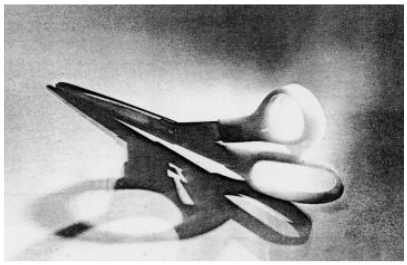
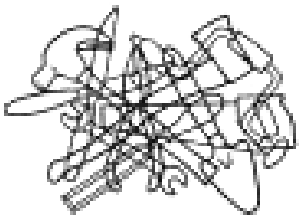
Pattern Recognition

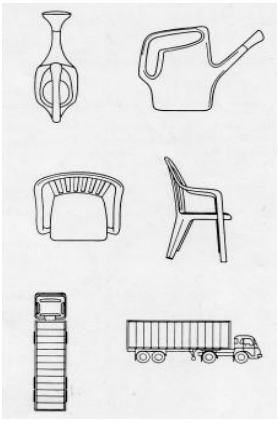
- The Amazing Flexibility of Human PR.
- What is PR and What Problems does it Solve?
- Three Heuristic Distinctions for Understanding PR.
  - Top-down vs. Bottom-up Processing.
    - Semantic Priming.
    - The Word-Superiority Effect.
  - The What vs. Where Systems.
    - Visual Agnosia.
    - Optic Ataxia & Attentional Neglect.
  - Local (Feature-based) vs. Global (Holistic) Processing.
    - Evidence for features vs. wholes in the process of PR.
- Cognitive Theories of PR.
- The Cognitive Neuroscience of PR.

Identify these objects…

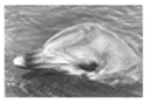


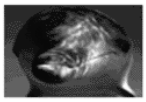


Psychological *Consistency* Despite Environmental *Variability*



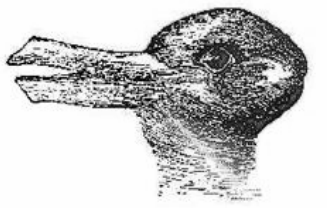
You perceive objects as constant despite changes in size, shading, orientation, occlusion, etc.



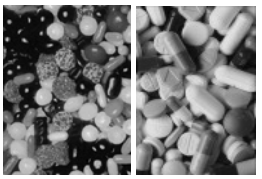


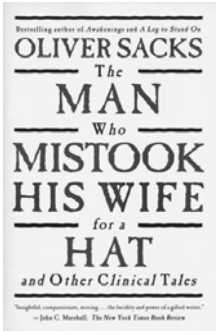
Psychological *Variability* Despite Environmental *Consistency*

However, the same object can also be perceived differently depending on the context (or your pov).



The Importance of PR





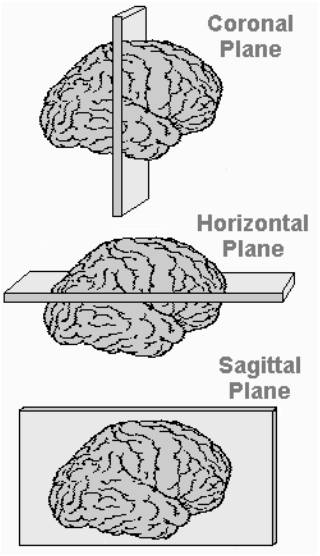
What is Pattern Recognition?

- **PR is the assignment of *meaning* to a stimulus; *categorizing* it as an instance of X.**
- ***Assigning meaning* can be thought of as matching a stimulus to a representation in memory.**

What problems does PR solve?

- ***What* is out there?** → **Identification**
- ***Where* is it?** → **Localization**

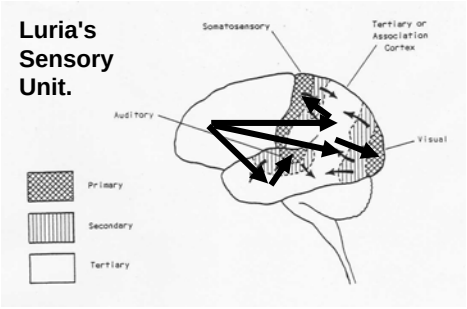
3 Distinctions for Understanding PR

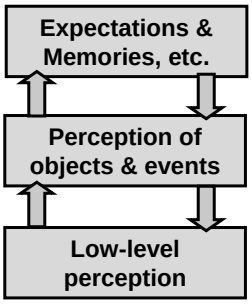


- **Bottom-up vs. Top-down processing.**
- **The What vs. Where Visual Pathways.**
- **Global (holistic) vs. local (feature-based) processing.**

Bottom-Up vs. Top-Down Processing

Luria's Sensory Unit.





- **Bottom-Up.**
  - **Association Areas: Integration of info across modalities.**
  - **Secondary Areas: Combines basic features.**
  - **Primary Areas: Basic features.**
- **Top-Down.**
  - **Association Areas: Integration of info across modalities.**
  - **Secondary Areas: Combines basic features.**
  - **Primary Areas: Basic features.**

Bottom-Up vs. Top-Down Processing

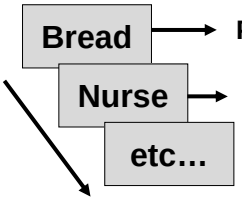
- aka. 'Data-driven'.
- Initiated by stimuli in the environment.

