Ch 6. Higher Perceptual Functions

Cognitive Neuroscience: The Biology of the Mind, 2nd Ed.,
M. S. Gazzaniga, R. B. Ivry, and G. R. Mangun, Norton, 2002.

Summarized by
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Higher Perceptual Functions

- Perception requires more than simply perceiving the features of objects.
  - When gazing at the coastline of San Francisco, we do not have the impression of blurs of color floating among a sea of various shapes.

Introduction

- The product of perception is intimately interwoven with memory. Object recognition is more than linking features to form a coherent whole.
- We consider the problems inherent in a computational system that not only processes sensory information but also links this information to memory.
- We must be precise when we use the terms like *perceive* or *recognize*.
  - Perception and recognition do not appear to be unitary phenomena but are manifest in many guises.

Contents

- Two Cortical Pathways for Visual Perception
- Computational Problems in Object Recognition
- Failures of Object Recognition
- Prosopagnosia
- The Relationship Between Visual Perception, Imagery, and Memory

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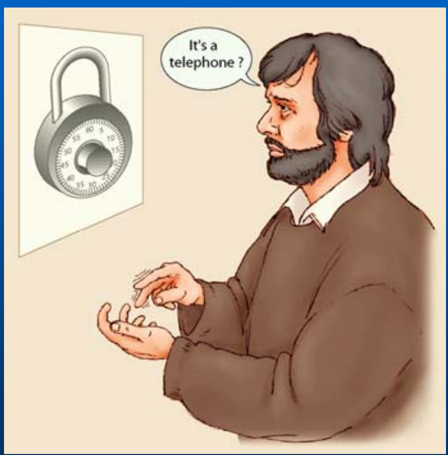
Agnosia: A Case Study (1/2)

- Agnosia
  - Failures of perception even when processes (the analysis of color, shape, and motion) are intact.
  - Visual agnosia: When the disorder is limited to the visual modality
- Patient G.S.
  - G.S has severe problems recognizing objects
  - Candle: reported as “long object”, after smelling it, reported correct answer “candle”.
  - His sensory abilities were intact.
  - He retained all the fundamental capabilities for identifying shapes and colors. (city navigating, using silverware, copying complex drawings)

Agnosia: A Case Study (2/2)

- Correct answer: “combination lock”
- Patient’s insist: “telephone”
- Similar components: numbers and dial
  - Some information is being processed.
- Patient’s hands mimed the actions that would be required to open a combination lock.

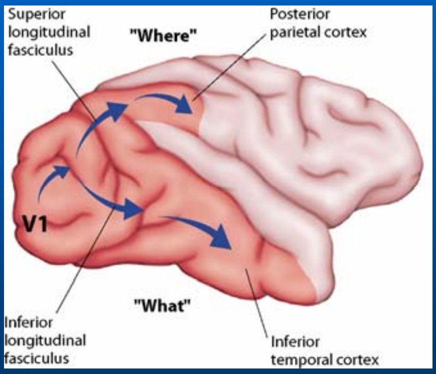


Two Cortical Pathways for Visual Perception

- Representation Differences Between the Dorsal and Ventral Pathways
- Perception for Identification Versus Perception for Action

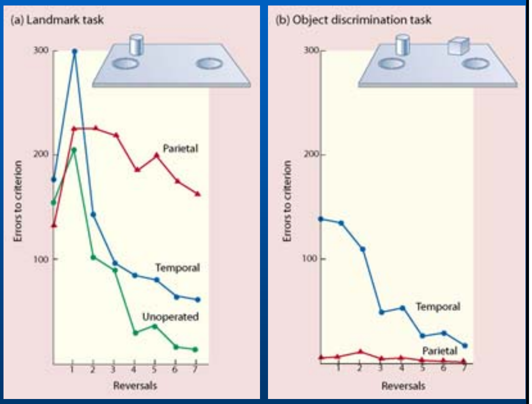
Two Cortical Pathways for Visual Perception

- Ventral (occipito-temporal) pathway:
  - Object perception and recognition
  - What it is we are looking at.
  - The superior longitudinal fasciculus includes axons terminating in the *posterior parietal* cortex
- Dorsal (occipito-parietal) pathway:
  - Spatial perception
  - Where an object is.
  - The inferior longitudinal fasciculus contains axons terminating in the *inferior temporal* cortex
- The outputs from the primary visual cortex (V1) follow two general path ways.



Double Dissociation in Support of the What-Where Dichotomy (1/2)

- Rhesus monkey experiments
- Landmark task
  - Monkey initially finds a reward in the food well closest to the cylinder
  - Reverse the rule so that the food is always placed in the well farthest from the cylinder
  - Control animals: show significant improvements
  - Animals with bilateral temporal lobe lesions: show significant improvements
  - Animals with *bilateral parietal lobe* lesions: fail to improve
- Discrimination task
  - The location of the food is associated with one of the objects
  - The animals with *temporal lobe* damage: show more impairment than those with parietal lobe lesions
  - Control animals were not tested

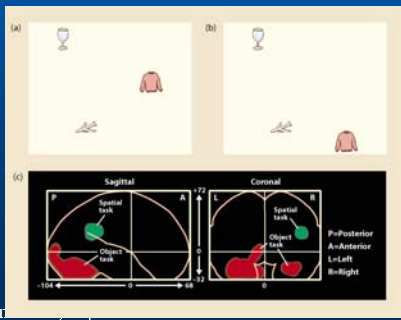


Double Dissociation in Support of the What-Where Dichotomy (2/2)

- Rhesus monkey Conclusion
  - Bilateral lesions of the temporal lobe selectively disrupted performance on the object discrimination task (what?)
  - Bilateral lesions of the parietal lobe selectively disrupted performance on the landmark discrimination task (where?).
- "What" processing is inter-hemispheric
  - combination lesions of left V1 and right temporal lobe has no effect because the inputs from right V1 can travel to the left temporal lobe.
- "Where" processing is intrahemispheric
  - combination lesions of left V1 and right parietal lobe disrupts "whe re" processing because right V1 and left parietal lobe can not funct ion independently in both hemispheres.

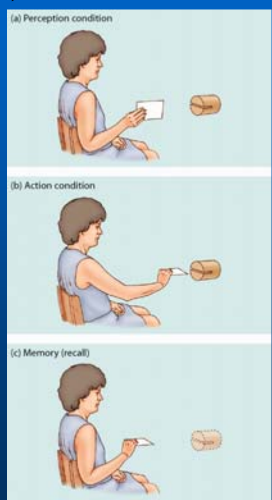
Representational Differences between the Dorsal and Ventral Pathways

- Many cells in *parietal lobe* are tuned eccentrically (large areas of retina or large visual field) to detect the *presence of the stimulus*. “Where ?”
- Many cells in *temporal lobe* are tuned centrally (fovea of retina) to *devote to object recognition*. “What ?”
- Neuroimaging studies with human subjects have provided further evidence that the parietal lobe (dorsal) and temporal lobe (ventral) streams are activated differently by “where” and “what” tasks.



Perception for Identification versus Perception for Action (1/2)

- Patient studies
  - The parietal cortex is central to spatial attention
  - The temporal cortex is for face (prosopagnosia) recognition
- Task: Match the *orientation* of the card to that of the slot
  - the patient demonstrated severe impairment
  - The patient (D.F.) had a severe disorder of object recognition
- Task: Insert the card in the slot
  - the patient produced the correct *action* without hesitation
  - Her performance indicated that she had processed the orientation of the task.
- Information accessible to *action systems can be dissociated* from information accessible to object recognition knowledge “what”



Perception for Identification versus Perception for Action (2/2)

- D.F.s knowledge of orientation was intact
  - The patient also did not show any impairment in the memory condition
- Patient with **optic ataxia -** The opposite dissociation example
  - Can recognize objects
  - Cannot use visual information to guide their action.
  - the inverse problem of D.F.'s:
    - they can report the orientation of a visual slot
    - they cannot use this information for moving their hand toward the slot.
- In sum,
  - the what-where, or what-how dichotomy offers a functional account of two computational goals for higher visual processing.
  - The dorsal and ventral pathways are not isolated from one another but communicate extensively.

