

# Announcements

- **Viewing comments on paper overview**

Don't just click on link Ben sent

Sign into google docs, with the same email address as Ben used to email you.

You may have to create a new account for this if you haven't already used google docs with that email address.

- **Term paper extension: Due Dec 15, by 10 a.m.**

no late papers accepted

leave in Mike or Rob's mailbox or under office door, or bring to class on final

- **Final exam period**

extra credit opportunity: oral presentation of term paper

email Mike if you will present

attendance is optional, but encouraged

# Announcements II

**Talk today**

**Mike Eisenberg**

**Engineering Center ECCR 265**

**3:30-4:30 p.m.**

**Rethinking Educational Technology: Some Early Steps**

# **Neuroscience of Situated Cognition**

# Tools

**Humans use tools to interact with environment.**

computer mouse

video game controls

teleoperation

shovels, hammers, etc.

automobile

## **Previously**

To what extent do we treat a notebook or blackboard as an extension of our cognitive system?

## **Current topic**

Does our brain consider tools to be extensions of our body?

Does our brain consider *icons* of tools to be extensions of our body?

# Representing Manipulable Man-Made Objects (Chao & Martin, 2000)

**Does the brain represent pictures of tools differently from how it represents other categories of objects?**

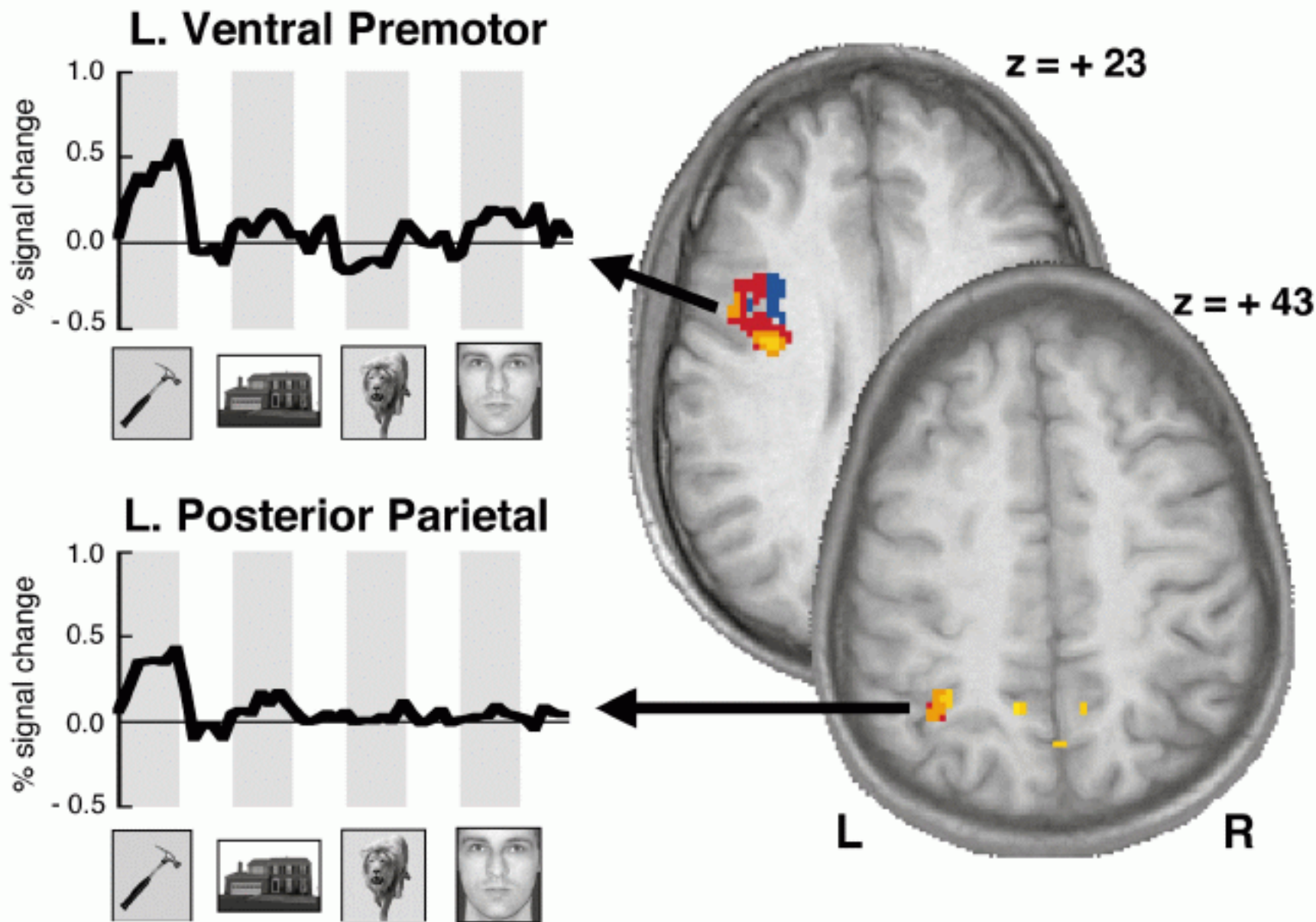
Tools are associated with specific hand movements.