- aka 'Concept-driven'.
- Initiated by context, knowledge, & expectation

Top-down influences on PR

Semantic Priming in the Lexical Decision Task

- ***Letter strings*** **are presented one at a time.**
- **S's task is to decide if string is a word or non-word.**
- **DV = RT.**

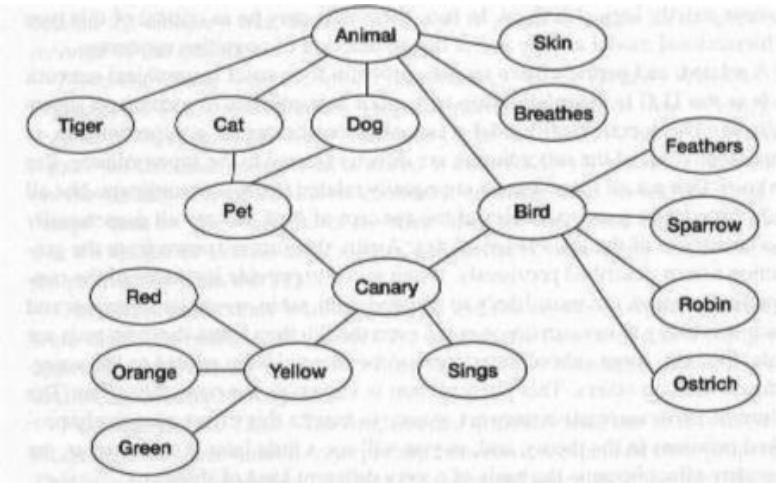


	Prime-Probe Relation	
	Unrelated	**Related**
Prime:	**Bread** (550 ms)	**Doctor** (550 ms)
Probe:	**Nurse** (550 ms)	**Nurse** (*450* ms)
Priming Effect:	0 ms	**100 ms**

◎ Words are identified (and pronounced) faster when they are preceded by semantically related words.

Top-down influences on PR

A small piece of a Semantic/Associative Network



Top-down influences on PR

The word superiority effect (Reicher, 1969)

- Letters presented very briefly, then "masked". Ss job is to ID the letter that appeared where the arrow is pointing.

	Target →	Mask →	Probe
Condition 1 (Alone):	K	&	_ ↑
Condition 2 (In Word):	WORK	$#@&	– – – _ ↑
Condition 3 (In Non-Word):	ORWK	$#@&	– – – _ ↑
			K or D?

- Main Result: Letters recognised faster & more accurately when presented as part of a word, compared to alone or as part of a non-word.

Errors from Top-Down Processing

Object Identification

Proofreading

Wishful thinking

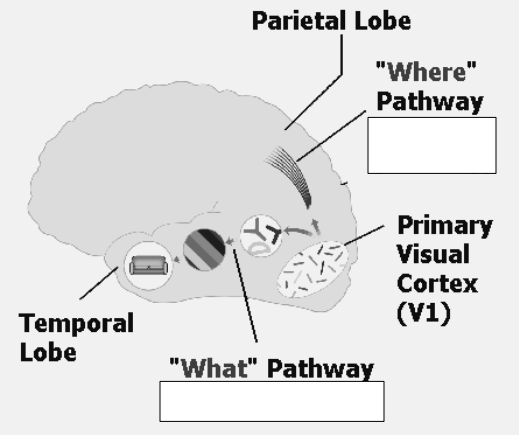
The *What* vs. *Where* Visual Pathways

■ **The *Where* Pathway**

- ⊙ "occipitoparietal".
- ⊙ "dorsal pathway".
- ⊙ localization of objects in space.

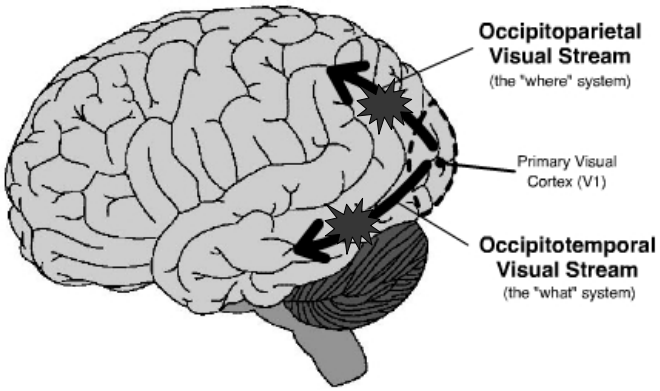
■ **The *What* Pathway**

- ⊙ "occipitotemporal".
- ⊙ "ventral pathway".
- ⊙ object identification (features, colors, shapes, etc.).