Computational Problems in Object Recognition

- Variability in Sensory Information
- View-Dependent or View-Invariant Recognition?
- Shape Encoding
- Grandmother Cells and Ensemble Coding
- Summary of Computational Issues

Computational Problems in Object Recognition

- *Object perception* depends primarily on the analysis of the shape and form
  - cf) Cues such as color, texture, and motion certainly contribute to *normal perception*.
- Despite the irregularities in how these objects are depicted, we have little problem in recognizing them.
- We may never have seen pink elephants or plaid apples, but our object recognition system can still discern the *essential feature*.

Variability in Sensory Information

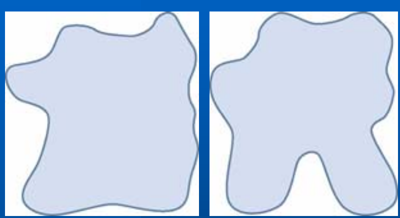
- Object Constancy
  - Refers to the ability to recognize an object in countless situations.
  - Sensory information depends highly on viewing position. ➔
  - Changes in the illumination of an object introduce a second source of sensory variability.(including shadows) ➔
  - Objects are rarely seen in isolation. (including occlusion) ➔

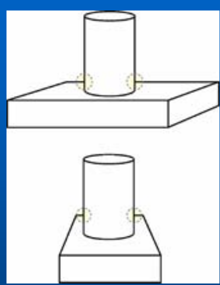
View-Dependent or View-Invariant Recognition?

- Where does recognition occur?
- View-dependent theories
  - Recognition processes are dependent on the vantage point.
  - Perception depends on recognizing an object from a certain viewpoint.

- A view-invariant frame of reference
  - Recognition does not happen by simply analyzing the stimulus information.
  - Sensory input defines basic properties; the object's other properties are defined with respect to these basic properties.
  - A critical property for recognition is establishing the major and minor axes inherent to the object.
  - Recognition may depend on an inferential process based on *a few salient features*.

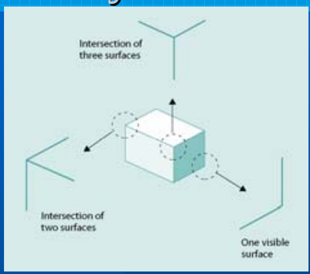
Shape Encoding - Exploiting Salient Sources of Information



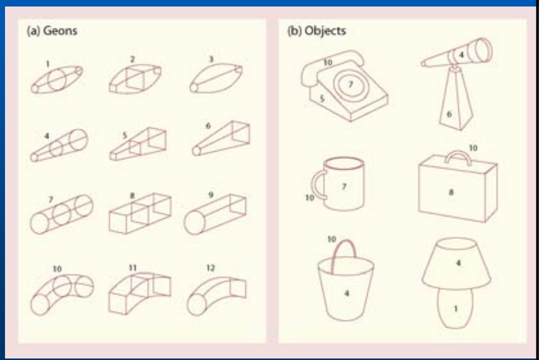


- Redrawing from memory
  - The points of greatest curvature provide the most salient sources of information
  - The representations would include the most salient aspects of the stimulus.
- Certain perceptual cues are invariant across vantage points
  - Parallel edges - invariant
  - Border between two objects - variant

Shape Encoding - Recognition by Parts Analysis

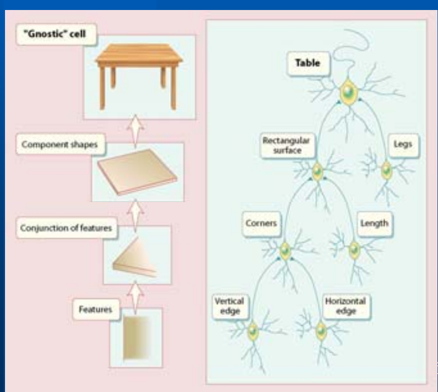


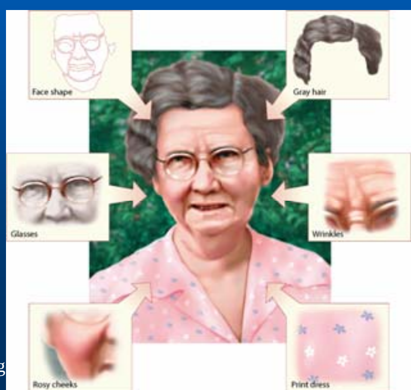
- Invariant cues to surface perception(for intersection) – upper figure.
- The geon theory posits that object recognition is based on identifying the defining geons, or geometrical "ions," that constitute an object – right figure.



Grandmother Cells and Ensemble Coding

- Hierarchical coding hypothesis
  - Elementary features are combi ned to create Gnostic units tha t recognize complex objects.
- Ensemble coding hypothesis
  - An object is defined by the si multaneous activation of *a set of defining properties*





Summary of Computational Issues

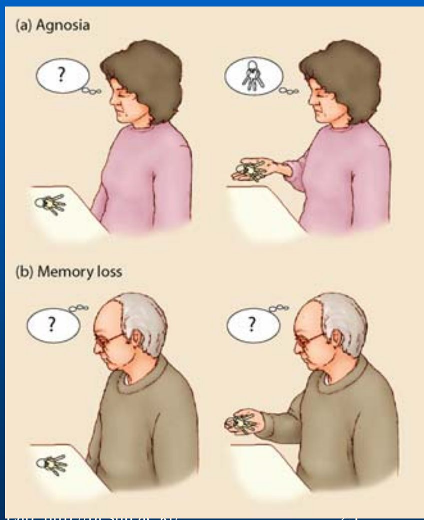
- Information is represented on multiple scales.
  - Early visual input – specify simple features
  - Object perception – envolves intermediate stages of representation where features are assembled into parts.
- Objects are not determined solely by their parts; they are defined by relations between parts.
- The perceived spatial relations among parts should not vary *over viewing conditions*.

Failures of Object Recognition

- Subtypes Agnosia
- Integrating Parts into Wholes
- Category Specificity in Agnosia
- Computational Account of Category-Specific Deficits

Failures of Object Recognition

- Visual agnosia
  - a failure to recognize visual object
  - Unable to recognize the keys by vision alone
  - But immediately recognizes the keys when she picks them up.
  - The patient with a memory disorder is unable to recognize the keys even when he picks them up.



Subtypes of Agnosia (1/2)

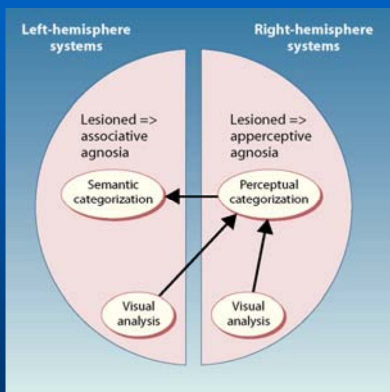
- **Apperceptive agnosia**
  - Can distinguish small differences in brightness and color. Yet his ability to discriminate between *even the simplest shapes* was essentially nonexistent.
  - Failures in object recognition linked to problems in perceptual processing.
    - Could not read letters except for those composed of straight segments (e.g., I), nor could he copy drawings.
    - Face perception was impossible for him.
  - The patient's *ability to achieve object constancy* is disrupted.

Subtypes of Agnosia (2/2)

- **Associative agnosia**
  - **Patients derive normal visual representations but cannot use this information to recognize things,** or a failure of visual object recognition that cannot be attributed to perceptual abilities.
  - Patients with left-sided lesions
    - Can frequently recognize objects in isolation, but *cannot make functional connection* between the two visual percepts.
    - Ex) They lack the semantic representations needed to link the functional association between the open and closed umbrella.

