Extension: Representations

CS786

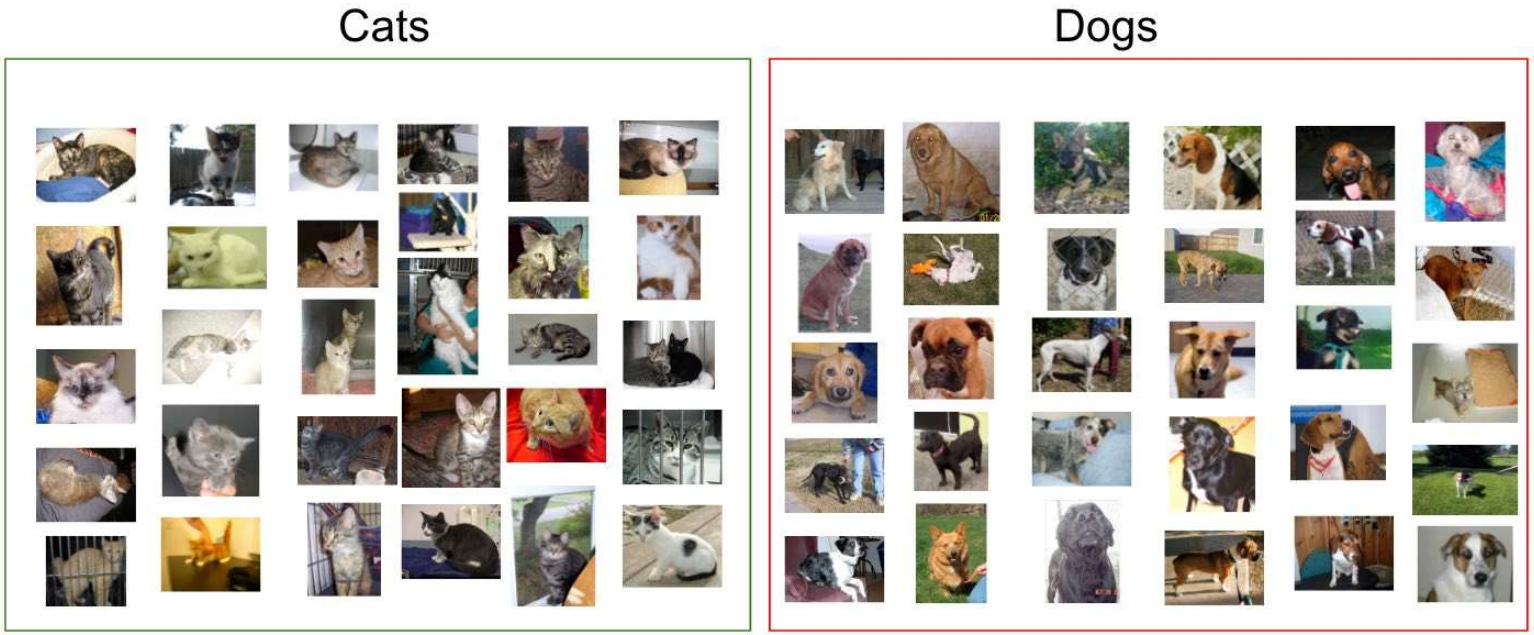
28th October 2024

Categorization

- Ordering the world into distinct sets

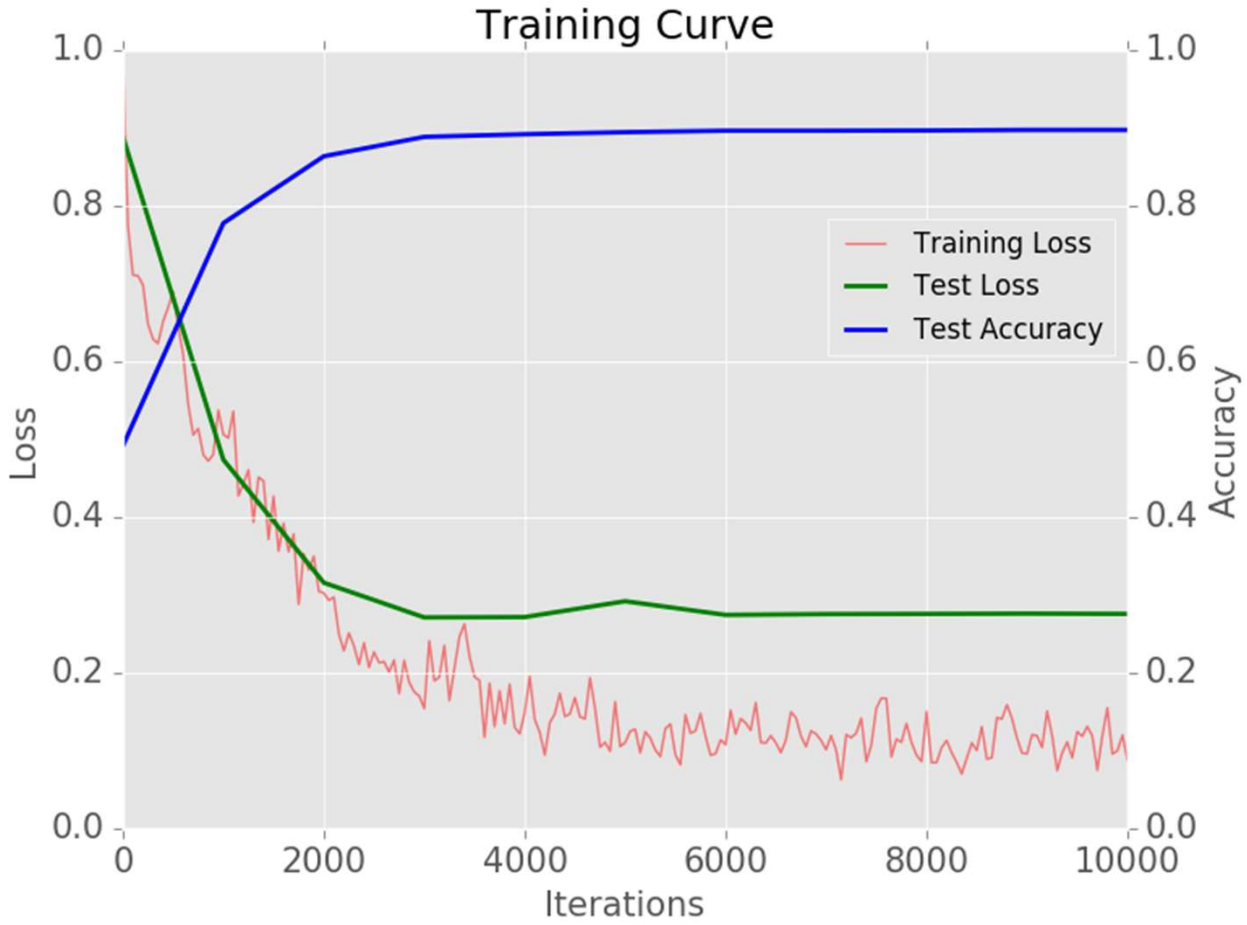
Can solve this using machine learning?

