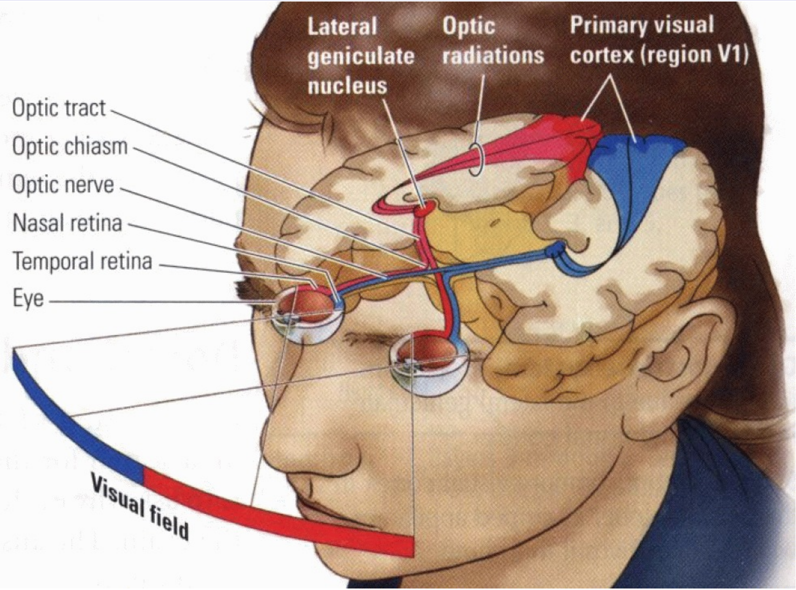
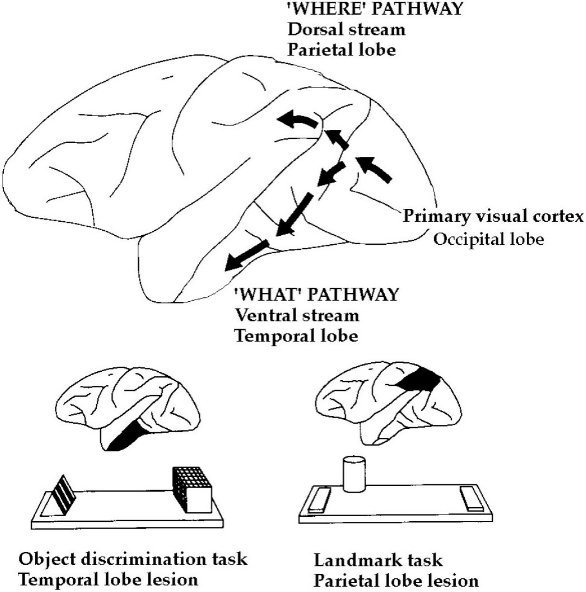
Contralateral organization of the visual system

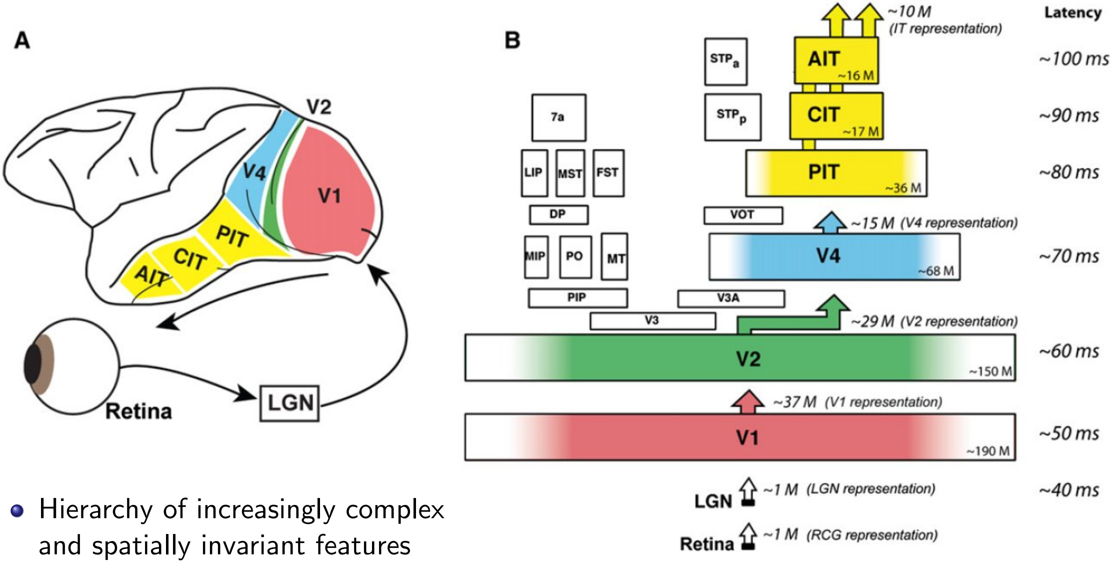


Two cortical visual systems (Ungerleider & Mishkin, 1982)



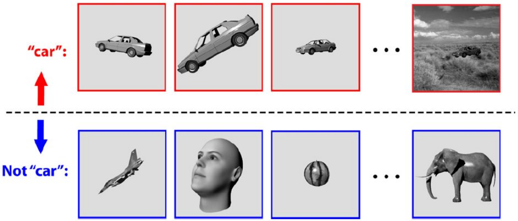
- **Dorsal (where) pathway** (upper) important of object localization
  - discrimination which food location is closer to a single object
- **Ventral (what) pathway** (lower) important for object recognition
  - discriminating between two different objects to find food
- Most deep convolutional neural networks (DCNNs) are models of the ventral pathway

