How Do Brain Areas Work Together When We Think, Perceive, and Remember?

J. McClelland
Stanford University

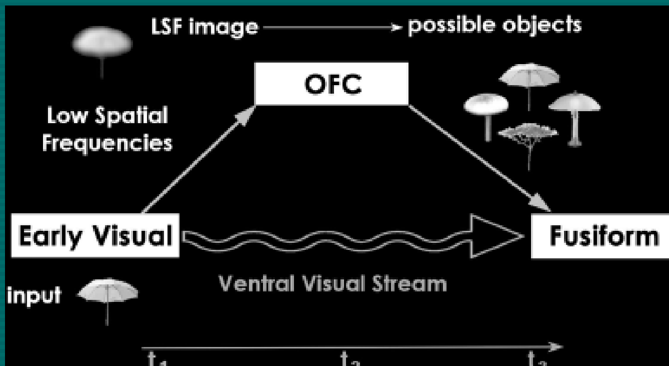
Examples of situations in which there must be coordination between brain areas

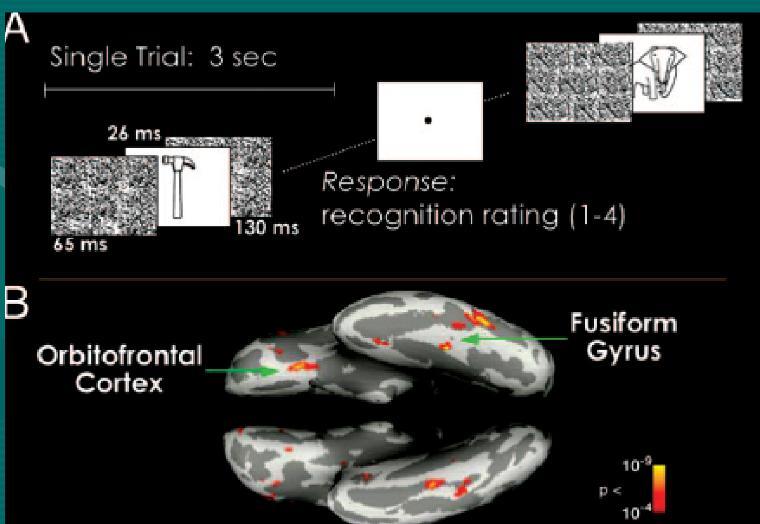
- Cross-modal integration for perception, action and spatial awareness
- Speech perception (McGurk Effect…)
- Coordination of what and where in perception
- Coordination of meaning and syntax in language
- Attention and working memory
- Comprehension of language in a natural setting
- Memory for events and experiences

Feed-Forward or Cooperative Computation?

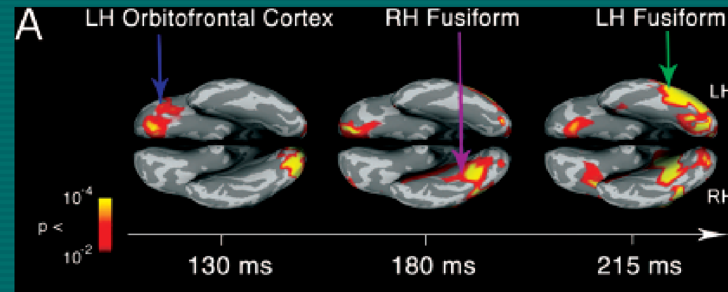
Top-down facilitation of visual recognition

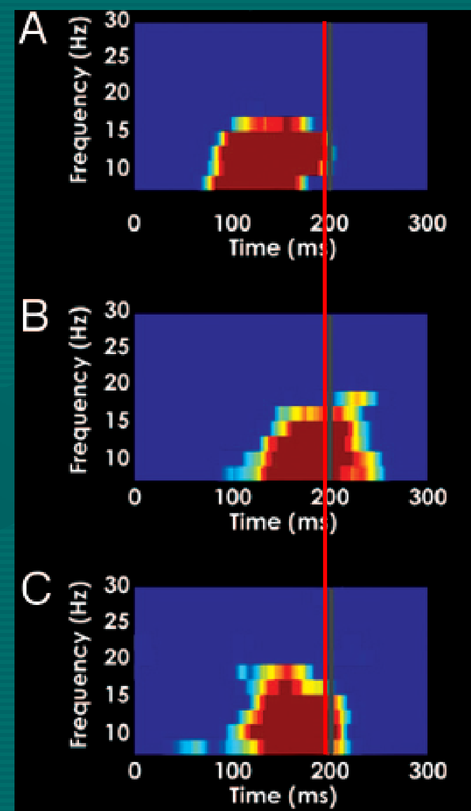
M. Bar*†, K. S. Kassam*‡§, A. S. Ghuman*§¶, J. Boshyan*, A. M. Schmid*, A. M. Dale*, M. S. Hämäläinen*, K. Marinkovic*, D. L. Schacter‡, B. R. Rosen*, and E. Halgren*