- That's a major thrust of modern ML



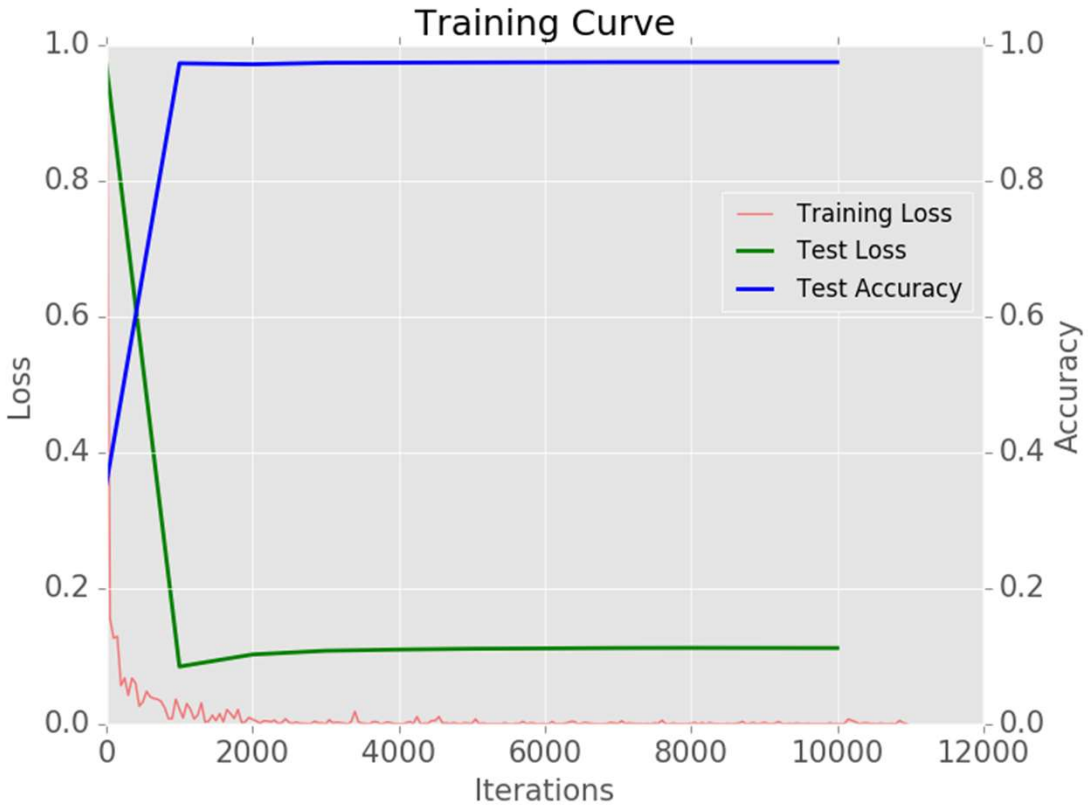
Sample of cats & dogs images from Kaggle Dataset