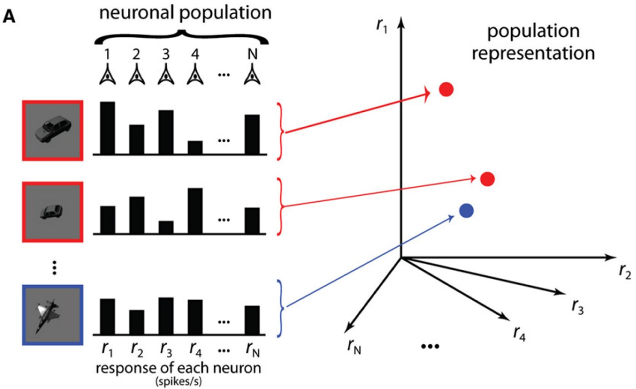
Ventral pathway



- Hierarchy of increasingly complex and spatially invariant features

Object recognition

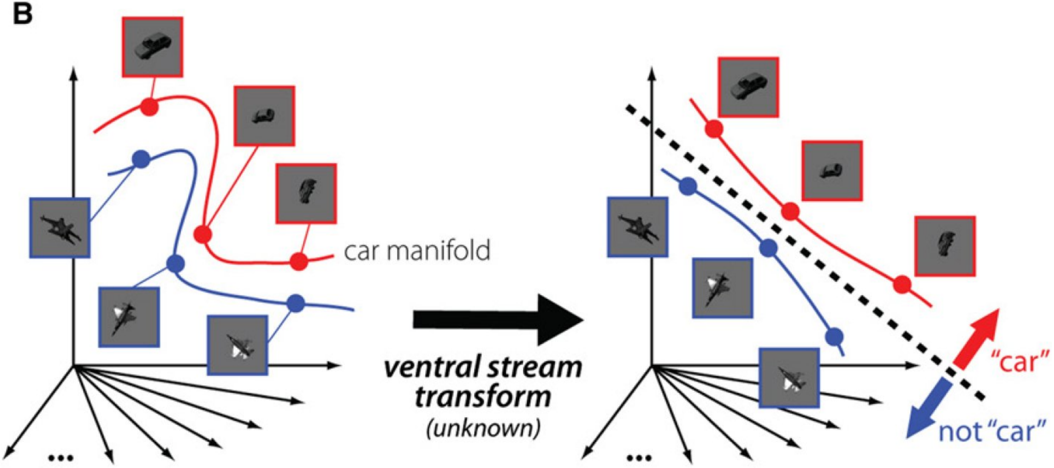




(Distributed representations in state space)

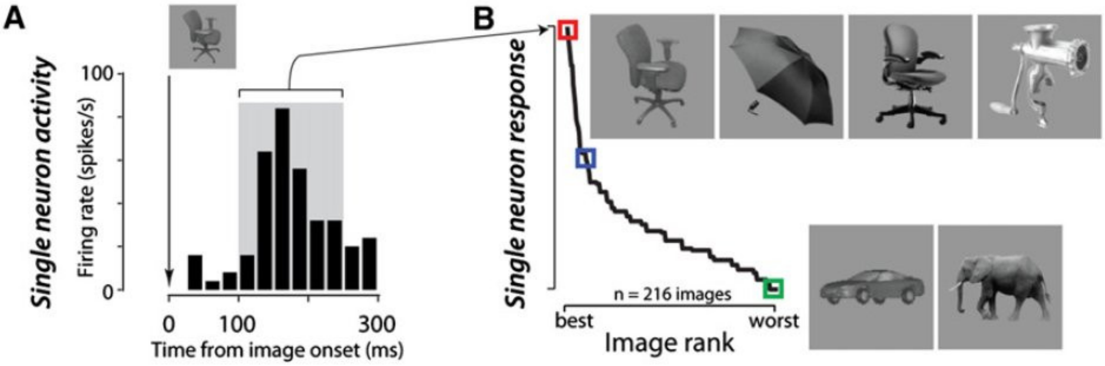
- Goal of recognition is to distinguish all images of each class/category from all other images
- Difficult because between-class image similarity can be greater than within-class similarity

Recognition as untangling object "manifolds"

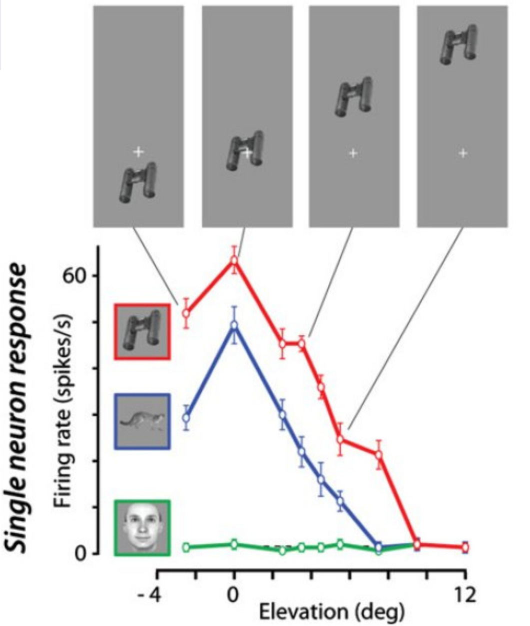


- Ventral stream must progressively alter similarity structure of representations so that different categories become linearly separable in the final layer

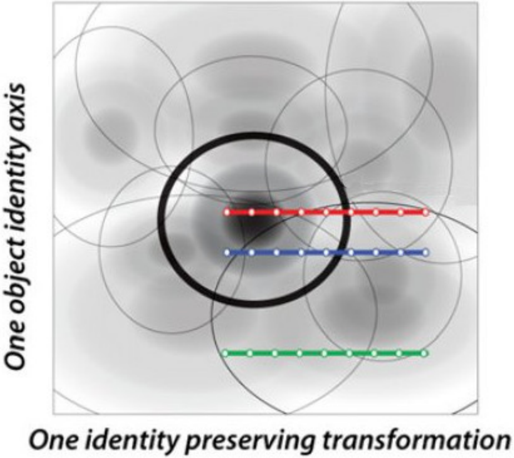
Single neuron responses in inferotemporal cortex (IT)



