Cognition

PSYC 2040

W5: Categorization

Thursday’s class

5	T: February 18, 2025	W5:Categorization
5	Th: February 20, 2025	W5 continued…
5	Su: February 23, 2025	**Week 5 Quiz due**
6	M: February 24, 2025	**Project: SPARK due**
6	T: February 25, 2025	W6: Language
6	Th: February 27, 2025	W6 continued…
6	Su:March 2, 2025	**Week 6 Quiz due**
7	T: March 4, 2025	W7: Loose Ends / Midterm review
7	W: March 5, 2025	**Jennifer: Midterm Review (4.30-6.30 pm, Kanbar 200)**
7	Th: March 6, 2025	**Midterm Exam**

quiz questions

Morris, Bransford, and Franks demonstrated evidence for the transfer appropriate processing principle in a memory task. What pattern would have been predicted by the **levels of processing principle**?

- In the standard recognition task, memory would be better for the semantic compared to rhyming encoding condition; but, in the rhyming recognition task, memory would be better for the rhyming compared to the semantic encoding condition
- In both recognition tasks memory performance would be better for words from the rhyming compared to semantic encoding conditions
- In both recognition tasks memory performance would be better for the words from the semantic compared to rhyming encoding conditions
- In the standard recognition task, memory would be worse for the semantic compared to rhyming encoding condition; but, in the rhyming recognition task, memory would be worse for the rhyming compared to the semantic encoding condition

Flashbulb memories suggest that

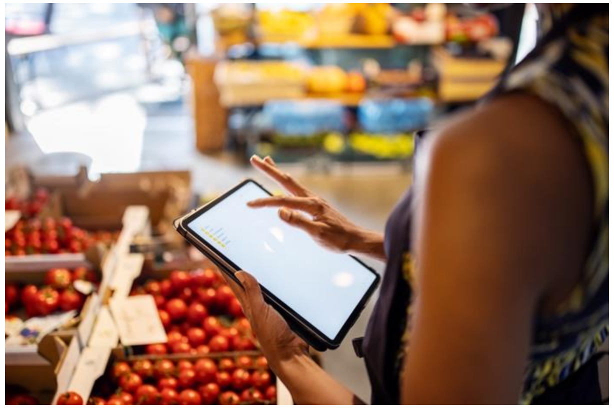
- Confidence and accuracy are highly correlated with one another
- Confidence and vividness do not predict accuracy consistently
- Memory for highly emotional events is less accurate than memory for non-emotional events
- Memory for highly emotional events is very accurate over time

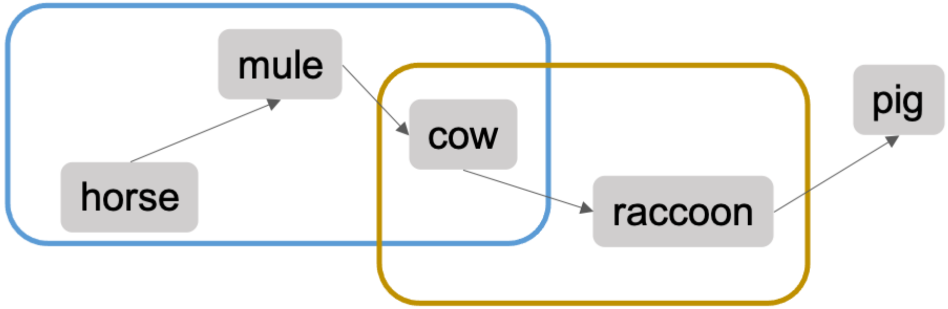
lingering question

- can we use studies from outside class when discussing empirical evidence in exams?

