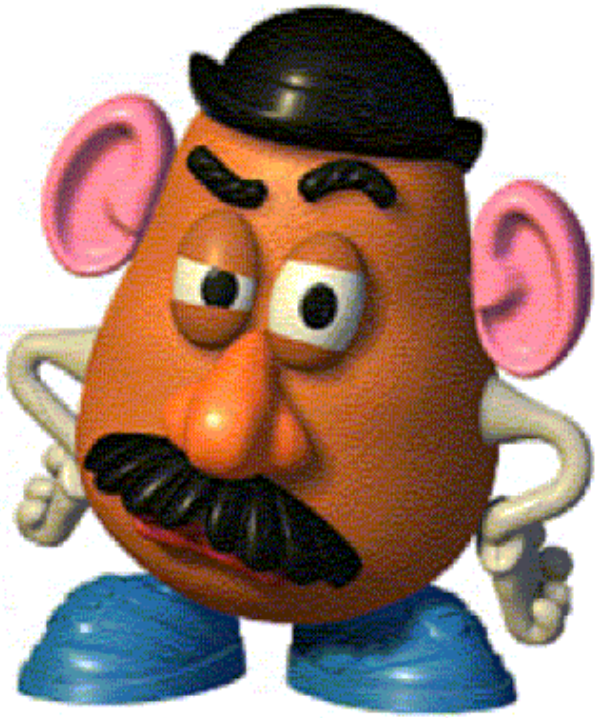
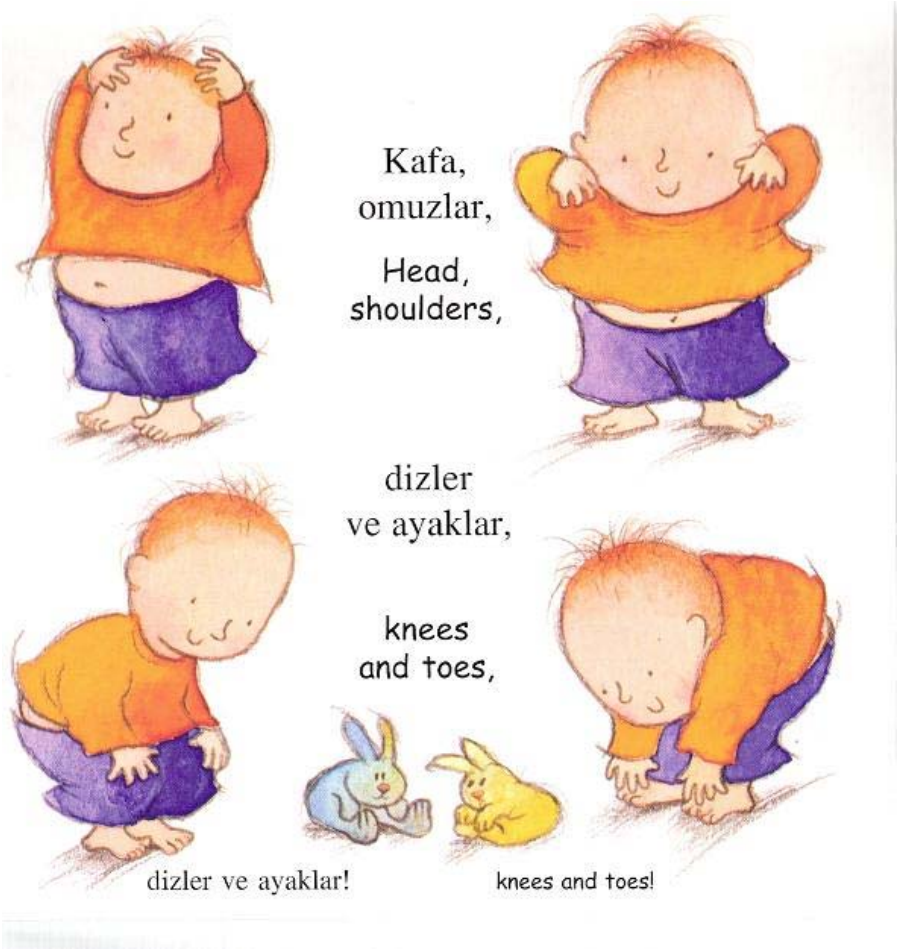
Studying Objects Concepts by Combining Feature Norms, Connectionist Networks, and Modality-specific Representations

Ken McRae

Semantic Features of Objects

Kids learn features





Feature Norms

cherry

a fruit
has a pit
has a stem
is red
is round
is small
eaten in pies
grows on trees
is delicious
tastes sweet

1970's

Rosch & colleagues

typicality: bird

>

family resemblance

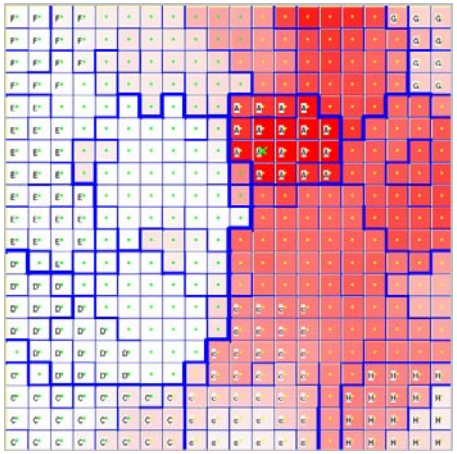
basic level

1980's

although features remained basis for virtually all theories of concepts

limited to lists of independent features

Interesting Stuff Goes Well Beyond



- learning distributional statistics
  - performance based on them
- features are correlated/clustered

