Learning
What you see is what you learn

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1 To Learn or Not To Learn
   • Variations on Learning
   • When, What, Where

2 Special Case for Hyperacuity
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Variations on Learning

"Relatively Permanent Change Of Perception/Behavior caused by previous Experience/Training"

- Relatively Permanent Change
  - Habituation, Sensitization...

- Priming...

- Change of Behavior/Perception
  - Positive:
  - Negative:

- caused by Experience/Training
  - Motivation, Attention: Relevance of the Task for the Organism
  - Acquisition Speed: Task Difficulty, Available Feedback
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Variations on Learning II

An Important Distinction:

- Explicit, Declarative:
- Implicit, Procedural:
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An Important Distinction:

- Explicit, Declarative: "I know he is a bad guy because his wears a beard like Osama"

- Implicit, Procedural:
An Important Distinction:

- Explicit, Declarative: Accessible, Verbalizable, Communicable Features
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- Explicit, Declarative: Accessible, Verbalizable, Communicable Features
- Implicit, Procedural: "No idea why, but i know this girl is the right one."
Variations on Learning II

An Important Distinction:

- Explicit, Declarative: Accessible, Verbalizable, Communicable Features
- Implicit, Procedural: Non-Accessible, Non-Verbalizable, Non-Communicable Features
Variations on Learning II

An Important Distinction:

- Explicit, Declarative: Accessible, Verbalizable, Communicable Features
- Implicit, Procedural: "Automatic", Consciously not Accessible Modification
When To Learn

Ready, Steady - Learn?

- **General Prerequisites: Arousal, Motivation.**
- Passive Learning: Simple Exposure to Stimuli Enough to Trigger Learning?
- Active Learning: If Reacting while exposure, what are the conditions to trigger learning?
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- **Learn Now:** A Global Signal? Which Neuromodulatory Systems Involved (Ach, DA, NA,...)
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Choosing what aspects are relevant according to task and situation.

- **Task Relevancy: Focusing only on task relevant stimuli?**
- **Selection Process: Link to Attentional Mechanisms?**
- **Generalization: What Determines Grade Of Transfer to Other Tasks or Situations?**
What to Learn

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What to Learn

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Where to Learn

Plasticity is potentially given on many stages of processing.

- **Locus Of Learning**: Early, Middle, Late Stage or All Together?
- **Gating Learning**: Restricting Modifications to Certain Sites
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- **Locus Of Learning:** Early, Middle, Late Stage or All Together?
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Visual Acuity

Measurement of Spatial Resolution of The Eye Apparatus
Visus = 1 / \( \alpha \)  
\( \alpha = \text{minimal detected Angle of Vision in Angle Minutes} \)

Visus Identification with Landolt-Ring

Vernier Acuity
\( \alpha = 10'' \quad (1/360°) \)
\( d' \sim 0.5 \text{ (!) } \mu m \)

maximal Resolution
\( \alpha = 1' (1/60°) \)
\( d' \sim 5 \mu m \)

foveal Cone Mosaic
\( x \sim 2.4 - 2.6 \mu m \)
Retinal Density

### Visual Acuity

- **Papilla nervi optici (blind spot)**
- **Photopic (Daylight)**
- **Scotopic (Twilight)**

### Receptor Density

- **Rhodes**
- **Cones**

### Graph Details

- **Visual Acuity (Minutes of Angle)^-1**
- **Receptor Density (1000/mm^2)**
- **Fovea**
Visual Acuity

Measurement of Spatial Resolution of The Eye Apparatus

- **Visual Acuity**: Inverse of The Maximal Measured Resolution (in Minutes of Visual Angle)
  - Normal Acuity: \( \frac{1}{\alpha} = 1.0 \), with \( \alpha = 1' \) (corresponds to \( 5\mu m \) distance on retina)
  - Retinal Mosaic: two cones in foveal area are approx. \( 2.4 - 2.6\mu m \) apart

- **Vernier Acuity**: Hyperacuity in Discrimination of Line Segment Shifts
  - Hyperacuity: \( \frac{1}{\alpha} = 6.0 \), with \( \alpha = 10'' \) (corresponds to \( 800nm \) distance on retina)
  - Training: Shift Detection Threshold can be substantially lowered (up to 5 times lower)
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Standard Stimuli

Landolt-Ring
Standard Stimuli

Vernier Lines
General Experiment Setting [Fahle, 2004]

Subjects exposed to series of Vernier Elements

- **Fixed Offset Sizes**
- Presented for 100 – 150 ms
- Active Exposure
  - Binary Forced-Choice Task: Press one of two buttons to indicate offset (left/right, up/down)
  - Without time pressure (optionally restricting reaction time to 5 s)
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Hyperacuity suffers Hyperspecificity

Rapid Learning, Well Persisting

- Improvement within only one hour of training
- Performance remains constant over night

However, Learning is highly specific to

- Trained Orientation: No Transfer to Other, even Slightly Deviating Orientations.
- Trained Position: No Transfer to Other Positions in Visual Field, Even if They are Neighboring.
- Trained Eye: No Transfer to Another Eye.
- Trained Task: No Transfer to Another, Similar Task.
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Figure: No Transfer To Another Orientation
Hyperacuity suffers Hyperspecificity

Figure: No Transfer To Another Position
Hyperacuity suffers Hyperspecificity

Figure: No Transfer To Another Eye
Attention and Feedback matter

Attention: choosing one task while suppressing another.

