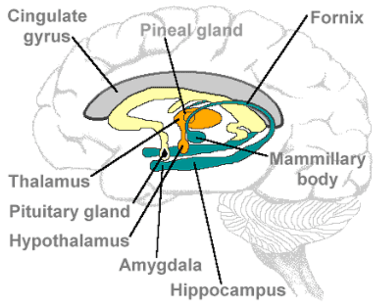
Plasticity: Learning and Long-Term Memory

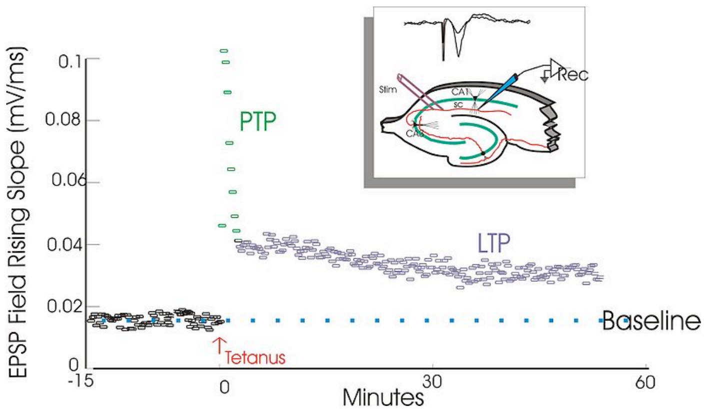
Declarative Memory and the Hippocampus

- Declarative : memory of facts; textbook learning and knowledge (semantic memory) or knowledge about personal experience in a specific time and place (episodic).

- Medio-temporal lobe. in particular, Hippocampus.
- patient H.M.
- Alzheimer's disease
- Stress



http://www.youtube.com/watch?v=Yrl8ibsiiZ4



- Memory associated with long-term changes in strength of synapses
- Such changes have been observed (LTP, LTD)

Procedural Memory : distributed

- long-term memory of skills and procedures, or "how to" knowledge, e.g. riding a bike, playing the piano, dancing tango

- In different parts of the brain; Independent from declarative memory; distributed.

- not well understood

Procedural memory : Practice makes perfect

- Learning means wiring your brain differently, changing strength of connections (LTP, LTD).

- The more you train (and the more complex the task) the wider the changes: the brain of experts is different ...

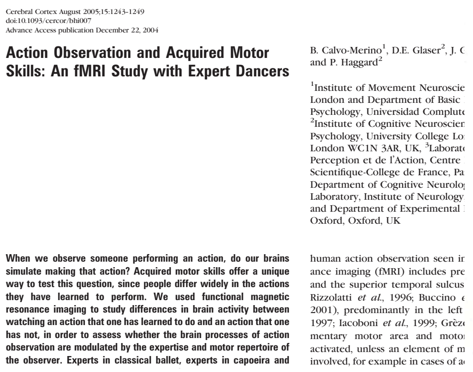
- Plasticity of sensory systems is greater in critical period during development, but it is not limited to it, also in adult.

The Brain of Musicians as a model of plasticity

- altered motor and sensori-motor maps dependent on instrument
- increased inter-hemispheric processing -- coordinate sensori-motor processing across the effectors

- Changes in auditory processing
- listening induces responses in M1.
- Visio- spatial processing

Dancers too.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Action Observation and Acquired Motor Skills: An fMRI Study with Expert Dancers

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When we observe someone performing an action, do our brains simulate making that action? Acquired motor skills offer a unique way to test this question, since people differ widely in the actions they have learned to perform. We used functional magnetic resonance imaging to study differences in brain activity between watching an action that one has learned to do and an action that one has not, in order to assess whether the brain processes of action observation are modulated by the expertise and motor repertoire of the observer. Experts in classical ballet, experts in capoeira and

human action observation seen in
ance imaging (fMRI) includes pre
and the superior temporal sulcus
Rizzolatti *et al.*, 1996; Buccino
2001), predominantly in the left
1997; Iacoboni *et al.*, 1999; Grèze
mentary motor area and moto
activated, unless an element of m
involved, for example in cases of a

- e.g. watching steps of your dance style will activate premotor system (mirror neurons)

Video-Games make you perfect

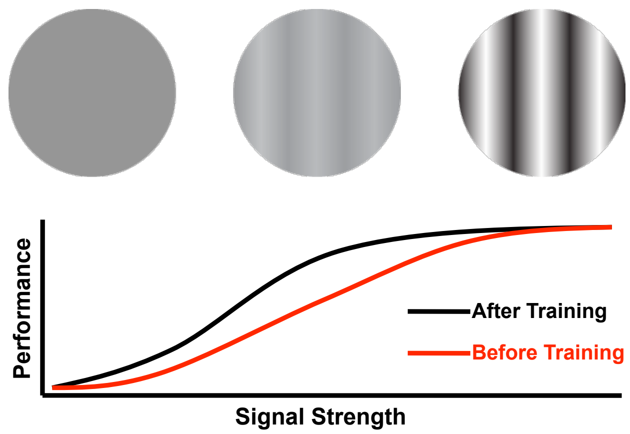
- Daphne Bavelier and others show that action video games training lead to
1) increase attentional performances
2) increase constrast sensitivity.

