows statistical parametric maps, such as those shown in Fig. 8.
- Spatial mean time series result was generated for each of the driving functions (Fig. 9).
- For each of the five sets of data, all models in Fig. 5 were evaluated as effective connectivity hypotheses.
- Based on comparisons of the computed Bayesian evidence (Ref. 4) for each hypothesis, the correct connectivity hypothesis was selected in only two of the five cases (Models 2 and 3).
- Additionally, examination of measurement data-repeatability showed that model evidence (i.e., Bayesian evidence, estimated value for the connectivity matrices in Eq. (1)) was substantially less repeatable than the spatial imaging results (Fig. 3).
- The preceding result suggests the utility of performing additional forward-posterior model-building studies, i.e., to evaluate model utility of output variables of the hemodynamic model (p) and in Eq. (1) i.e., in the 1 Hz sho也不可能 guilty disease.
- The five effective connectivity hypotheses are specified in Eq. (1). The model is a bilinear model 
\[ \hat{x}(t) = A \cdot x(t-1) + B \cdot y(t) + C \cdot u(t) \]
- Where x, y, and u are time-varying activity in a user-specified number of cortical regions.

Conclusion
An issue of central importance for fNIRS or fNIRS-EEG imaging analysis is the accuracy of recovered signals. To accomplish this it is necessary to have an ability to design experiments where the "ground truth" is unequivocally known a priori. The availability of an experimental testbed, such as the one described here, facilitates the development and testing of algorithms for analysis of functional neuroimaging data.

References

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Mathematical basis for fNIRS-EEG imaging analysis is the accuracy of recovered signals. To accomplish this it is necessary to have an ability to design experiments where the "ground truth" is unequivocally known a priori. The availability of an experimental testbed, such as the one described here, facilitates the development and testing of algorithms for analysis of functional neuroimaging data.