Is there a close link between the visual image of tools and the representation of actions associated with their use?

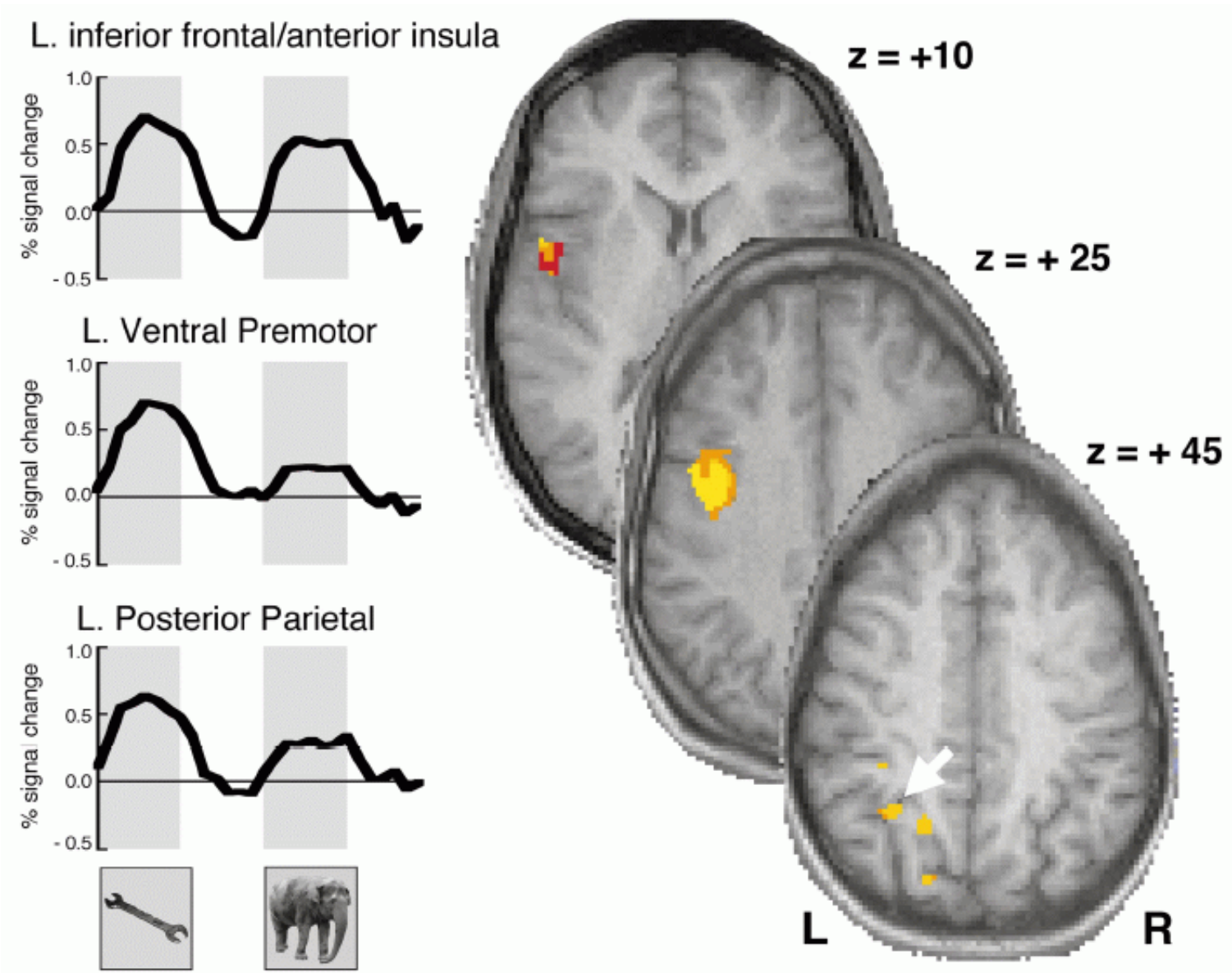
## **Monkey data**

single-cell activity in premotor cortex to visual presentation of graspable objects, even in the absence of motor activity

# Simple Viewing Task



# Silent Naming Task



# Conclusion

## (Chao & Martin, 2000)

**“Close link between manipulable objects and information about the actions associated with their use.”**

### **Mirror neurons**

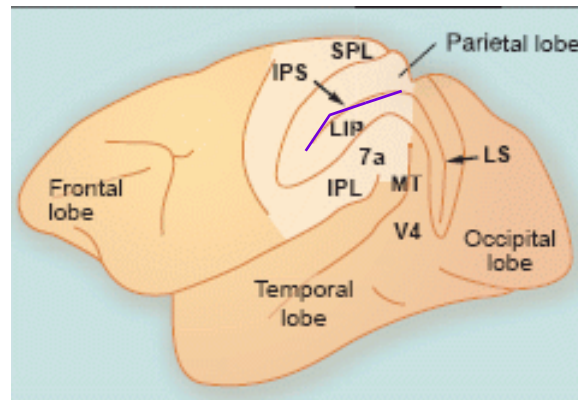
neurons that fire both when perceiving and performing action

