Perceptual Learning (2)

Readings:
Tsodyks and Gilbert, Neural networks and perceptual learning (2004)
Seitz and Watanabe, A unified model for perceptual learning (2005)

[Thanks to Aaron Seitz for many slides of this lecture]

Summary of last lecture

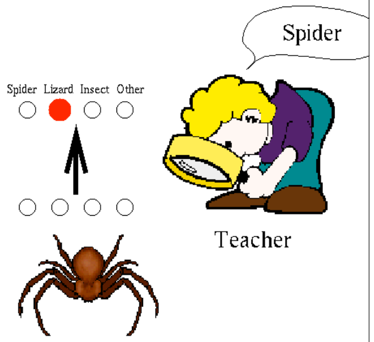
- Studying perceptual learning to understand plasticity in adult.
- Perceptual learning leads to dramatic improvements in detection and discrimination task (e.g. orientation discrimination, often 2-3 fold).
- Learning is often very specific to trained configuration (position, orientation etc..) which 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'.

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?

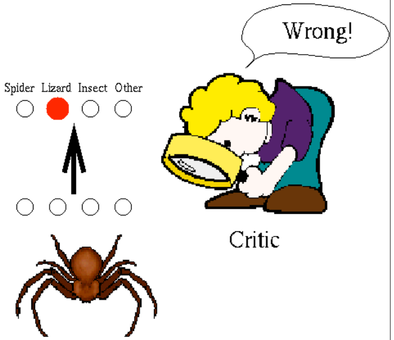
Models of Learning : Supervised Learning

- 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: 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

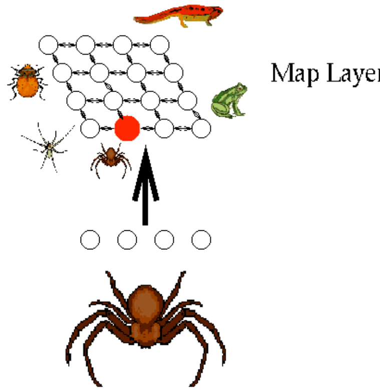


Models of Learning : Unsupervised Learning

• 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)



Learning hypotheses

• Passive learning.
Learning is just controlled by statistics of the world.
'Bottom-up'. Prediction: some task transfer

• Task-related Learning.
Learning is related to the task. Some top-down signal is needed, possibly about neural representations relevant to the task ('tag'), and/or level of performance / error / reward (supervised- reinforcement).
Prediction: no task transfer.

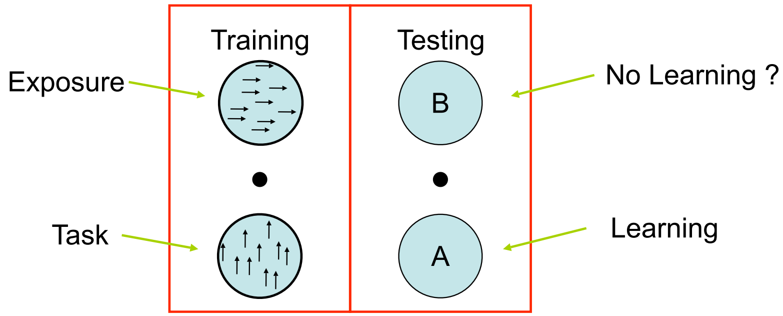
• Attention 'selects'/'tags' the appropriate neural representation/ networks ?
prediction: no learning if stimulus unattended or not perceived.

Does feedback guide learning ?

• Giving feedback during training // supervised - reinforcement learning.
• Numerous of report of successful learning in absence of feedback, specially in easy tasks (e.g. Shiu and Pashler, 1992).
• but feedback often facilitates / accelerates learning in some tasks (Herzog & Fahle, 1997)
• Block feedback (percentage correct after eg 80 trials) is as effective as trial by trial feedback (Herzog & Fahle, 1997)
• Incorrect feedback slows learning (Herzog and Fahle, 1997).