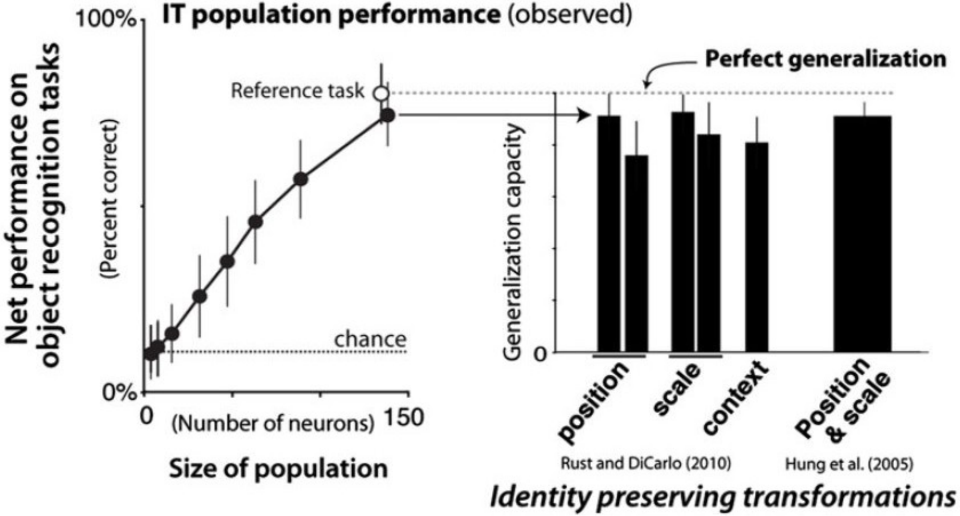
- The responses (firing rates) of individual neurons at the top layer (IT) show a degree of selectivity for different objects
    - Strong activation to few (red is best), moderate to many (blue), weak/none to most (green)



- Single neurons are **not** spatially invariant

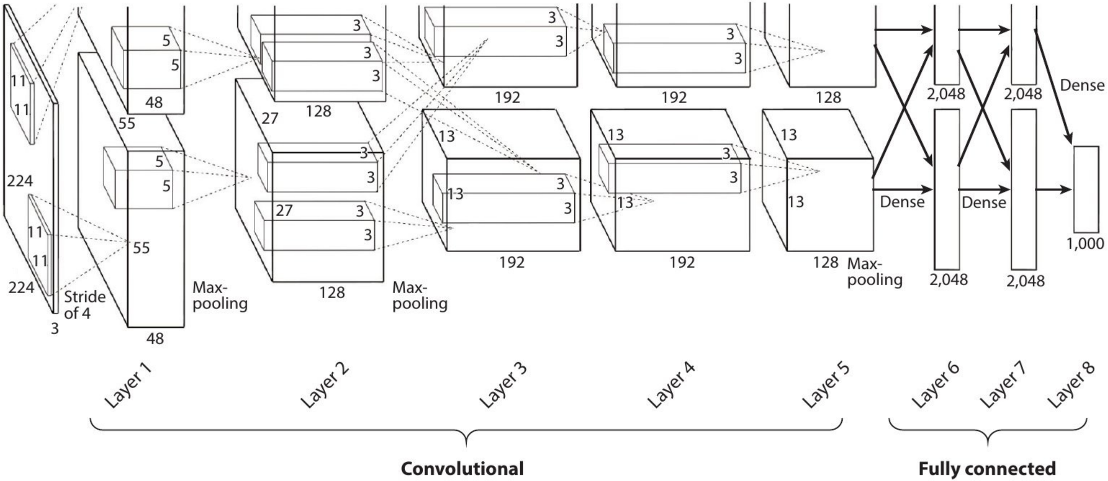


Preserving identity across viewing conditions: Population code



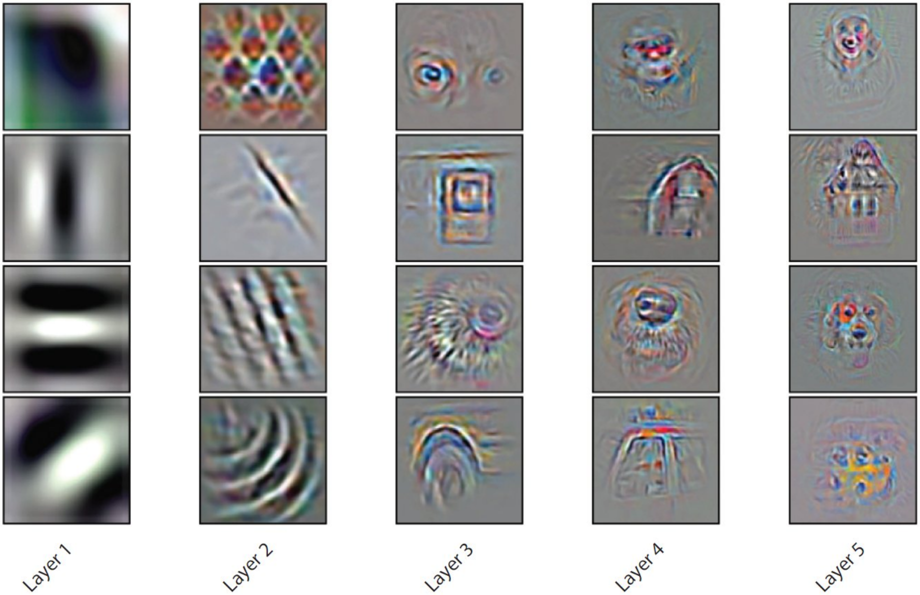
- Combining a population of IT neurons (~150) **does** support spatially invariant recognition

Deep convolutional neural networks (CNNs)