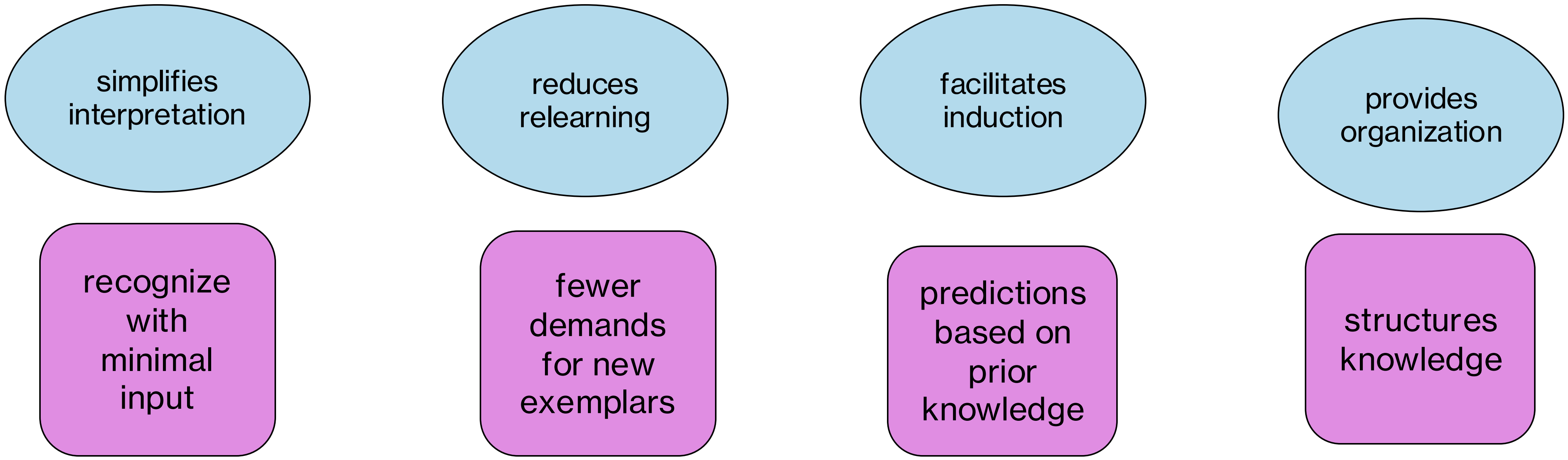
categorization

- why do we categorize things?
- how do we categorize things?



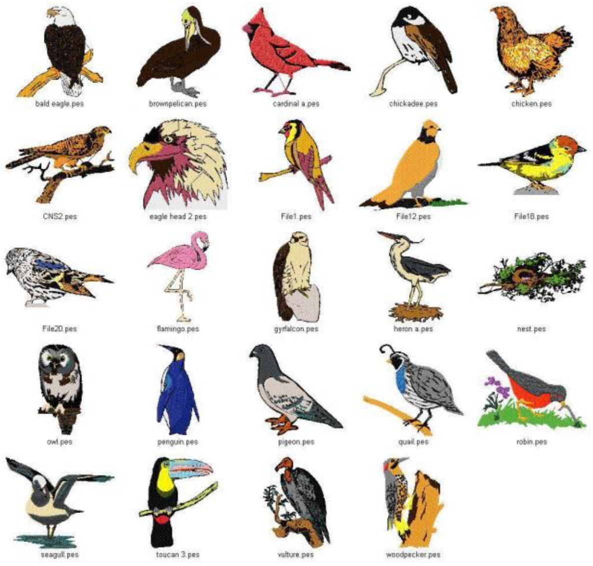


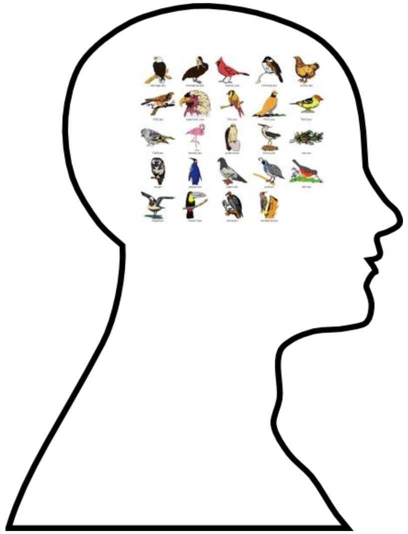
cognitive benefits



terminology

- category: group of objects that have something in common
- exemplar: an instance or member of a category
- concept: mental representations of concepts