Similarity-based approaches are data-intensive

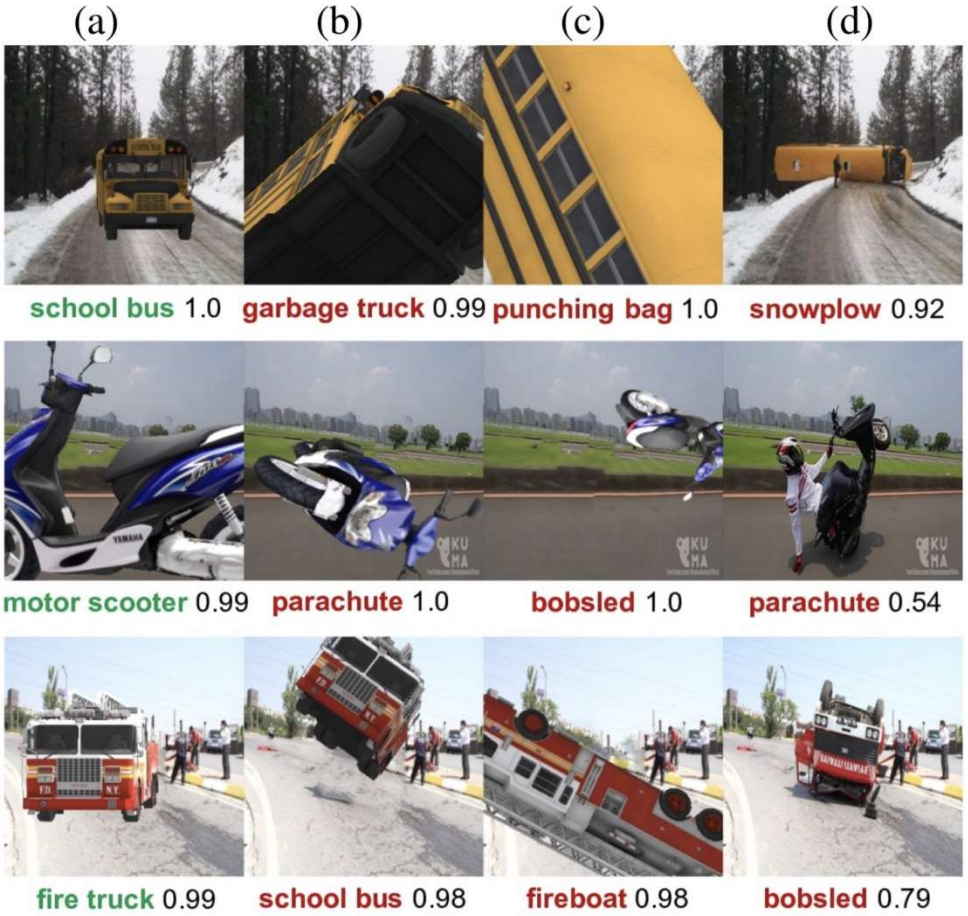


http://adilmoujahid.com/posts/2016/06/introduction-deep-learning-python-caffe/

Even assuming transfer learning

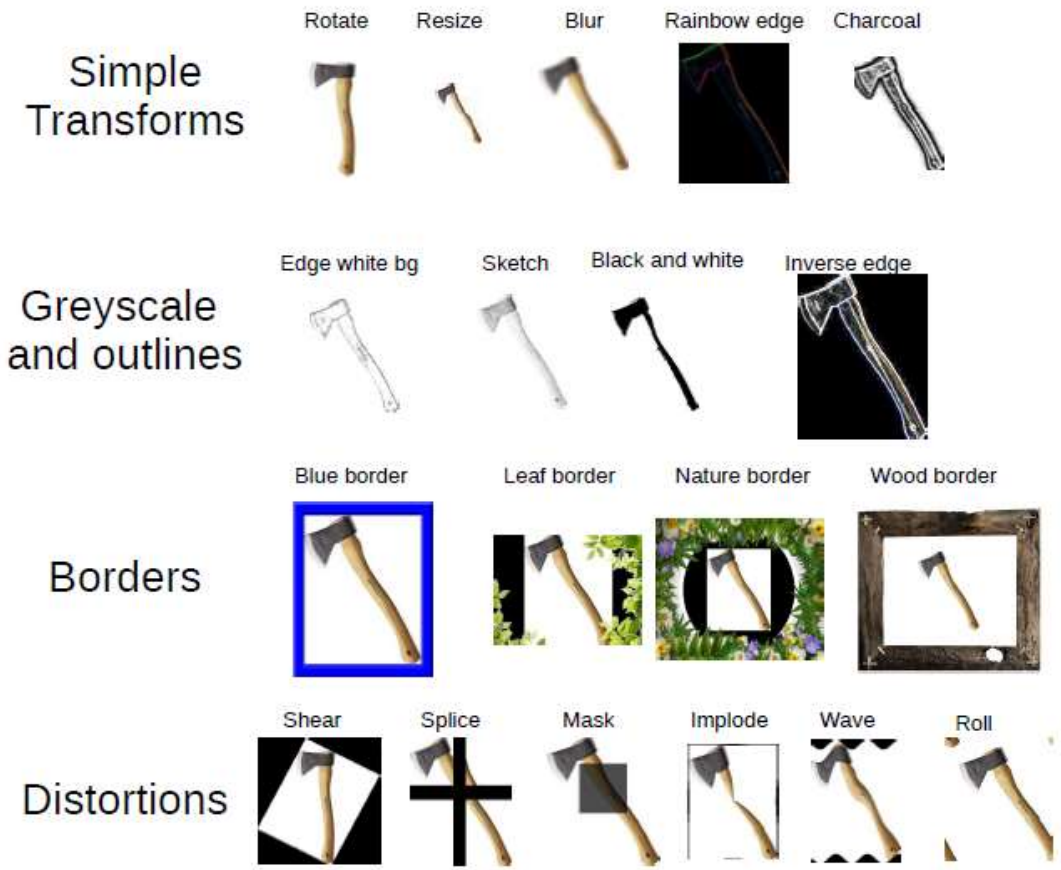


Machine classification fails gracelessly



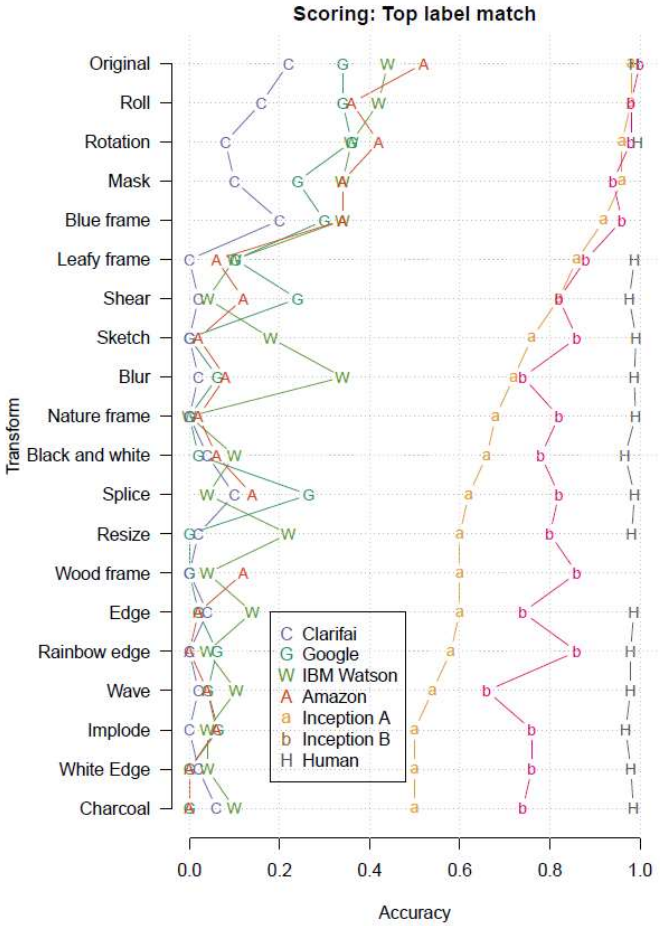
https://arxiv.org/pdf/1811.11553.pdf

… and for the simplest of causes



… and for the simplest of causes

- Untransformed images are classified with 98% and 100% accuracy
- Transformed image accuracy drops enormously
- Human performance is unaffected
- Humans know when they are going to have trouble