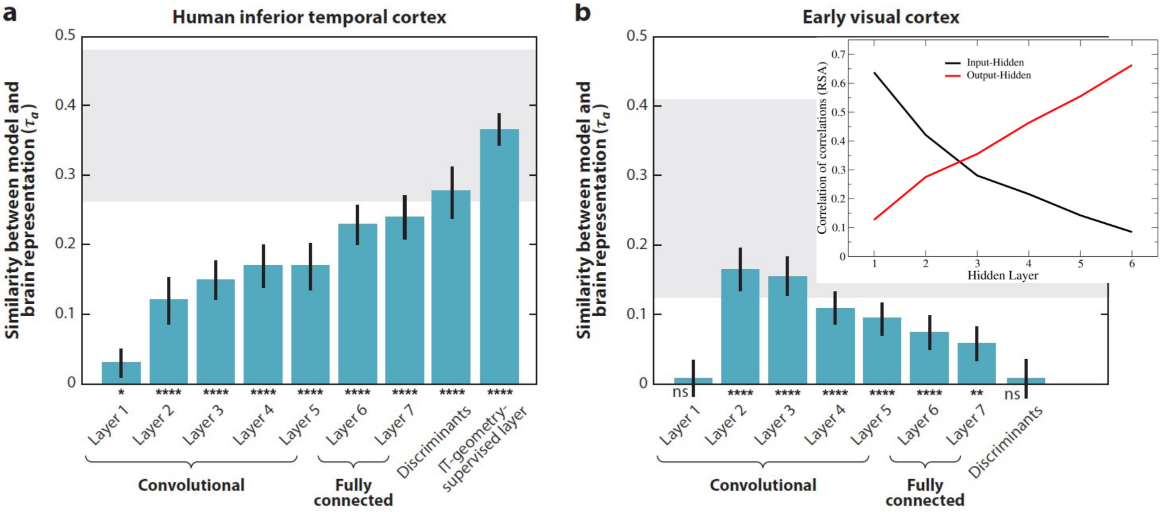


Krizhevsky, Sutskever, and Hinton (2012) "AlexNet"

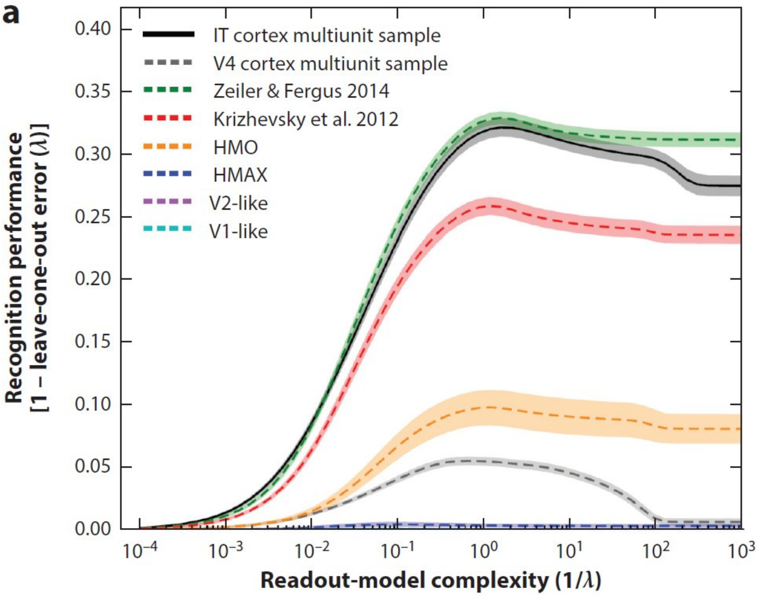
Learned features



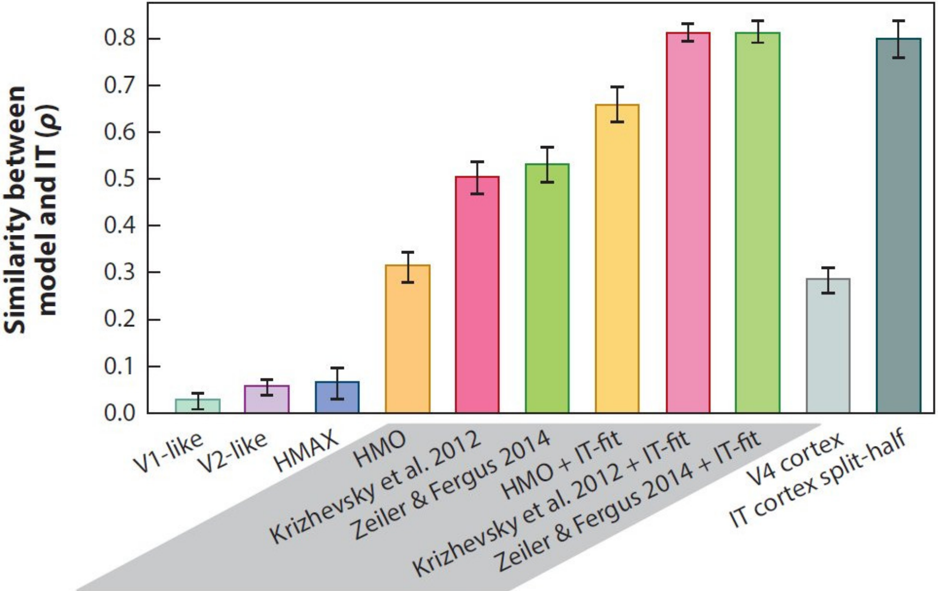
Similarity of hidden representations to neural representations



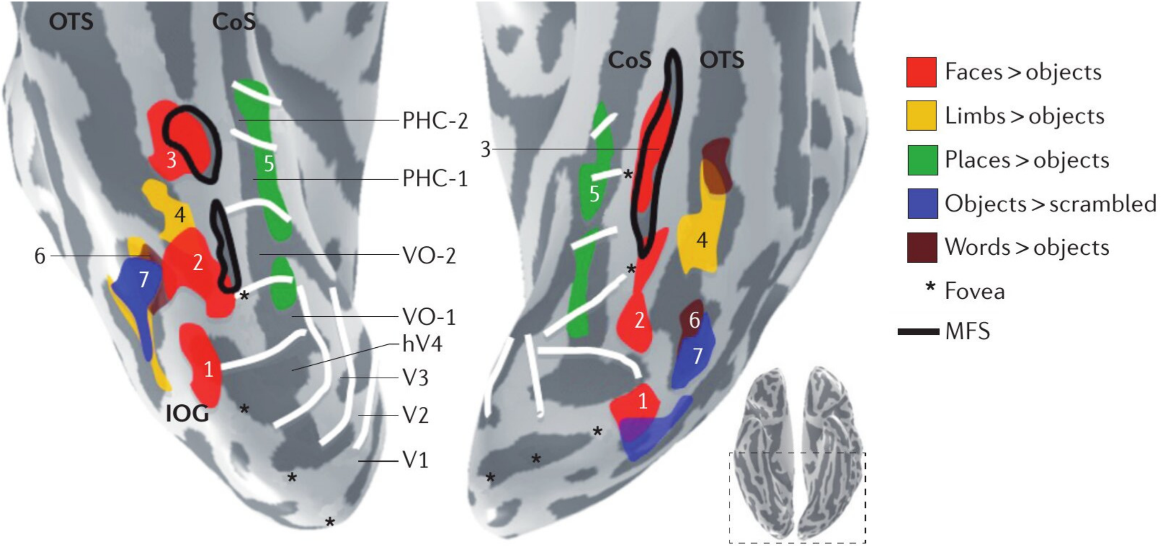
Discrimination accuracy as a function of model complexity