- Presenting two vernier tasks simultaneously: horizontal and vertical
- Improvement persists only for attended task: No Transfer by Switching although Stimulus Stays The Same

Feedback: None is Better than Wrong.

- No External Feedback: Improvement is there, but Learning significantly slower
- Partial Feedback: Providing Feedback on Half of Responses almost as Fast as Full Feedback.
- Uncorrelated Feedback: Effectively Preventing Improvement.
- Block Feedback: As Useful As Normal Feedback, Uncorrelated Version Prevents Improvement, too
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**Figure:** No Transfer To Unattended Task
High and Low

Low-Level Modifications Under High-Level Control

- Specificity Of Improvements points on modifications of neuronal responses in early, primary areas.
- Influence of Feedback and Attention: Hints for Modulation from Higher Areas.
- Hypothesis: Early Modification and Selection through Top-Down Control.
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Task Irrelevant Learning

- **Learning without focusing attention?**
  - Hypothesis on Proof: Only attended, task relevant stimuli are subject to learning.
  - Trick [Seitz and Watanabe, 2005]: use a *subliminal stimulus*, which is not only task irrelevant, but would not even cause a conscious perception.
  - Test for Improvement on *supraliminal stimulus* in comparison to performance before learning.
  - Presenting three types of stimuli: task relevant target and distractor together with subliminal, task irrelevant stimulus.

- **Stimulus:** Dynamic Random-Dot Displays (DRD), local coherent moving dots
  - Level Of Coherency: 5% is subliminal (detection at chance level), 10% is supraliminal (over change level)
Learning without focusing attention?

- Hypothesis on Proof: Only attended, task relevant stimuli are subject to learning.
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- Test for Improvement on supraliminal stimulus in comparison to performance before learning.
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  - Presenting three types of stimuli: task relevant target and distractor together with subliminal, task irrelevant stimulus.

- **Stimulus:** Dynamic Random-Dot Displays (DRD), local coherent moving dots
  - Level Of Coherency: 5% is subliminal (detection at chance level), 10% is supraliminal (over change level)
Learning without focusing attention?

- Hypothesis on Proof: Only attended, task relevant stimuli are subject to learning.
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Three Stages of Experiment [Seitz and Watanabe, 2005]

- **Pre-Test Stage**: Testing for Performance on sub- and supraliminal Stimulus
  - Present Sequence of Letters with subliminal dot motion in background, motion direction is the same along the sequence.
  - Targets are light gray letters, distractors are black letters.
  - At the end of the sequence, target letters have to be written down.

- **Exposure Stage**: Exposure to Task Together With Irrelevant Stimulus.

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(a) Test → Exposure → Test
5% and 10% coherent motion → 5% coherent motion → 5% and 10% coherent motion

(b) Exposure stage
Q: what are white letters?

(c) Test Stage
Q: which direction?

(d) Test Stage Results
% Correct vs. Relative motion direction (deg)
Passive Learning

Result

- **On Subliminal Coherence Level (5%):** No Changes Observed, Detection Still at Chance Level
- **On Supraliminal Coherence Level (10%):** Detection Performance is greatly improved for the used stimulus orientation
- Learning Effect Retained After Month Without Training
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Reinforcing the Irrelevance: Experiment
[Seitz and Watanabe, 2003]
Not Passive, Unspecific Active

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- Improvement Is Still Achieved...

- ... But Only On The Moving Direction Paired with The Targets.

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Alerting

Task-irrelevant learning

Target recognition

Task-relevant learning

Irrelevant feature

Task target

Orienting

To Learn or Not To Learn

Special Case for Hyperacuity

Quest For Relevancy

A Way To The Invariance

Never Ending Learning
Learning spreads to task-irrelevant stimuli via diffuse Alert Now signal

- Coincidence of diffuse alert signal and task-irrelevant stimulus required
- Potential Sources Of Alert Now Signals: numerous widely releasing neuromodulatory systems:
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Tracing For A Certain Feature over The Sequence [Foldiak, 1991]

- **Building A Trace Of Unit’s Activation:**
  \[ \tilde{y}_i(t) = (1 - \delta)\tilde{y}_i(t-1) + \delta y_i(t) \]

- Neurophysiological Mechanism: Self-sustained population activity, or concentration of activity-dependent substance in single cell.

- Learning According To Trace: \[ \Delta w_{ij}^{(t)} = \alpha \tilde{y}_i^{(t)}(x_j^{(t)} - w_{ij}^{(t)}) \]

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Assuming Object Identity Is Stable While It is Not [Cox et al., 2005]

- **Hypothesis**: visual system exploit the stability of object identity while saccading to its position.
- **Manipulation**: Replace The Object with Similar One During Temporary Blindness in Course Of Saccade.
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- Learning Process Involves Coherent Interplay Of Various Low- and High-Level Subsystems.

- Great Part of Perceptual Learning Is Implicit in Nature, it happens out of conscious awareness or access.

- Invariances are reflecting nature of environment, they may be not rigid and finalized, but continually evolving.

- Adapting To Changed Environment Conditions Can Happen Very Fast, If Changes Are Consistent Enough.
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Thank you for your attention, focused or diffuse!