PNAS | January 10, 2006 | vol. 103 | no. 2 | 449–454



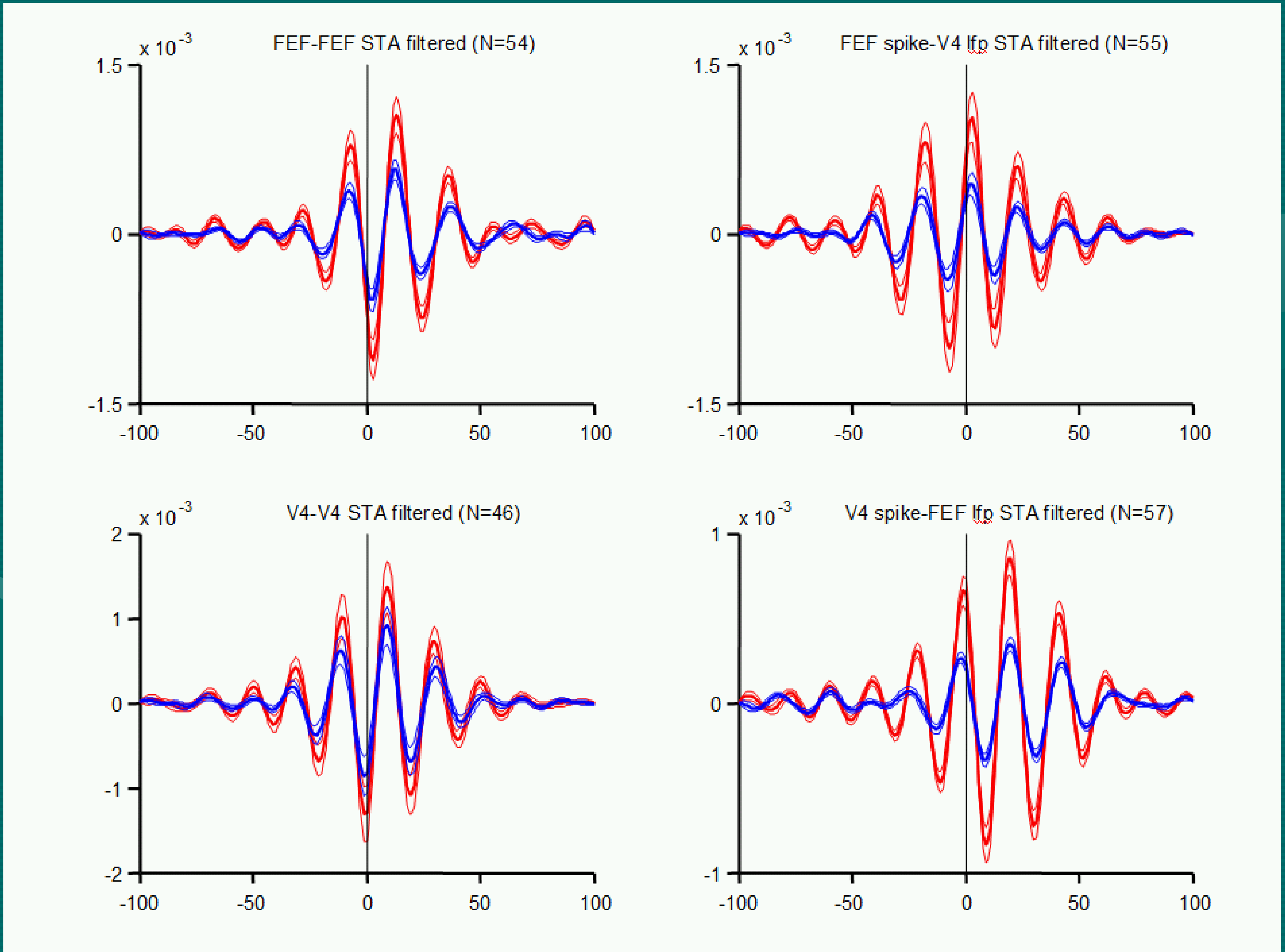


Occ-OFC Phase locking

Fusiform-OFC Locking when Recog succeeds

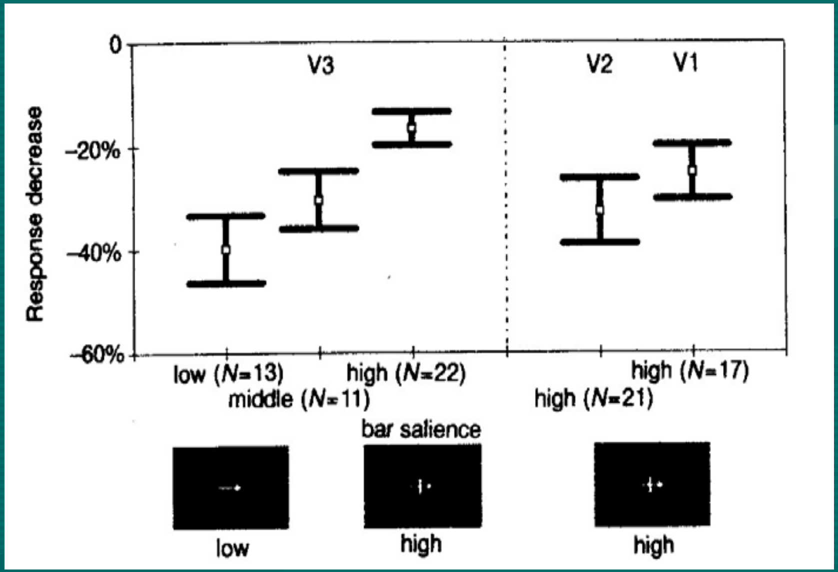
Fusiform-OFC Locking when Recog fails

Coherent Engagement of Two Brain Areas in Selective Attention (Gotts, Desimone, et al)



Hupe, James, Payne, Lomber, Girard & Bullier (Nature, 1998, 394, 784-787)

- Investigated effects of cooling V5 (MT) on neuronal responses in V1, V2, and V3 to a bar on a background grid of lower contrast.
- Cooling typically produces a reversible reduction in firing rate to the cell's optimal stimulus.
- Similar effects occur in many other tasks and contexts.



Could it be…

- That conscious experience depends on coherent activity distributed across many brain areas?
- That our ability to think deeply and insightfully depends on coherent engagement of multiple brain areas that each contribute their own crucial element to successful thinking?
- That individual differences in the ability to achieve such coherent engagement underlie successful performance in intellectually challenging and cognitively demanding tasks?

The time has come

- Multi-regional cooperative computation is the rule in nearly all aspects of human cognition
- The reason we don't generally think this way is that we have not until now had to tools to study cooperative engagement of brain areas
- We now have the tools – over the next 5 years we can use them convergently to understand how parts of the brain work together.

Experimental Approaches

