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3 - 14 September 2007

Visual Object Recognition (processing)

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Visual Object Processing

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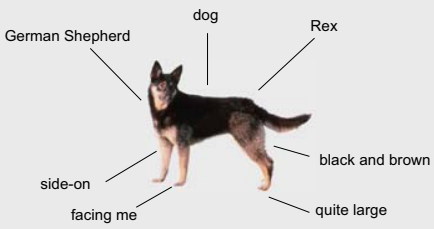
Part 1:
Representations and Stages in Object Recognition

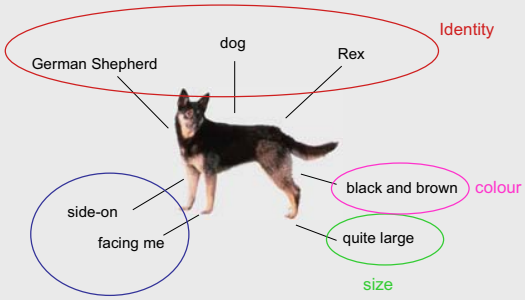
Background

Visual processing of objects is complex, yet seemingly effortless



Background

Visual processing of objects is complex, yet seemingly effortless



Background

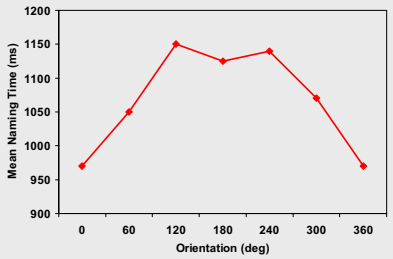
How are objects represented?

1. Like an image (image-based representation)
   - Holistic
   - Viewpoint-dependent
   - ➢ Poggio & Edelman (1990); Tarr & Bülthoff, (1998)

2. On the basis of parts and their spatial relations (structural description)
   - Analytic
   - More viewpoint-invariant (though not completely)
   - ➢ Biederman (1987); Hummel & Biederman (1992)

Background

Recognition is harder when objects are in unfamiliar views



(adapted from Jolicoeur, 1985)

Background

Capacity limitations in information processing

- Perception has an enormous processing capacity, but our cognitive system is much more limited
  - Traditionally, working memory capacity estimated to be 7± 2 (e.g. Miller, 1956)
  - Visual working memory has a limit of ~4 objects (Luck & Vogel, 1997)
  - Some recent studies even suggest limit is 1 object! (e.g. Olsson & Poom, 2005) – when one can't use verbal strategies
- Must select important stimuli for more in-depth processing, while filtering out irrelevant information

Background

Two stages of processing

- Pre-attentive stage
  - First pass processing, extract visual features
  - Detect potential important stimuli
- Selection and encoding
  - Binding of visual features
  - Requires attention and is serial
  - Creates a processing bottleneck

∴ Temporal selection is also severely limited!

Background

Using Rapid Serial Visual Presentation (RSVP) to study recognition

- Stimuli presented rapidly for ~100ms each in same spatial location
- Limits amount of processing of each stimulus
- Can reveal what happens very early in processing, between initial registration and selection/consolidation for report
  - provides insight into the nature of perceptual representations

Background

Using Rapid Serial Visual Presentation (RSVP) to study recognition

- Can also reveal how attention modulates different aspects of object processing
  - ➢ contrast processing of attended objects (*targets selected for report*) and ignored objects (*distractors*)
  - provides insight into the processes involved in the consolidation of objects in visual short-term memory (crucial for explicit recognition and report)

…..Repetition Blindness…..

Repetition Blindness

- Failure to detect and report a repeated stimulus under RSVP conditions
  - at presentation rates faster than 5 items/s
  - when the two critical items (C1 and C2) are separated by less than 400 ms

When Nancy spilt the ink there was ink all over
When Nancy spilt the liquid there was ink all over

Repetition Blindness

RB has been demonstrated for

- Words (within sentences, or lists)
- Letters and digits
- Pictures
- Phonologically and orthographically similar words
- Pictures and words – e.g. cat, 

Repetition Blindness

Kanwisher (1987)

"Type recognition without token individuation"

- The two instances of a repeated item activate the same identity type, but are not assigned separate episodic tokens

→The repetitions are not coded as separate events and only one item enters awareness