- Green & Bavelier, Nature 2003.

Perceptual Learning

idea: study training for a very simple sensory task, so as to understand mechanisms of learning.

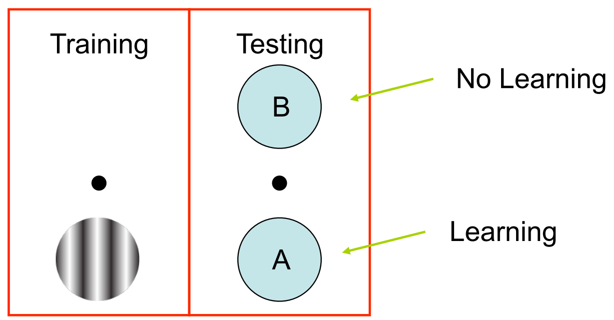
Contrast detection



(Adini et al., 2002; Fiorentini & Berardi, 1980; Furmanski et al., 2004; Rainer et al., 2004; and others . . .)

Perceptual learning leads to specific performance improvements

- Plasticity of sensory systems is greater in critical period during development, but it is not limited to it.
- In the adult, Practice leads to improvement in performance on a variety of simple sensory tasks, e.g. contrast detection, orientation discrimination, direction discrimination, vernier acuity, bisection task.
- Improvements are often very specific to the trained configuration.

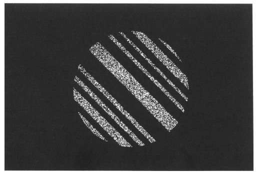


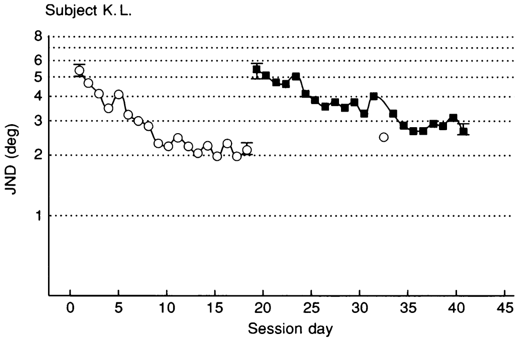
(Fiorentini & Berardi, 1980; Fahle & Edelman, 1995; Watanabe et al, 2002; and others . . .)

Example 1: Orientation discrimination

- Learning of Orientation discrimination leads to dramatic improvements. [Schoups et al, 1995]

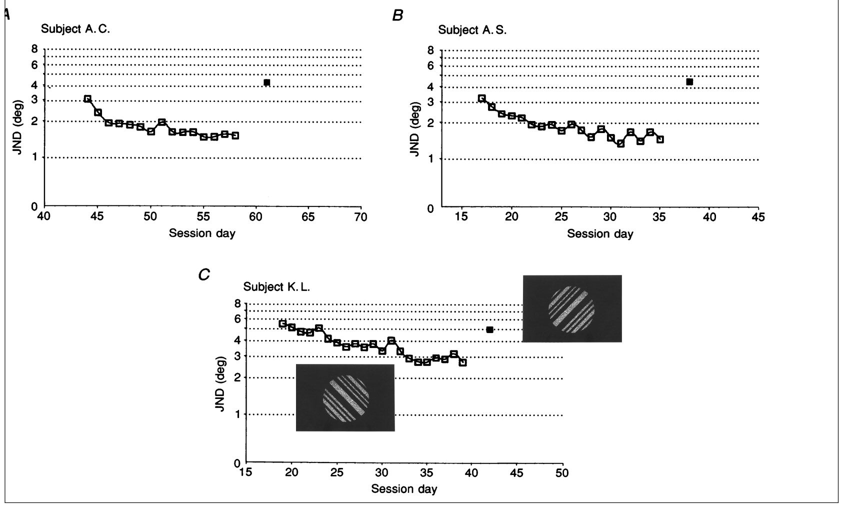
- Learning is precisely specific to position





Example : Orientation discrimination

- PL in orientation discrimination is specific to the trained orientation.