Categorization

- Ordering experience into distinct sets

Human categorization is much more frugal

- My 3 year old knows which is a cat and which is a dog

And resilient to visual differences

Similarity is not the only source of category information

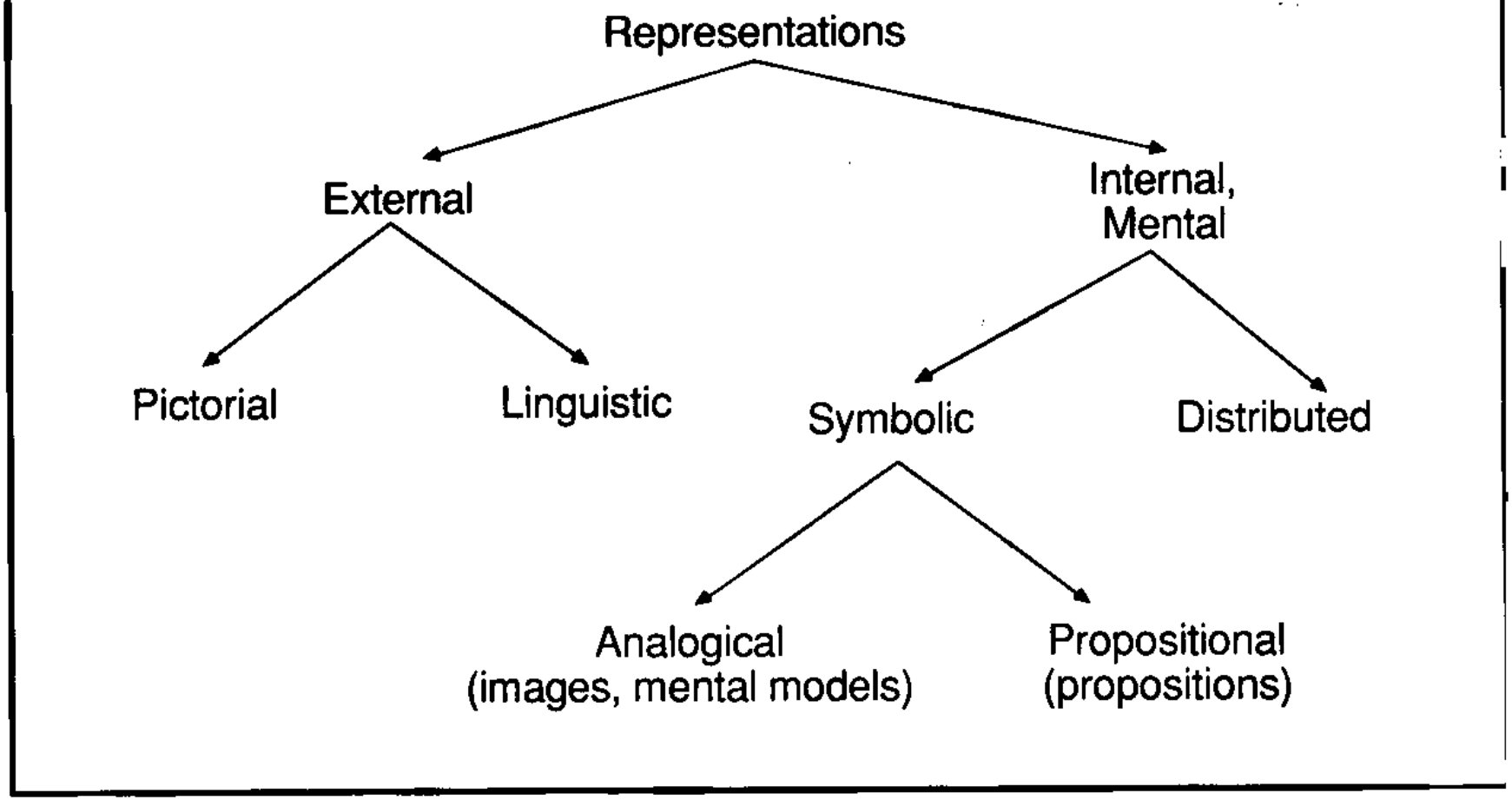
Same category?

Different category?

Representation

- "any notation or sign or set of symbols which 're-presents' something to us…that is, stands for something in the absence of that thing"
  - objects of the external world (things)
  - objects of the internal world (ideas)
- The "what" and "how" of representation is critical to most core issues in cognitive psychology
- implies some storage of information
- key problem: what is stored?
- nature of representation can be revealed through performance, but there are limitations

FIGURE 9.1


Representations
External
Internal,
Mental
Pictorial
Linguistic
Symbolic
Distributed
Analogical
(images, mental models)
Propositional
(propositions)

The big debate

- **Perceptually-based representations**
  - Imagery (encodes visual+spatial structure)
    - visual (object-based)
    - spatial
  - Linear Orderings (encodes sequence)
- **Meaning-based representations (e**ncode what is significant about an event)
  - Propositions (code relations 'linguistically')
  - Schemas (large, complex units of knowledge)
    - event schemas (scripts)
    - object schemas (concepts)
      - attributes
      - prototypes

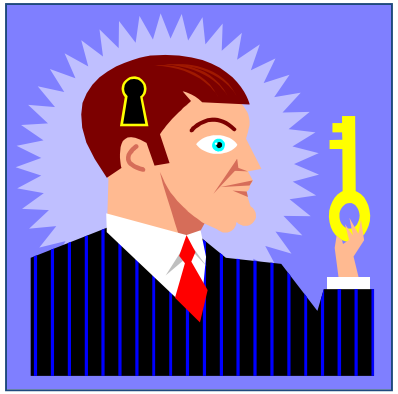
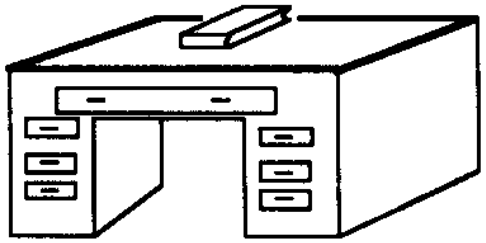