Disorders of Pattern Recognition

- **<u>Damage to *Where* Pathway</u>: Optic Ataxia; Spatial Neglect**

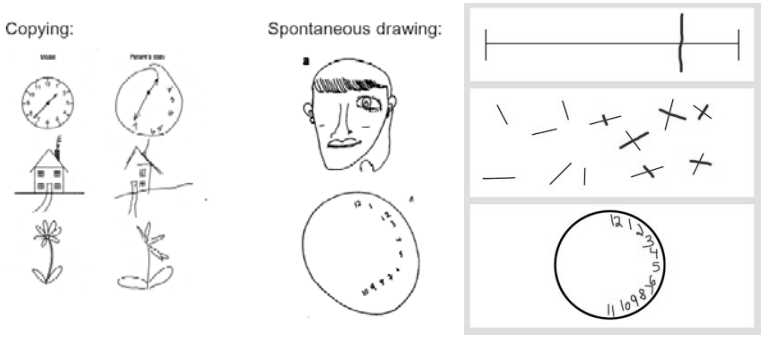


- **<u>Damage to *What* Pathway</u>: Visual Agnosia**

Damage to the "Where" Pathway

Patients with where-system damage can identify objects, but have trouble localizing them in space or acting on them.

- **Optic Ataxia** [cf. Balint's syndrome]**:** Impairment in the control of eye movements & visually-guided actions.
- **Spatial Neglect** [aka. Unilateral or Hemi-spatial Neglect]**:** A failure to acknowledge or attend to objects that are located in the side of space opposite to the brain lesion.

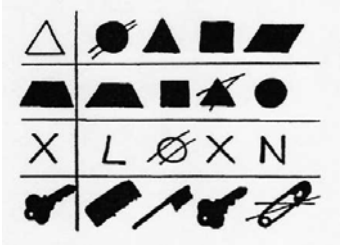


Damage to the "What" Pathway: Agnosia

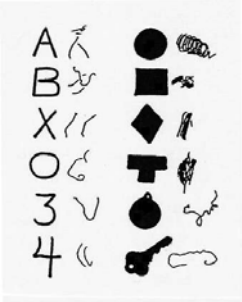
- From the Greek, meaning *lack of knowledge.*
- Refers to an inability to recognize (identify) objects even though basic sensation & perception is intact.
- *Not due* to sensory damage, memory impairment, or a deficit in intellectual functioning.
- Two basic types...
  - Apperceptive Agnosia.
  - Associative Agnosia.

Apperceptive Agnosia

- Most severe form of agnosia.
- Patients unable to identify basic/low-level features of objects, showing an "inability to form a stable percept".
- Most patients cannot identify basic object features, even when objects are familiar.
- Unable to *copy* simple line drawings.
- Patient must use other senses to recognize objects.



Multiple-Choice Object-Matching Test



Drawing Test

Apperceptive Agnosia

- **Interestingly, some patients are still able to draw objects from memory, despite being unable to *copy* them.**

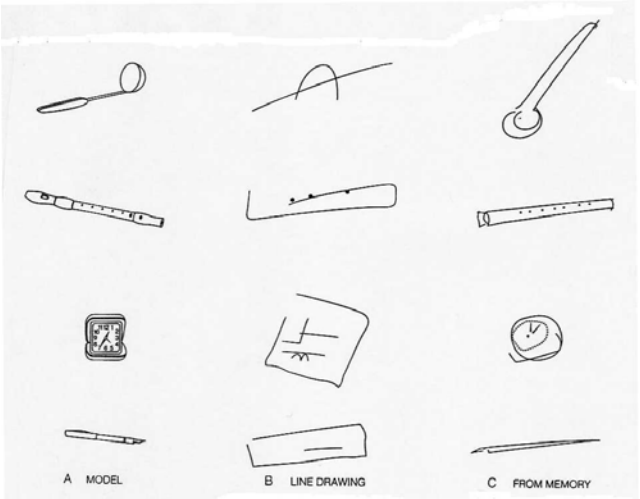


FIGURE 11.9. Samples of D. F.'s drawings. *A.* Examples of the original line drawings presented to D. F. *B.* Examples of D. F.'s drawings of the models. *C.* D. F.'s drawings based on memory of the models. Note that the drawings from memory are superior to the copies of the model line drawings.

Associative Agnosia

- **"Perception without meaning".**
- **Basic perception intact, but unable to recog object.**
- **Can copy objects, but still fail to recognize them.**
- ***Prosopagnosia*: Agnosia limited to faces; pt. is unable to id. people from their face (but may show unconscious rsp to familiar faces).**