Similarity of representations to neural representations in IT

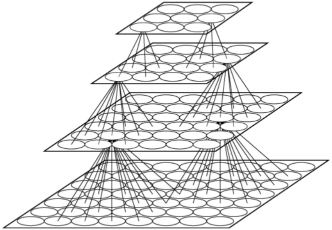


Domain-specific modules? (Grill-Spector & Weiner, 2014)



Computational principles of neural organization

Cooperation and competition among representations



Representations are hierarchically organized

The representation of information at each level, as a pattern of neural activity, **cooperates** with (i.e., mutually activates and reinforces) the representations of consistent information at lower and higher levels.

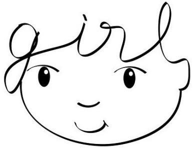
Cooperation depends on available connectivity

Connectivity is strongly constrained to minimize axon length (total volume); cooperating representations **need to be close** to each other.

Inconsistent representations compete

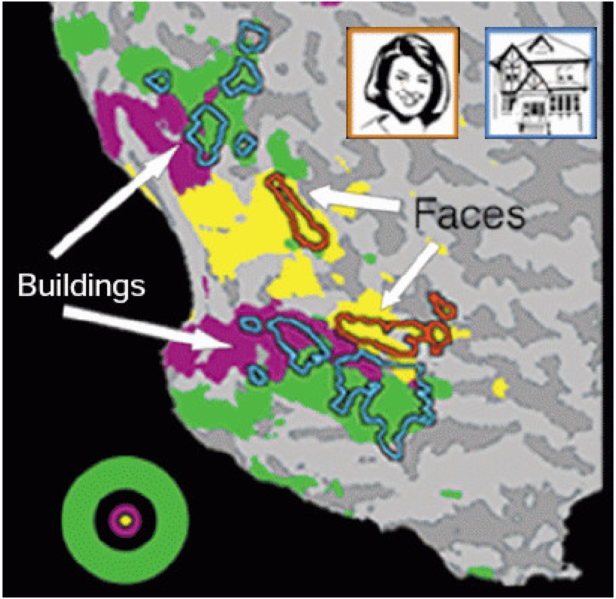
Representations of inconsistent information **compete** with each other to become active, and to become stronger through learning.

Interdependence of face and word processing (Plaut & Behrmann, 2011)

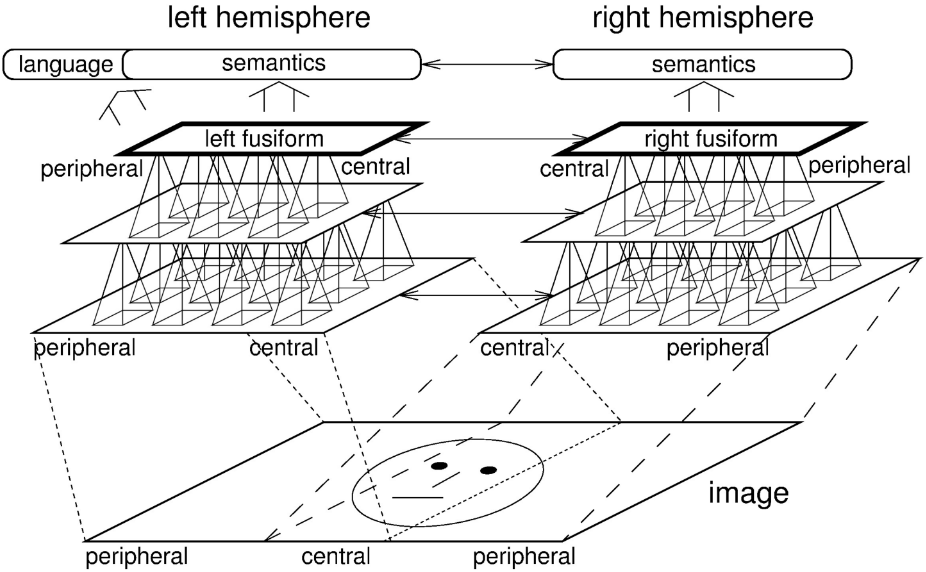


- As visual objects, faces and words are unrelated.
- However, both face and word recognition place extensive demands on **high-acuity visual information** from central vision (Malach et al.)
- Due to topographic constraints on neural organization, central visual information is **localized** in each hemisphere of the brain
- Both face and word representations need to be near central visual information to cooperate with it, but they compete with each other
- Words also need to cooperate with language-related representations (esp. phonology) which are typically left lateralized
- As a result, words become stronger in the left-hemisphere and faces become stronger in the right-hemisphere, but they are **mixed in both hemispheres** and therefore influence each other