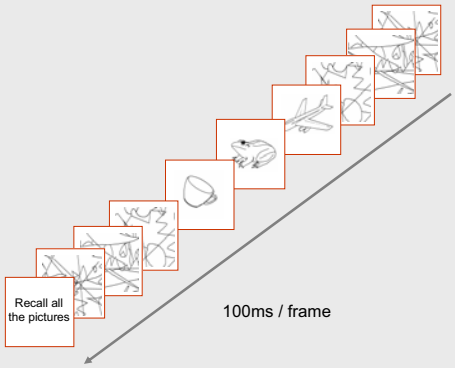
Repetition Blindness

RB as a tool

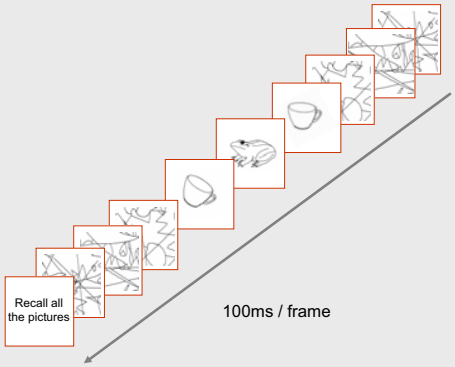
RB can be useful in characterizing the representations involved in recognition

- *What kind of stimuli are treated as identical by the visual system?*

Repetition Blindness

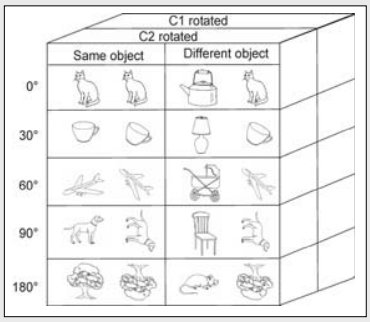


Repetition Blindness



Repetition Blindness

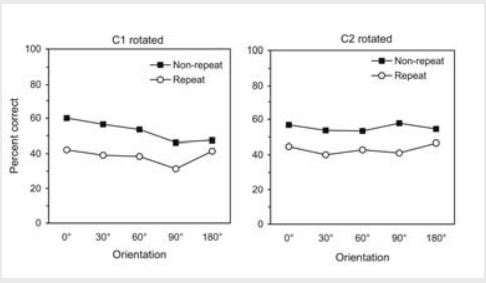
Design (2x2x5)



Harris & Dux, Cognition, 2005

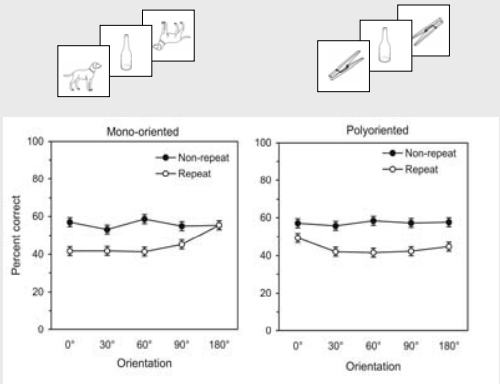
Repetition Blindness

RB is mostly orientation-invariant



Harris & Dux, Cognition, 2005

Repetition Blindness

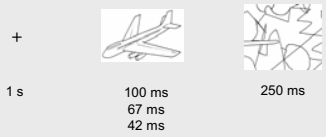


Harris & Dux, Perception & Psychophysics, 2005

Repetition Blindness

Determining object orientation

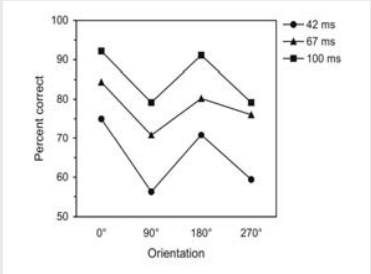
- Objects presented in 4 orientations (0°, 90°, 180°, 270°)
- Subjects indicated the orientation of the object



Harris & Dux, Cognition, 2005

Repetition Blindness

Orientation judgments

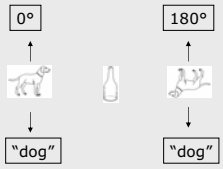


Harris & Dux, Cognition, 2005

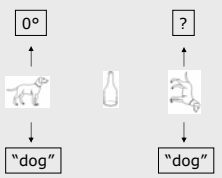
Repetition Blindness

= RB

Repetition Blindness



= No RB



= RB

Repetition Blindness

Interim Summary…

- Orientation is not a defining feature of the representations that mediate early recognition (without awareness)
- Information about usual orientation – when it exists – is stored in memory
  - Can facilitate interpretation of the object's principal axis
- Resolving the orientation is important for establishing a conscious representation of the visual event