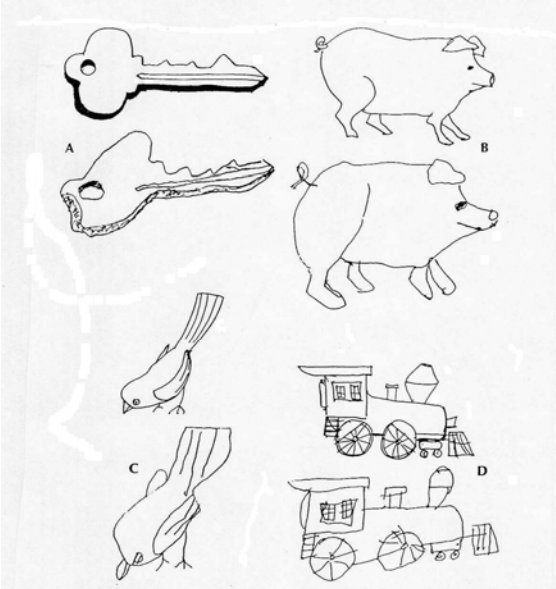
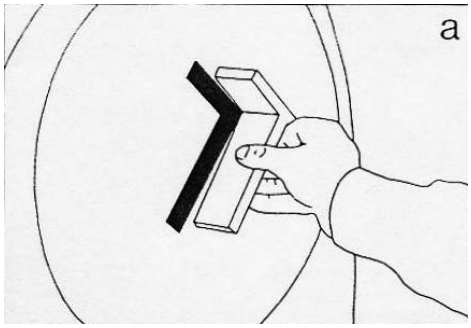


Fig. 9-2. Copies of line drawings by patient with associative visual agnosia. After copies were made, the patient still misidentified drawings as follows: A: "I still don't know." B: "Could be a dog or any other animal." C: "Could be a beach stump." D: "A wagon or a car of some kind. The larger vehicle is being pulled by the smaller one." (From Rubens and Benson, 1971.)

"Where" (*Location*) System or "How" (*Action*) System?

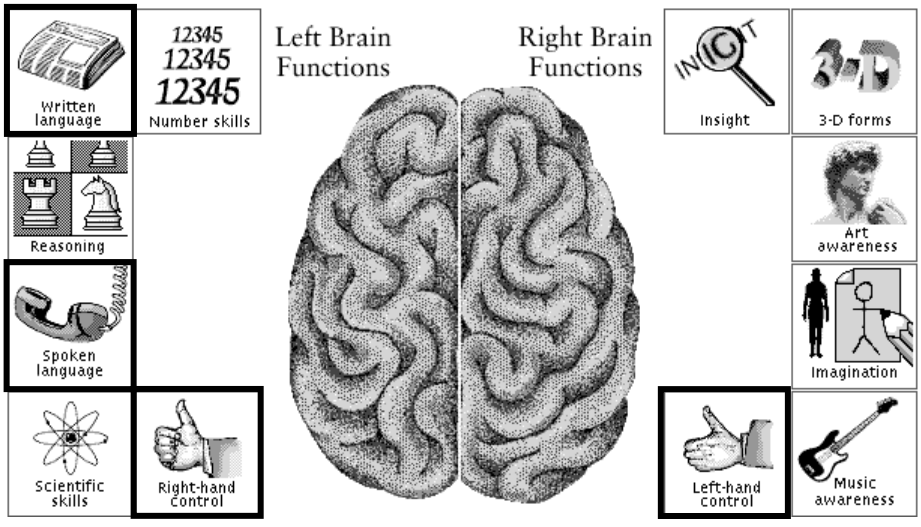


Patient DF

- Carbon monoxide poisoning resulting in temporal lobe damage.
- Cannot recognize simple features, lines, shapes, letters, etc.

- But can perform on-line visually-guided motor tasks tasks such as placing a shape in a oriented slot.
- Suggests that main role of ventral steam is to support visually-guided *actions* as much as object localization.

Local vs. Global Processing



Local vs. Global Processing

Left Hemisphere

Local.

Processing of fine details.

"The trees"

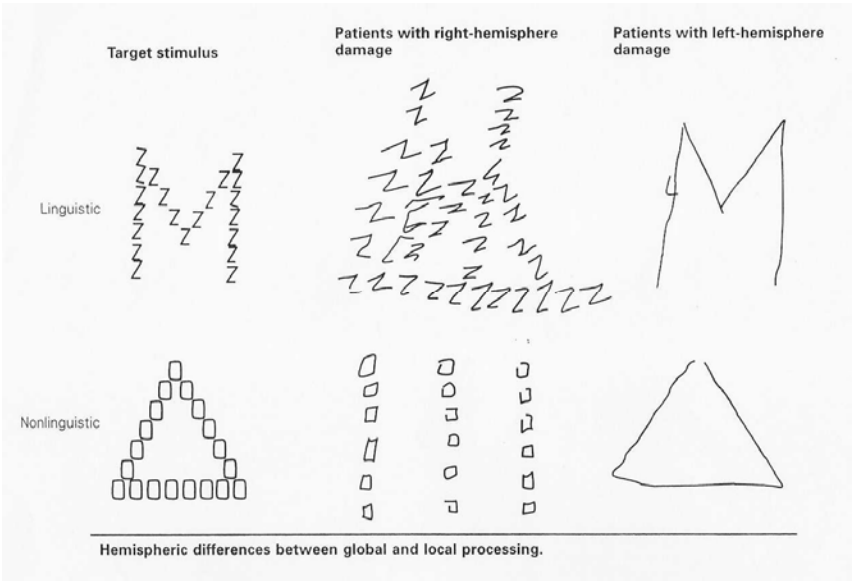
Right Hemisphere

Global.

Processing of holistic patterns.

"The forest"

Local and Global Processing revealed by patients brain damage



Hemispheric differences between global and local processing.