  <has a beak> <has features>

Temporal Dynamics Settles over Time

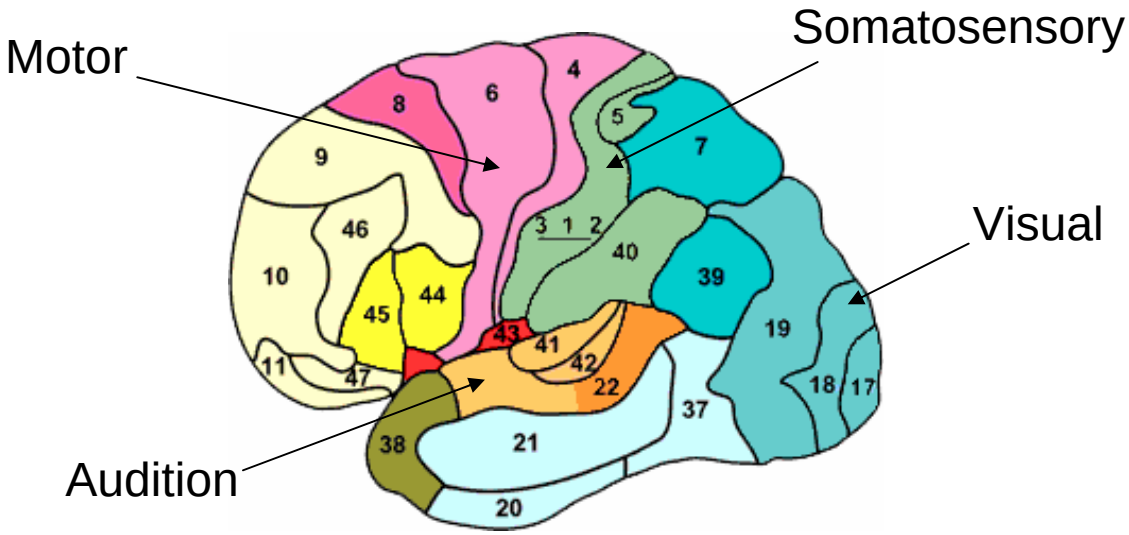
used by riding

Semantics features

Word Form

Bicycle

Interesting Stuff Goes Well Beyond

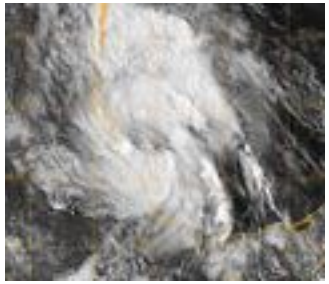


- modality-specific representations
- imaging
- patients with semantic deficits
  - category-specific

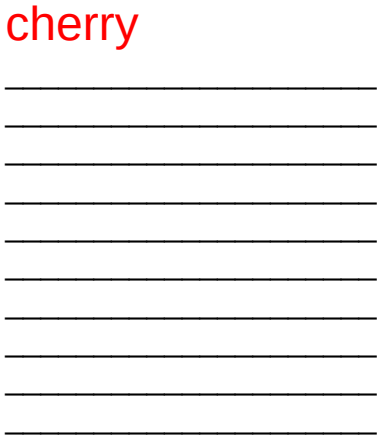
People Started Producing Them Again





Our Norms



- 541 living & nonliving basic-level things
- >750 total subjects
- 30 subjects/concept
- production frequency ≥ 5
- 2,526 features

- distributional statistics
- many other measures

(Superordinate) Categories

1. tool
2. weapon
3. vehicle
4. automobile
5. furniture
6. container
7. clothing
8. fashion accessory — Nonliving Things
9. house
10. shelter
11. building
12. appliance
13. machine
14. utensil
15. gun
16. miscellaneous

1. fruit
2. vegetable — Fruits & Vegetables
3. root/tuber
4. plant

1. mammal
2. bird
3. fish
4. insect
5. rodent
6. animal — Creatures
7. reptile
8. carnivore
9. herbivore
10. predator
11. scavenger
12. pet

musical instrument

food (nonliving)

superordinates without hierarchical structure
O'Connor, Cree, & McRae (in press)

Useful

- tightly controlled experiments
  - large number of variables
- modeling
  - empirically-based representations
  - reasonably valid distributional statistics
- sheer size

Caveats

- linguistically-based
  - miss some info
  - not literally content of people's concepts
  - "window into semantic memory"
- but still extremely useful

Basic Concept (name) Variables

- pronunciation
- word frequency (KF & BNC)
- AoA
- length: letters, phonemes, syllables
- bigram & trigram frequencies
- Coltheart N
- concept familiarity

Number of Features in a Concept

semantic richness

NoF effects

Pexman, Hino, & Lupker (2002)
Pexman, Holyk, & Monfils (2003)
Grondin, Lupker, & McRae (in press)

tent	blender
bucket	desk
hornet	pony
skunk	radish

Featural Similarity between Concepts

- matrix of cosines
- similarity priming & simulations
  - McRae & Boisvert (1998)
  - Bueno & Frenk-Meustre (2008)
  - Cree, McRae, & McNorgan (1999)
- picture-word interference & simulations
  - Vigliocco, Vinson, Lewis, & Garrett (2004)
- eye-movements in visual-world paradigm
  - Huettig & Altmann (2005)
  - Yee & Sedivy (2006)

Basic Feature (name) Variables

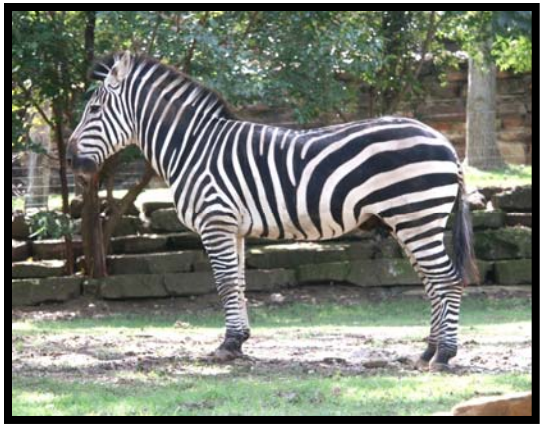
<has paws>
<used for carpentry>

- length: letters, words
- BNC frequency of content words
- number of concepts they appear in