### **Premotor neurons**

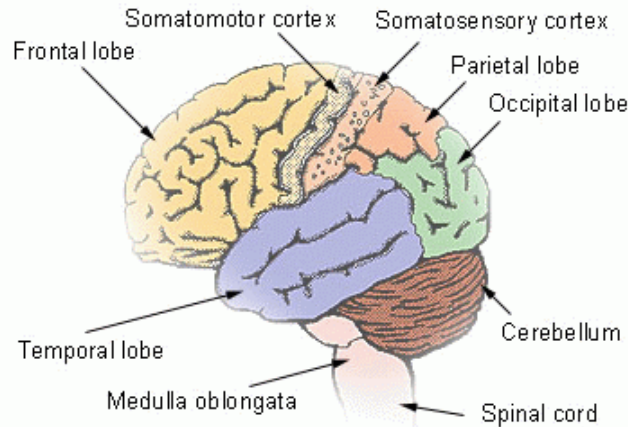
neurons that fire both when perceiving tool and using tool



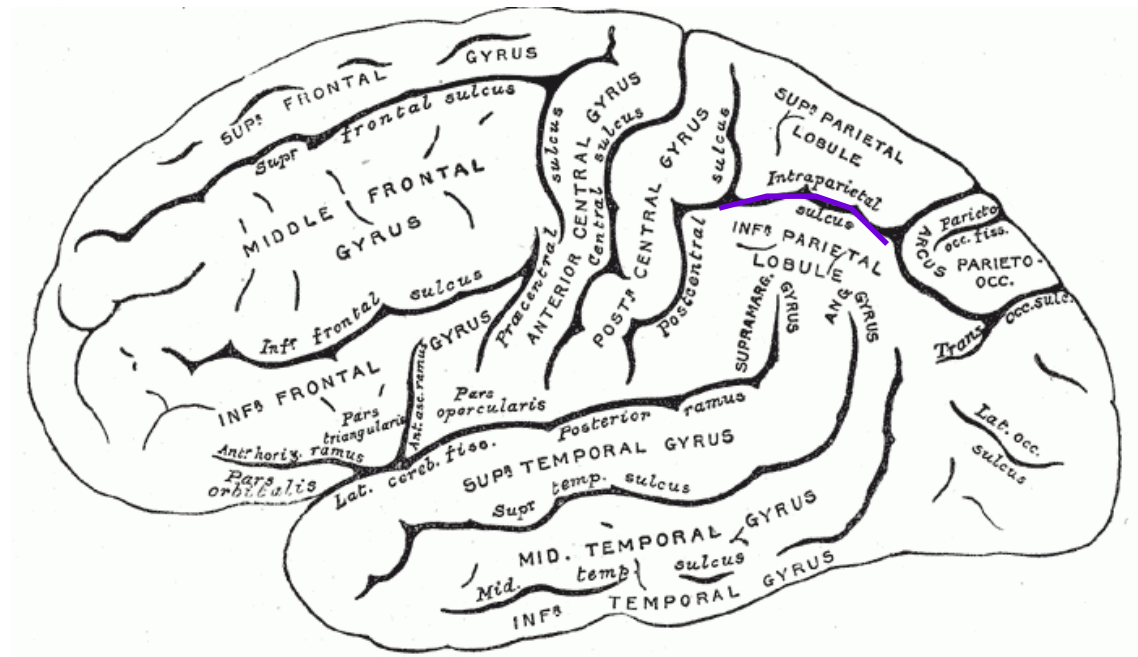
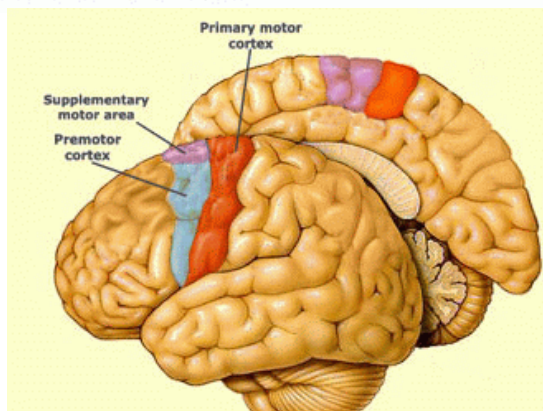
# Intraparietal Cortex



LIP: lateral intraparietal  
 IPS: intraparietal sulcus  
 SPL: superior parietal lobule  
 IPL: inferior parietal lobule  
 7a, MT: motion areas



**Lobes of the cerebrum**



# Intraparietal Cortex

## LIP

priority map

control of eye movements

integrating noisy sensory information over time relevant to choice (eye mvts)