Evidence for Features vs. Wholes in the Process of PR

Evidence that PR is Feature-driven

1. Feature-detection cells in primary visual cortex.
2. "Pop-out" effects in Visual Search.

Evidence that PR is driven by Holistic Representations

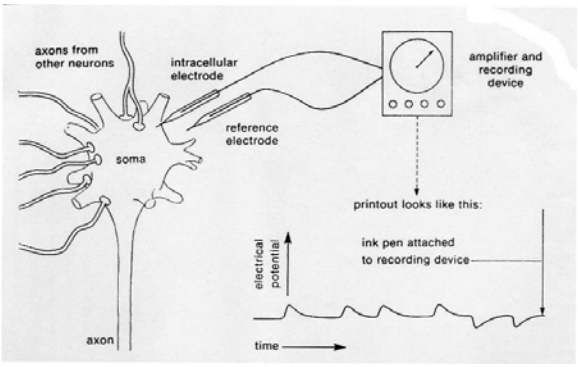
1. Top-down influences on PR (see above).
2. Face inversion effects.
3. Object detection cells in inferior-temporal (IT) cortex.

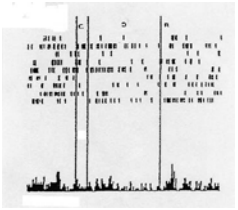
Evidence that PR reflects an interaction between features & wholes

- Global & local precedence effects.

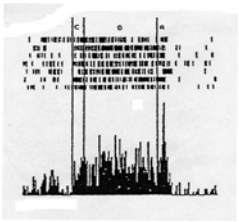
Evidence for Feature-based PR

Single-Cell Recording





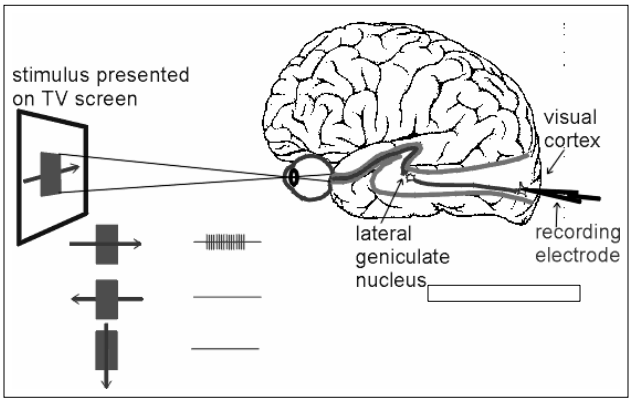
Low Response



High Response

Evidence for Feature-based PR

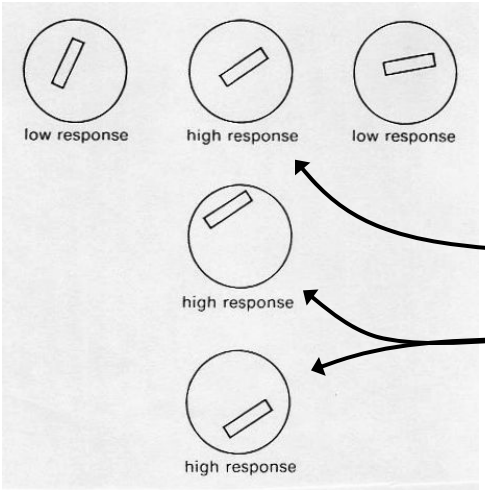
- D. Hubel & T. Wiesel.



- Rate of firing changes when stimulus is in cell's receptive field *and* the cell is sensitive to that stimulus (e.g., orientation, direction of motion, etc).

Evidence for Feature-based PR

Feature-Detection Cells



- H&W found neurons in primary visual cortex (V1) that responded selectively to lines of different orientations; called them "*Simple Cells*".
- *Later work revealed "Complex cells"* - cells that have larger receptive fields.

Evidence for Feature-based PR

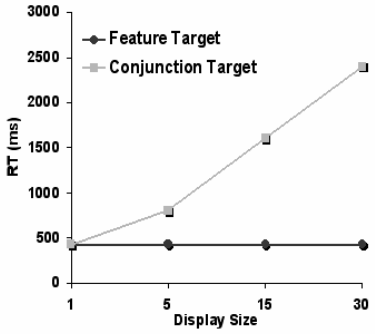
Visual Search Tasks

- It is easier to detect a target defined by a single feature (a 'feature singleton') than one defined by a combination of features.
- Targets that can be identified by a single feature appear to ‘pop out’ of crowded backgrounds.
- ‘Pop out’ effects can be asymmetric, providing information about what perceptual features the visual system considers a "basic".