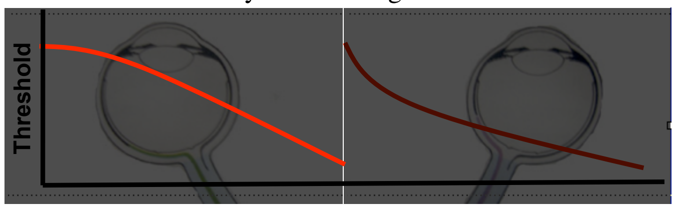


Other types of specificity

Configuration

Orientation

Eye of Training



(Gilbert, 2001; McKee & Westhei ner, 1978; Poggio et al., 1992; Seitz et al., 2005; and others . . .)

So perceptual learning must lead to changes in the brain,

Where? Which?

Neural Basis of Perceptual Learning

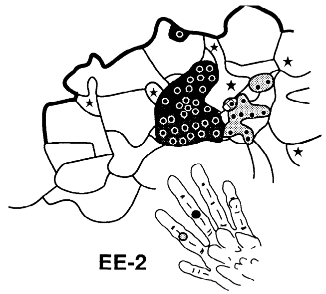
• Specificity of Learning suggests that learning takes place in early sensory cortex, where neurons have such specificity.

• The simplest assumption is that the neural representation (of e.g. orientation, direction) in early sensory cortex (e.g. V1) is changing during learning.

• Electrophysiological studies in awake monkeys to test this hypothesis in auditory and somatosensory cortex (Recanzone et al 1992), and visual cortex MT(Zohary et al 1994), V1 (Schoups et al, 2000, Ghose et al 2001) and V4 (Raiguel et al 2006, Yang & Maunsell 2004)

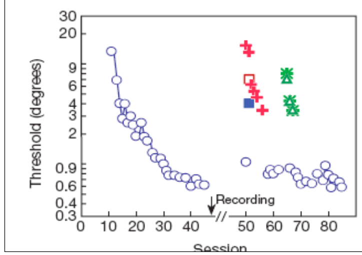
Plasticity in somato-sensory, motor and auditory cortex

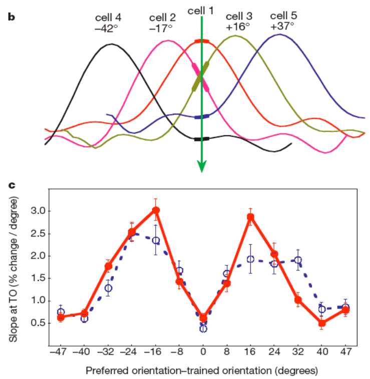
• Monkey trained to discriminate the frequency of tactile vibrations applied on the finger show increase in topographic representation of the part of the hand that was stimulated in somatosensory area 3B.
• Similarly, monkeys trained to discriminate tone frequencies show increase in tonotopic representation in A1 for trained frequency (Recanzone et al, 1993).



Orientation discrimination : Perceptual Learning in V1 ?

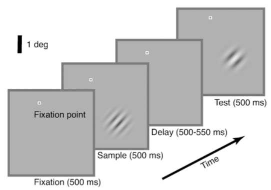
• Changes are controversial in V1
• Schoups et al (2001) found an increase in the slopes of neurons with flanks at the trained orientation.
• Ghose et al (2002) found no change.
• Difference might be in level of difficulty of the task



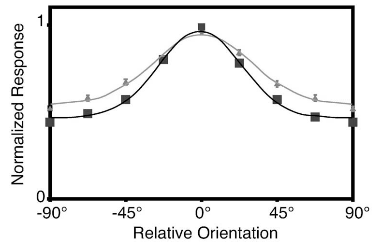


Orientation discrimination : Perceptual Learning in V4 ?

• Changes are more pronounced in V4 than V1, but still modest.
• Yang and Maunsell, 2004 in V4 : neurons with preferred orientations close to the trained range had stronger response and narrower tuning curves after learning.
• Raiguel et al, 2006, argue on the contrary neurons with flanks at trained range increase their slope after learning.