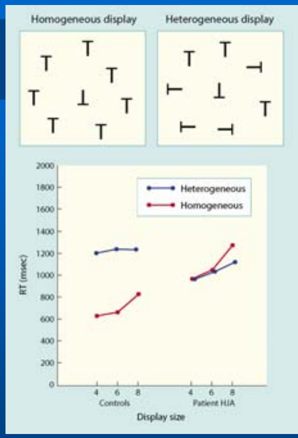
Integrating Parts into Wholes

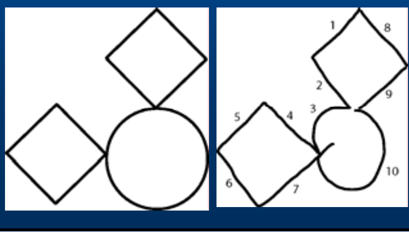
- Warrington's two stage model
  - an anatomical model of the cognitive operations required for object recognition
- The first stage
  - The processes required to overcome the perceptual variability in the stimulus.
  - Dependent on the *right hemisphere*. The damage to the right hemisphere causes apperceptive agonosia.
- The second stage
  - Semantic categorization in which the perceptual representation is linked to semantic knowledge.
  - Dependent on the *left hemisphere*. The damage to the left hemisphere causes associative agnosia.



Integrative Agnosia

- Difficulty in integrating the parts of an object into a coherent whole.
- Unable to perceive an object “at a glance”.
- Fail to group ➔
- Instead, his ability to identify objects depended on recognizing salient features of parts.
  - To recognize a dog, the patient must independently perceive each of the legs and the characteristic shape of the body and head. These part representations are then used to identify the whole.





Category Specificity in Agnosia

- For patient J.B.R., most notable about his agnosia was that it was disproportionately *worse for living objects* than inanimate ones.
  - We recognize that birds, dogs, and dinosaurs are animals because they share common features.
  - Manufactured objects are easier to recognize because they activate additional forms of representation.
  - Notice the greater similarity (and thus confusability) of the living things: they tend to have rounded bodies and appendages of some sort. There is little similarity among the set of non-living things.

Computational Account of Category-Specific Deficits

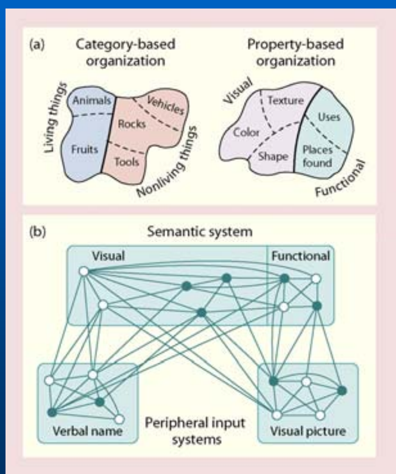
- When the lesion was restricted to the ***visual*** semantic memory units, the model showed much more impairment in correctly associating the name and picture patterns *for the living things*.
- When the lesion was restricted to the ***functional*** semantic memory units, the model showed impairment only in associating the input patterns *for non-living things*.

- **Semantic memory is organized according to the properties that define the objects.**

- Category-specific deficits are best viewed as an emergent property of the fact that different sources are needed to recognize living and nonliving objects.
- Our knowledge of *living things* is highly dependent on *visual information*, whereas this dependency is lessened for nonliving objects.

Two Hypothesis Concerning the Organization of Semantic Knowledge

- A category-based hypothesis
  - Semantic knowledge is organized according to our categories of the world.
- A property-based hypothesis
  - Semantic knowledge is organized according to the properties of objects.
- In the architecture of Farah and McClelland's(1991) model of a property-based semantic system, there are no connections between the two input systems. The names and pictures are linked through the semantic system.



Prosopagnosia

- Are Faces Special?
- Dissociations of Face and Object Perception
- Two Systems for Object Recognition

Prosopagnosia

- The inability *to recognize faces*, the most common form of visual agnosia.
- Causes: damages to an area of inferior temporal cortex.
- Their recognition problems for face are disproportionate to their ability to recognize other objects.

Are Faces Special? (Is Face Perception Processing Involves a Special Processing Mechanism?)

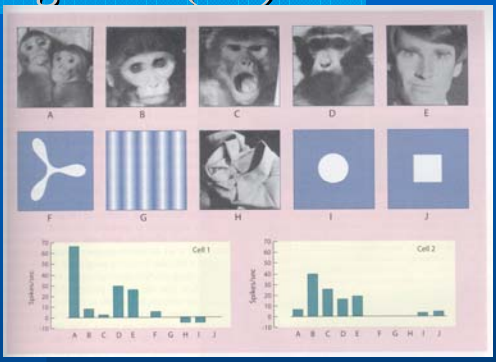
- **Do the processes involve physically distinct mechanisms?**
  - Do face perception and other forms of object perception depend on different regions of the brain?
- **Are the systems functionally independent?**
  - Can each operate without the other?
- **Do the two systems (face and other forms of objects) process information differently?**

Table 6.1 Summary of Lesion Foci in Patients Described as Prosopagnosic*

Bilateral (n = 46)	65%
Temporal	61%
Parietal	9%
Occipital	91%
Left only (n = 4)	6%
Temporal	75%
Parietal	25%
Occipital	50%
Right only (n = 21)	29%
Temporal	67%
Parietal	28%
Occipital	95%

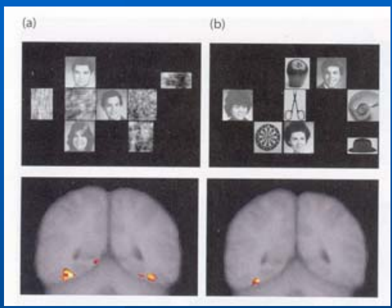
*Within each subcategory, the percentages indicate how the lesions were distributed across the temporal, parietal, and occipital lobes. The sum of these percentages is greater than 100% because many of the lesions spanned more than one lobe. The majority of the patients had bilateral lesions. Adapted from Farah (1990).

Neural Mechanisms for Face Recognition (1/2)



- Face cells in the superior temporal sulcus of the macaque monkey.(upper figure)
- Cells in two distinct regions of the temporal lobe are preferentially activated by faces: the superior temporal sulcus and the inferior temporal gyrus.

Neural Mechanisms for Face Recognition (2/2)



- fMRI studies: stronger BOLD response in fusiform gyrus
  - The fusiform gyrus in right hemisphere has been referred to as fusiform face area (FFA)
  - This support the first criterion: Face perception appears to utilize distinct physical processing systems

Dissociation of Face and Object Perception

- First criterion:
  - Face perception appears to utilize distinct physical processing systems
- Second criterion:
  - Whether face and other objects perception can be dissociated?
- Patients with severe object recognition problems without any evidence of prosopagnosia - to support the second criterion.

Two Systems for Object Recognition

- Alexia
  - Error usually reflect visual confusions. The word *ball* may be mislead as *doll* or *snake* as *stale*.
- Object recognition
  - Decomposes a stimulus into its parts.
- Face perception
  - More holistic
  - Individual parts are not sufficient
  - Analyzing the structure and configuration of features is what count

그림넣기

	Prosopagnosic	Alexic
Read words	able	unable
Recognize the handwriting	unable	able

Two extremes

- Two extremes
  - Integrative agnosia: cannot identify the critical parts that form the object
  - Prosopagnosia: may succeed in extracting these parts, but cannot derive the holistic representation necessary for face perception
- Higher-level perception reflects the operation of two, distinct representational systems. (analysis-by-parts and holistic systems)
- Recognizing objects falls somewhere between the two extremes of words and faces.
  - Agnosia for objects can occur with either alexia or prosopagnosia.

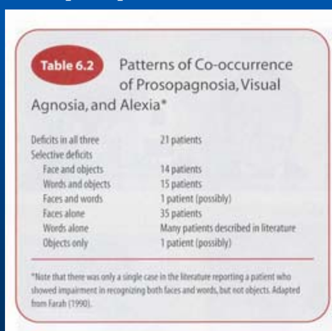


Table 6.2 Patterns of Co-occurrence of Prosopagnosia, Visual Agnosia, and Alexia*

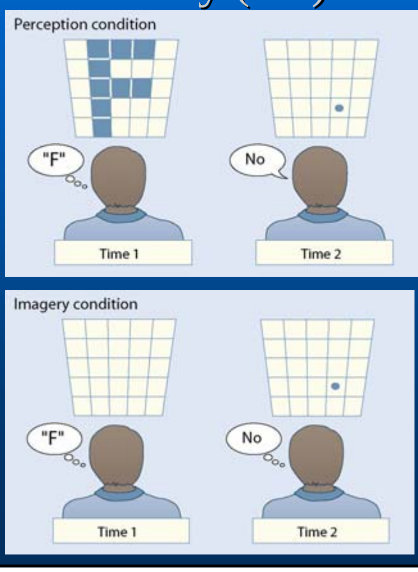
Deficits in all three	21 patients
Selective deficits	
Face and objects	14 patients
Words and objects	15 patients
Faces and words	1 patient (possibly)
Faces alone	35 patients
Words alone	Many patients described in literature
Objects only	1 patient (possibly)

*Note that there was only a single case in the literature reporting a patient who showed impairment in recognizing both faces and words, but not objects. Adapted from Farah (1990).