Distinctive Features

distinctive = occurs in few concepts

<moos> vs. <has 4 legs>



Category-specific Deficits

Garrard, Lambon Ralph, Hodges, & Patterson (2001)
Cree & McRae (2003)

RT tasks & Simulations

Randall, Moss, Rodd, Greer, & Tyler (2004)
Cree, McNorgan, & McRae (2006)

Representational Modality

Brain region taxonomy

Cree & McRae (2003)

Visual – form & surface
has legs

Visual – Motion
flies

Visual – Colour
is brown

Function
used by turning

Touch
is soft

Taste
is sweet

Smell
is musty

Sound
barks

Encyclopaedic &
Taxonomic (omitted)

Modality Salience by Concept

Cree & McRae (2003)

- category-specific deficits
  - sensory vs. functional features
  - living vs. nonliving things
  - intuition
- brain region taxonomy
  - 8 feature types
  - many categories
  - distinguished among them in subtle ways

Feature Correlations

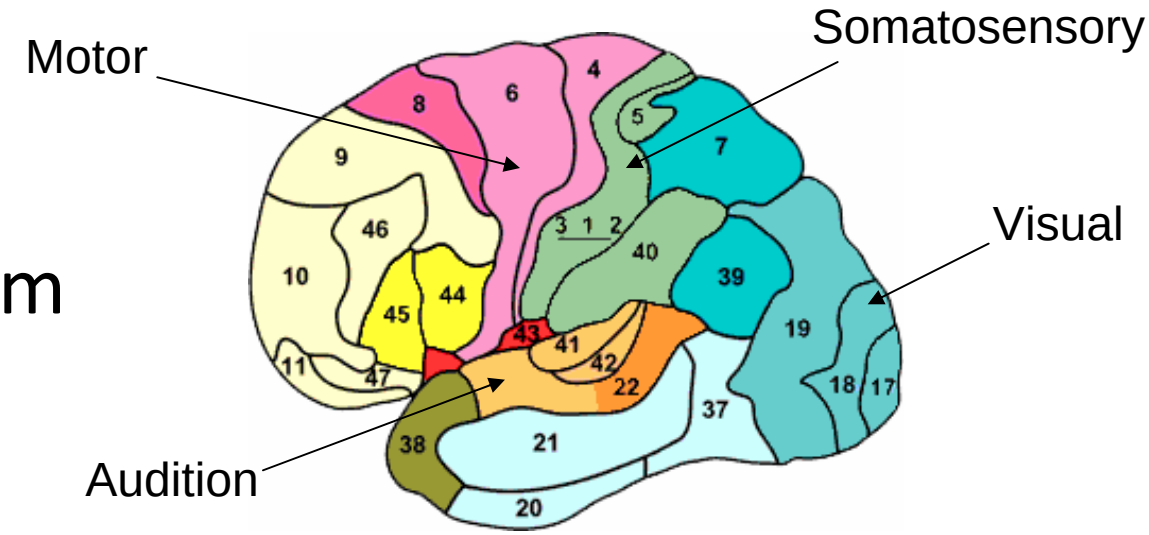
- <has a beak> <has feathers>
  - across basic-level concepts
- influences processing dynamics in models
- same for humans
  - McRae, de Sa, & Seidenberg (1997)
  - Cree, McRae, Westmacott, & de Sa (1999)
  - Tyler & Moss (2001)

Feature Correlations & Causal Relations

- causal relations
  - robin can fly because it has wings
  - a blade is necessary for cutting

- both matter
  - McNorgan, Kotack, Meehan, & McRae (2007)

How are multi-modal Concepts Integrated?



- binding problem
- combines feature correlations, neuroscience, & cognitive neuropsychology
- Chris McNorgan

Goal

Investigate possible mechanisms for communication within and between representational knowledge types