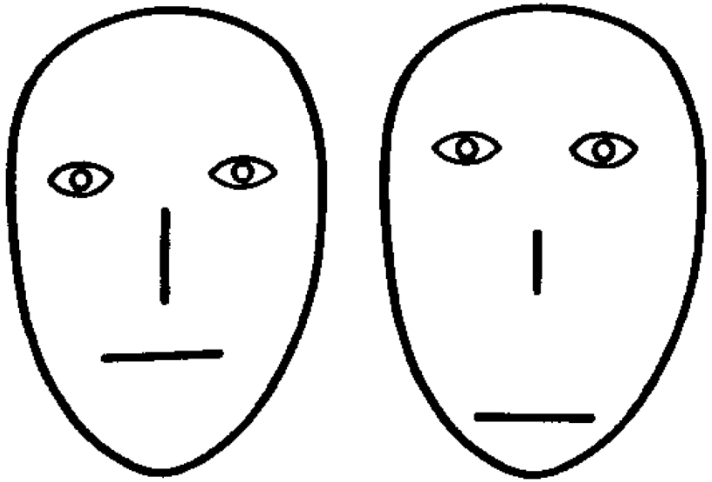


activity: cartoon face experiment

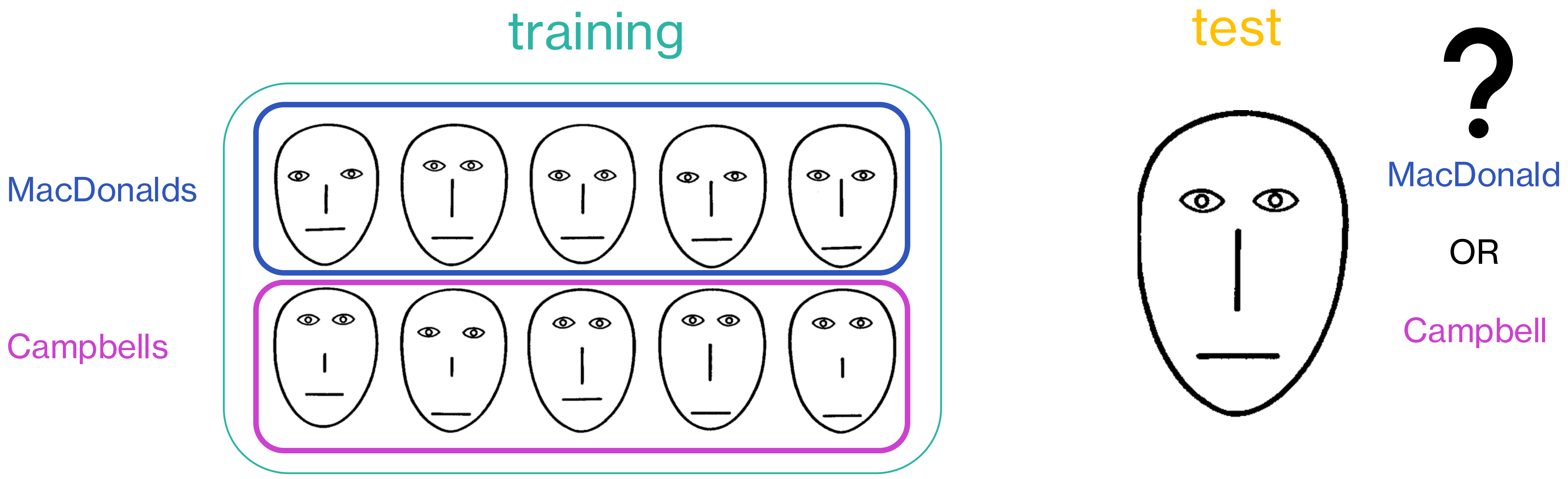
- you did the faces experiment before class
- discuss
  - how did you do the task?
  - was there anything special about MacDonalds or Campbells?

Nosofsky (1991) experiment

- training phase: classify cartoon faces
  - MacDonalds and Campbells
- test phase:
  - classification: classify faces and rate confidence
  - recognition: provide old/new judgments



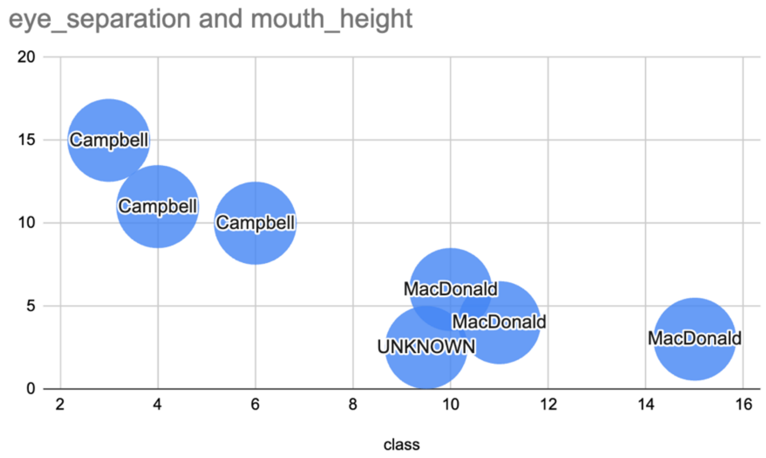
how do we classify/categorize?



classifying faces

- faces defined on two dimensions: eye separation and mouth height
- can you differentiate between MacDonalds and Campbells?
- what about the TEST face, is it a MacDonald or Campbell?