FIGURE 9.3

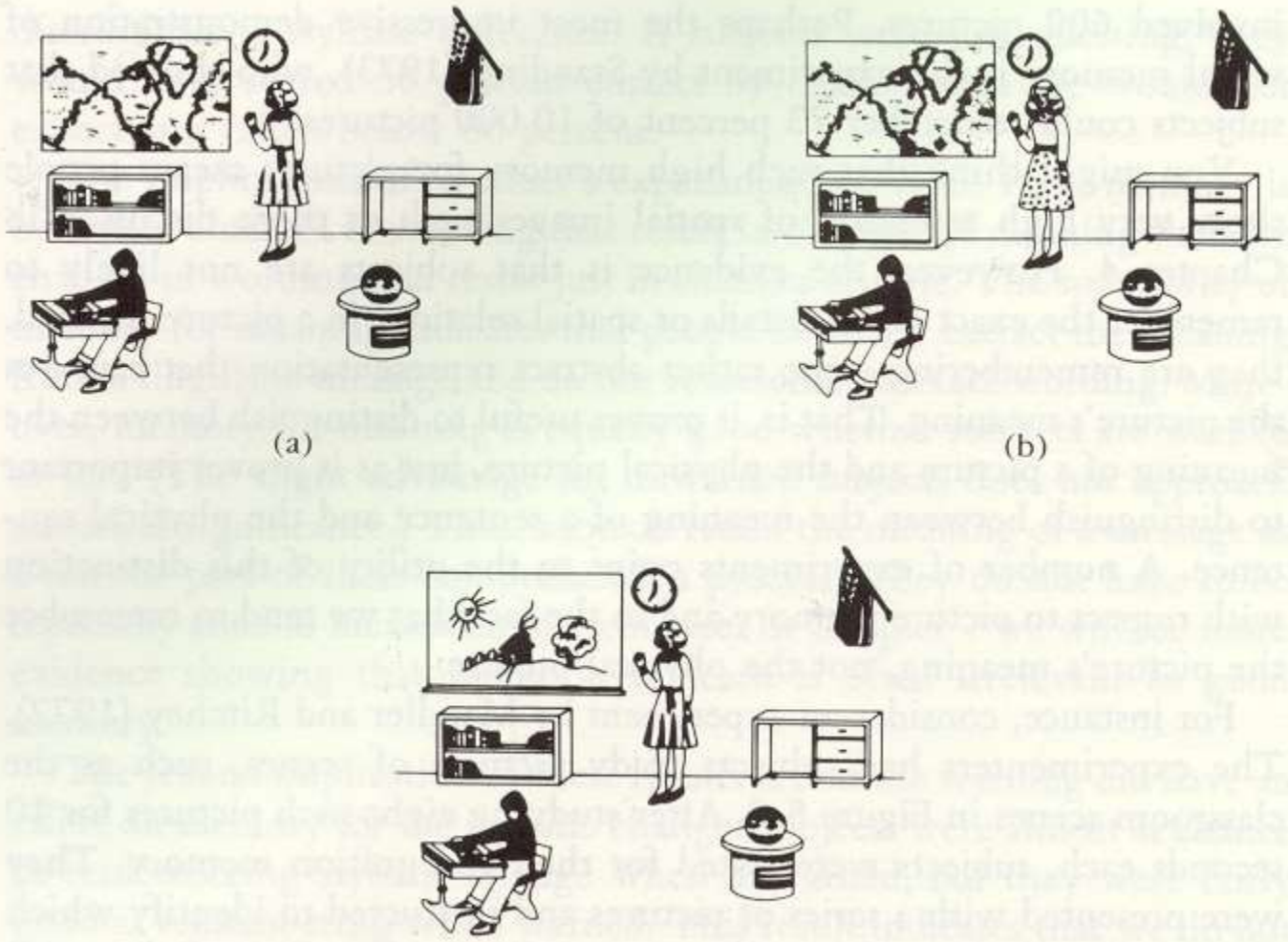
Language	Picture
"The book is on the desk"	
1. Discrete symbols	1. No discrete symbols
2. Explicit, needs symbol for relation	2. Implicit, no separate symbol for relation
3. Grammatical, clear rules of combination for types of symbol	3. No clear rules of combination or symbol types
4. Abstract	4. Concrete

Images vs. Propositions

- Are images really different from propositions?
  - YES (Paivio dual-coding theory)
  - NO (Pylyshyn, Anderson & Bower)
- Does imagery have any functional significance?
- What is the relationship between perception and imagery?

Memory for Visual Images

- Although people are generally good at remembering the general 'gist' (meaning) of pictures, memory for picture details is relatively poor
- Representative studies:
  - Mandler & Ritchey (1977): study classroom pictures, present with distractors (next slide)
  - Nickerson & Adams (1979): people virtually at chance in reproducing the correct configuration of a penny
- Conclusion: meaning-based representations ARE really different from perceptually-based representations


(a)
(b)
(c)

Paivio's Dual-Coding Theory

- Two basic coding systems: verbal and nonverbal
- Each is specialized for encoding, storing, organizing and retrieving information
- Each system consists of sensorimotor subsystems
- Basic representational units: *logogens* and *imagens*
- Systems interconnected by 'referential links'