## IPS

visual and somatosensory inputs

recovery of 3D structure (surface orientation) from stereo, texture cues, and motion

Posterior: coordinate transforms of space following saccades

Anterior: multimodal representations of the body and peripersonal space [space surrounding the body which can be reached by limbs], used for sensorimotor transformations [movement planning -- reaching, grasping]

visual information represented in hand-centered coordinates, not retinotopic coord.

neglect following IPS lesions: more pronounced near face than far

# Previous Work (Iriki et al.)

## recording from IPS neurons

visual and somatosensory receptive fields around hand (as determined by touch, moving visual stimulus)

## Rake used to retrieve a distant object

### “Tool assimilated to the hand”

neurons responded to visual stimulus along tool

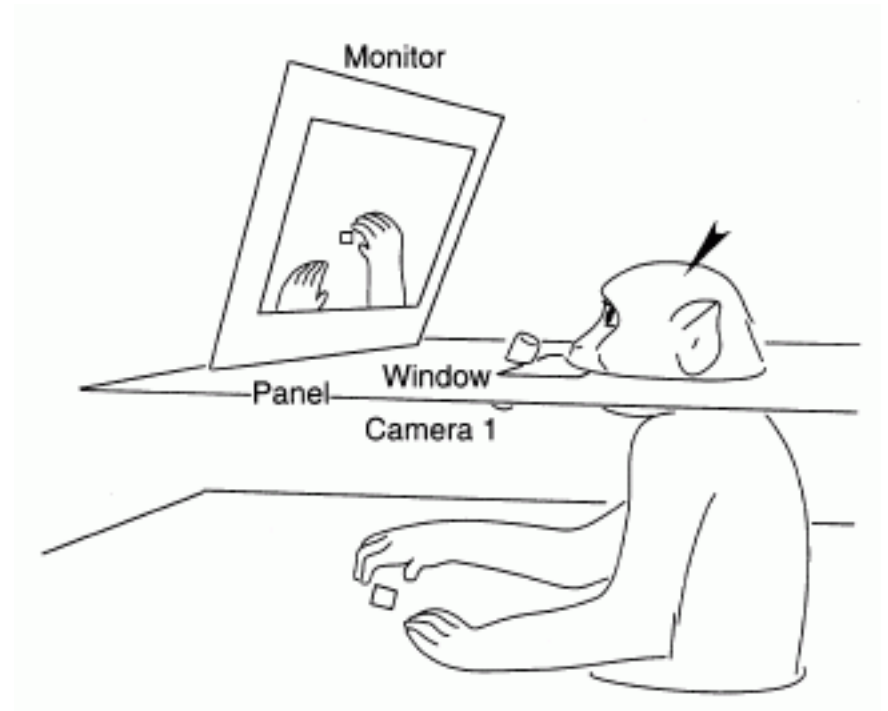
## No change in receptive field when tool was simply held in hand

# Iriki et al. (2001)

## Monkeys trained to retrieve food by watching their hand movements through a real-time video monitor

Also could view directly through window during first stage of training.

Training included use of rake to prevent monkey from groping for food, and to aid self recognition.



## Question

Will the visual receptive field (VRF) of neurons that ordinarily respond around hand be projected onto the video screen?

I.e., Will video image of hand be treated as extension of the self?

