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METHODS - ANALYSIS

Blind Decomposition Reveals Novel Hemodynamics Response Features

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Current analytical techniques for fMRI data require a priori knowledge of the time course of the hemodynamic response (HR) and assume the homogeneity of both HR and noise across different brain regions and even across different subjects. These approaches may be problematic when the expected time course is unknown or the hemodynamic assumptions are invalid. Here we describe results of a data-driven fMRI analysis method based on Independent Component Analysis (ICA) for detecting unforeseen HRs in event-related fMRI experiments.

Six subjects (two male and four female, aged 22 +/- 3 years) participated four 5-min fMRI sessions in which bursts of 8-Hz flickering checkerboard stimuli were presented for 0.5 sec (short-stimulus sessions) or 3 sec (long-stimulus sessions) at inter-stimulus intervals of 30 seconds. Five axial slices were acquired with an EPI protocol (TR = 500 ms; TE = 70 ms; flip angle = 90 degrees; matrix = 64 by 64; FOV = 250 by 250 mm; slice thickness = 5 mm with 2-mm gap). The obtained fMRI time series were first subjected to a slice-timing process to adjust image intensity inhomogeneity arising from different image acquisition timing of the image slices. Then logistic Infomax ICA was applied to the matrix of fMRI time series from all within-brain voxels. ICA decomposed the data into maximally spatially independent components.

In each subject, the HR of components accounting for activity in primary visual cortex (PVC) and medial temporal cortex varied significantly across trials. Following short (0.5-sec) stimuli, three of six such component time courses were biphasic, contained two separate HR increases, the second peaking 3-6 sec after the first. Time courses of spatially homologous components from the three other subjects included inconsistent ripples following the initial response peak. The initial peak would be the only HR feature modeled in conventional hypothesis-driven analyses. In long (3-sec) stimulus sessions, by contrast, for each subject a PVC component with a nearly identical active region exhibited a conventional single-peaked HR beginning 3-5 sec after stimulus onset (somewhat later than the initial peak in the PVC components from the short-stimulus sessions). The HR time courses of the long-stimulus PVC components were also more stable across trials than those obtained from short-stimulus sessions.

ICA also revealed significant variability in the time course of HRs between brain areas. For example, for some subjects a component active in the motion-sensitive area (MT/V5) exhibited clear stimulus-evoked HR features, while in other subjects an active MT/V5 component was not found, or was not clearly time locked to stimulus presentations.

Together, these results demonstrate that HRs from fMRI experiments may be site-dependent, subject-dependent and task-dependent and may vary widely from trial to trial. The causes of single-trial HR variability, while unknown, probably include variations in subject cognitive strategy or state. Since HRs in brain areas involved in higher cognitive functions may be expected to be more variable than HRs in primary sensory and motor areas, use of data-driven analysis methods such as ICA appears essential to identify and explore their individual, time-varying features.