Evidence for Features: Pop-out effects

Typical Findings
(e.g., Treisman & Geldade, 1980)

- **Feature Targets pop out**
  - **Flat display size function**
- **Conjunction targets demand serial search**
  - **Non-zero slope**



Evidence for Holistic-based PR

Face Inversion Effects

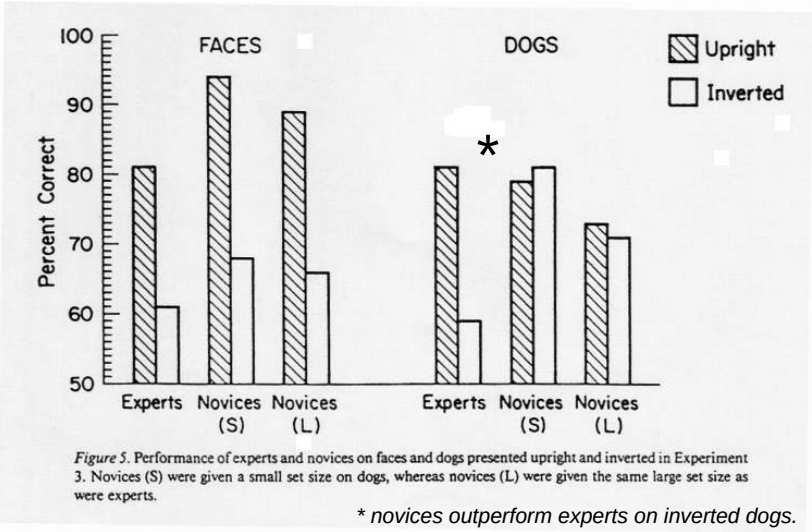
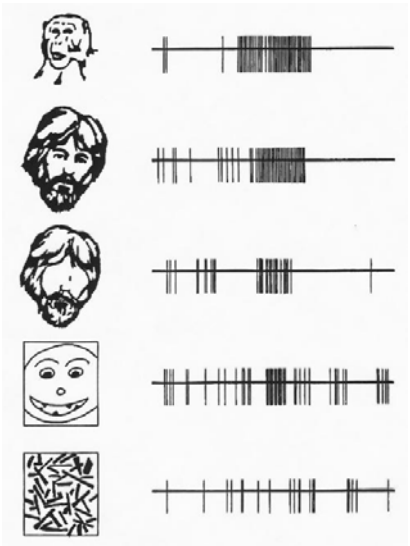


Figure 5. Performance of experts and novices on faces and dogs presented upright and inverted in Experiment 3. Novices (S) were given a small set size on dogs, whereas novices (L) were given the same large set size as were experts.

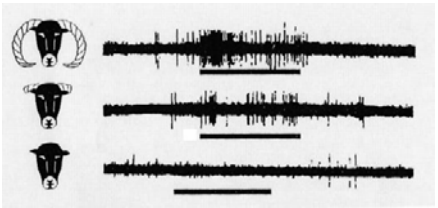
** novices outperform experts on inverted dogs.*

Evidence for Holistic-based PR



Response of neuron in monkey's IT cortex.

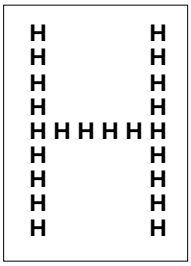
Object-detection ("grandmother") cells in inferior-temporal cortex.



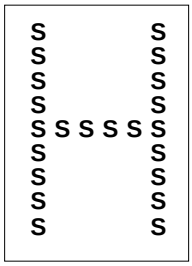
Response of neuron in IT cortex of a Dalesbred (horned) Sheep.

Hierarchical (Compound-Letter) Stimuli

Congruent



Incongruent



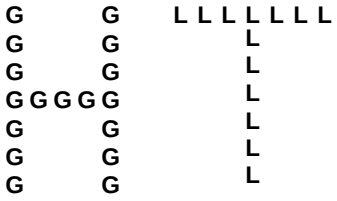
Global Precedence Effects:

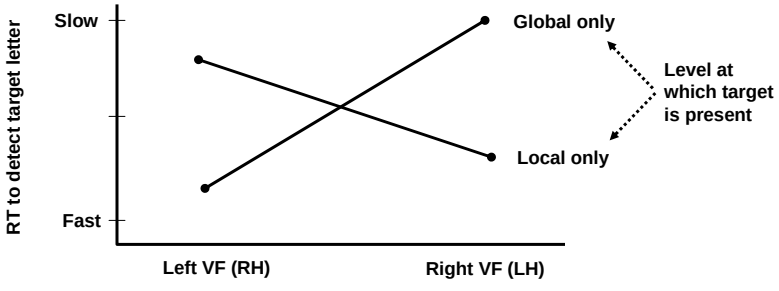
- **RT to name letter: Global < Local.**
- **Global interference (global level slows naming of local letters) but no local interference (local level does not slow naming of global letter).**

Global/Local processing as a function of visual field / cerebral hemisphere

Hierarchical stimuli presented to either the left visual field (RH) or the right visual field (LH).

Subject's task is to detect either an "H" or an "L" irrespective of the level at which it occurs.