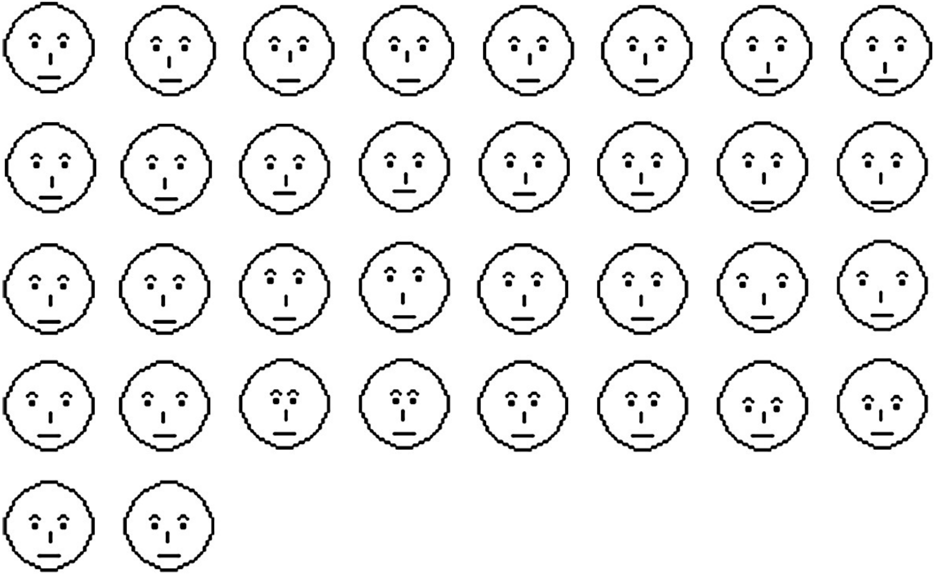
Face regions are adjacent to central visual information (Malach et al., 2002)



Simulation (Plaut & Behrmann, 2011)



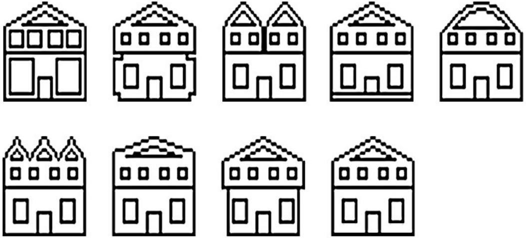
Stimuli: Faces



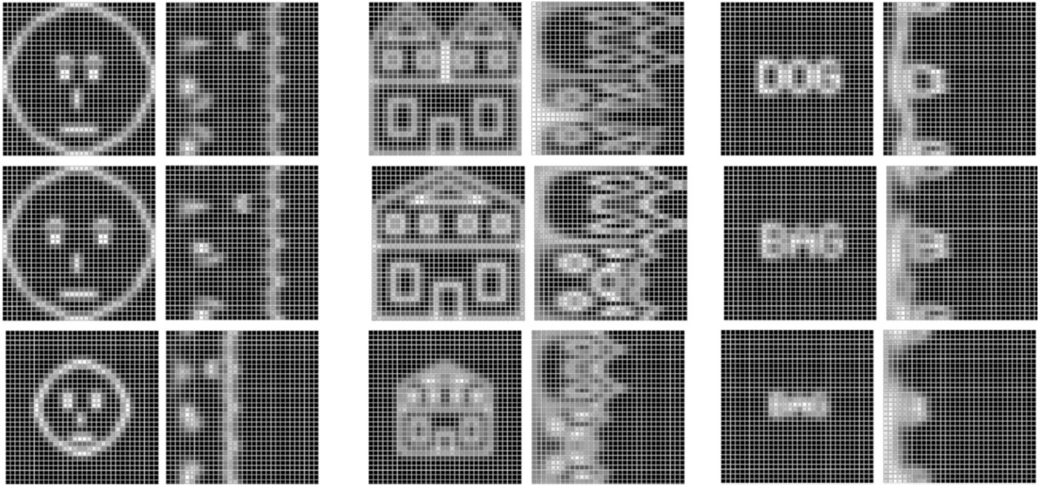
Stimuli: Words

BAG	BED	BEG	BET	BID	BIG	BIT	BUD
BUT	DAD	DID	DIG	DIP	DOG	DOT	DUG
MUD	MET	MEN	MAT	MAP	MAN	MAD	PAD
PAN	PEN	PET	PIG	PIP	POP	POT	PUT
TAG	TAN	TAP	TEN	TIN	TIP	TON	TOP