FIGURE 9.4

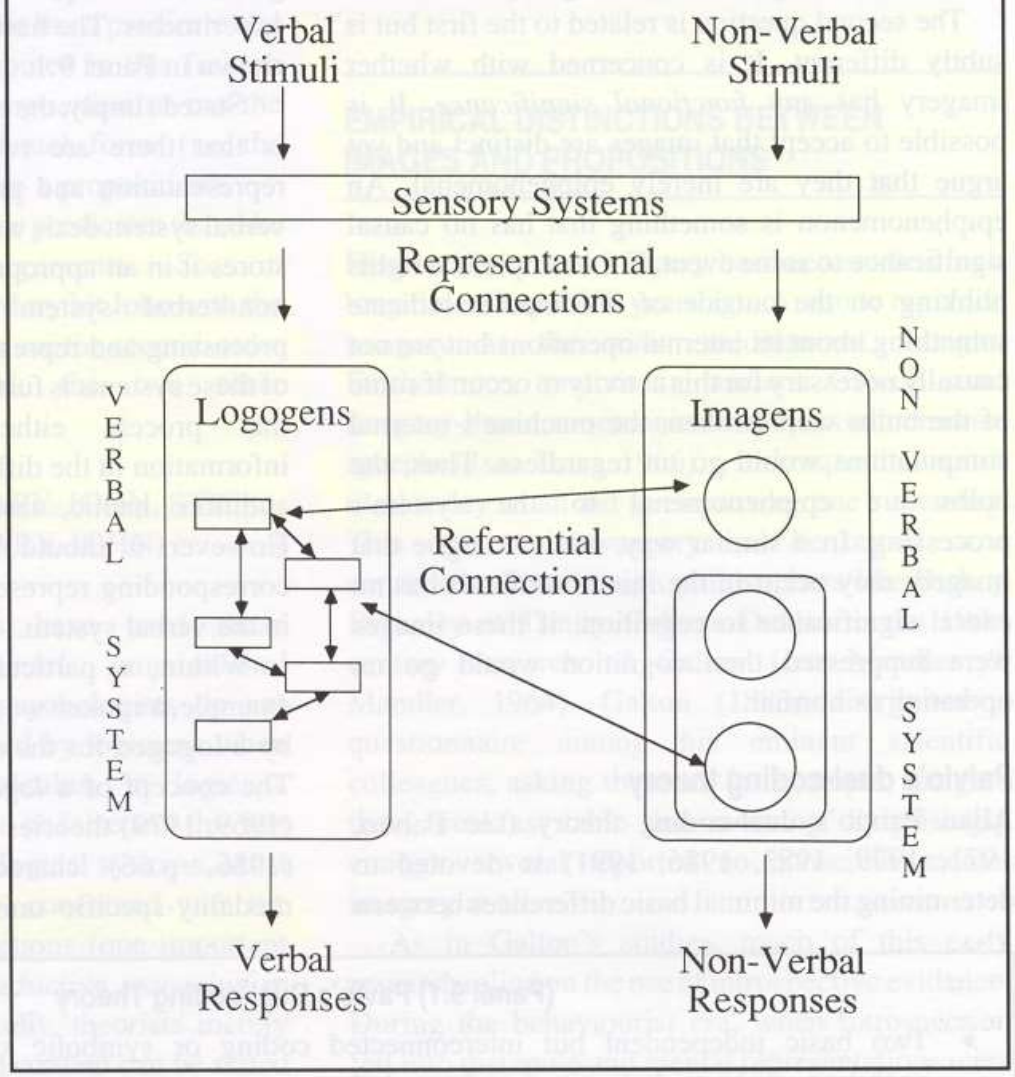

Verbal Stimuli
Non-Verbal Stimuli
Sensory Systems
Representational Connections
VERBAL SYSTEM
Logogens
Imagens
NON VERBAL SYSTEM
Referential Connections
Verbal Responses
Non-Verbal Responses

TABLE 9.2

The Relationship Between Symbolic and Sensorimotor Systems and Examples of the Types of Information Represented in Each Sub-system in Paivio's Dual-coding Theory

	Symbolic systems	
Sensorimotor	*Verbal*	*Non-verbal*
Visual	Visual words	Visual objects
Auditory	Auditory words	Environmental sounds
Haptic	Writing patterns	"Feel" of objects
Taste	—	Taste memories
Smell	—	Olfactory memories

Evidence for and against dual-coding theory

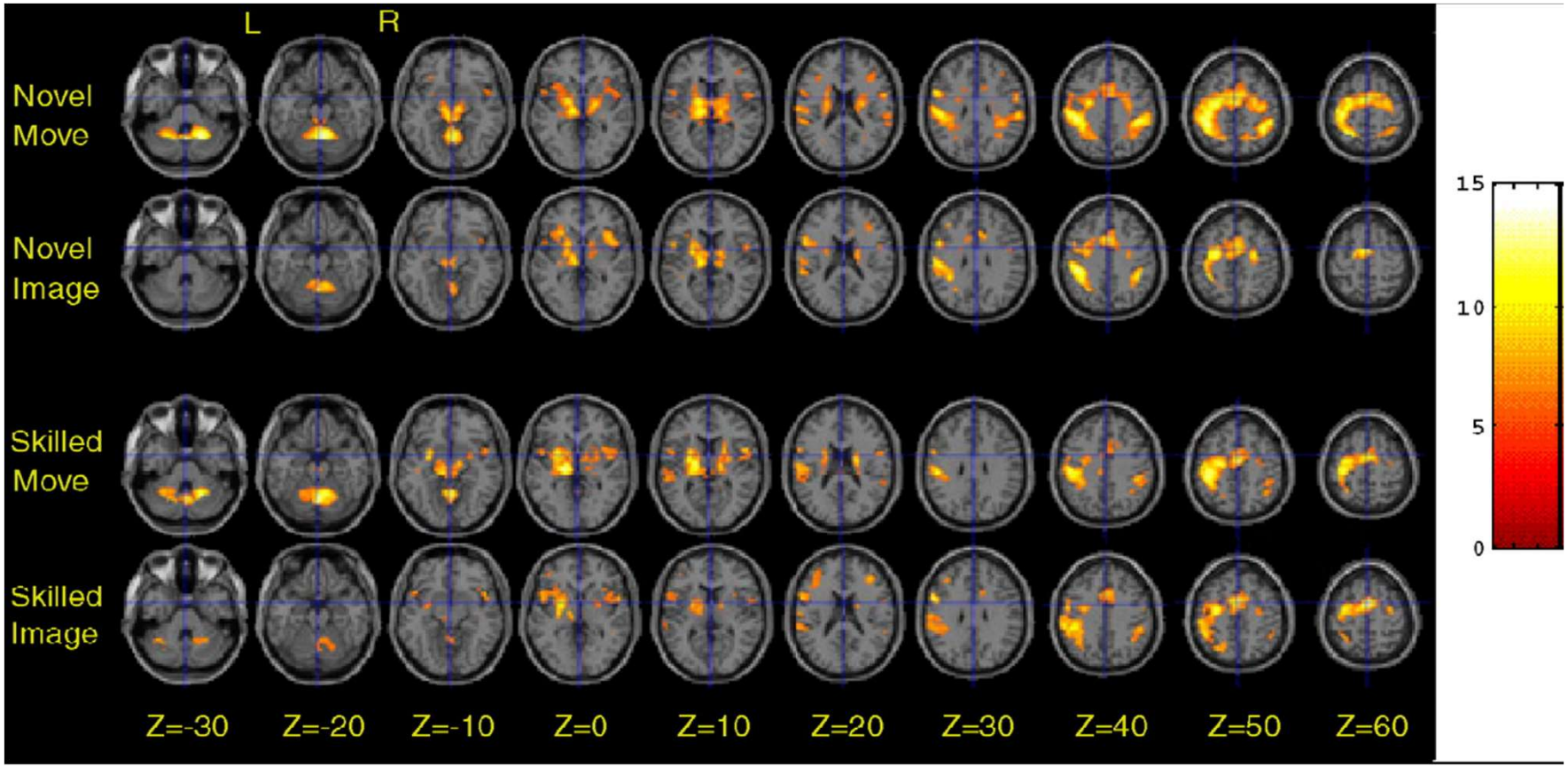
FOR

- **Free recall of pictures > words**
- **Concrete words > abstract words**
- **Free recall of words encoded with imagery instructions > pronunciation**
- **Spatial interference effects (Baddeley et al., Brooks)**
- **Hemispheric differences in abstract-concrete word recognition**

