Expertise, Millisecond by Millisecond

Tim Curran, University of Colorado Boulder
Expertise, Millisecond by Millisecond

1. Behavioral/Computational Time-Course Studies
   – Palmeri Lab (Vanderbilt)

2. Human EEG Studies
   – Tanaka (Victoria) & Curran (Colorado) Labs

3. Monkey Electrophysiology
   – Sheinberg Lab (Brown)
Expertise, Millisecond by Millisecond

1. Behavioral/Computational Time-Course Studies
   - Palmeri Lab (Vanderbilt)

2. Human EEG Studies
   - Tanaka (Victoria) & Curran (Colorado) Labs

3. Monkey Electrophysiology
   - Sheinberg Lab (Brown)
Basic-Level Advantage and Subordinate-Level Shift with Expertise

adapted from Tanaka & Taylor 1991 Cog Psy
Basic-Level Advantage and Subordinate-Level Shift with Expertise

adapted from Tanaka & Taylor 1991 Cog Psy
Exemplar Theories of Categorization

- Specific exemplars/instances of category members are stored.
- New things are categorized by comparison with all stored instances.

Exemplar theory

Memory
Novice Exemplar Representations

Birds
- Blue Bird
- Indigo Bunting

Dogs
- Yellow Lab
- Golden Retriever

"bird" vs. "Indigo Bunting" categorization level
- response time
- basic vs. subordinate

Novice
Novice Exemplar Representations

Birds

- Blue Bird
- Indigo Bunting

Dogs

- Yellow Lab
- Golden Retriever

Easy

Fast

Response time

Category level

“bird”

“Indigo Bunting”

Novice

Basic

Subordinate
Birds

Dogs

Novice Exemplar Representations

Hard

Slow

“bird”

“Indigo Bunting”

Novice
Birds

- Blue Bird
- Indigo Bunting

Novice Exemplar Representations

Dogs

- Yellow Lab
- Golden Retriever

Expert Exemplar Representations

- Blue Bird
- Indigo Bunting

High Memory Sensitivity

Low Memory Sensitivity

response time

categorization level

“bird”

“Indigo Bunting”

basic

subordinate

Novice

Expert
Same processes for both levels of categorization.
Separate Basic and Subordinate Level Processes

Novice:

low-level perception → basic-level (entry-level) categorization → subordinate categorization

“bird” → “Indigo Bunting”

fastest means first

Mack, Wong, Gauthier, Tanaka, & Palmeri 2009 JoV
Separate Basic and Subordinate Level Processes

Novice:

1. low-level perception
2. basic-level (entry-level) categorization
3. subordinate categorization

"bird"

"Indigo Bunting"

Expert:

1. low-level perception
2. expert entry-level for birds

"Indigo Bunting"

"bird"

"Indigo Bunting"

response time

Mack, Wong, Gauthier, Tanaka, & Palmeri 2009 JoV
Category Verification Task

Superordinate

Animal

Plant

Basic

Bird

Dog

Subordinate

Robin

Sparrow

YES  NO

YES  NO

Mack, Wong, Gauthier, Tanaka, & Palmeri 2009 JoV
Speeded Verification
(Response Signal Method)

Accuracy

Time Allowed for a Response

Mack, Wong, Gauthier, Tanaka, & Palmeri 2009 JoV
dynamics of categorizations decisions

Time Allowed for a Response

Categorization Accuracy

Novice:

- low-level perception
- basic-level (entry-level) categorization
- subordinate categorization

"bird"

"Indigo Bunting"
dynamics of categorizations decisions

Categorization Accuracy

chance

Novice:

low-level perception basic-level (entry-level) categorization subordinate categorization

"bird"

"Indigo Bunting"

Time Allowed for a Response
dynamics of categorizations decisions

Categorization Accuracy

Novice:

low-level perception → basic-level (entry-level) categorization → subordinate categorization

Time Allowed for a Response

"bird" "Indigo Bunting"

Mack, Wong, Gauthier, Tanaka, & Palmeri 2009 JoV
dynamics of categorizations decisions

Categorization Accuracy

Chance

basic

subordinate

Novice:

low-level perception → basic-level (entry-level) categorization → subordinate categorization

"bird"

"Indigo Bunting"

Time Allowed for a Response

Mack, Wong, Gauthier, Tanaka, & Palmeri 2009 JoV
dynamics of categorizations decisions

Categorization Accuracy

Time Allowed for a Response

Expert:

low-level perception

subordinate categorization

"Indigo Bunting"

basic

subordinate

chance

Mack, Wong, Gauthier, Tanaka, & Palmeri 2009 JoV
Novice Results
1. Behavioral/Computational Time-Course Studies
   - Palmeri Lab (Vanderbilt)

   - RT differences between basic and subordinate categorization may reflect differences in memory sensitivity rather than different stages of processing.
   - Subordinate-level shifts seen with expertise similarly can be explained as an increase in memory sensitivity rather than as bypassing a basic-level processing stage.
Expertise, Millisecond by Millisecond

1. **Behavioral/Computational Time-Course Studies**
   - Palmeri Lab (Vanderbilt)

2. **Human EEG Studies**
   - Tanaka (Victoria) & Curran (Colorado) Labs

3. **Monkey Electrophysiology**
   - Sheinberg Lab (Brown)
Neurons Produce Tiny Electrical Fields
Neurons Aligned within the Cortex Produce Summed Electrical Fields = Scalp EEG
EEG can be measured with Scalp Electrodes
Event-related potentials (ERPs)
Scalp ERPs

• Excellent Temporal Resolution
  – Milliseconds

• Poor Spatial Resolution
  - Anatomical sources difficult to localize.
The N170 is larger for faces compared to other objects categories (e.g. Bentin et al., 1996; Botzel et al., 1995; Eimer, 2000; Rossion et al., 2000)
What’s Special about Faces?