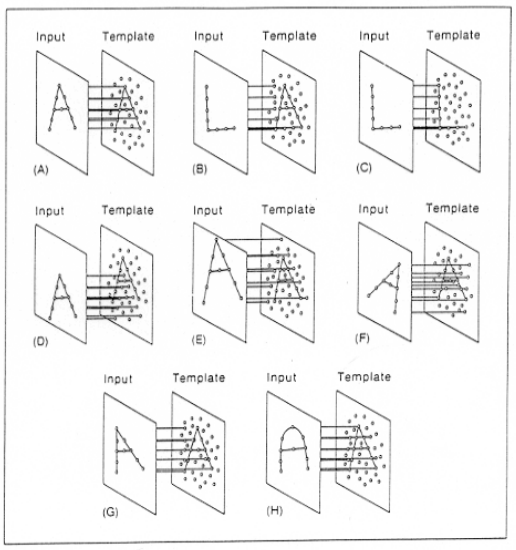




Cognitive Theories of Pattern Recognition

- **Template Matching Approaches.**
- **Feature Extraction Approaches.**
  - Pandemonium.
  - Feature Network models.
- **Interactive (bottom-up/top-down) Approaches.**
  - Connectionist (PDP) models.
  - Recognition-by-Components (Geons).

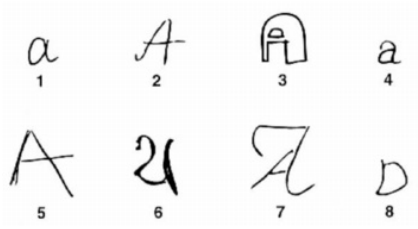
Template Matching



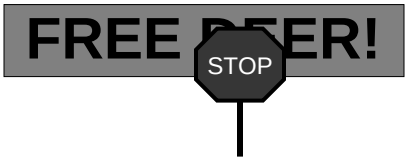
- **Input image is maintained as holistic pattern and matched to "templates" (holistic reps) in memory.**
- **Widely used in machine-recog. systems.**

Limitations of Template Matching

- **Requires exact match btw. image & template.**



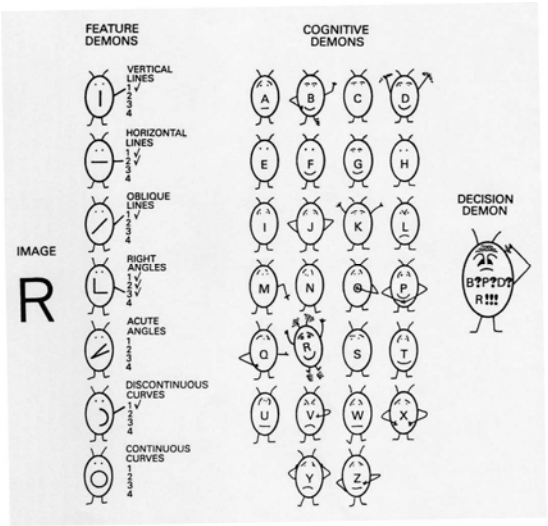
- **Inputs vary widely in size, orientation, etc.**
- **Inputs are often degraded or occluded.**



- **For real-world applications, a large number of templates would be required.**

Feature Extraction: Pandemonium

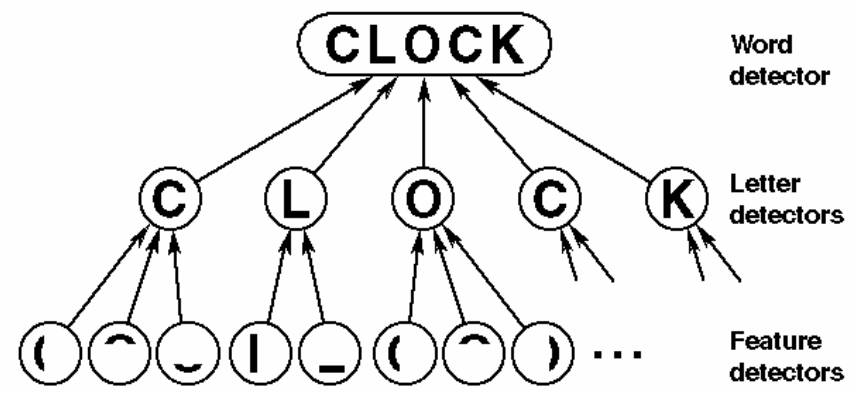
(Selfridge, 1959; Selfridge & Neisser, 1963)



"Feature demons" become active when their feature is presented, thereby activating "cognitive demons".

A "decision demon" decides what letter was presented.

Feature Network Models



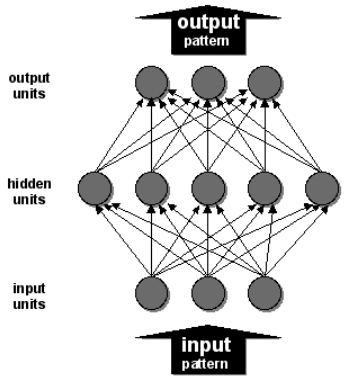
Just like neurons, feature detectors have a baseline activation (resting) level and a response (firing) threshold. Some detectors fire more easily than others due to frequent or recent input (cf. 'priming'). A strong input or several weak inputs can cause a detector to fire. If a detector fires, it activates detectors at the next level in the network.