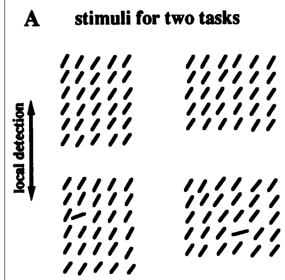
• suggests that learrning doesn't rely on a 'teacher signal'.
However, feedback can be used when present, in a complex way.

Is attention selecting locus of change ?



Ahissar & Hochstein, 1993; Karni & Sagi, 1995; Shiu & Pashler, 1992; and others . . .

Attention selects what is learnt



✳Vertical or Horizontal?

✳is there an odd element?

[Ahissar and Hochstein , 1993]

- Same stimulus -- different tasks
- no transfer
- A&H propose that attention selects which aspects of the neural representation are learnt.
- Similarly Shiu & Pashler 1992 (contrast vs orientation discrimination of line)

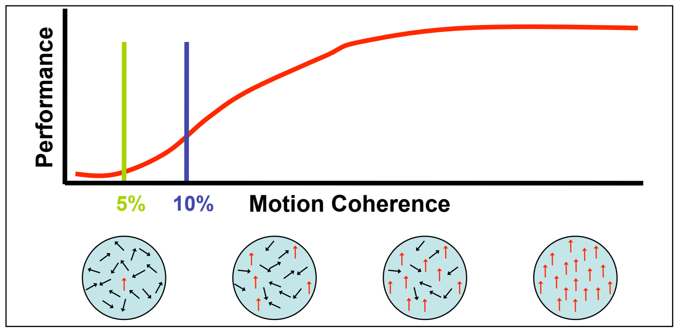
Watanabe & Seitz: Attention really needed ?

How to study exo-attentional learning?

1) Use a distracting task - requires subjects to "attend" away from training stimulus

2) Use a subliminal stimulus - subjects cannot attend to it even if they try

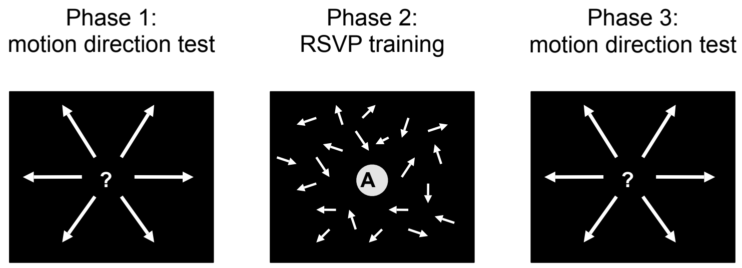
Subliminal motion



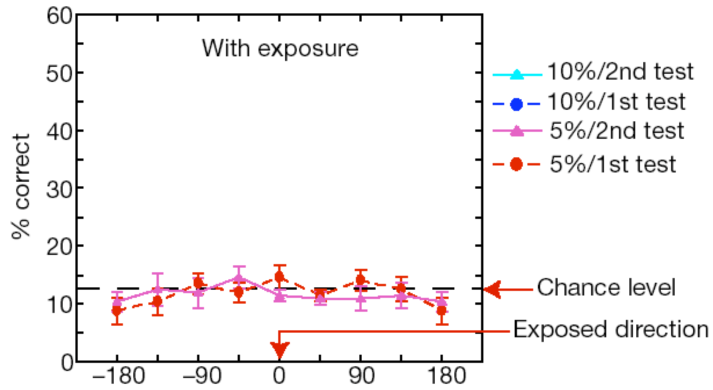
5% coherence - subliminal, used for training