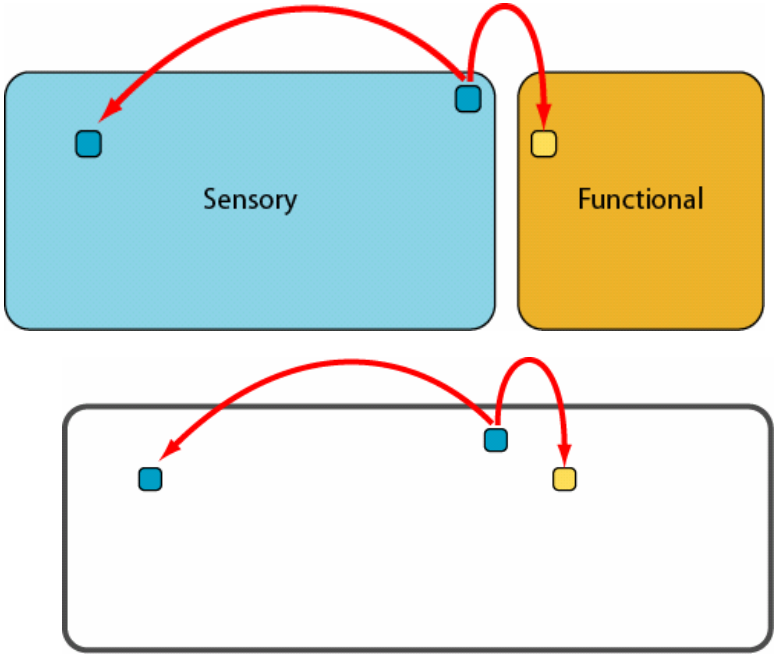
Multimodal Communication

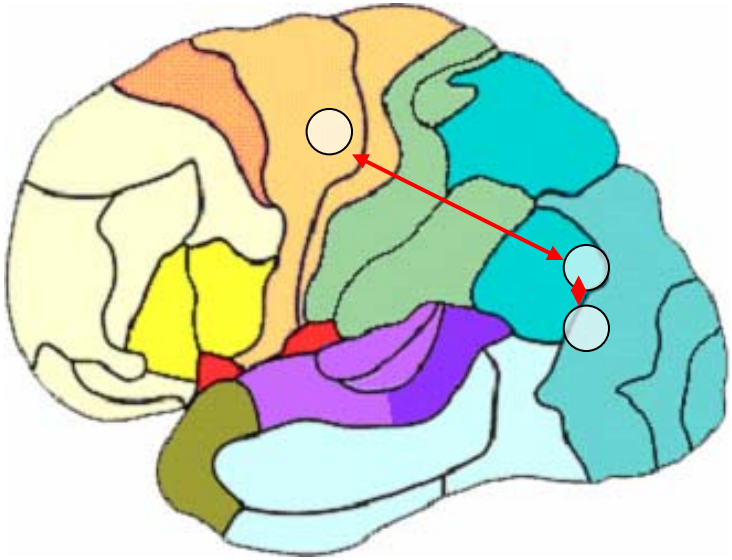
- 2 classes of models
  - ➢ different untested predictions

- differentiated by assumed hierarchy of convergence zones (Damasio, 1989)
  - location(s) where information is integrated

Hierarchically Shallow models

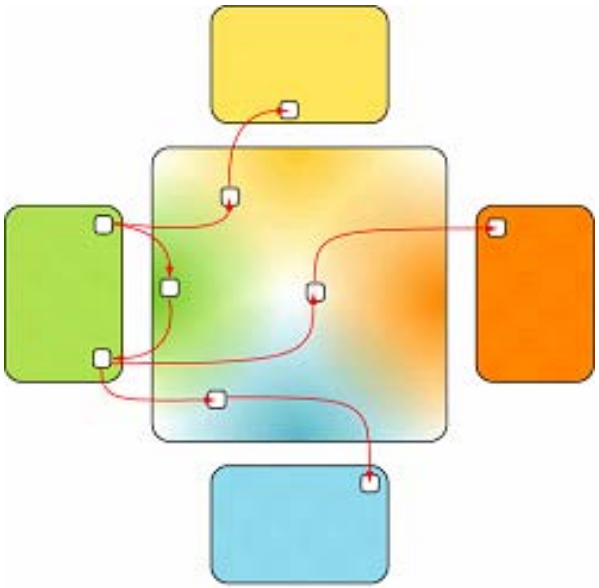
- direct connectivity
  - Farah & McClelland (1991)
  - McRae et al. (1997)

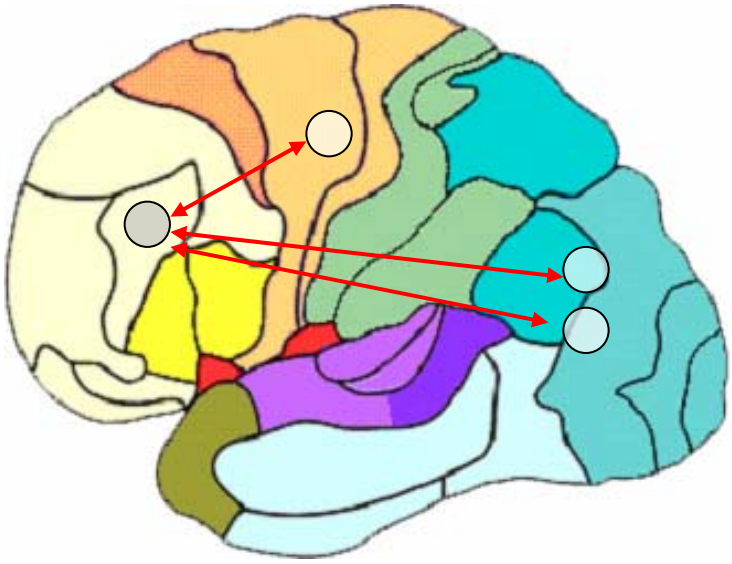




Hierarchically Shallow models

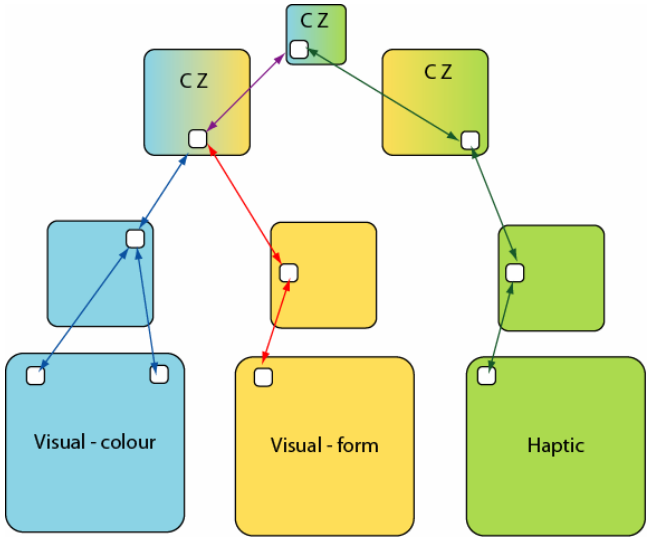
- 1 multimodal convergence zone
  - Humphreys & Forde (2001)
  - Patterson et al. (2007)