- Investigate timing and synchronization of neural activity across brain areas using simultaneously recorded spikes, local field potentials, scalp EEGs, and/or MEG.
- Investigate effects of congruity between inputs in different modalities on neural processes using above methods.
- Couple the above with fMRI and DTI tractography to pin-point cooperating brain areas.
- Use animal models as well as cognitive neuroscience methods in humans. Small-scale and large-scale systems.
- Explore the roles of experience and development of long-range connectivity in effective cross-regional engagement.
- Explore how intrinsic properties of neurons, local circuit structure, neuro-modulatory influences support mutual engagement within and between brain areas.
- …

Convergent Computational Approaches

- Pursue the computational theory of cross-regional cooperative computation. Why does such cooperative engagement occur?
- Explore biologically realistic models of the mechanistic basis for cooperative engagement across brain areas.
- Explore learning methods that would support mutual engagement of neural populations in diverse brain areas.
- Exploit advanced data analysis methods and new statistical concepts to infer directional (and bi-directional) influence among brain areas, and to incorporate known structural and biophysical constraints.

Applicable Topic Areas

- Perception
- Cross-modal integration of sensory information
- Motor Control
- Attention
- Working Memory
- Spatial Cognition
- Language perception, comprehension and production
- Reading
- Mathematical Cognition
- Semantic Cognition
- Causal Reasoning
- Episodic Memory