…The Attentional Blink…

Attentional Blink

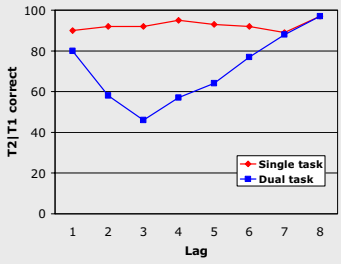
Failure to report the second of two *different* targets under RSVP conditions

- When presented within 500ms of Target 1

Attentional Blink

Typical AB pattern

(adapted from Raymond et al, 1992)



Attentional Blink

Some facts about the AB

1. *All items briefly activate categorical information*
   - Target selection
   - Distractors semantically prime later targets (Maki et al, 1997)
   - Conceptual info about distractors influences the AB (Dux & Coltheart, 2005).

BUT this information decays rapidly.

Attentional Blink

Some facts about the AB

2. *Further processing is required to consolidate an item in reportable form*

- Capacity-limited
- Demands attention
  - More difficult Target 1 tasks → bigger blink (Jolicoeur, 1999)
  - Sensitive to attentional demands between initial registration and consolidation

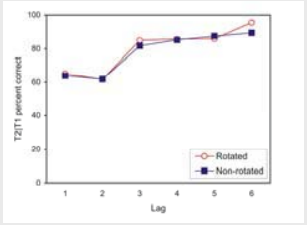
Attentional Blink

Predictions for object recognition in RSVP:

1. *If initial recognition is orientation-invariant, orientation of distractors will not affect the AB*

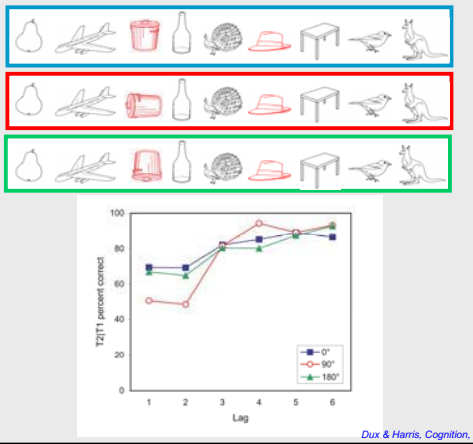
2. *If viewpoint costs arise during consolidation, the size of AB will be affected by the orientation of Target 1*

Attentional Blink



Dux & Harris, Cognition, 2007

Attentional Blink



Dux & Harris, Cognition, 2007

Attentional Blink

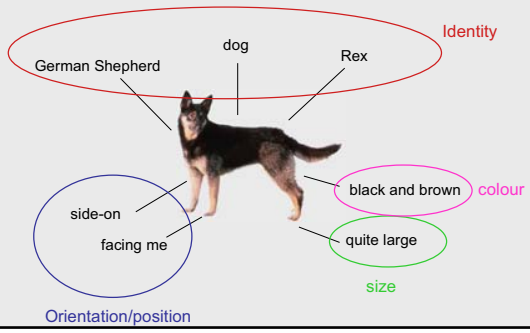
Conclusions from the AB…

- Initial identification of objects (stage 1) is orientation-invariant
- Orientation is coded when objects are consolidated for report
  - Rotated objects require more processing time and attentional resources than upright objects
  - Need to reconcile conflicting spatial reference frames

Part 2: Neural Bases of Object Processing

Background

Visual processing of objects is complex, yet seemingly effortless

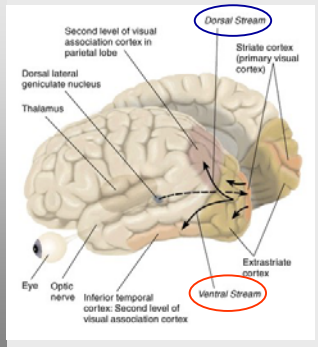


Background

- Different visual attributes are processed in distinct processing modules
- Widely distributed across the cortical surface

