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When and where are components independent? On the applicability of spatial- and temporal- ICA to functional MRI data.

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Independent component analysis (ICA) is a method for recovering underlying signals from linear mixtures of those signals. ICA draws upon higher-order signal statistics to determine a set of "components" which are maximally independent of each other. When working with series of images, the independence may be assumed to be in either space or time; each choice yields a corresponding timecourse or component map.

Functional magnetic resonance imaging (fMRI) data have been analyzed using ICA, assuming either spatially- [1] or temporally- [2] independent components. This study was designed to explore the applicability and generality of the assumptions of spatial or temporal independence. Four novel visual activation paradigms were designed to yield fMRI data sets each consisting of two spatiotemporal components which were either spatially independent, temporally independent, both spatially and temporally independent, or neither spatially nor temporally independent, respectively. Regression analysis [3] of data resulting from these novel paradigms yielded spatiotemporal components in good agreement with the paradigm design; these "self-evident" components were treated as benchmarks for assessment of spatial- and temporal- ICA (sICA [1] and tICA [2]) of the data.

All paradigms used an 8 Hz reversing checkerboard pattern located in different portions of the visual field; "on" refers to the presentation of the pattern, "off" refers to a dark screen. Three spatial positions and three temporal patterns were combined to create the four paradigms. The positions were right visual field (R), left visual field (L), center (foveal) visual field (F), so that (R) and (L) were spatially overlapping with (F) but independent of each other. The temporal waveforms were each 240s in duration and consisted of repeating patterns that were A) on and off for 20s each then on and off for 40s each; B) on for 20s and off for 40s; C) on for 1s and off for 14s, so that patterns (A) and (B) were not temporally independent, but were each independent of (C). The four paradigms were then 1) RC;LA, 2) RB;FA, 3) RB;LA, and 4) RC;FA. Throughout the task, subjects were instructed to fixate on a crosshair located in the center of the screen.

Blood oxygen level dependent (BOLD) fMRI data were acquired in a Gyroscan NT PT-6000 operating at 1.5 Tesla (Philips Medical Systems) using single-shot Gradient Echo EPI (64x64 matrix; TE 40 msec; TR 1 s; 5 mm slices; 0.5mm gap) while visual stimuli were provided on a rear-projection screen via an LCD projector. Data were analyzed using regression analysis [3] and by both spatial- and temporal- ICA [4].

The regression analysis yielded "self-evident" results in good spatial agreement with the positional placement of the paradigm. Thus when the right (left) visual field was stimulated, activation was noted in the left (right) visual cortex. Likewise, foveal stimulation resulted in bilateral visual cortical activation.

Each ICA analysis was performed using 55 independent components. The temporal component correlating most highly with each "self-evident" temporal waveform was compared with the corresponding spatial representation. The s(t)ICA analysis agreed with "self-evident" results only when these "self-evident" components were spatially (temporally) independent.

In summary, four novel visual activation paradigms have been created and tested. Each yielded fMRI data much of whose variance could be accounted for by two "self-evident" spatiotemporal components which were, in agreement with the paradigm designs, spatially independent, temporally independent, both spatially and temporally independent, or neither spatially nor temporally independent, respectively. Spatial- and temporal- ICA were applied to each of these data sets, with the general result that ICA components agreed with "self-evident" components only where expected (e.g., tICA "worked" only for paradigms designed to yield temporally independent components), and "failed" (i.e., yielded independent components unrelated to the "self-evident" components) otherwise. These results suggest that the choice of spatial- or temporal- ICA should best be made with the knowledge of whether a given paradigm may reasonably be expected to be subserved by either spatially- or temporally- independent neuronal components.

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2. Biswal & Ulmer, J. Comp. Asst. Tomog. 23:265, 1999.
3. Friston, et al., Neuroimage., 7:30, 1998.
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