• Special face processing module(s)?
  (Kanwisher, Bentin)

• Greater identification experience with faces than other objects?
  – “perceptual expertise hypothesis”
    (Gauthier, Tarr, Tanaka)
Question

• Is N170 amplitude sensitive to differences in experience/expertise?
Expertise Effects on the N170

(Bird Experts vs. Dog Experts)

(Tanaka & Curran, 2001)
Perceptual Car Expertise

- Same/Different Judgments
- Same Trials are not physically identical.
  - Cars: Same Make/Model (different years, color, perspective)
  - Birds: Same Species (different exemplars)

Car Expertise Index:
\[ \Delta d' = d'_{\text{cars}} - d'_{\text{birds}} \]

Gauthier, Curran, Curby & Collins (2003)
N170 Correlates with Degree of Expertise

Gauthier, Curran, Curby & Collins (2003)
Expertise, Millisecond by Millisecond

2. Human EEG Studies
   - Tanaka (Victoria) & Curran (Colorado) Labs
   - The N170 is sensitive to visual expertise, and does not just reflect a face-specific mechanism.
   - Changes in N170 amplitude with expertise are consistent with changes in the underlying representations whereas the fastest means first hypothesis might predict N170 timing differences between expert and novice conditions that were not observed.
Expertise, Millisecond by Millisecond

1. Behavioral Time-Course Studies
   – Palmeri Lab (Vanderbilt)
2. Human EEG Studies
   – Tanaka (Victoria) & Curran (Colorado) Labs
3. Monkey Electrophysiology
   – Sheinberg Lab (Brown)
How does long term experience with complex objects affect the brain’s response to these stimuli?

Highly familiar
(Learned over months of training)

Novel
Chronic skull based EEG recordings from monkeys viewing objects over the course of many days reveal general enhanced evoked responses.

(Peissig et al., 2007, *Cerebral Cortex*)
EEG familiarity effects for complex pictures, measured between 120ms and 250ms after stimulus onset, gradually dissipate over many days.
Post-synaptic Field Potentials (0.3Hz-300Hz)

Spiking Activity (100Hz-6000Hz)

Performance
Eye Position
Reaction Time

100ms

Post-synaptic Field Potentials (0.3Hz-300Hz)

Spiking Activity (100Hz-6000Hz)
Familiar Stimuli

Learned in match to sample task and seen many times in viewing only conditions (over 4-6 months)

Novel Stimuli

Pulled from same database as familiars but introduced for the first time in each session

Woloszyn & Sheinberg, 2012
First example cell

Rank 1

Firing Rate (Hz)

- [Image of graph showing firing rate for familiar and novel stimuli]

Woloszyn & Sheinberg, 2012
Second example cell

Woloszyn & Sheinberg, 2012

.... 75 more pairs
Second example cell

... 75 more pairs

Woloszyn & Sheinberg, 2012
Third example cell

.... 75 more pairs

Woloszyn & Sheinberg, 2012
Not all cells are alike

Kawaguchi & Kubota (1997)

Woloszyn & Sheinberg, 2012
Putative inhibitory cell

.... 75 more pairs

Woloszyn & Sheinberg, 2012
Effects of familiarity depend on cell type and timing

Kawaguchi & Kubota (1997)

Woloszyn & Sheinberg, 2012

- Putative Excitatory (n = 73)
- Putative Inhibitory (n = 15)

(only top 3 stimuli for each cell)
Effects of familiarity depend on cell type and timing

Kawaguchi & Kubota (1997)

Woloszyn & Sheinberg, 2012

75 - 200 ms

200 - 325 ms

Putative Excitatory (n = 73)
Putative Inhibitory (n = 15)
(only top 3 stimuli for each cell)
Expertise, Millisecond by Millisecond

3. Monkey Electrophysiology

- Sheinberg Lab (Brown)

- Scalp ERPs, action potentials, (and local field potentials, not shown) all show differences between familiar and novel stimuli around the same time as the human N170 ERP.

- Recordings from individual IT neurons indicate that excitatory neurons prefer familiar stimuli whereas inhibitory neurons prefer novel stimuli.
  - These two cell types differ in the timing of their action potentials as well as in the timing of their responses to familiarity.
Expertise, Millisecond by Millisecond

1. Behavioral/Computational Time-Course Studies
   - Palmeri Lab (Vanderbilt)
2. Human EEG Studies
   - Tanaka (Victoria) & Curran (Colorado) Labs
3. Monkey Electrophysiology
   - Sheinberg Lab (Brown)