Two Major Limitations of Feature-detector Models like Pandemonium

- **Completely bottom-up.**
  - **No chance for higher-level demons (representations) or context to influence the PR of low-level features.**
- **Relations among features are lost.**
  - **Not easy to distinguish between patterns that share multiples features (e.g., O vs. Q, F vs. P, etc.).**

Connectionist Models

(*aka. Parallel Distributed Processing*)



A small PDP network

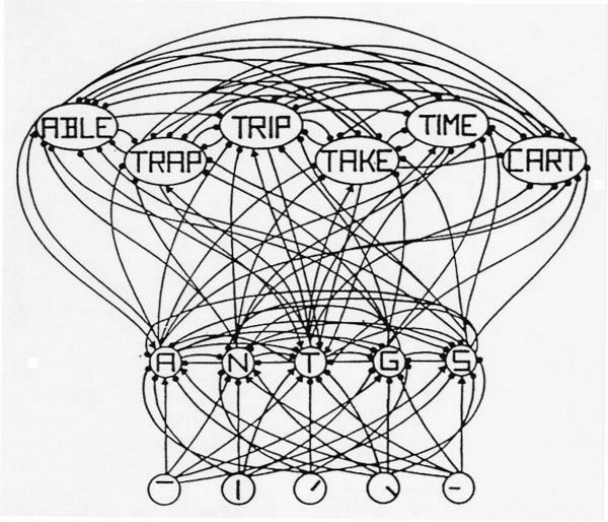
<u>Units</u>: Neuron-like processing nodes that take on values.

<u>Connections</u>: The links between units (cf. axons); connections have weights (+/-) that determine how a unit is affected by activation.

<u>Hidden Units</u>: Units that have no connection with the outside world (cf. interneurons).

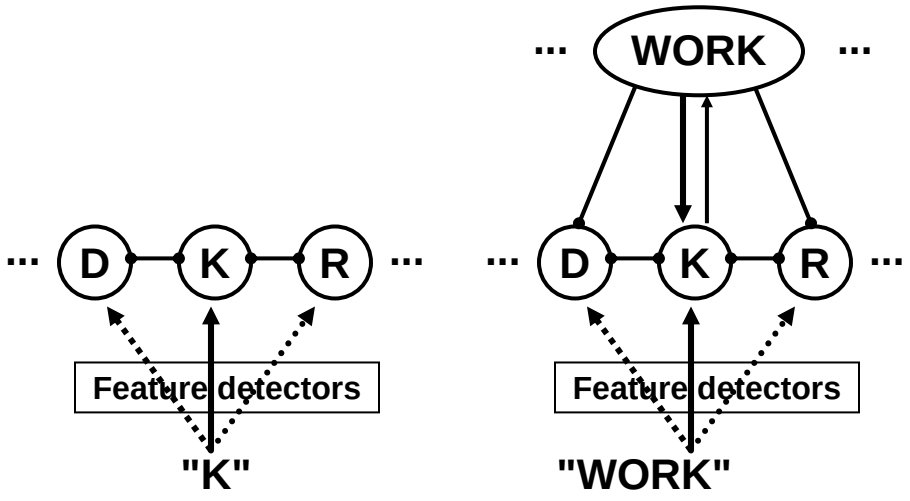
Knowledge is embedded in the connections among units

Connectionist Models



- **Bottom-up *and* top-down connections.**
- **Excitatory *and* inhibitory links.**
- **Activation (and thus recognition) occurs gradually (over time), thus allowing word units to "guide" feature analysis.**

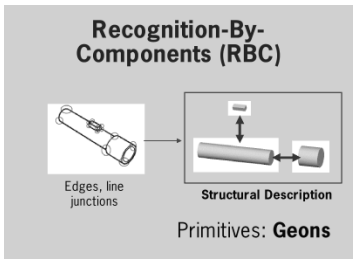
Connectionist Account of Word-Superiority Effect

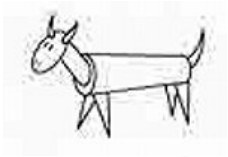


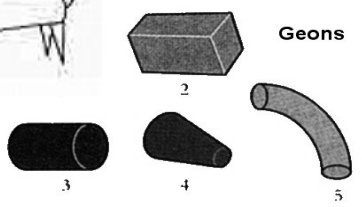
Recognition by Components

Irving Biederman

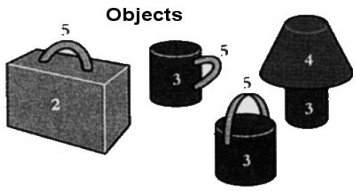
Theory of 3D Object Recog that proposes the existence of object primitives ("geons") which combine to form objects.







- Geons constitute an "alphabet" of primitives
- Structural descriptions code both geons and relations between geons
- Structural descriptions (partially) represent 3D structure



Limitations of Template Models

- **Possible mismatch between (noisy) incoming sensory info and stored template.**

Limitations of Feature-based Models

- **Completely bottom-up (does not allow priming).**
- **Relations among features are lost.**

- **Interactive models (PDP & Geons) get around the above problems by…**
  - **Allowing both bottom-up & top-down processes to operate quickly and simultaneously.**
  - **Allowing holistic representations ("templates") to influence/facilitate the processing of features.**

The Cognitive Neuroscience of PR