The Relationship between Visual Perception, Imagery, and Memory

The Relationship Between Visual Perception, Imagery, and Memory (1/2)

- Findings in investigating the relationship between visual perception, imagery, and memory
  - Whether imagery uses the same neural machinery as perception uses.
  - Several studies demonstrated similarities in how we process images and percepts. ➔
- Mental imagery uses many of the same processes critical for perception
  - The sights -> activate visual areas of the brain
  - The sounds -> activate auditory areas
  - The smells -> activate olfactory areas



The Relationship Between Visual Perception, Imagery, and Memory (2/2)

- It is premature to conclude that the imagery and perception are identical.
- There are dissociations between imagery and perception.
  - The ability to draw objects from memory may be spared in agnosia.
  - Patient C.K.'s drawings of a map of the United Kingdom and an electric guitar are shown
  - His ability to generate an internal visual representation would appear to be intact.
  - However, he was unable to recognize the objects in his own drawings on a subsequent visit

Summary

- Overview of the higher-level processes involved in visual perception
  - Eyes: identify not only *what* it is we are looking at, but also *where* to look, to guide our actions.
  - Interactive processes
  - To accomplish a skilled behavior(catching a thrown object)
- Object recognition
  - Achieved in a multiplicity of ways
  - Involves many levels of representation
  - Must overcome the variability inherent in the sensory input
  - Contents of current processing(perceptual) must be connected to our stored knowledge about visual object
- Recognizing conspecifics
  - Analyze the parts
  - Analyze configural form of representation
    - Face perception
  - Two forms of representation interact

Key Terms

agnosia
analytic processing
associative agnosia
dorsal (occipito-parietal) pathway
gnostic unit
integrative agnosia
prosopagnosia
ventral (occipito-temporal) pathway
view-invariant frame of reference
alexia
apperceptive agnosia
category-specific deficits
fusiform gyrus
holistic processing
object constancy optic ataxia
visual agnosia
view-dependent theories

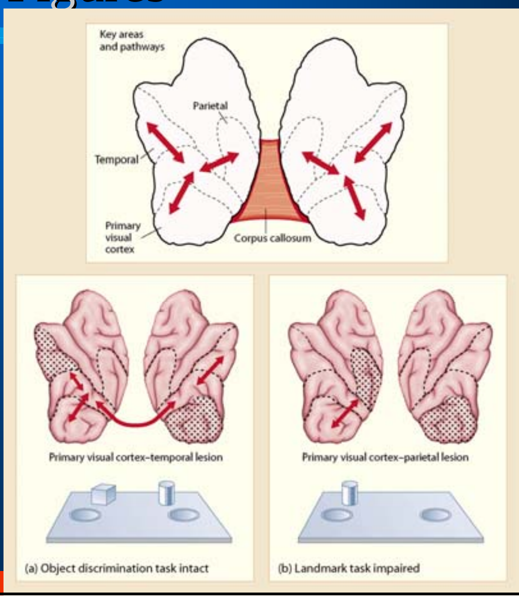
Thought Questions (1/2)

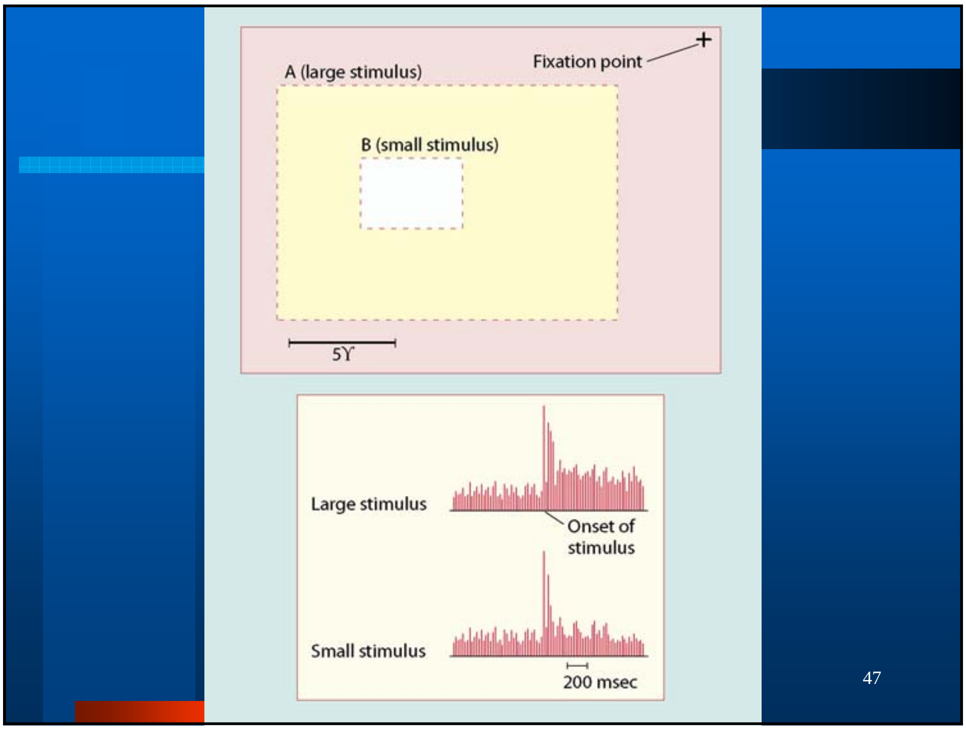
- What are some of the differences between processing in the dorsal and ventral visual pathways? In what ways are these differences useful? In what ways is it misleading to imply a functional dichotomy of two distinct visual pathways?
- Mrs. S recently suffered a brain injury. She claims to have difficulty in “seeing” as a result of her injury. Her neurologist has made a preliminary diagnosis of “agnosia,” but nothing more specific is noted. In order to determine the exact nature of her agnosia, a cognitive neuropsychologist is called in. What behavioral tests could the neuropsychologist use to make a more specific diagnosis? Remember that it is also important to conduct tests to determine if her deficit reflects a more general problem in visual perception or memory.
- A scientist working with the MRI system at the hospital hears aout the case. Which anatomical and functional neuroimaging tests would the scientist recommend, and what specific results would support each of the possible diagnoses?

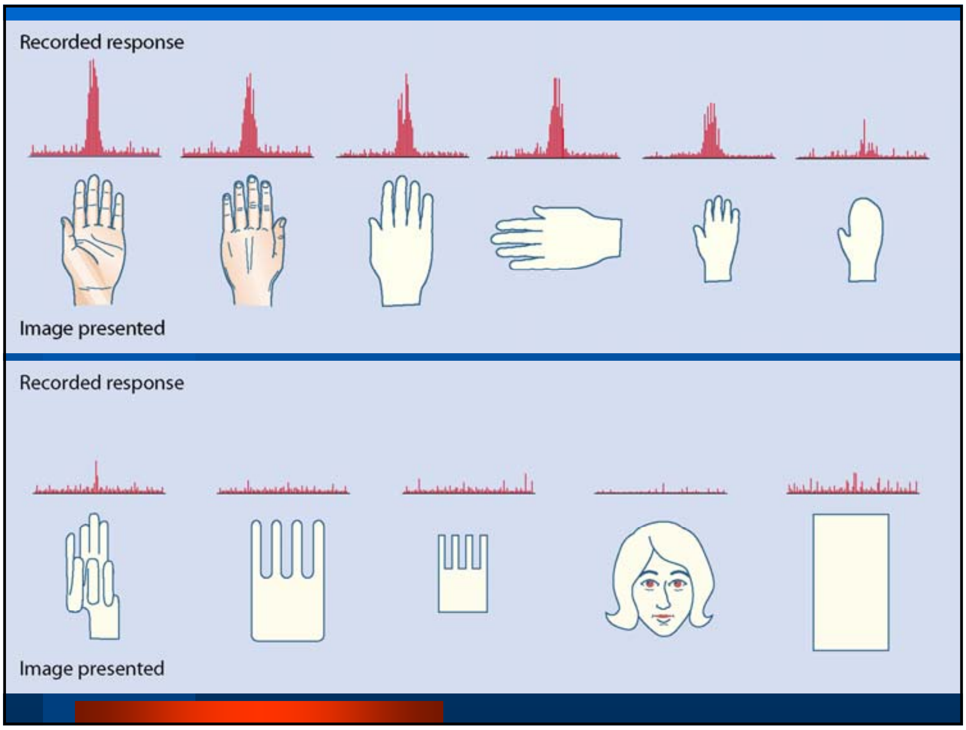
Thought Questions (2/2)

- Review different hypotheses concerning why brain injury may produce the puzzling symptom of disproportionate impairment in recognizing living things. What sorts of evidence would support one hypothesis over another?
- As part of a debating team, you are assigned the task of defending the hypothesis that the brain has evolved a specialized system for perceiving faces. What arguments will you use to make your case? Now change sides. Defend the argument that face perception reflects the operation of a highly experienced system that is good at making fine discriminations.