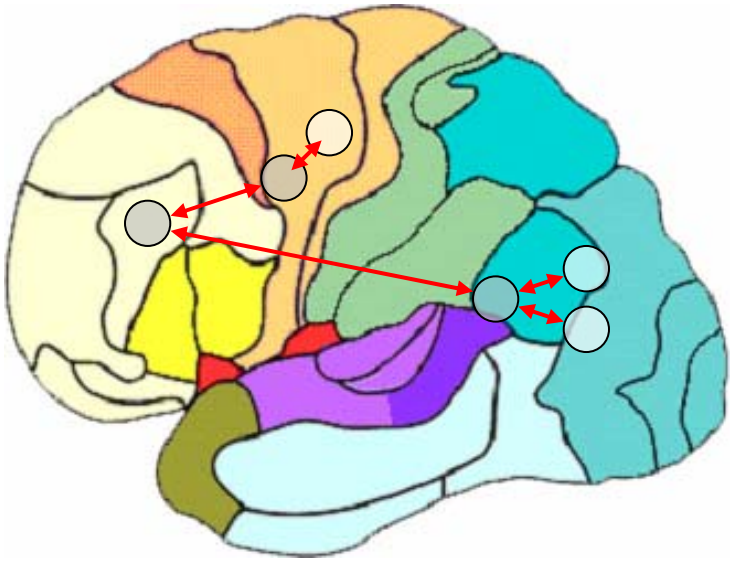




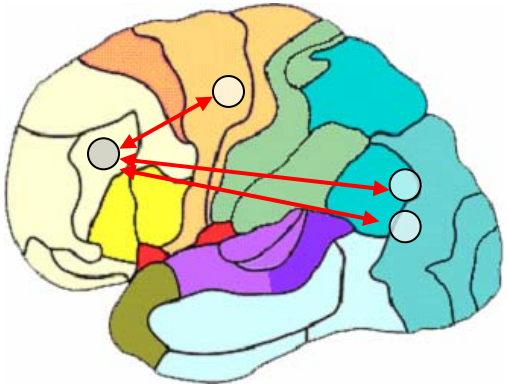
Hierarchically Deep models

- convergence zones with successively broader receptive fields
  - Damasio (1989)
  - Simmons & Barsalou (2003)

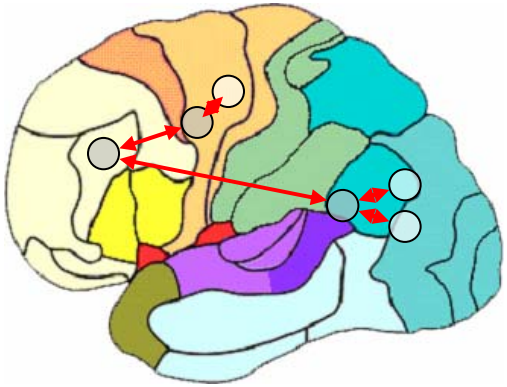




Question



VS



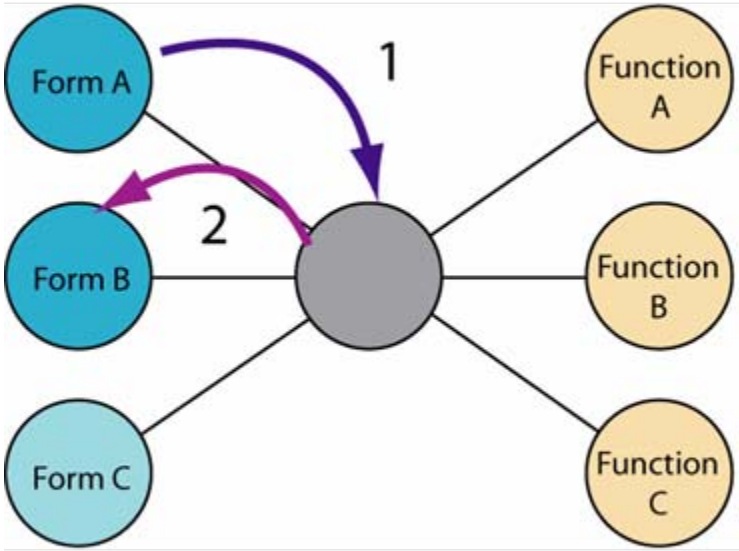
Shallow

Deep

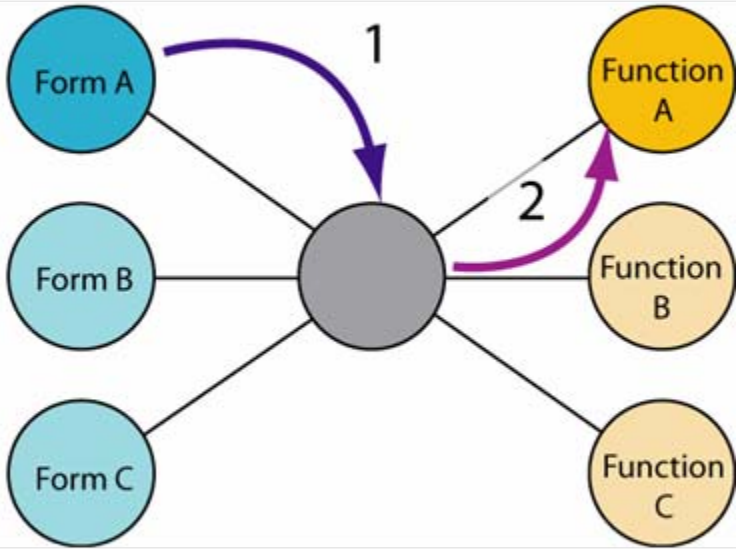
- 2 tasks
- test whether integration speed depends on modality