Background

Two visual streams



30+ visual areas arranged along two major pathways:

Dorsal stream

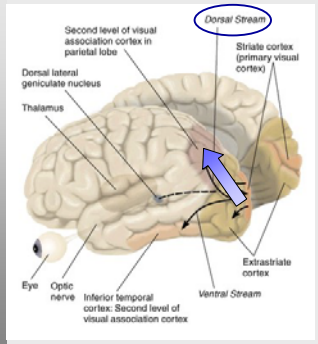
- From primary visual cortex (V1) to posterior parietal lobe (*occipito-parietal*)

Ventral stream

- From primary visual cortex (V1) to inferior temporal cortex (*occipito-temporal*)

Background

Two visual streams



Dorsal stream

"where"

(Ungerleider & Miskin, 1982)

- Computes spatial location

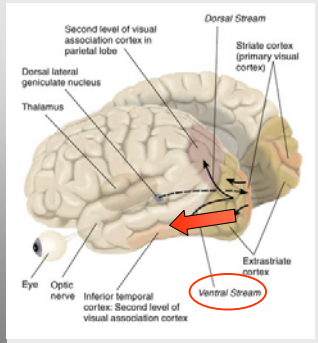
"how"

(Goodale & Milner, 1992)

- Uses vision to guide action
- Strong interactions with motor system

Background

Two visual streams



Ventral stream

"what"

- Computes shape and object identity

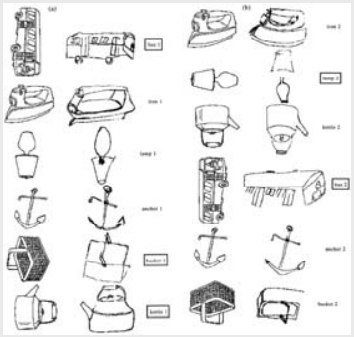
(Both theories agree about this)

- Contributes to conscious perception and awareness

(Milner & Goodale)

Orientation Agnosia

Dissociations between object identity and orientation



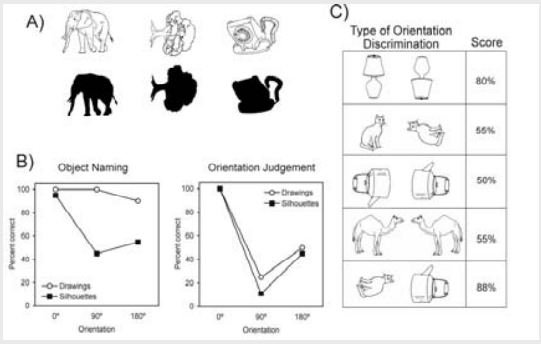
Turnbull et al, Neuropsychologia, 1997

Orientation Agnosia

Dissociations between object identity and orientation

Orientation Agnosia

Dissociations between object identity and orientation



Harris, Harris & Caine, J Cog Neurosci, 2001

Orientation Agnosia

- Evidence for an orientation-invariant route to object recognition
  - via features
- Dissociated from orientation processing
- Stored representations contain information about the usual orientation

Orientation Agnosia

- Parietal lobe seems to be important for processing object orientation
  - all patients with orientation agnosia have lesions there
  - imaging and single cell recording evidence that regions of the intraparietal sulcus code orientation (Faillenot et al, 1997; Sakata et al, 1997)
- Lateralized to the right hemisphere?

Parietal lobe involvement in recognition?

- Parietal lobe is activated during object recognition tasks (Kosslyn et al, 1994; Altmann et al, 2005)
- Patients with right parietal lesions have difficulty recognizing objects from unusual views (Warrington & Taylor, 1973)
  - Known as *apperceptive agnosia*

Parietal lobe involvement in recognition?

- Is it a necessary neural substrate for recognition?
- Or is it involved in determining what view of an object one is looking at?
  - i.e. a spatial judgment

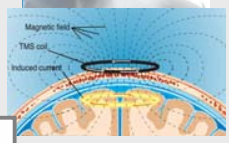
…TMS Study…

Transcranial Magnetic Stimulation

Tony Barker, the inventor of TMS, demonstrating its effects

Large electrical current (10+ kWatts)
passed through coil (100 μsec)
↓
magnetic field (~2.5T)
↓
electrical currents
in brain (~15 mA/cm²)
→ depolarises neurons

Non-invasive brain stimulation



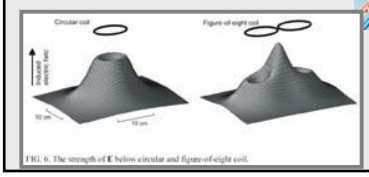


FIG. 6. The strength of E below circular and figure-of-eight coil.