Extra Figures




A (large stimulus)
Fixation point
B (small stimulus)
5°
Large stimulus
Onset of stimulus
Small stimulus
200 msec
47


Recorded response
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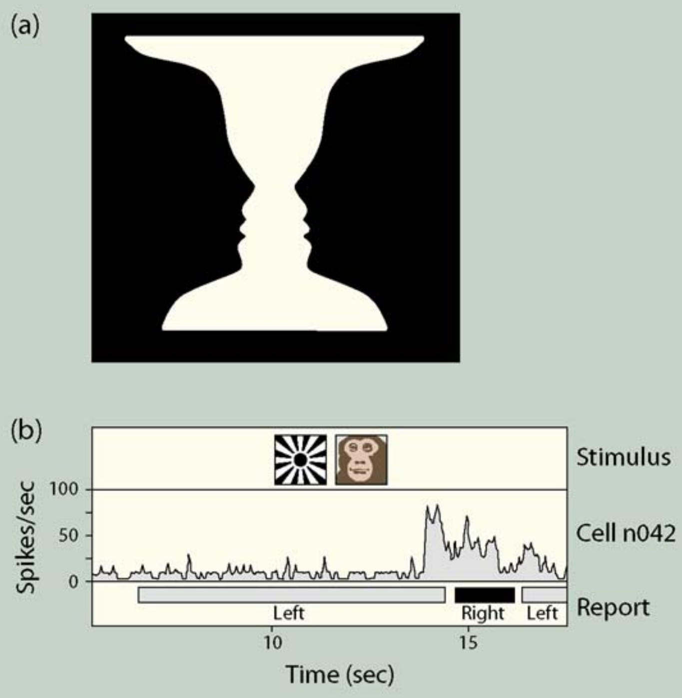
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Stimulus
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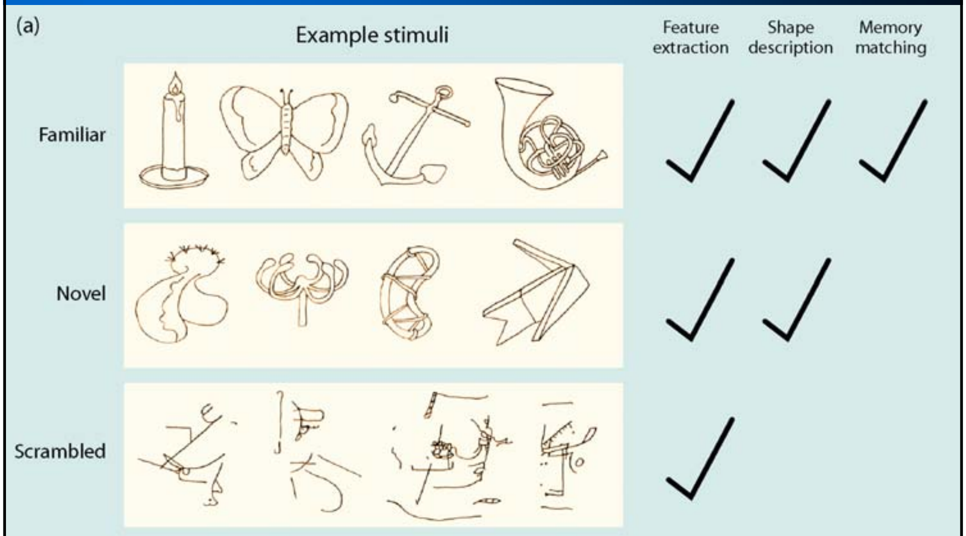
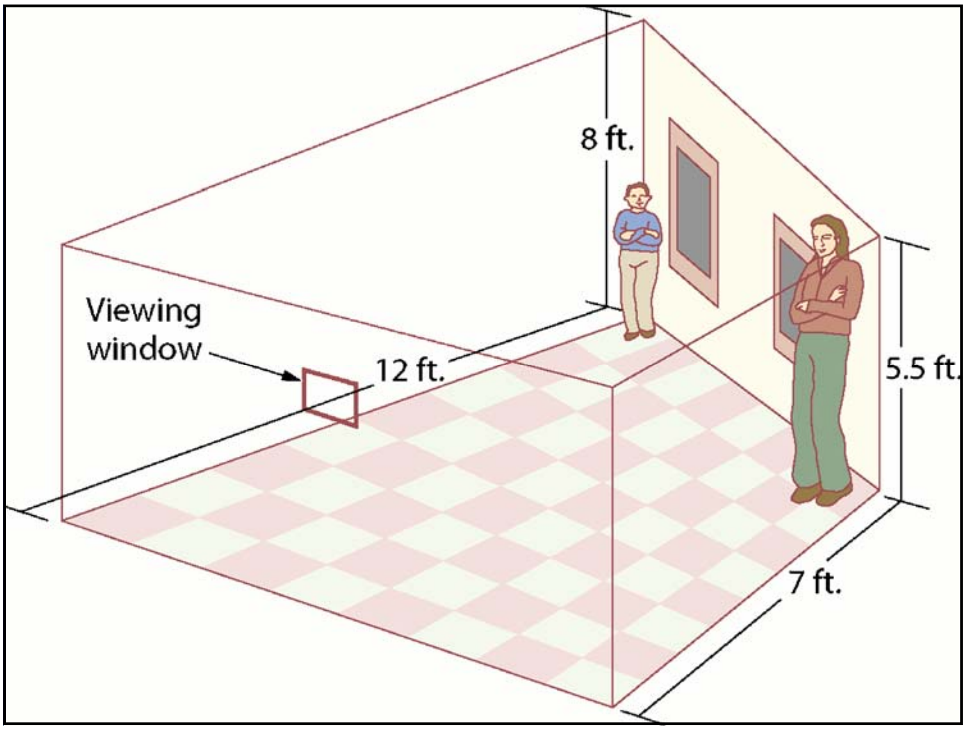