Feature-Feature Relations:
Shallow

<has a blade>
<has a handle>



<has a blade>
<used for cutting>



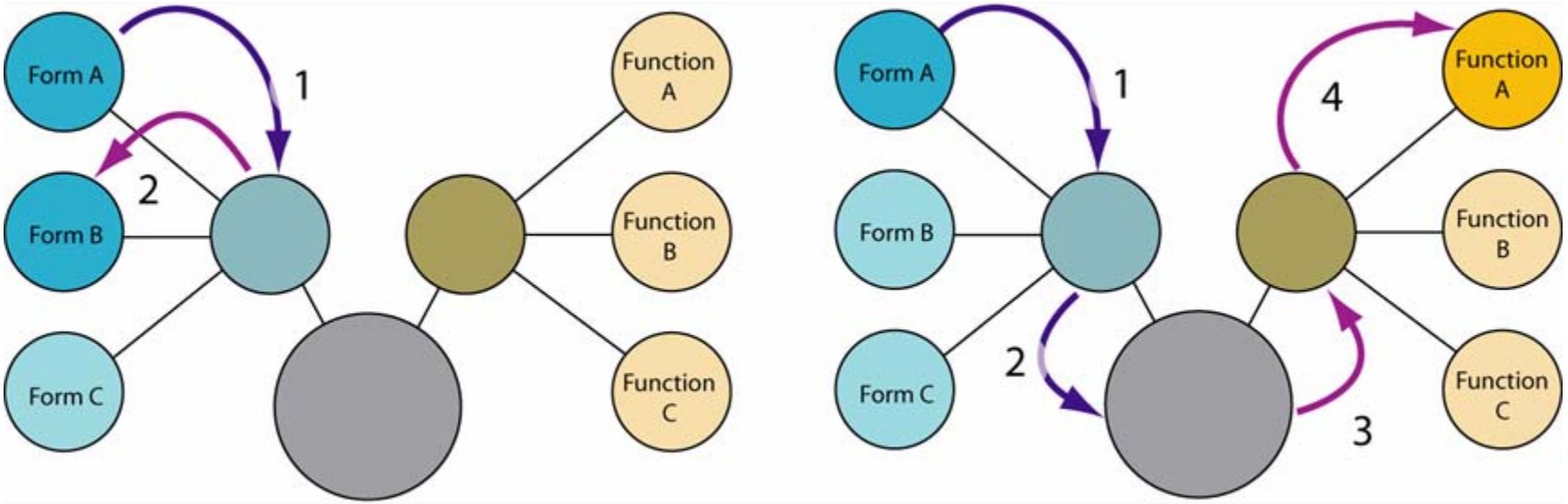
Within-modal = Cross-modal

Feature-Feature Relations

Deep

<has a blade>
<has a handle>

<has a blade>
<used for cutting>



Within-modal < Cross-modal

Feature-Feature Relations

- untimed relatedness rating task
  - ➢ insensitive to processing steps

has a handle
has a blade

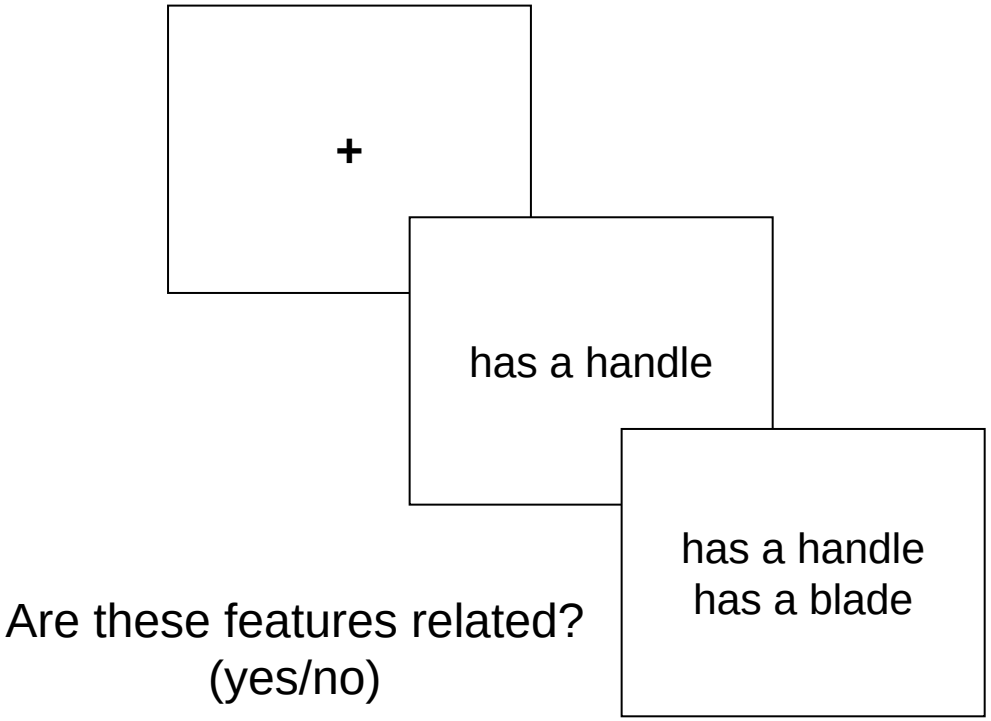
How related are these two features?