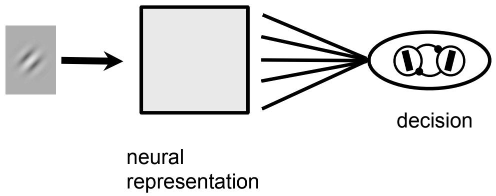


Yang and Maunsell, 2004

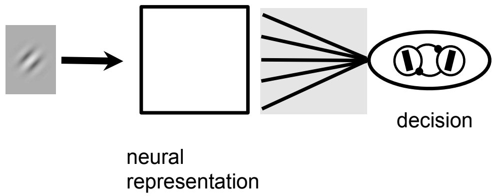


An alternative hypothesis: learning is in the ‘read-out’

• learning changes the neural representation

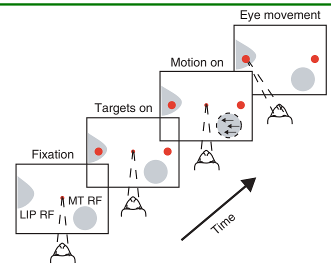


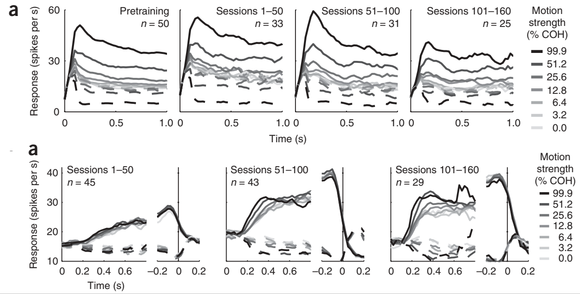
• learning changes the read-out, a.k.a `selective reweighting’



Learning of the ‘decoder’: Physiological evidence

• Law and Gold, *Nat Neuro* (2008): ‘neural correlates of perceptual learning in a sensori-motor (LIP), but not a sensory (MT), cortical area.





Summary

• Studying perceptual learning to understand plasticity in adult.

• Perceptual learning leads to dramatic improvements in detection and discrimination task (e.g. orientation discrimination, often 2-3 fold).

• Learning is often very specific to trained configuration (position, orientation etc..) which suggests that learning can take place in ‘early’ visual processing areas.

• Electrophysiological recordings in V1 and V4 find some changes in tuning curves (sharpening) after learning, but probably too modest to explain behavioral improvements.

• One possibility is that learning affects not only the ‘neural representation’ but also the ‘read-out’.

Research topics

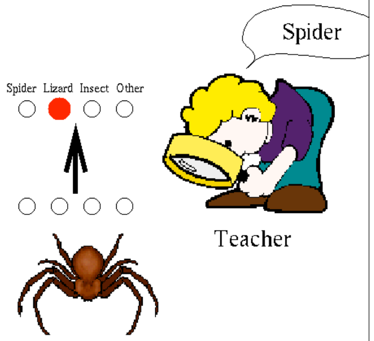
Mechanisms of learning ?

• How does the brain ‘know’ which neurons/ connections to change? how to change them ?

• What are the signals that control/guide learning? (attention? reward?)

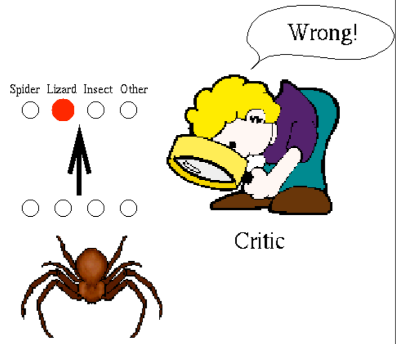
Models of Learning (1): Supervised Learning

- Teacher is provided.
- Training data consists in pairs (X,Y)
- System has to learn the mapping function.
- Learning = Minimization of 'error' computed at output (e.g. sq. error between obtained Y and desired Y), by modifying the components of the system (weights of the neural network).
- The error signal controls learning.
- After training, system can generalize to inputs close to learnt inputs.



Models of Learning (2): Reinforcement Learning

- Some reward is given following actions due to Y.
- The system learns to maximize the reward.
- Takes longer than supervised learning, but more biologically plausible.
- reward /reinforcement signal controls learning

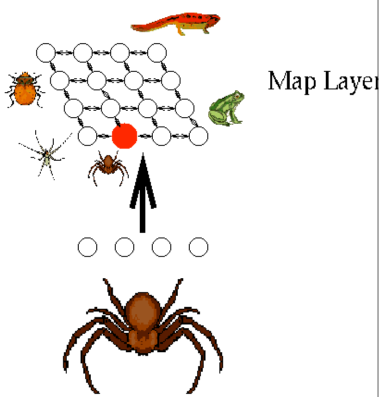


Models of Learning (3) : Unsupervised Learning

- Only X is given, and a cost function guiding the self-organization of the system
- internal criterion is used to guide learning.

- Optimize representation.

- Example : hebbian learning = learning is only dependent on level of activity of presynaptic and postsynaptic cells, models of development (e.g. maps)



- all forms of learning are supposed to exist in the brain

- reinforcement learning often thought to be the most widespread

- one reason for this is the discovery of dopamine neurons signaling expected reward in the VTA.