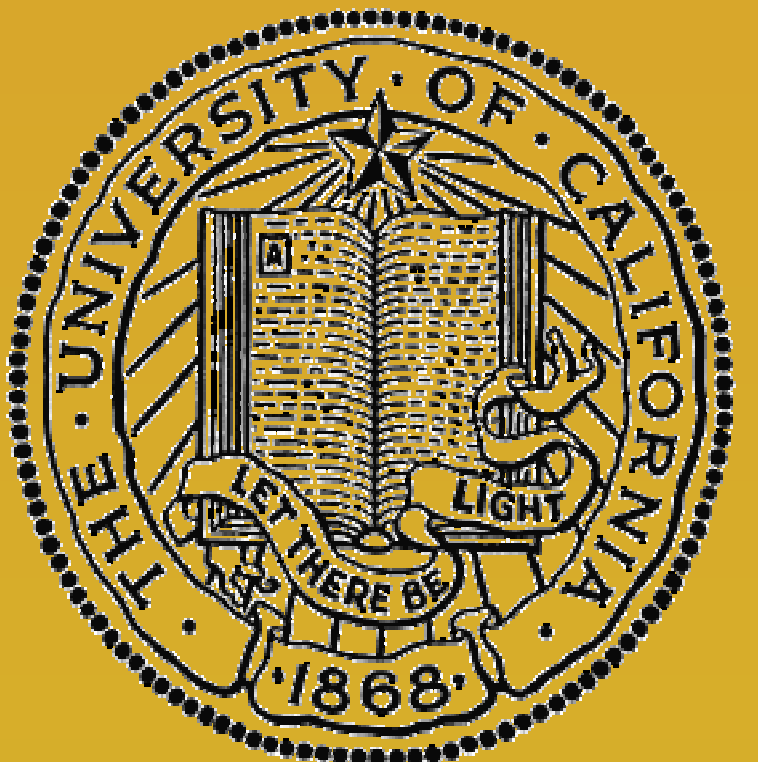




Sustained Attention Decreases Spatial Spread of Visual Responses in Human Primary Visual Cortex

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Background

- Previous functional MRI (fMRI) studies have shown that sustained attention to a visual stimulus increases the amplitude of the fMRI response in early visual cortex relative to the response to an ignored stimulus in the opposite hemifield (Gandhi et al., 1999).
- Functional MRI Blood Oxygenation Level-Dependent (BOLD) signal that is correlated with an increase in neural activity (relative to baseline) for a given stimulus is classified as positive BOLD, and the signal that is correlated with a decrease in such activity is classified as negative BOLD (Shmuel et al., 2006).

Purpose:

To determine the effects of sustained visual attention on the spatial spread of primary visual cortical responses to a visual stimulus.