1	2	3	4	5	(6)	7

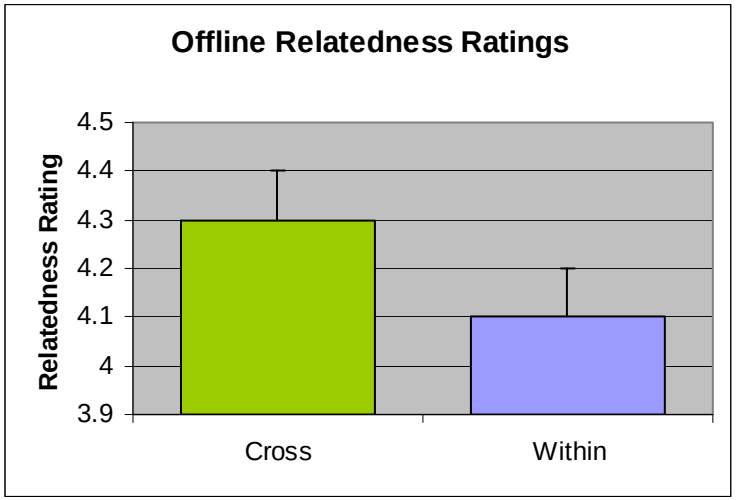
Not at all related — Very highly related

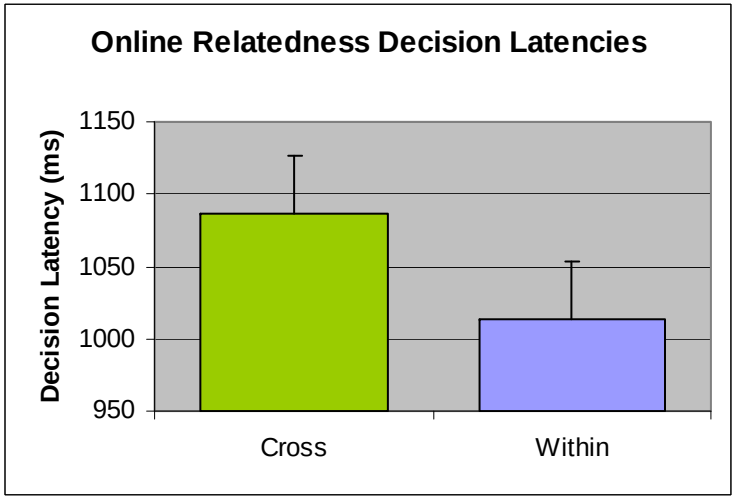
Feature-Feature Relations

- speeded relatedness decision task



Feature-Feature Relations
Supports Deep Hierarchy





Cross-modal
MORE related

BUT

Within-modal
FASTER!

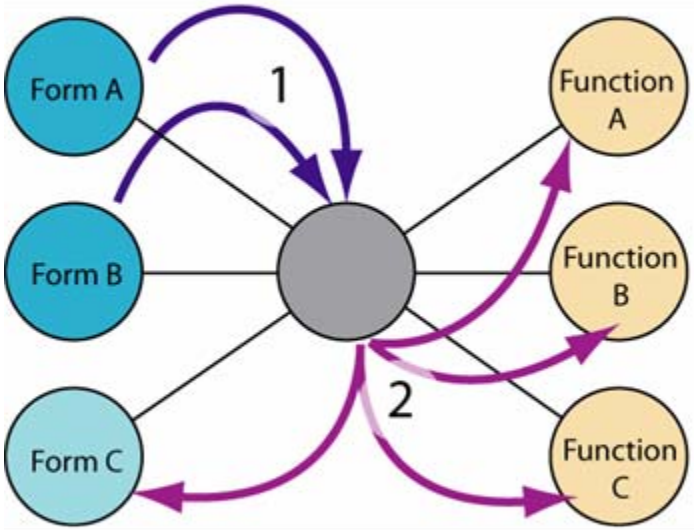
Feature-Concept Pattern Completion

- pattern completion from pair of features
- <has taps> <has a drain>
  - could it be a bathtub?
- includes other modalities