Spatial resolution of TMS:

about 1-2 cm with figure-of-eight coil

TMS Study

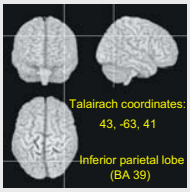
TMS protocol

Magstim Super Rapid, max output 2.2 T

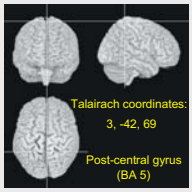
110% of motor threshold

Train of 5 pulses @ 12 Hz frequency

Right Parietal Stimulation Site

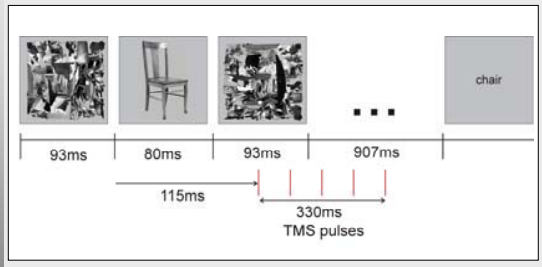


Vertex (control) Stimulation Site



TMS Study

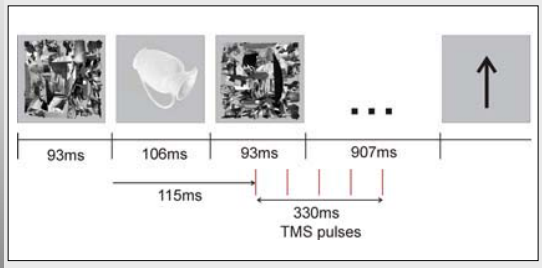
Identification Task



Harris, Benito, Ruzzoli & Miniussi, J Cog Neurosci, in press

TMS Study

Orientation Task

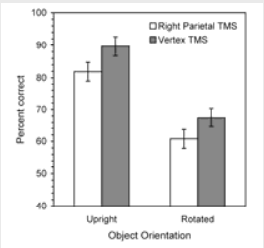


Harris, Benito, Ruzzoli & Miniussi, J Cog Neurosci, in press

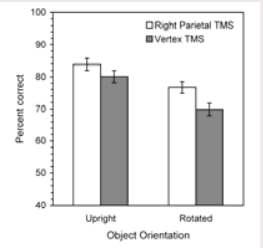
TMS Study

Right Parietal TMS impaired orientation judgments

Orientation Judgments



Identification



But improved object identification!

Harris, Benito, Ruzzoli & Miniussi, J Cog Neurosci, in press

TMS Study

Conclusions

- Right parietal lobe is critical for orientation processing
- It is *not* necessary for object identification
- But…nonetheless affects the recognition process in some way

TMS Study

A potential role for the R parietal lobe in recognition?

- Set up a spatial reference frame for the object
  - the object as seen from a specific viewpoint
  - this process requires one to evaluate an unexpected orientation/viewpoint
  - introduces costs in performance
  - Removing the orientation information may remove a source of conflict, thus speeding up the recognition

TMS Study

A potential role for the R parietal lobe in recognition?

- Is involved in the consolidation stage of object recognition
- Allows conscious perception
- Allows one to act on the object

TMS Study

Clinical Implications

- Confirms that the critical lesion in agnosia for object orientation is located in the right IPS/ inferior parietal lobe
- Suggest that apperceptive agnosia reflects a spatial impairment rather than a pure recognition disorder

Conclusions

- Object recognition proceeds in several distinct temporal stages
  - Initial activation of identity representation via the ventral stream
    - Mediated by salient object parts
    - Orientation-invariant
  - Consolidation of identity for report
    - Place object features in a spatial reference frame
    - Derive object orientation
    - Contributes to conscious recognition
    - Dorsal stream involvement

Conclusions

- Different object attributes are processed by different brain systems
- But have to be bound together to give rise to a conscious percept
- This requires attention and creates potential bottlenecks in performance

Further readings

Object recognition models

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