AGAINST

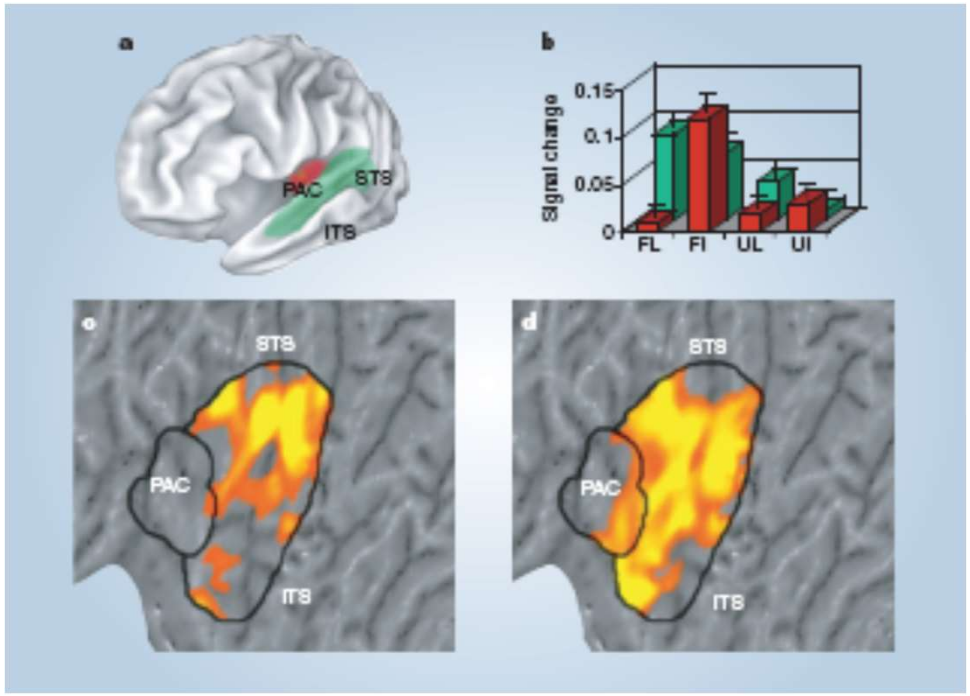
- **Interactive imagery instructions enhance cued-recall, but separate-imagery instructions do not (enhance relational organization)**
- **Little evidence for cognitive mechanisms of imagery (but see next slides; this may be changing)**

Motor imagery task produces more congruent activation (compared to actual movement) in motor cortex after practice



Lacourse, et al., 2005, Neuroimage, 27, 505-519.

Auditory Cortex Shows Activation during 5-sec gaps in songs; effect is greater for familiar songs