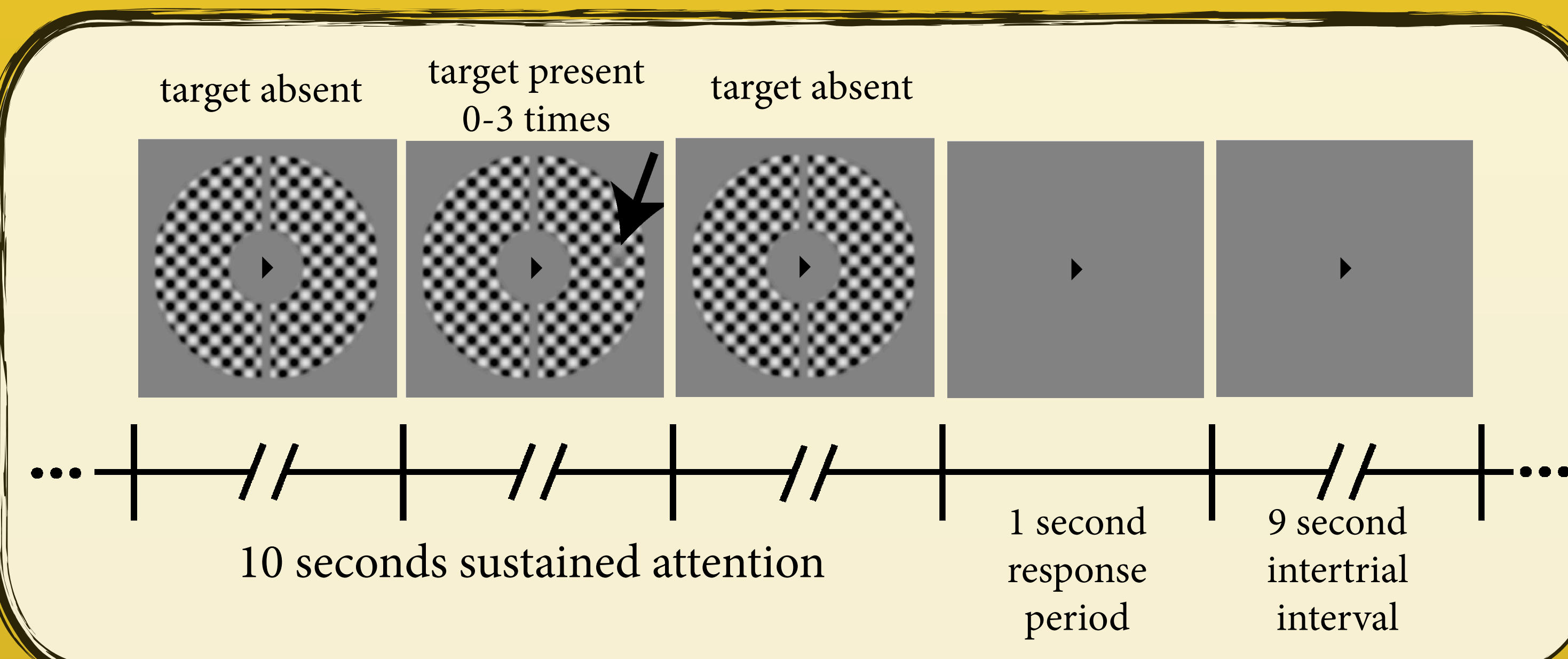
Methods

Subjects / Retinotopy

- Four healthy human volunteers participated in two fMRI sessions each
- The boundaries of V1 were defined in independent fMRI sessions for each subject, using standard phase-encoded retinotopic mapping techniques