(a)
Example stimuli
Feature extraction
Shape description
Memory matching
Familiar
Novel
Scrambled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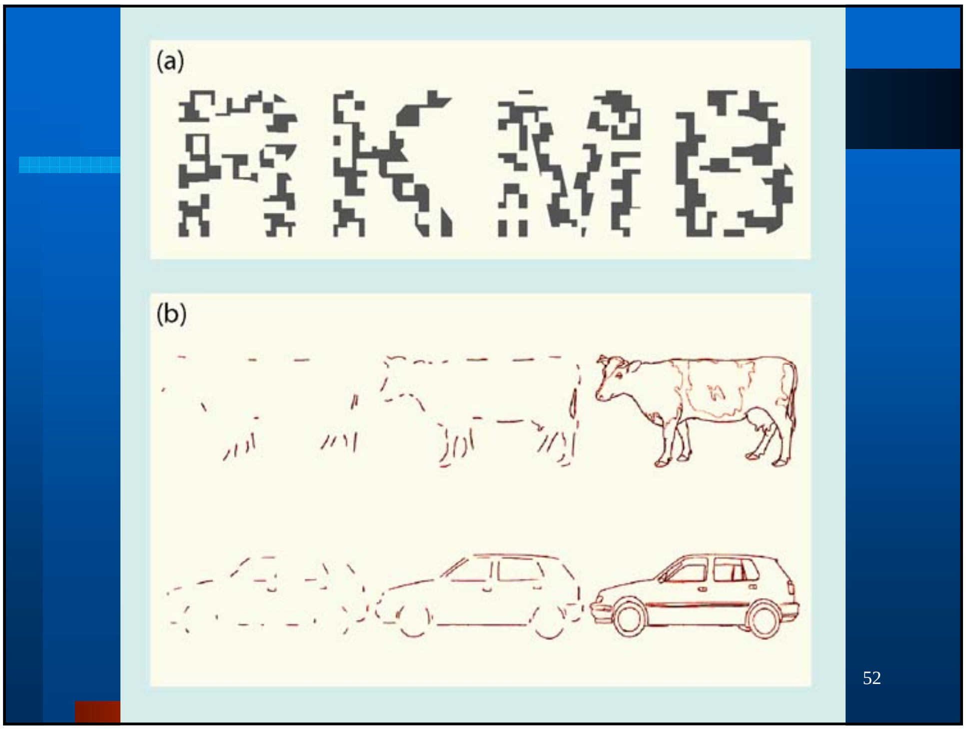
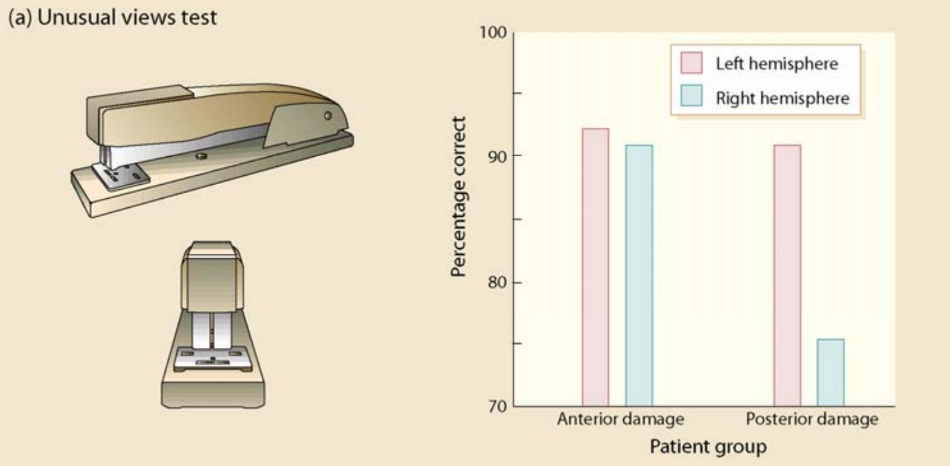
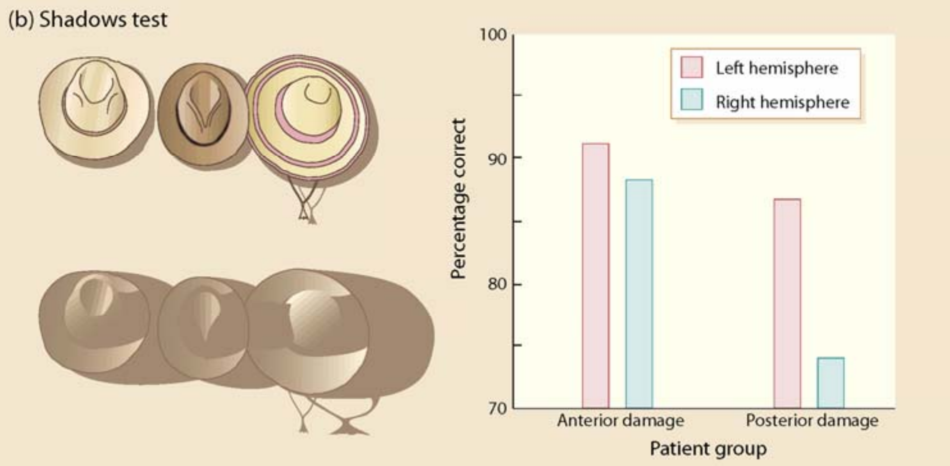
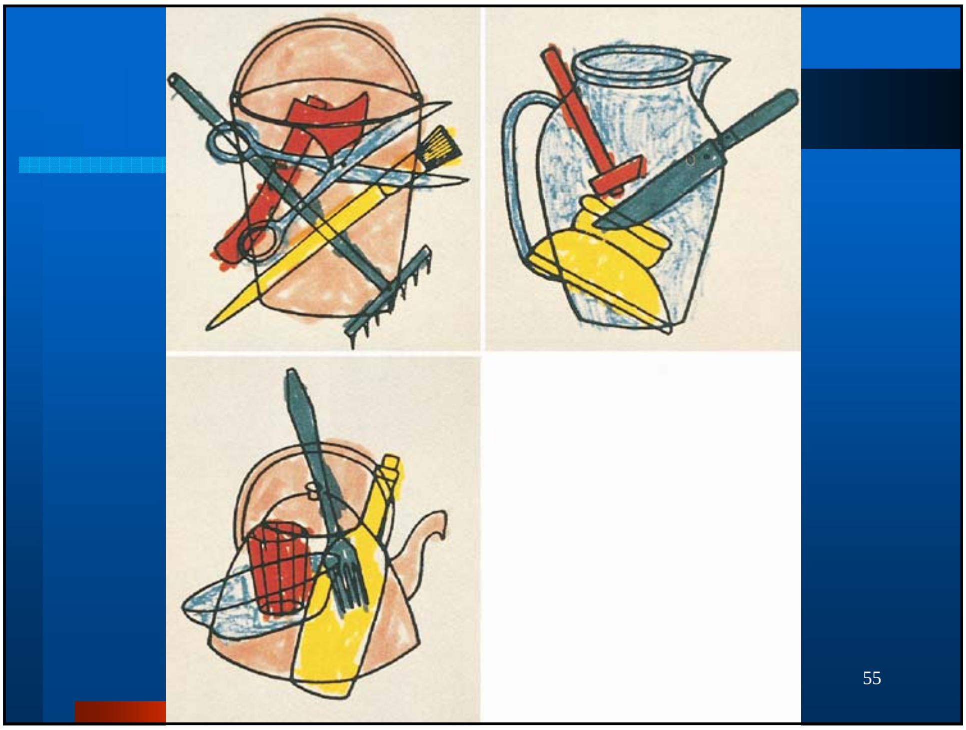
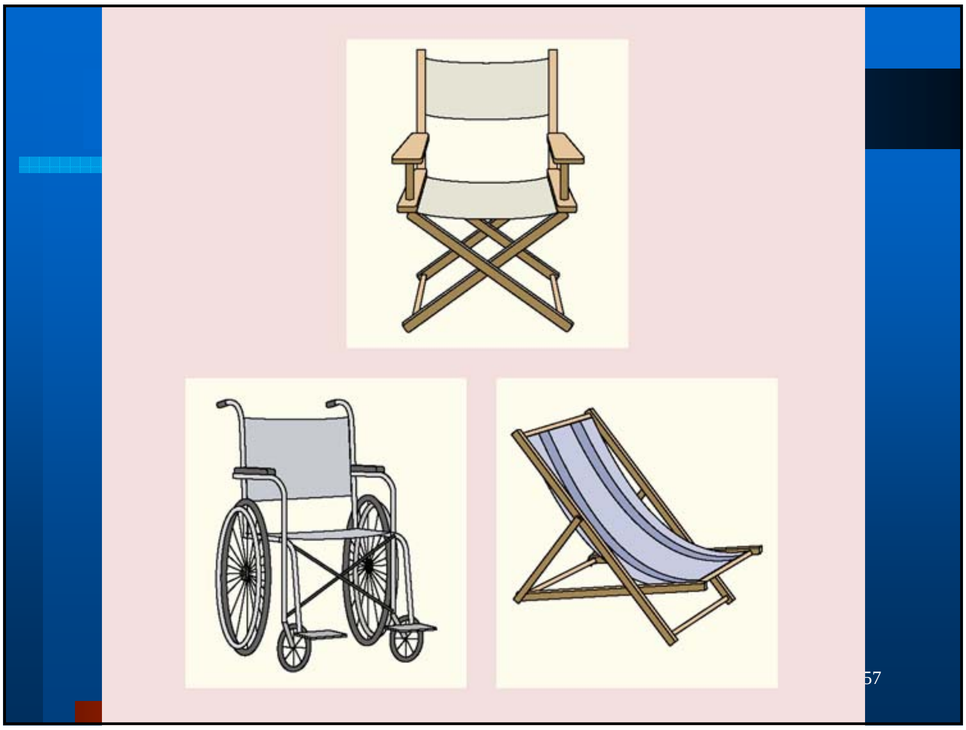