FL=familiar songs w/ lyrics

FI=familiar instrumentals

UL=unfamiliar songs w/ lyrics

UI=unfamiliar instrumentals

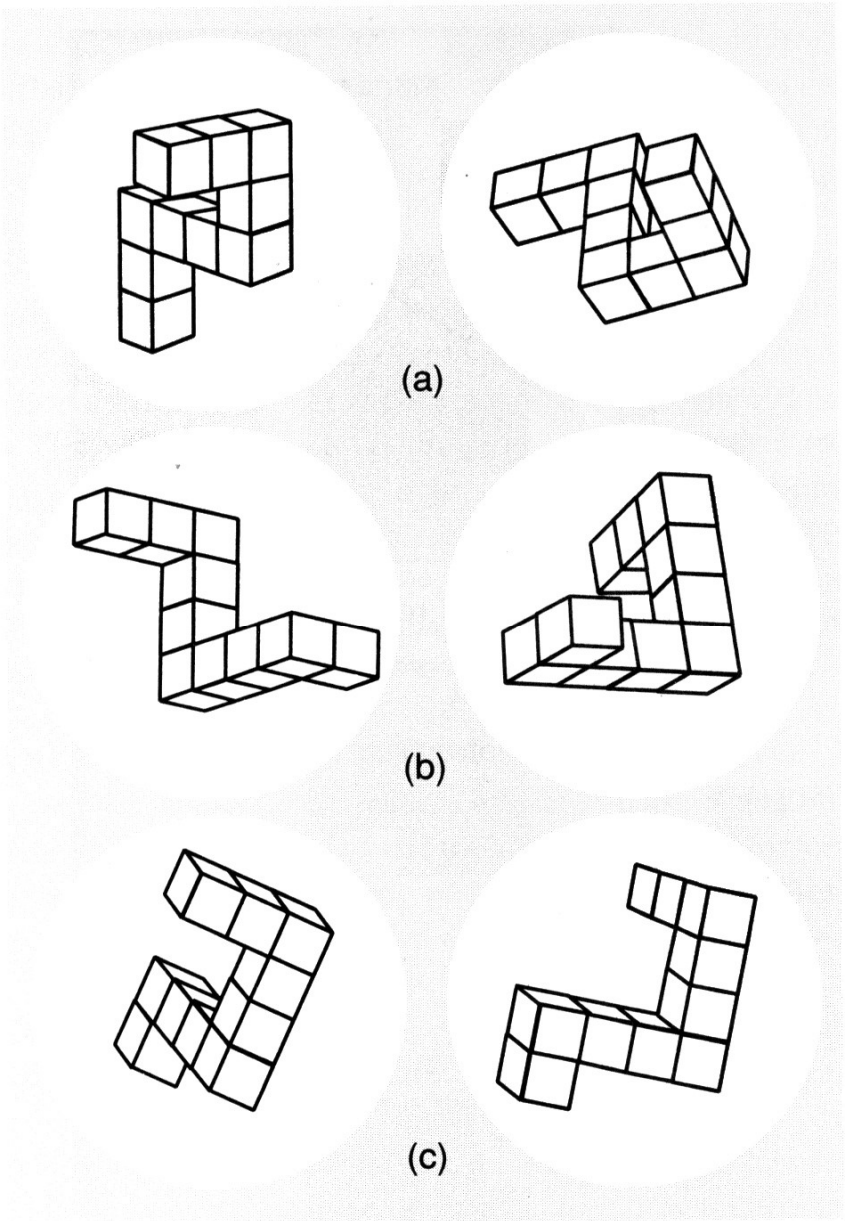
Famil - Unfamil Songs With Lyrics

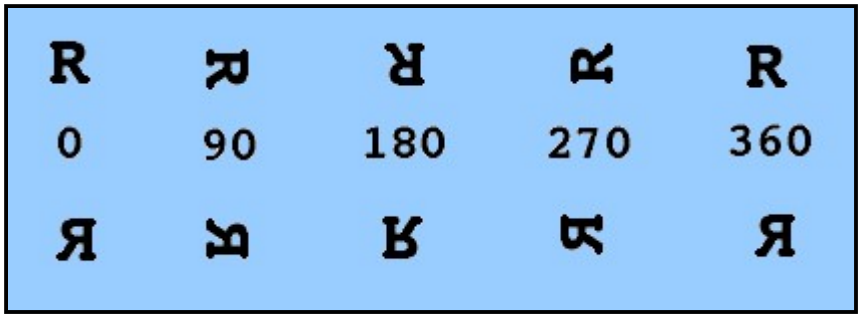
Famil - Unfamil Songs Without Lyrics

Kraemer, et al., Nature, 2005, 434, 158.

Structure of Images

- **From psychological studies, results suggest that mental operations on images are similar to mental operations on percepts**
  - MENTAL ROTATION: RT to determine if a figure is mirror reversed is related to how much it is rotated (Cooper & Shephard)
  - IMAGE SCANNING: time to scan between two points is a linear function of the distance between them (Kosslyn)
- **Images have both visual and spatial properties**


(a)
(b)
(c)


0
90
180
270
360

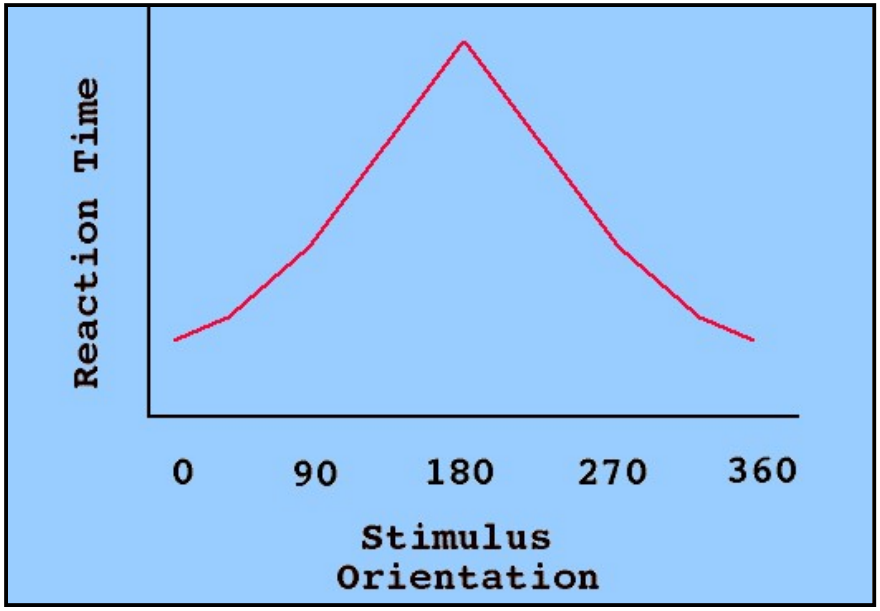
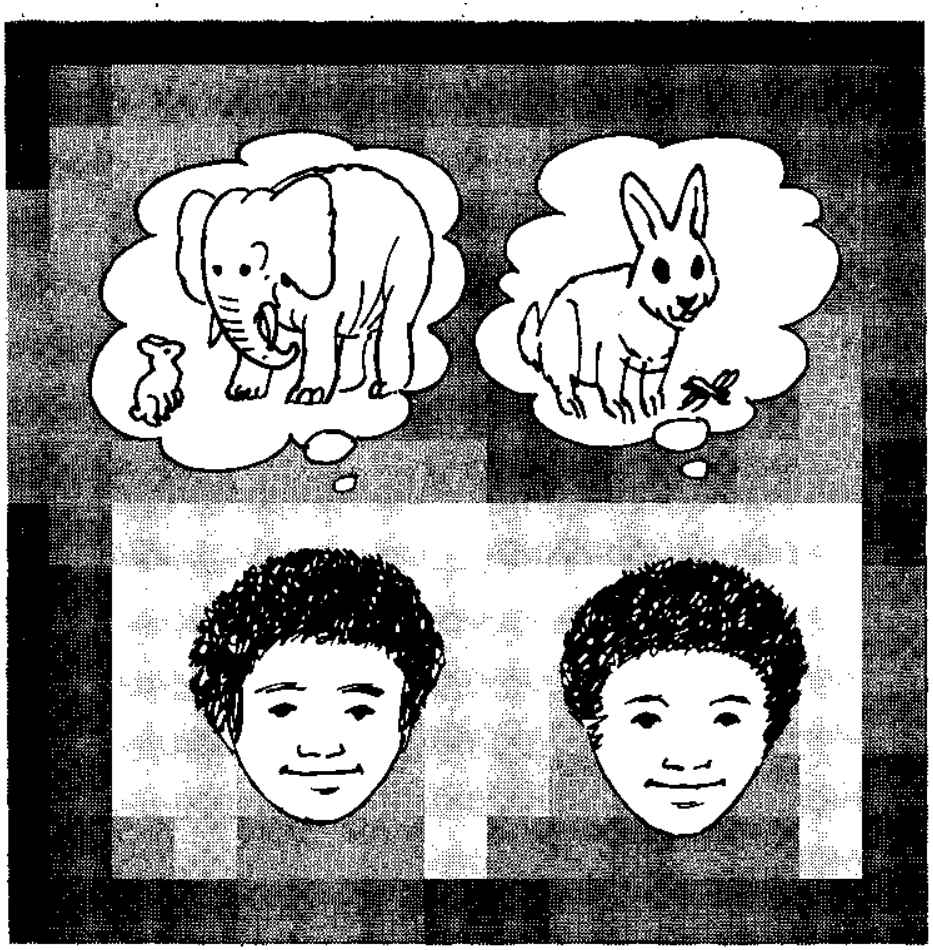

Reaction Time
0
90
180
270
360
Stimulus
Orientation

Image granularity matters



Summary

- There is evidence that people have at least two types of knowledge representations
  - Propositional
  - Imagery-based
- How do we define similarity judgments in either case?
- How do we make categories using both sources of information?