# Response to Self Image in Monitor

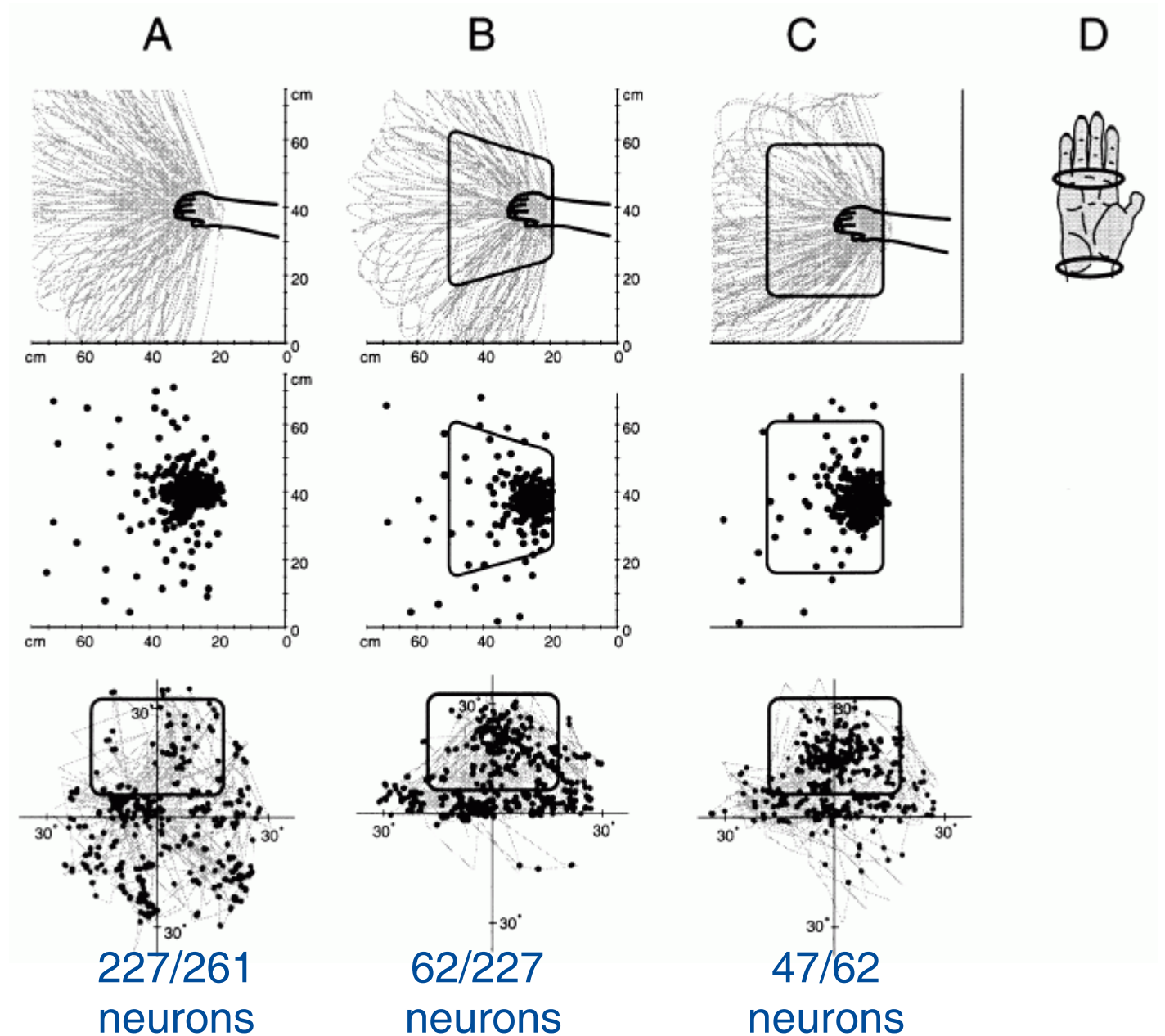
A: direct viewing

B: viewing on monitor, with visual probe presented near hand

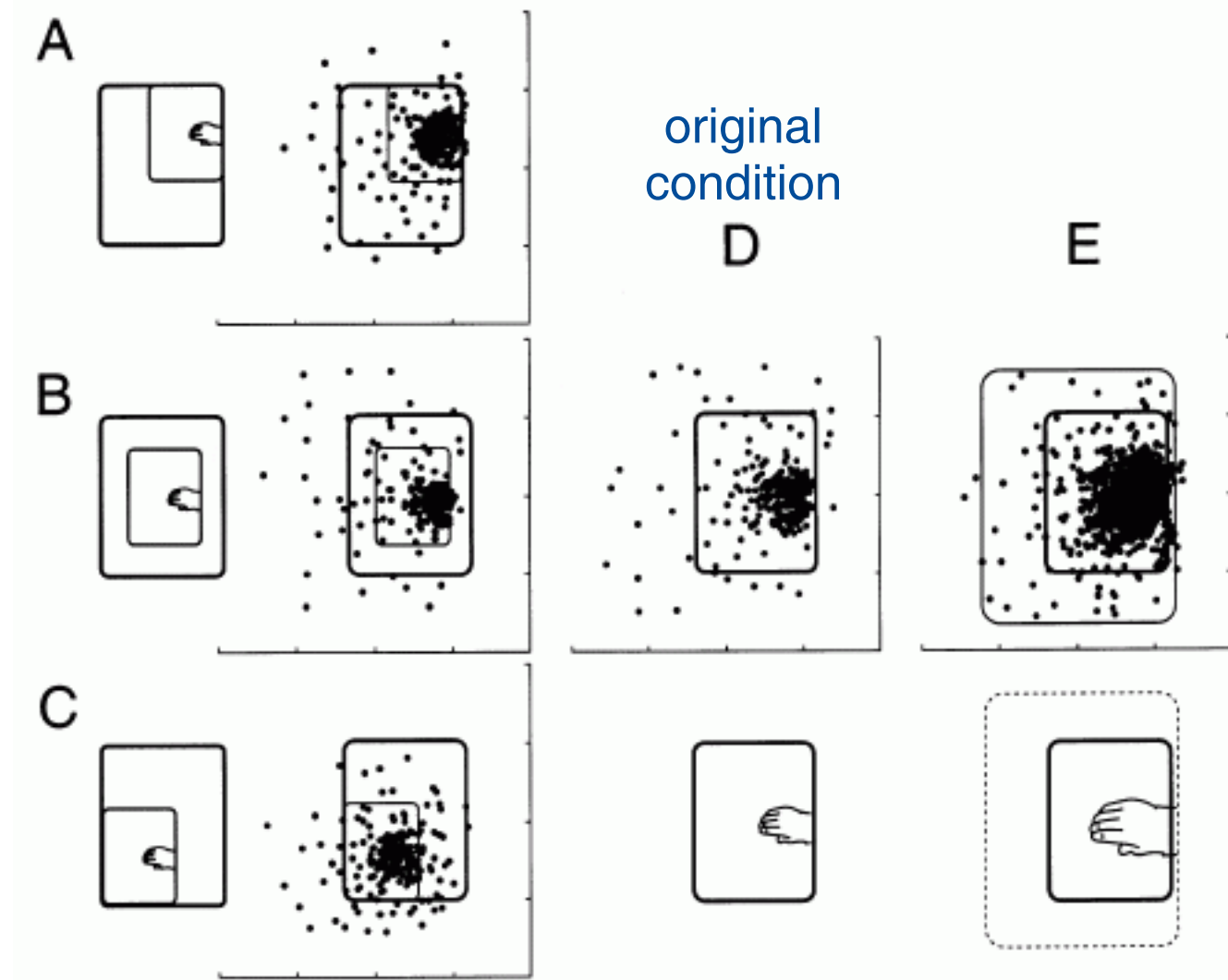
C: viewing on monitor, with visual probe superimposed on monitor using chromakey effect