Sustained Attention Task

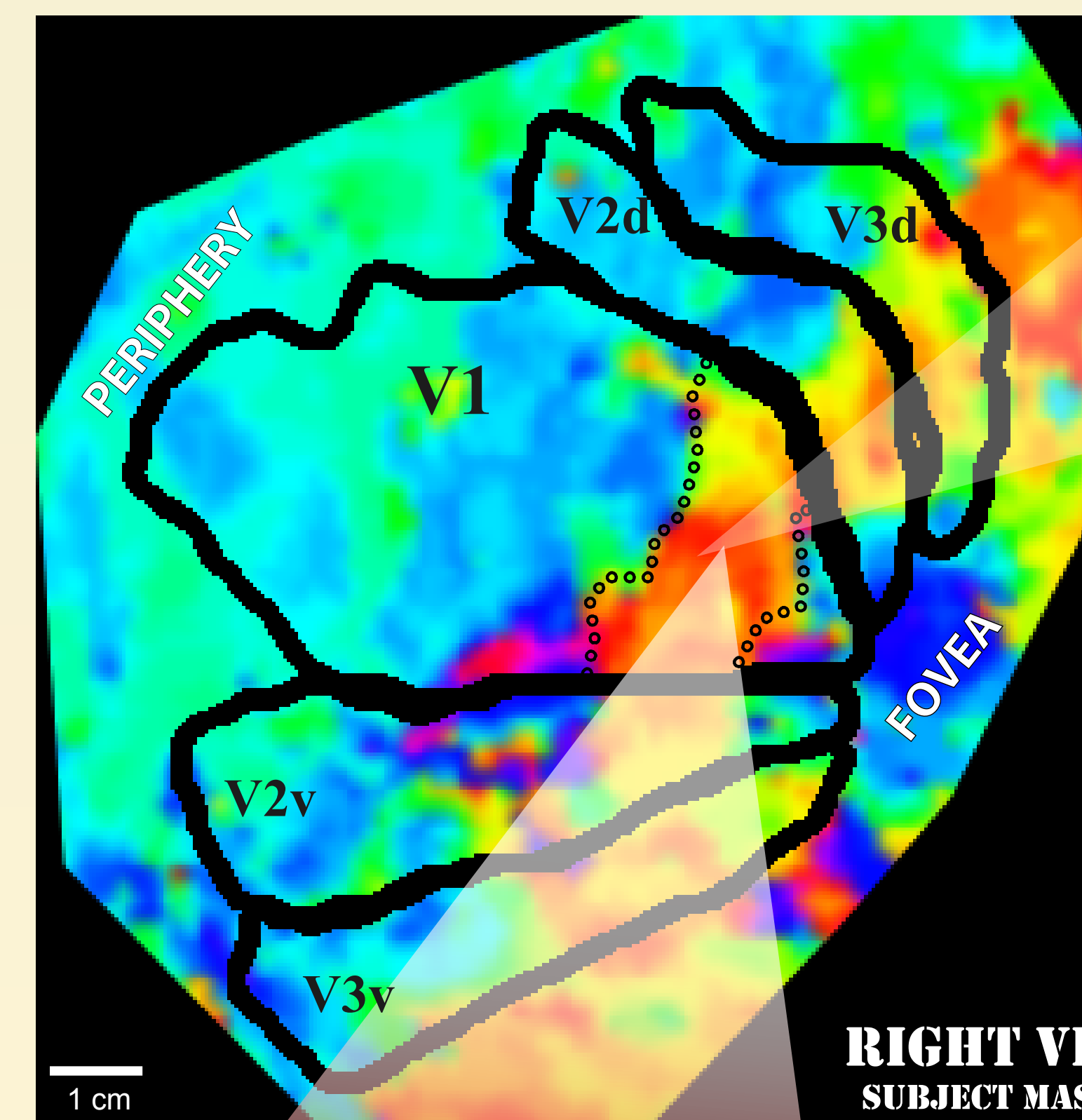
- Subjects viewed a contrast-reversing checkerboard annulus (with diameter subtending 3-9 degrees of visual angle) that was presented in a block-alternation design, with periods of 10s of continuous stimulus presentation alternating with 10s of a blank screen (uniform gray except for the fixation point):



- Subjects were instructed to continuously maintain fixation and were cued at the start of each run to either passively view the stimulus annulus or to covertly attend to its left or right half while performing a target (contrast decrement) detection task.
- On sustained attention trials, targets occurred at random times and locations within the annulus, thereby requiring subjects to maintain attention over the entire cued hemiannulus for the full stimulus duration.