10% coherence - supraliminal, used for testing

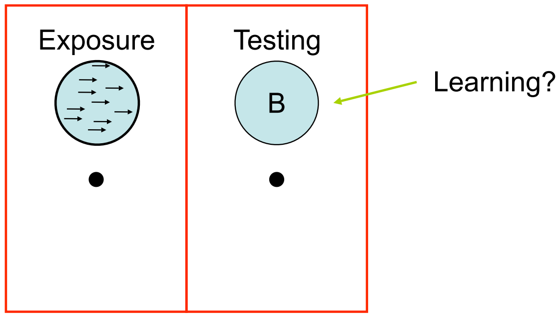
Experimental Design



Watanabe et al, *Nature*, 2001



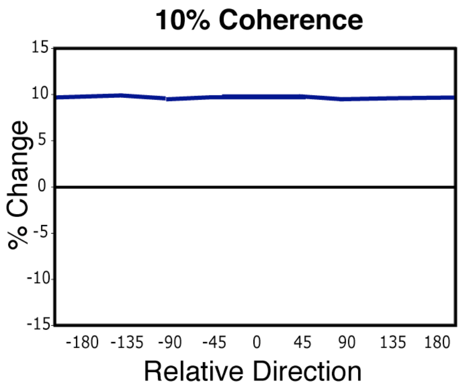
Passive Perceptual Learning ?



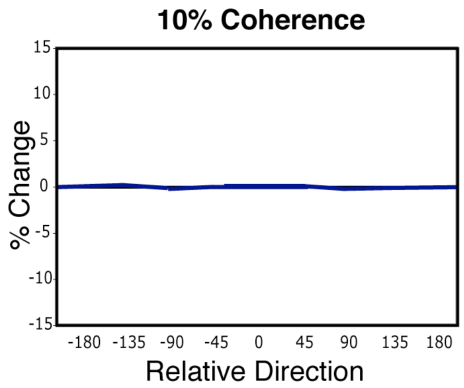
Fiser & Aslin 2001, 2002; Watanabe et al 2001, 2002

Seitz and Watanabe, 2003

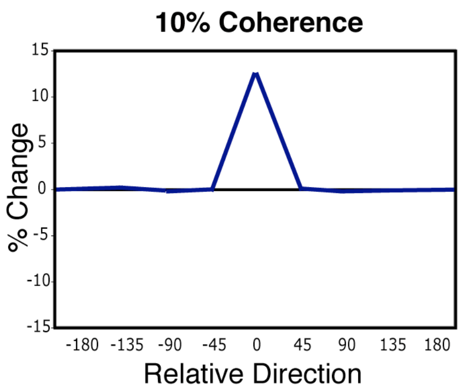
Passive Learning Prediction



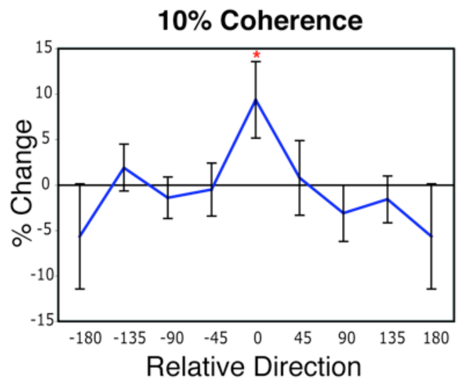
Specific Attention Prediction



Reinforcement Learning Prediction



Results



Main effect ($p<.01$, ANOVA test)

($p<.01$, t-test vs. other directions)

Adapted from Seitz & Watanabe, Nature 2003

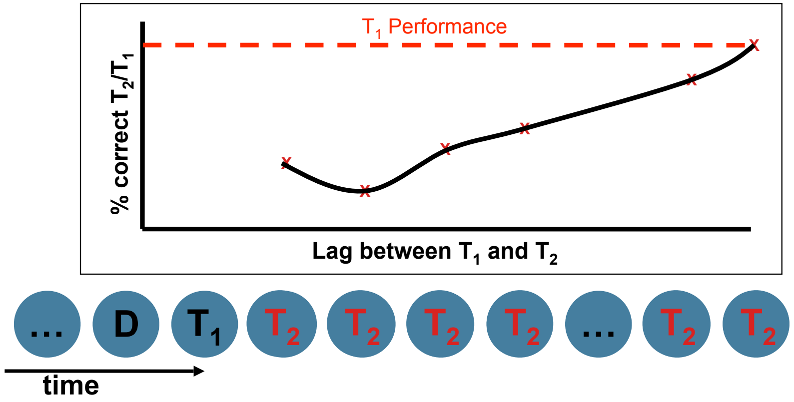
Summary of Watanabe 2001 & Seitz and Watanabe, 2003

- Learning found for subliminal feature
- only when paired with the task target

- Results are at odds with both the specific attention and passive learning hypotheses.
- Reinforcement learning hypothesis supported : successful recognition of target evokes an alertness or internal reward signal that triggers plasticity of simultaneously presented features.