exclude possible artifact of monkey sensing approaching probe

D: somatosensory RF



# Scaling and Translation Invariance

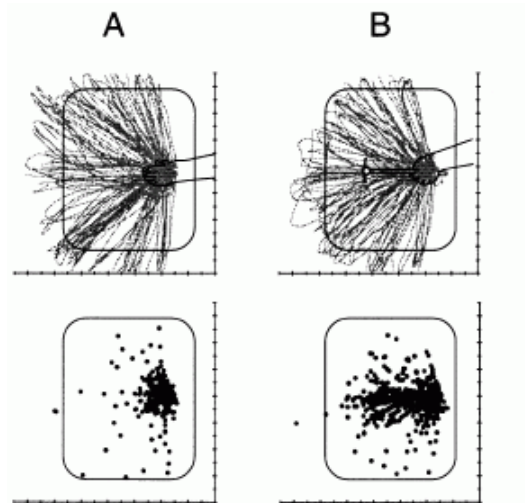


**Further evidence that retinotopic coordinates transformed into hand/body centered coordinates**

# Use of Tool to Retrieve Food

**As in earlier study, visual RF of neurons extended to include handheld tool.**

Phenomenon happens when tool is viewed through video monitor as well.  
A - hand alone; B - hand with tool in place.



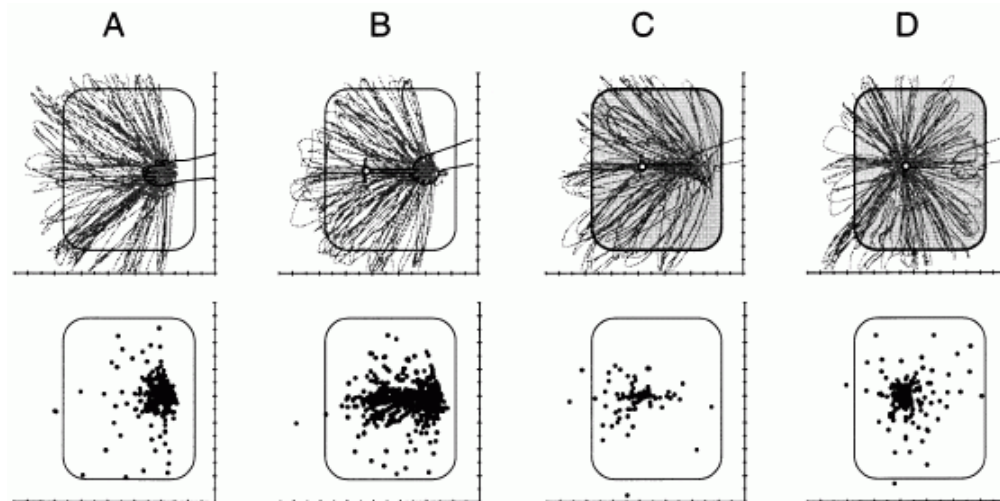
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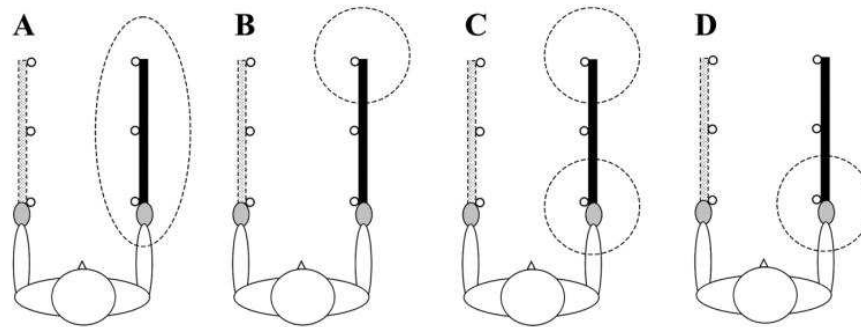
**When image of tool erased except for bright spot at end (like a cursor), only tip of tool yielded most activity.**