(a)
(b)
52

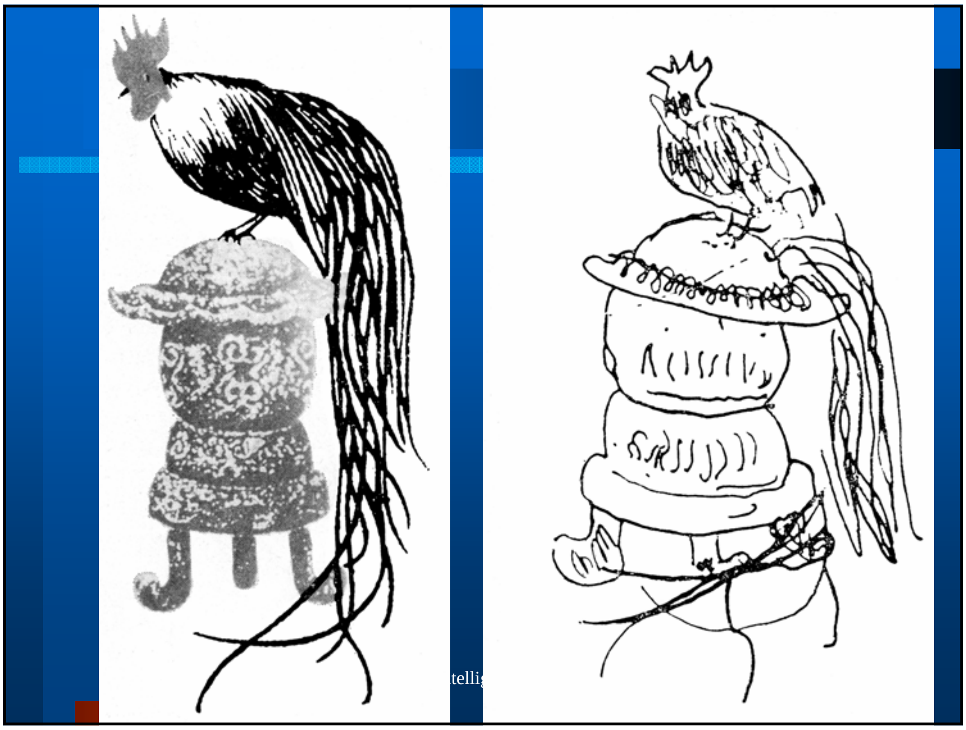

(a) Unusual views test
100
90
80
70
Percentage correct
Left hemisphere
Right hemisphere
Anterior damage
Posterior damage
Patient group

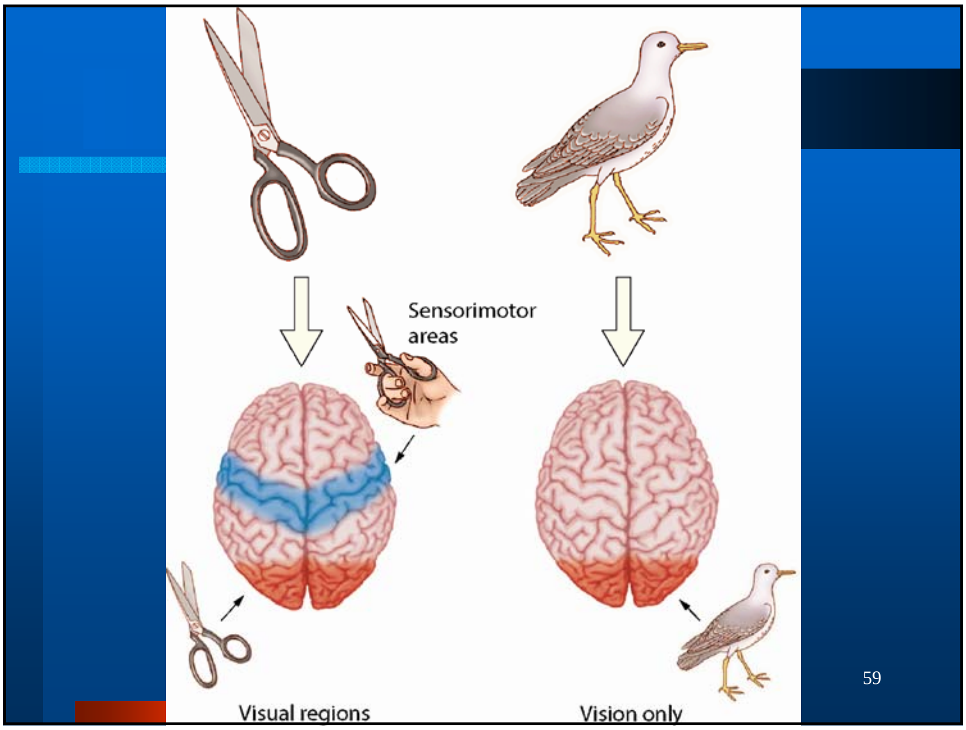

(b) Shadows test
100
90
80
70
Percentage correct
Left hemisphere
Right hemisphere
Anterior damage
Posterior damage
Patient group