Stimuli: Houses

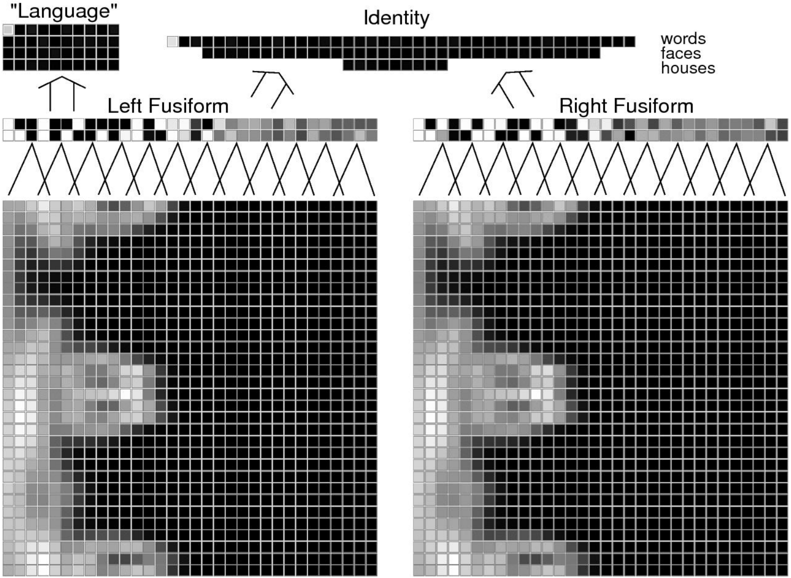


Polar coordinates; Variation in scale

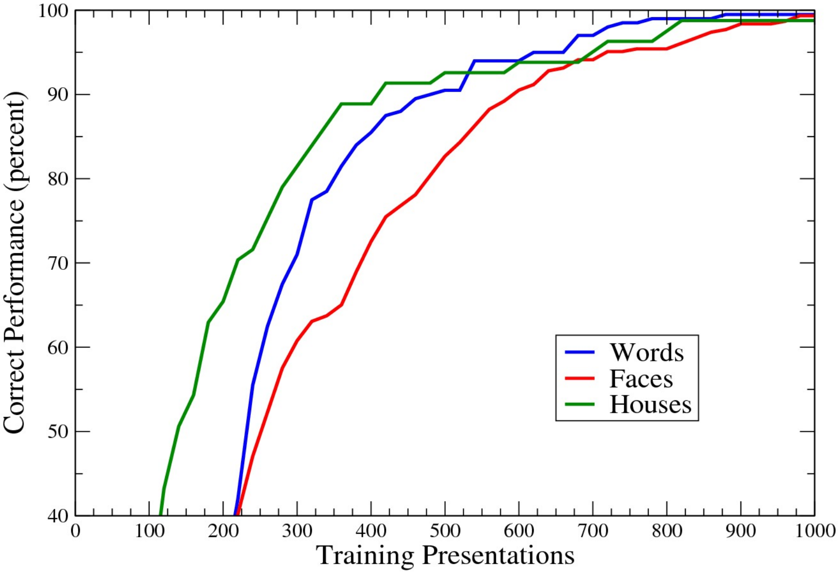


- 34 faces, 9 houses, 40 words, varying in scale
- Input in polar coordinates (eccentricity, angle)

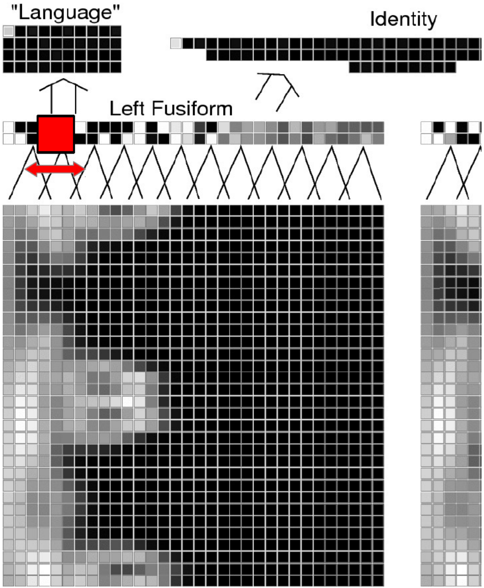
Network architecture



Acquisition

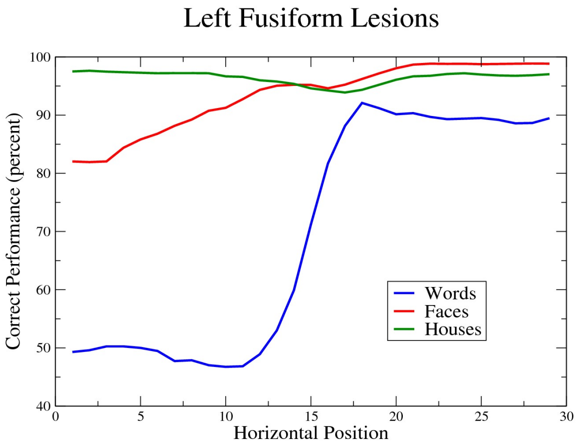


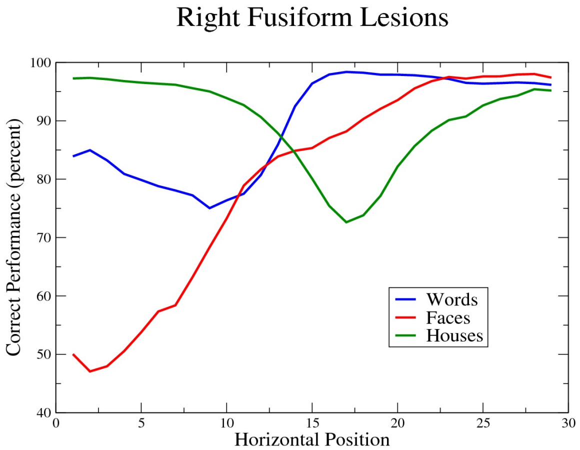
Lesioning method



- For each horizontal position (central to peripheral) in each hemisphere, remove three adjacent columns of intermediate (fusiform) units
- Measure recognition performance on faces, words and houses (across all scales)

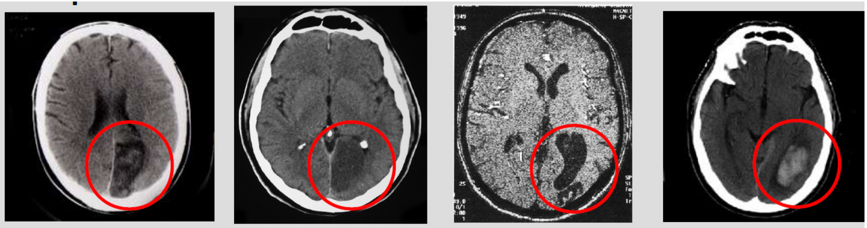
Lesioning results





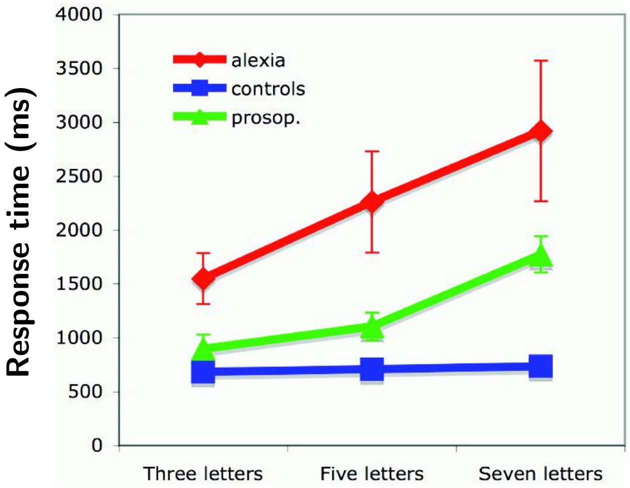
Neuropsychological data (Behrmann & Plaut, 2012)