C - probe moved toward hand; D - probe moved toward tip  
Neural activity only when movement of spot coincident with movement of tool.  
=> Cursor functionally substitutes for hand





# How Does Tool Extend Boundaries of Peripersonal Space? (Holmes, Calvert & Spence, 2004)



(A) tool use extends peripersonal space

(B) visual receptive fields around the hands are projected to the tips of tools

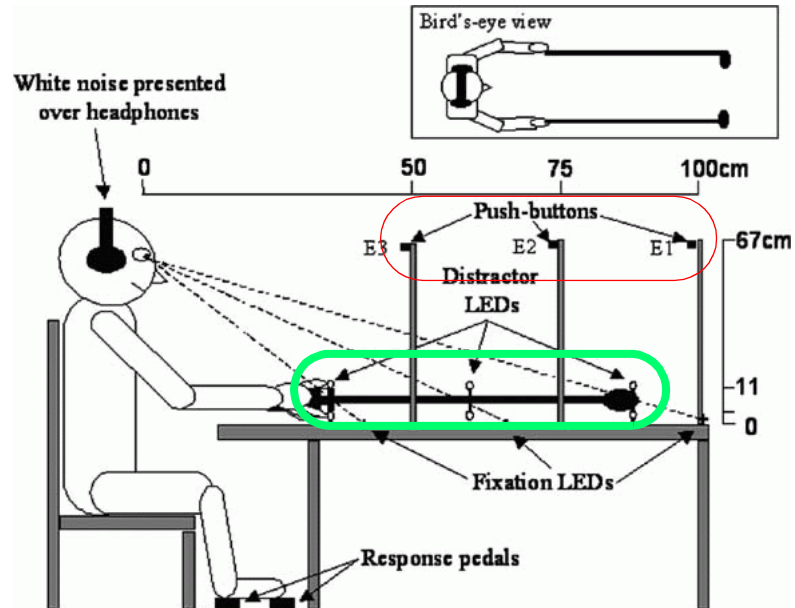
(C) new visual receptive fields form around the tips of tools, and the original receptive fields near the hands remain unchanged

(D) tool use has no effect on visual receptive fields of bimodal neurons

**Hypotheses A-C are equally compatible with most studies.**

Iriki expt seems to suggest B; can we get confirmation in humans?

# Human behavioral study



Primary task: discriminate elevation of vibrotactile stimuli presented to either thumb (upper) or forefinger (lower) of each hand

Visual distractors presented at one of three distances and two elevations.

Visual distractor is congruent or incongruent (same or different elevation).

Amount of interference from incongruent distractor tells us whether the location in space of distractor is being represented by subject.

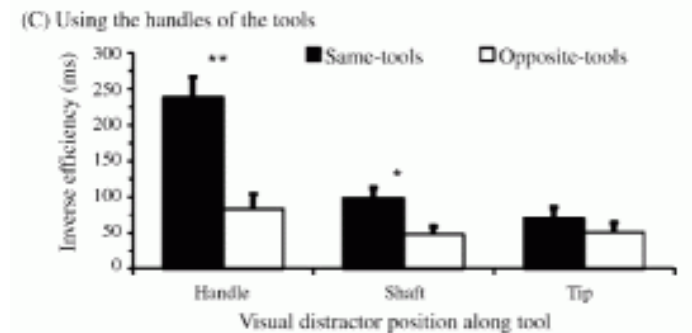
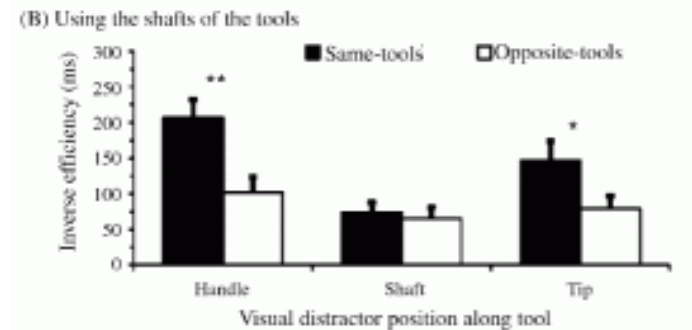
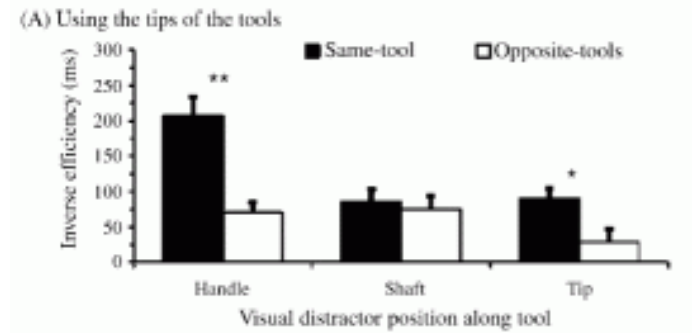
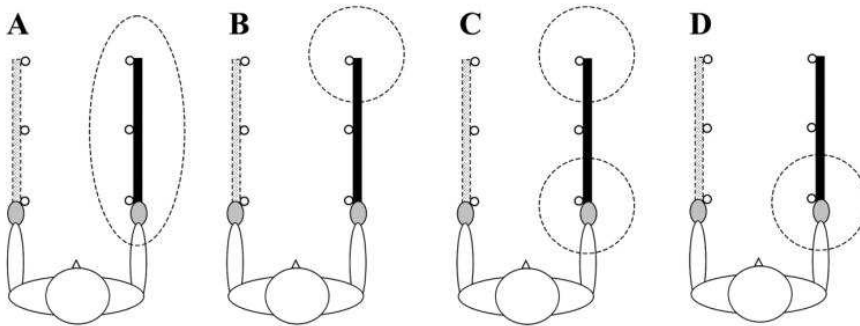
One tool held in each hand.