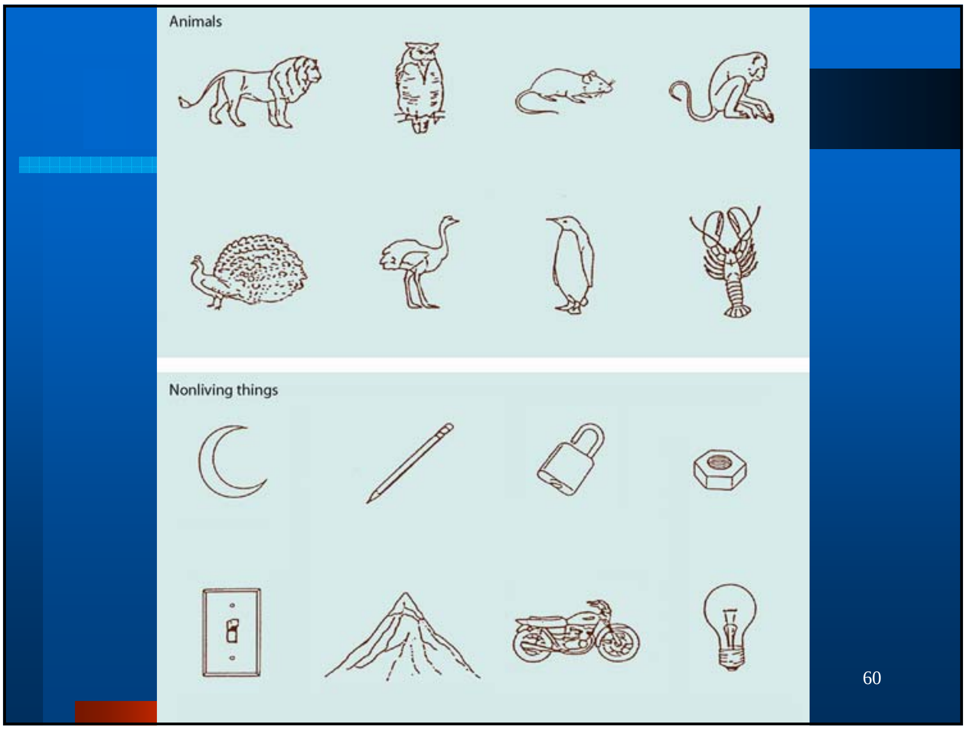

55

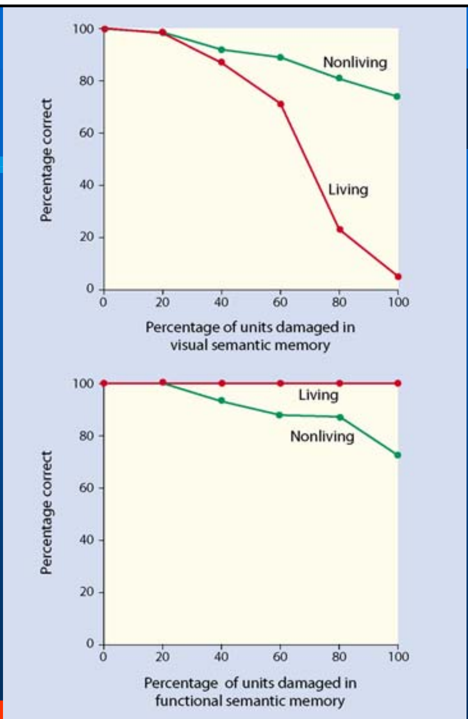

56

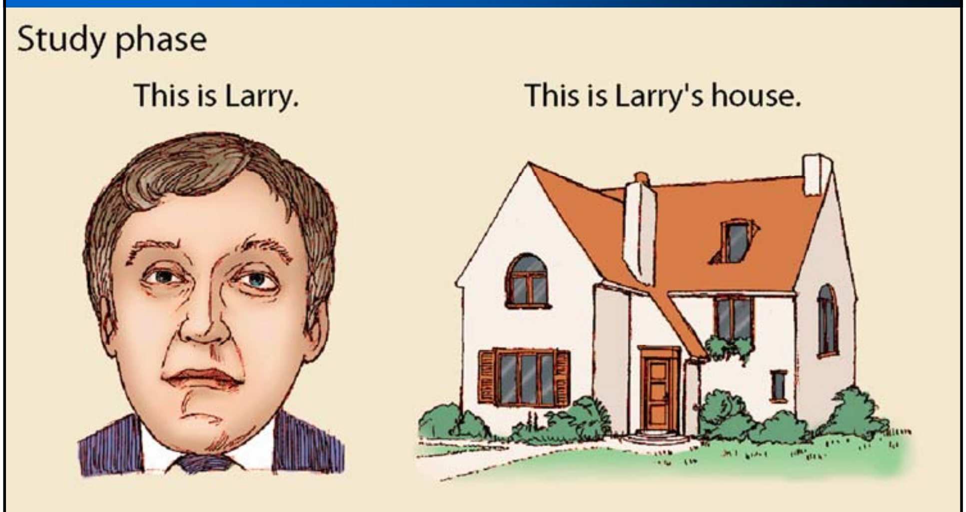

57

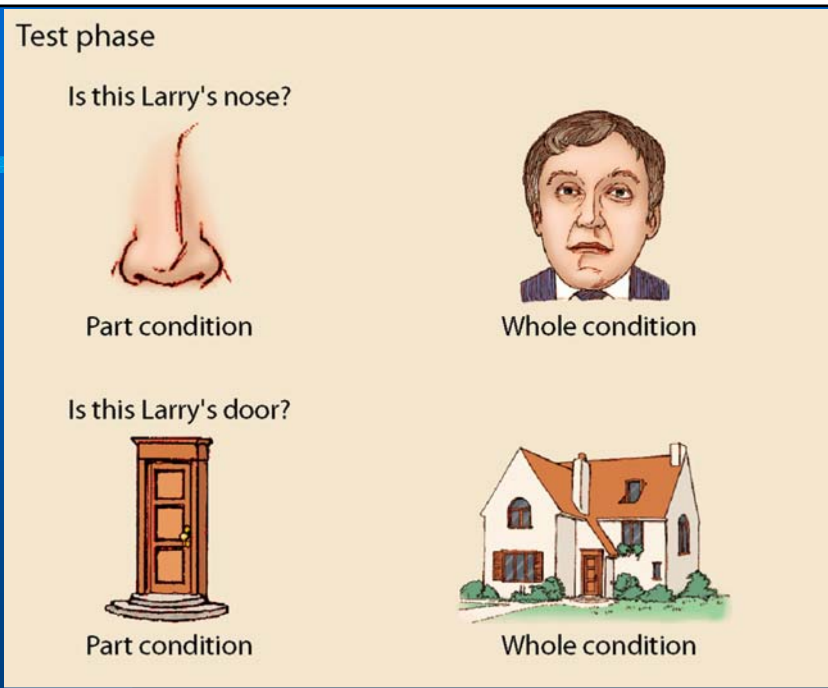



Sensorimotor
areas
Visual regions
Vision only
59

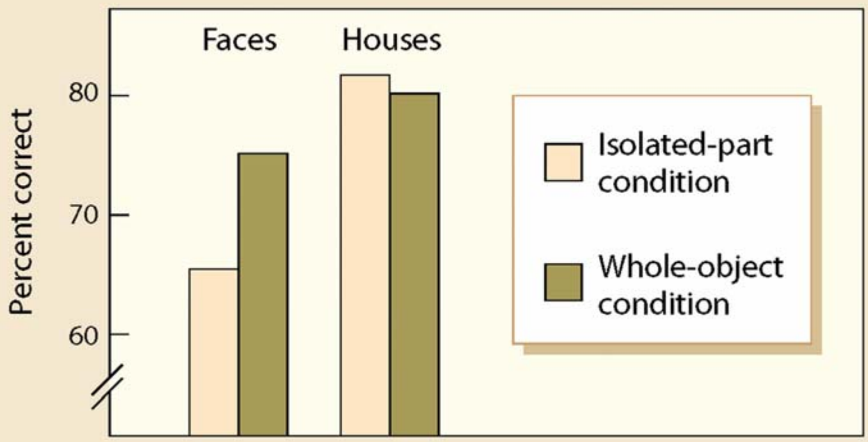

Animals
Nonliving things
60


Percentage correct
Nonliving
Living
Percentage of units damaged in visual semantic memory
Living
Nonliving
Percentage correct
Percentage of units damaged in functional semantic memory

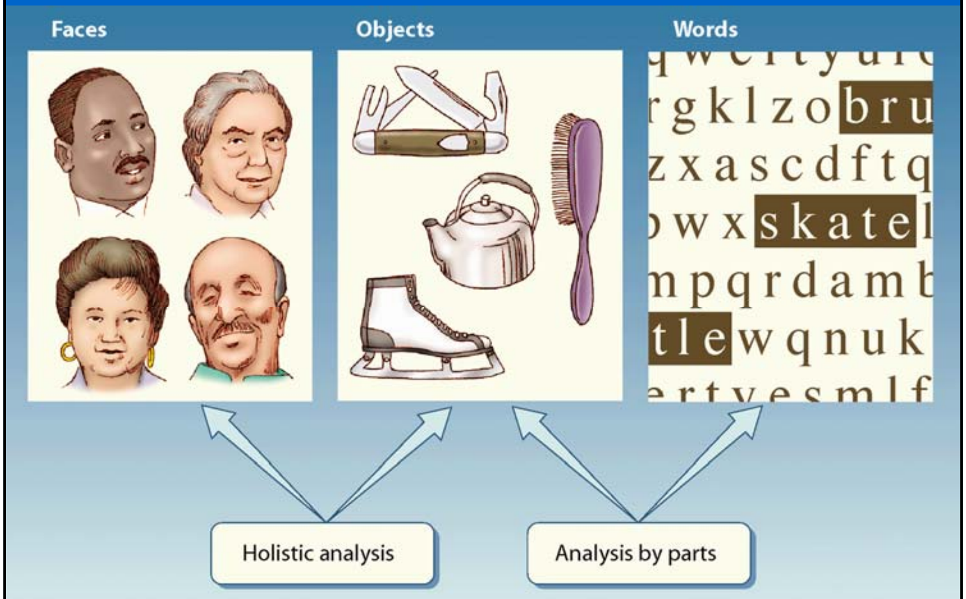

Study phase
This is Larry.
This is Larry's house.



Test phase
Is this Larry's nose?
Part condition
Whole condition
Is this Larry's door?
Part condition
Whole condition



Faces
Houses
Percent correct
80
70
60
Isolated-part condition
Whole-object condition



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