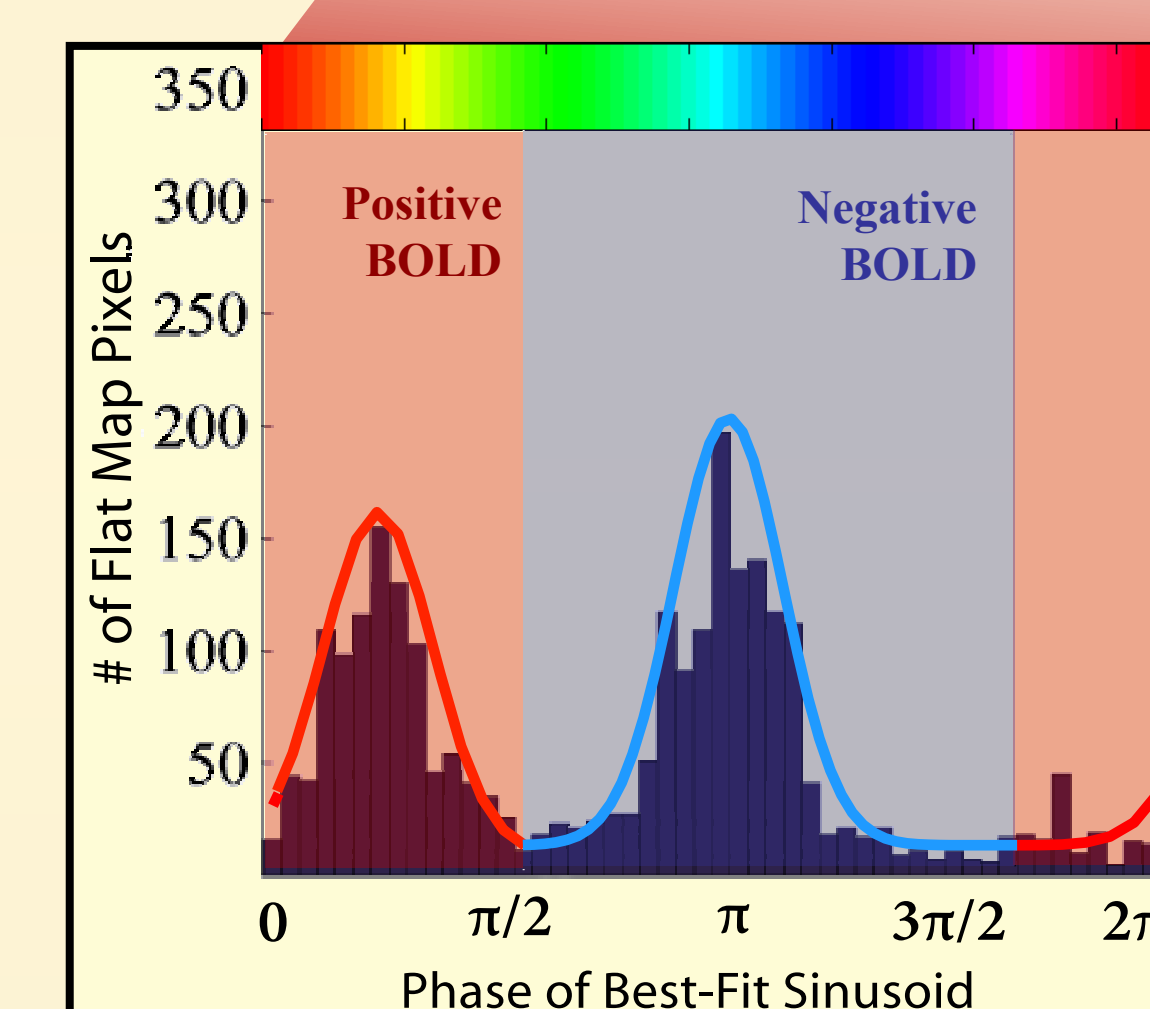
fMRI Analysis

A 0.05 Hz sinusoid (same frequency as the stimulus block alternation) was fit to the fMRI time series for each voxel within V1, and a phase was assigned to each voxel corresponding to the temporal delay of the response relative to the block alternation. The spatial distribution of response phases was displayed on flat maps of visual cortex:



- Voxels with positive BOLD responses were clustered within V1 with boundaries corresponding to the inner and outer edges of the stimulus annulus (see schematic outline above and to the left). This band of positive responses in V1 was flanked on either side by regions displaying negative BOLD.