Occasional task required using handle, shaft, or tip of tool to press buttons.

# Result

When task required using the shafts or tips, evidence for (C).

When task required using just the handle, evidence for (D).



# Conclusion

Tools don't just extend peripersonal space, but only the tips of tools actively manipulated are incorporated into the brain's representation of body and peripersonal space.

# Rubber Hand Illusion (Armel & Ramachandran)

## Experiment

Subject seated in front of rubber hand.

Their own hand obscured from view.

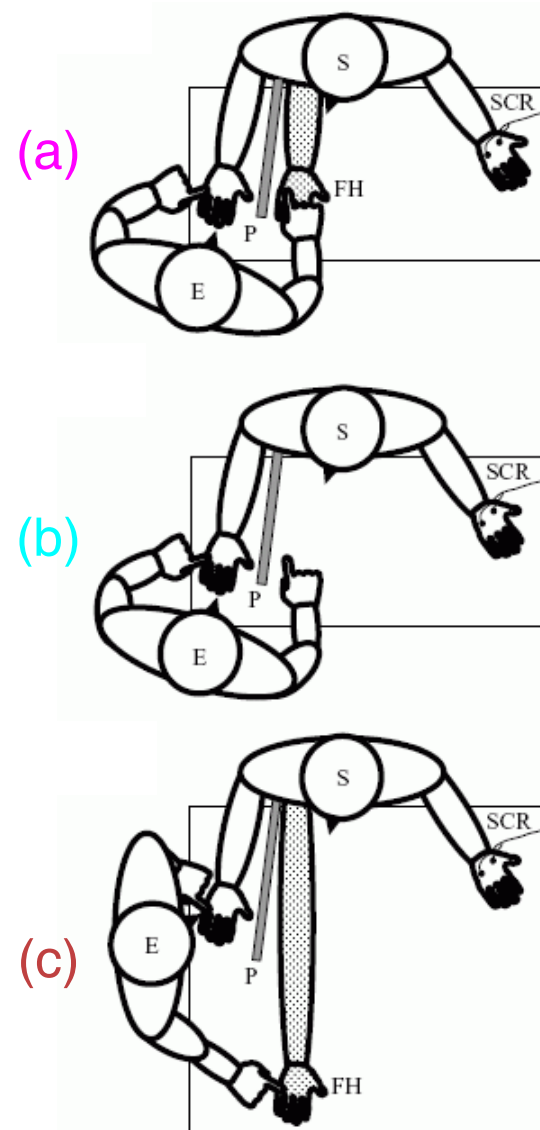
Rubber & real hands stroked or repeatedly tapped in synchrony (2-3 min).

After conditioning, rubber hand is 'injured'.

## Results

Intensity rating and skin conduction response is higher

- when rubber hand is present — (a) vs. (b)
- when there is synchrony
- when real hand is not visible (easier to assimilate rubber hand into one's body image).
- when hand is the right size — (a) vs. (c) — but illusion still present for (c)



“The illusion was very vivid for many subjects as evidenced by remarks such as, ‘wow’, ‘that was bizarre’ or ‘oh my God!’ Some subjects reported that the illusion was so convincing that they found themselves wondering why their hand was so white or how they had bruised their hand (there was a small ink smudge on the fake hand). Furthermore, during pilot work many subjects behaved as if they anticipated pain when the rubber finger was bent back: they laughed nervously, widely opened their eyes, flinched, and even pulled their real hand away from the experimenter (sufficient instruction prevented subject noise and movement during the experiments reported here). Two out of 120 study and pilot subjects even reported *feeling* pain when the fake finger was bent back.”

<http://www.stanford.edu/~kcarmel/papers/HandIllusion.pdf>

# Discussion

**Visual response to self image in video monitor occurs only after extensive training.**

Self recognition via markings, digitally superimposed snakes

**Immediately after monkey recognizes self image in monitor, neurons with RFs around the screen image formed.**

**Does our brain consider tools and icons to be extensions of our body?**

YES!