Attentional Blink

An imbalance in identification-accuracy of two masked targets presented in rapid succession.

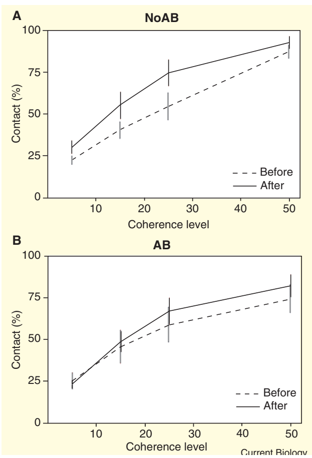


Perceptual Learning also Blinks

- Subliminal motion is paired with T2 and presented in or out the attentional blink, while subjects do the RSVP task.

- When motion is in the attentional blink, no clear performance change is observed.

- consistent with the idea that succesful recognition of target is necessary for learning of paired motion to occur / 'internal reward to be released'



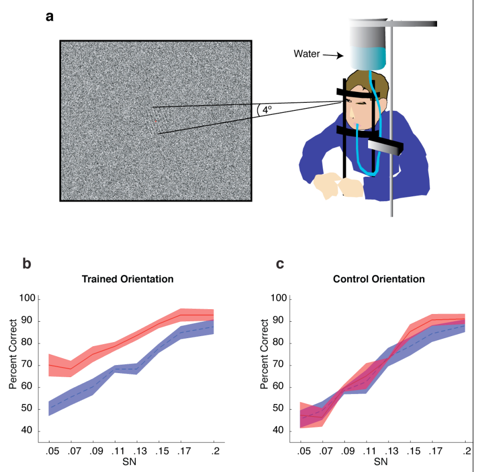
Seitz et al, 2005.

reward in absence of task nor awareness

- juice rewards to humans !

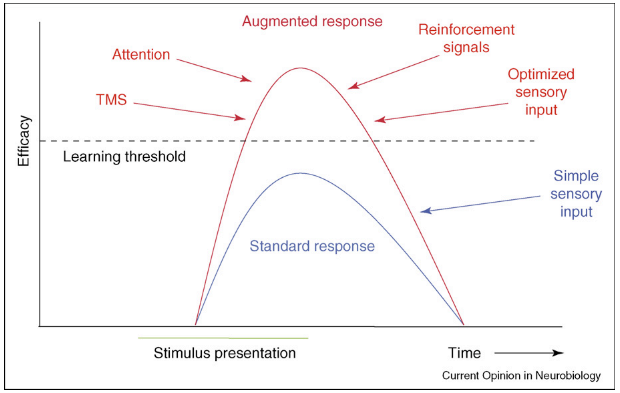
- no task - drop of juice is paired with one orientation, visible (exp 1) or made invisible using continuous flash suppression (exp 2)

- shows that reward, in absence of any task or awareness, is sufficient to cause visual learning



Seitz et al, SFN, 2007.

Current Picture



'common learning mechanism involves Hebbian learning process gated by neuromodulatory signals (e.g. acetylcholine and dopamine) that are activated both in attentional and reinforcement paradigms'

Seitz and Dinse 2007

Models needed !

- Huge amount of psychophysical data.
- Recently, physiological data.

- Simple models based on assumptions /
• neural representation vs read-out learning
• learning schemes: e.g. hebbian vs gated by reinforcement signals

- can make clear predictions about:
•stimulus transfer, task transfer, deterioration, biases in absence of signals
- provide framework to relate learning with neural coding / information transmission

ideally, help construct experiments that will disentangle all current hypotheses.