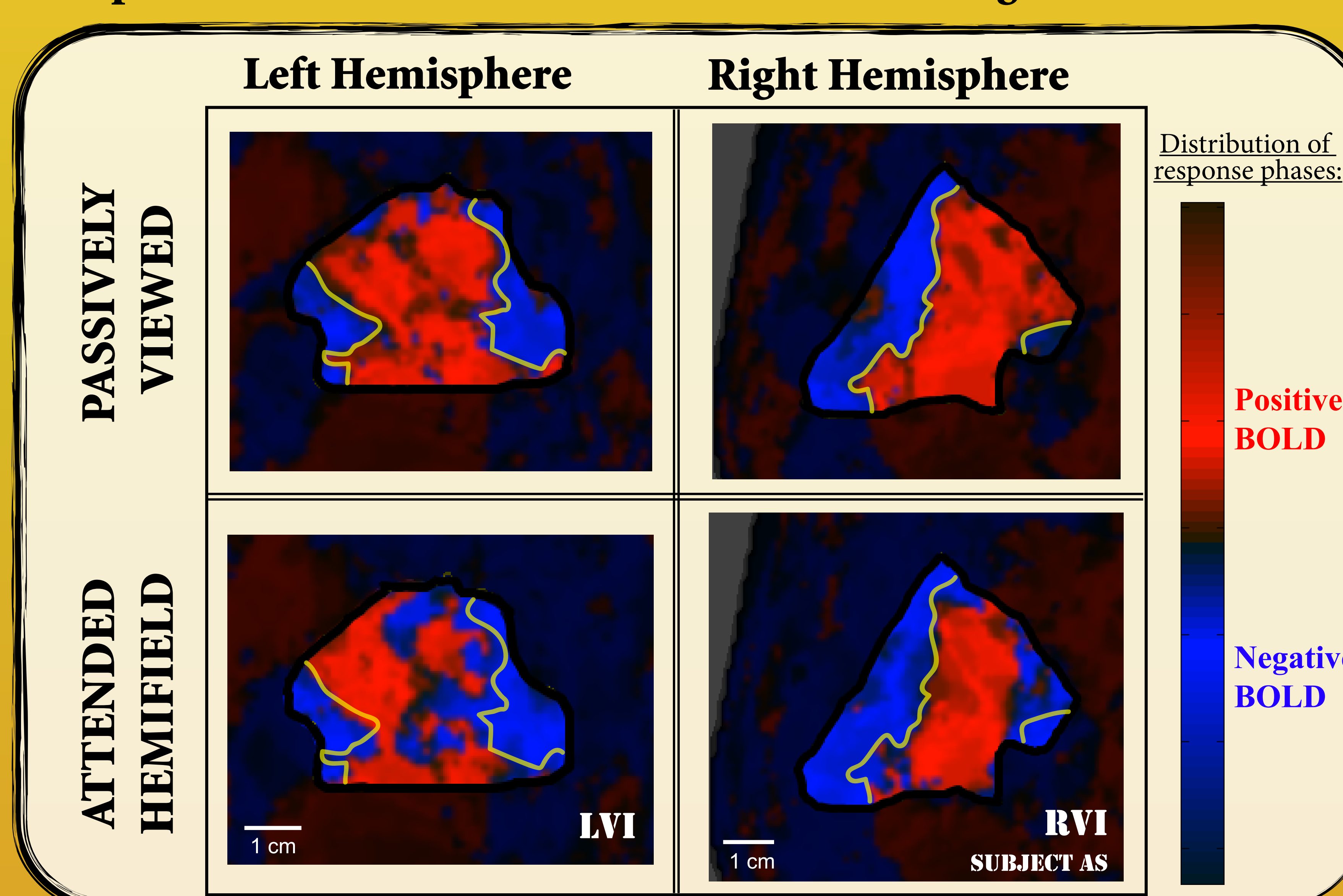
- The response phases had a bimodal distribution within V1. One population of voxels showed increased activity during visual stimulus presentation (positive BOLD response to the stimulus), and the second population was less active during stimulus presentation than during the blank screen control (negative BOLD response to the stimulus).