- **Pure-alexic** patients with unilateral left-hemisphere lesions (n=4)



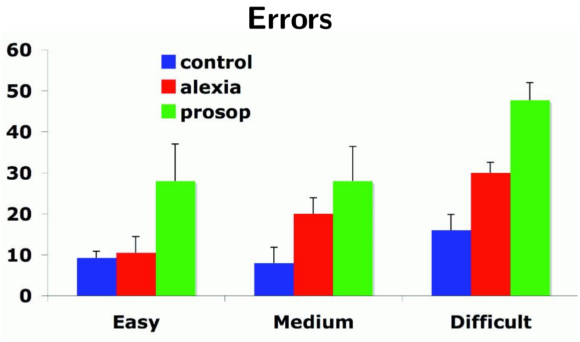
- **Prosopagnosic** patients with unilateral right-hemisphere lesions (n=3)

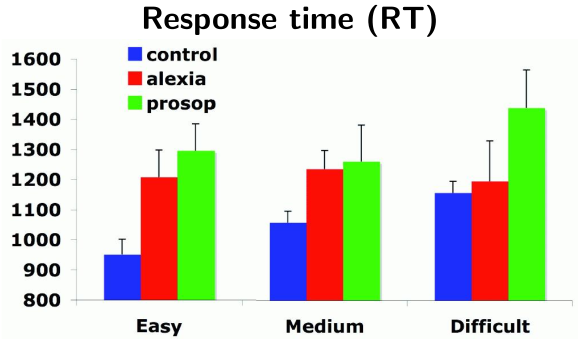
Word processing: Lexical decision



- Unlike normal controls (blue), pure alexic patients (red) read longer words much more slowly than shorter words (“letter-by-letter reading”)
- Prosopagnosic patients (green) are mildly pure alexic—show weaker but still abnormal length effect

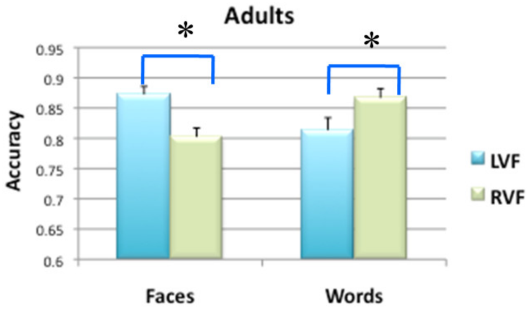
Face processing: Same-different judgements

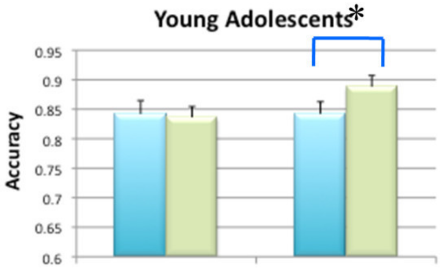


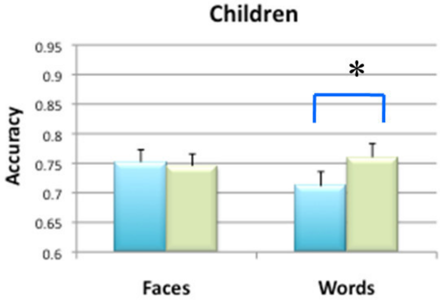


- Prosopagnosic patients (green) are much worse than controls (blue) at same-difference judgements with faces
- Pure alexic patients (red) are mildly prosopagnosic (worse than controls, better than prosopagnosics)

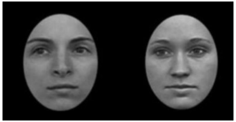
Word lateralization drives face lateralization (Dundas et al., 2012)



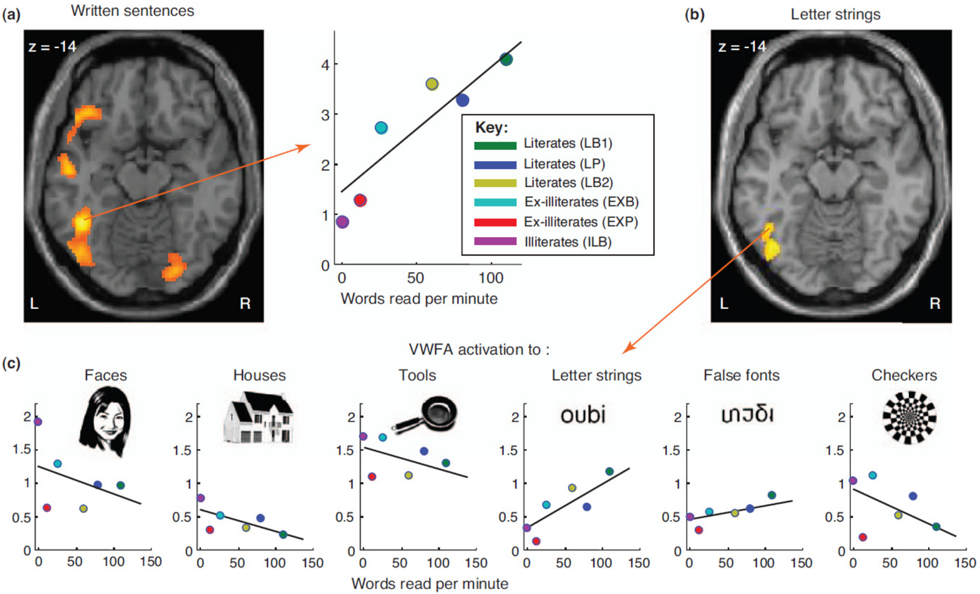




Sequential same-different judgment where second stimulus is presented to the left or right of fixation (LVF or RVF)



Effects of literacy on VWFA activation (Dehaene et al., 2010)



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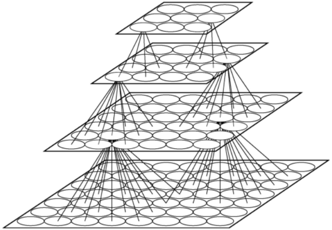

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