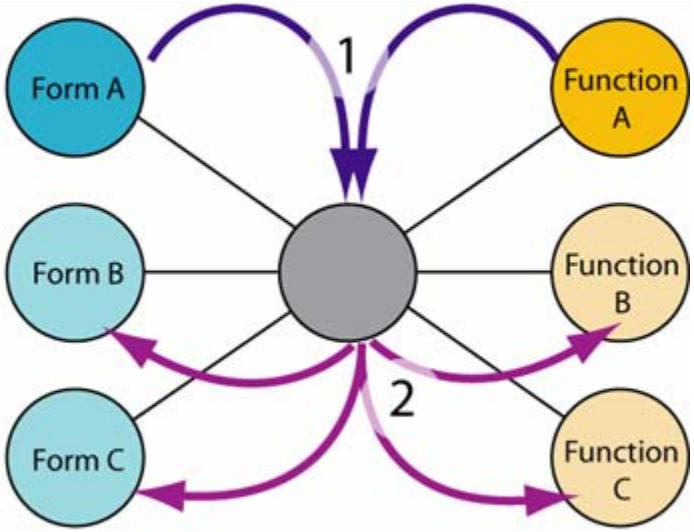
Feature-Concept Pattern Completion

Shallow Models

<has taps>
<has a drain>



<used for washing>
<has a drain>

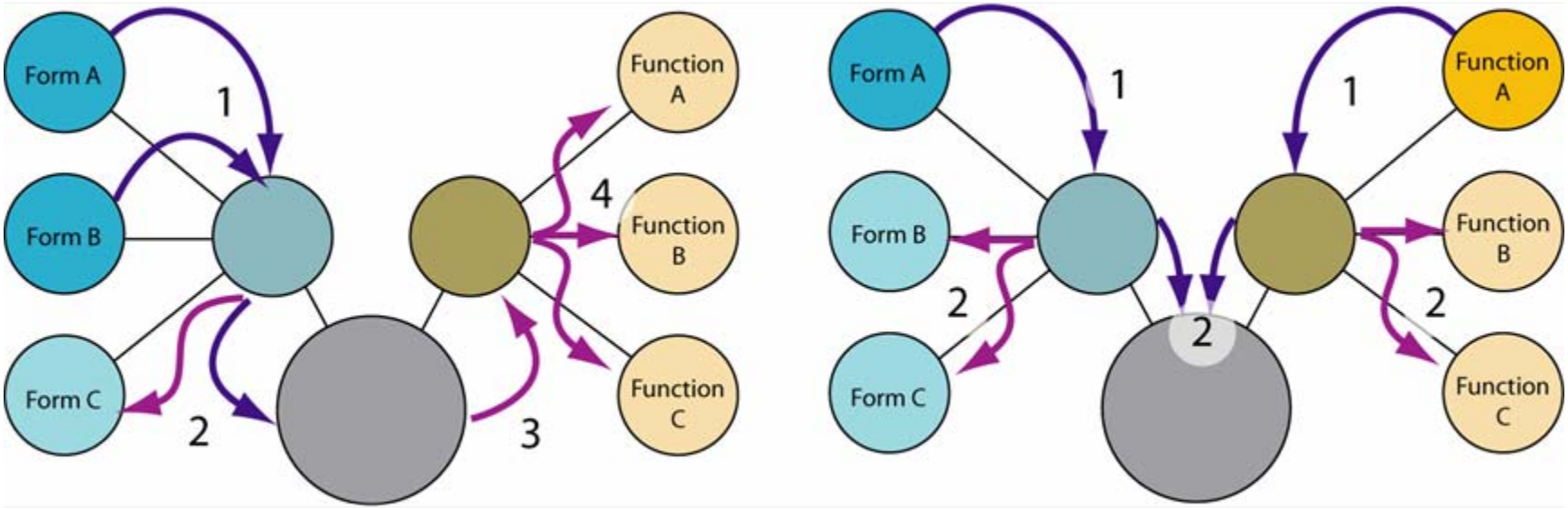


Within-modal = Cross-modal

Feature-Concept Pattern Completion
Deep Models

<has taps>
<has a drain>

<used for washing>
<has a drain>



Within-modal > Cross-modal

Feature – Concept Activation

- dual feature verification
  - ➢ transparent test of features activating concepts
  - ➢ predicts opposite effect from feature inference

- concepts preceded by within- and cross-modal pairs

has taps has a drain bathtub

vs

used for washing has a drain bathtub

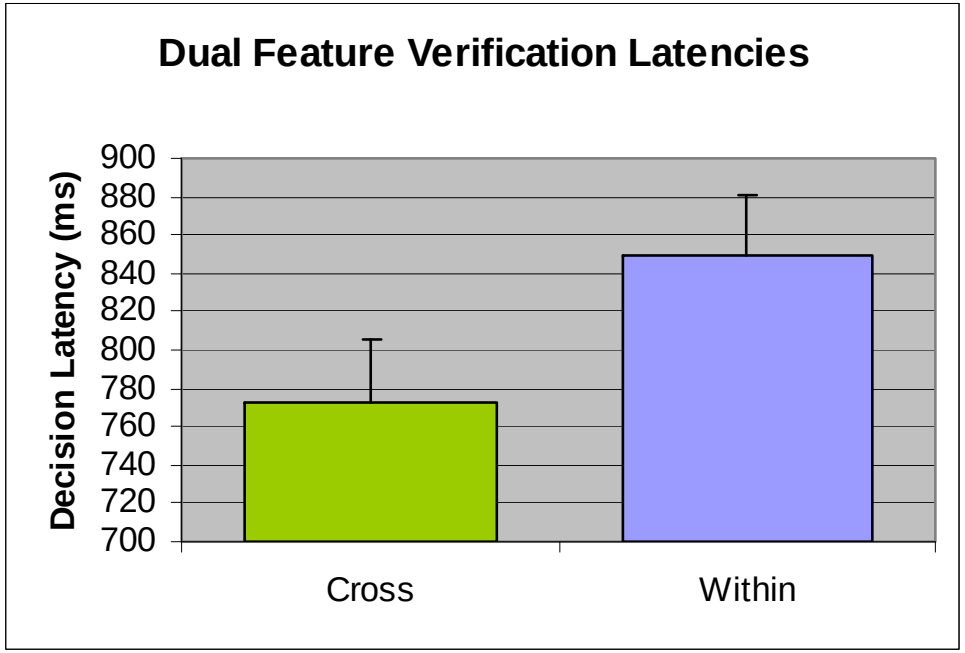
Feature – Concept Activation

has taps

has a drain

BATHTUB

Feature – Concept Activation



shorter cross-modal latencies

supports Deep Hierarchy

Conclusions

- supports deep hierarchy
  - ➢ opposite effects for two tasks
- inconsistent with shallow models
- inconsistent with amodal models
  - ➢ adds to evidence supporting distributed multimodal representations

Other Types of Concepts

- actions & objects
  - Vigliocco, Vinson, & colleagues
- thematic role concepts
  - McRae, Ferretti, & Amyote (1997)
- abstract concepts
  - Weimer-Hastings & Barsalou

Conclusions

- many insights that were not possible without them
- combined with computational modeling
- combined with feature type taxonomies
  - DRM Cann, McRae, & Katz
- combined with imaging
  - Mitchell's "mind reading" analyses

Avenues for Future

- combining concrete nouns, verbs, abstract nouns
- combining with models like Topics
- neural connectivity
  - functional
  - neuroanatomical?