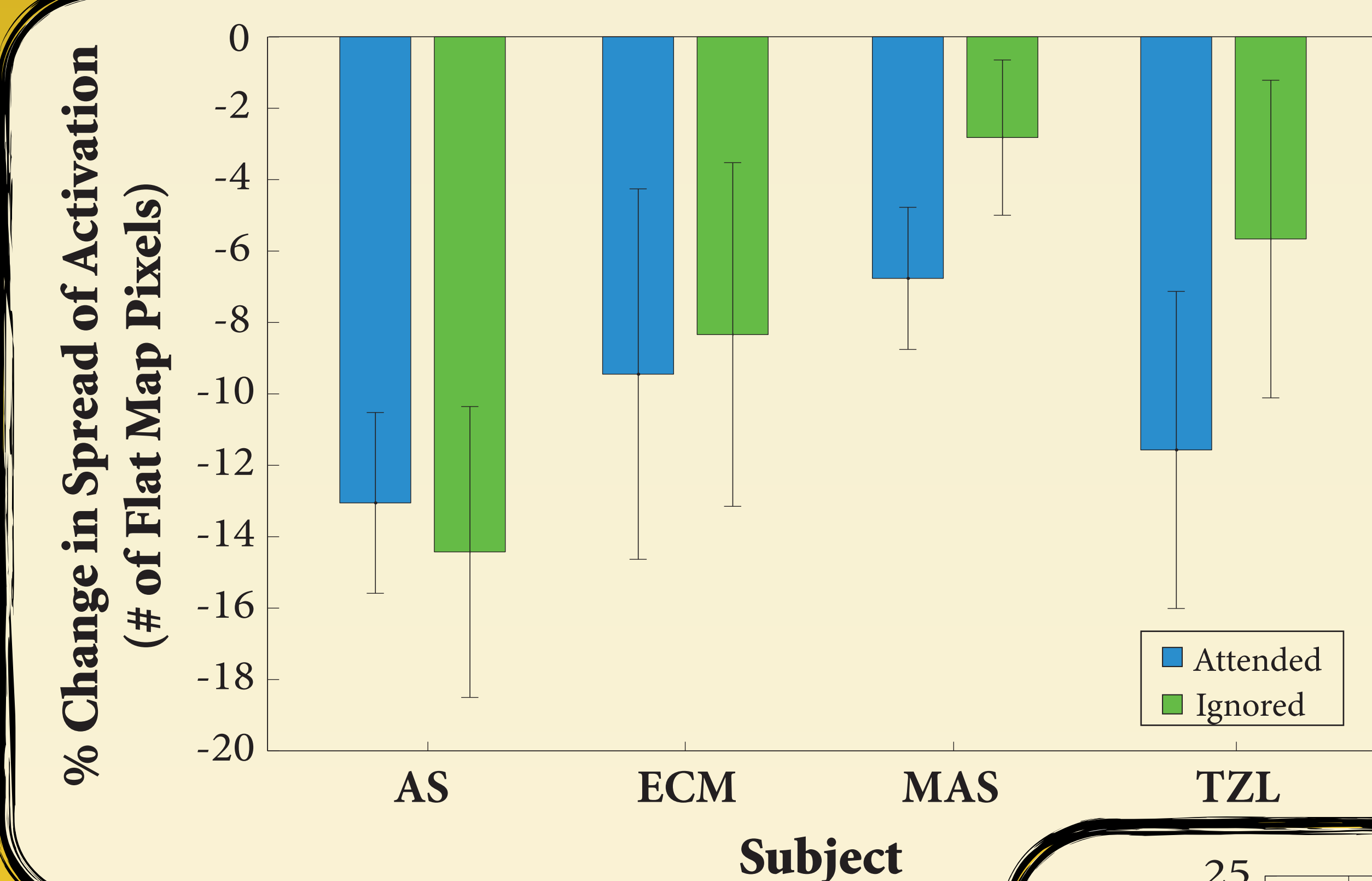
The distribution of response phases was fit with two Gaussian curves, and the parameters of the best-fit curves were used to define phase windows for positive and negative BOLD within each run.

Single Subject Results [examples of individual 5 min runs]

Relative to passive viewing (borders outlined in yellow below), attention decreased the number of positive BOLD and increased the number of negative BOLD voxels in V1:

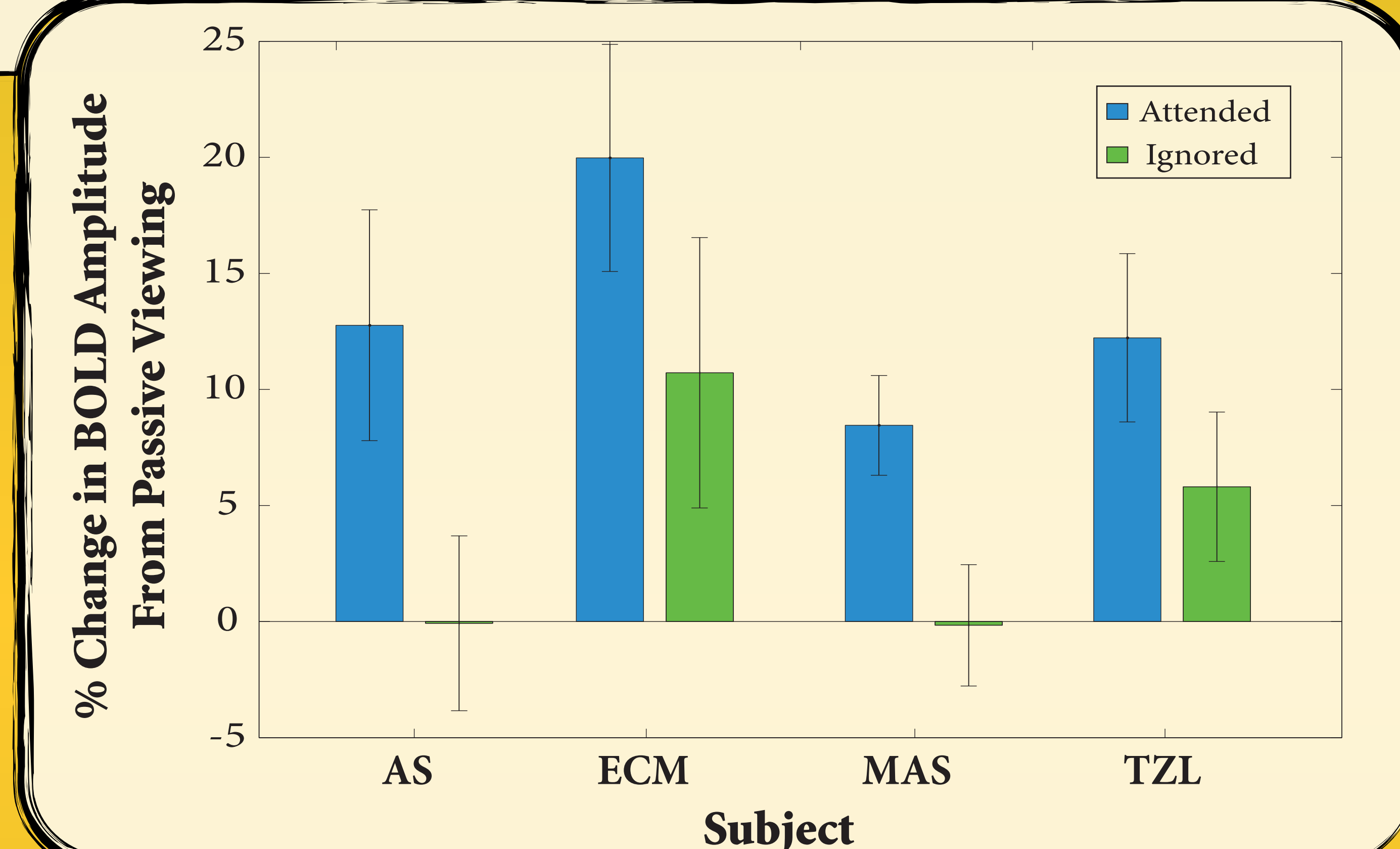


Group Results



Allocation of spatial attention decreased spatial spread of visual responses (relative to passive viewing) in both attended and ignored hemifields

Amplitude of visual responses was greater in attended than ignored hemifields



Conclusions:

- Sustained attention to a single hemifield reduced spatial spread of responses to a high-contrast stimulus for both attended and ignored hemifields in all four subjects. This suggests that the reduction in spatial spread is due to engagement of sustained attention rather than allocation to a particular location in space.
- However, sustained visual spatial attention increased amplitude of BOLD responses in attended relative to ignored hemifields.

Discussion

Acetylcholine and Visual Cortex

- Animal physiology studies suggest that the neurotransmitter acetylcholine (ACh) reduces lateral interactions in early visual cortex (Kimura et al., 1999; Roberts et al., 2005).
- In a previous study, we administered the Alzheimer's medication donepezil (Aricept®), a cholinesterase inhibitor, thereby increasing synaptic levels of ACh across the brain. We found that cholinergic enhancement with donepezil reduced the spatial spread of visual responses in area V1 (Silver, Shenhav, & D'Esposito, 2006).

Attention and Acetylcholine

- Basal forebrain axons release ACh over the entire cerebral cortex. Animal studies have shown that cortical ACh release is increased during periods of sustained visual spatial attention and that basal forebrain lesions impair performance on visual attention tasks (Sarter et al., 2005).

- Like sustained attention, cholinergic enhancement with donepezil reduced spatial spread of visual responses. This finding, combined with the results from animal experiments showing increased cortical ACh release during sustained visual attention, suggests that the attention effects on spatial spread described in this poster may be cholinergically mediated.
- These findings, together with results of animal physiology studies, suggest that the decreased spatial spread seen after administration of donepezil and with attentional engagement could be due to altered lateral intracortical connections in early visual cortex.

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