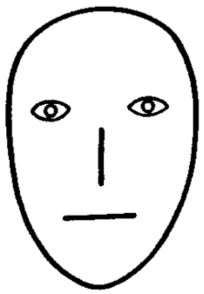
type	Face	class	eye_separation	mouth_height
training	I	MacDonald	10	6
training	2	MacDonald	11	4
training	3	MacDonald	15	3
training	4	Campbell	6	10
training	5	Campbell	4	11
training	6	Campbell	3	15
TEST	TEST	UNKNOWN	9.5	2.5



training

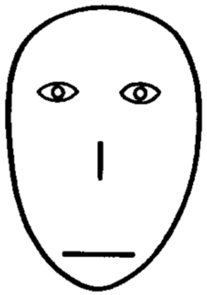
- x_i denotes the i^{th} exemplar presented during training
- each exemplar can be defined along *m* dimensions

x_i



[-1.025, 0.493, 0.048, -0.666]

x_j

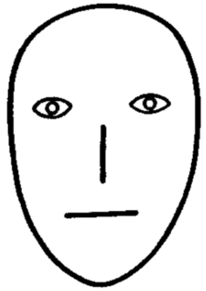


[-0.172, -0.557, 0.337, 0.163]

training

- Nosofsky (1991) varied the faces along 4 features (nose length, eye separation, etc.) such that there was a clear separation between the two classes (MacDonalds and Campbells)
- these features are often referred to as dimensions and can be placed in a multi-dimensional space

x_i



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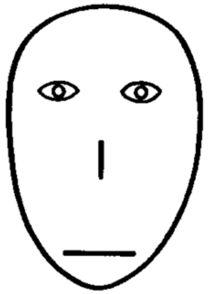
x_j



[-0.172, -0.557, 0.337, 0.163]

feature	face 1	face 2
eye height	23.5	19.5
eye separation	21.5	11.5
nose length	13.5	18
mouth height	16.5	12

training

- Nosofsky (1991) varied the faces along 4 features (nose length, eye separation, etc.) such that there was a clear separation between the two classes (MacDonalds and Campbells)
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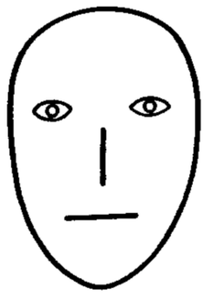
x_i



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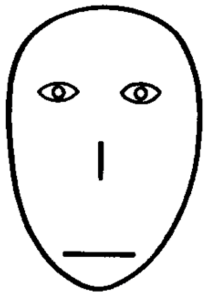
x_j



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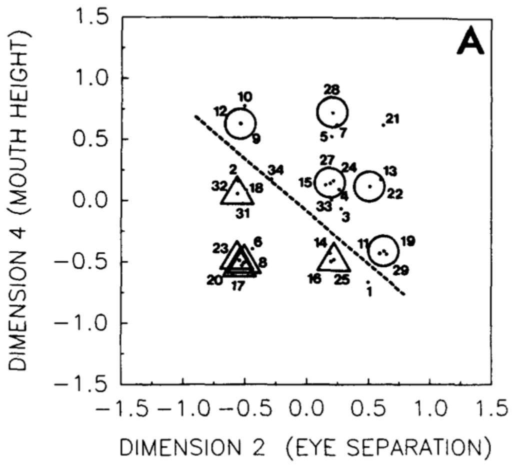
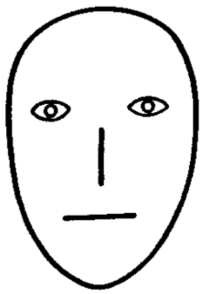


similarity

- the similarity between any two items (x_i and x_k) can be calculated using their coordinates in the multidimensional space
- this requires two steps:
  - calculating the Euclidean distance d_{ik} between the items i and k
  - translating distance to similarity through an exponential function

x_i



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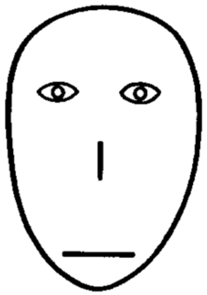
TEST (x_k)



[-0.172, -0.557, 0.337, 0.163]

$$d_{ik} = \sqrt[2]{\sum_m |x_{im} - x_{km}|^2}$$

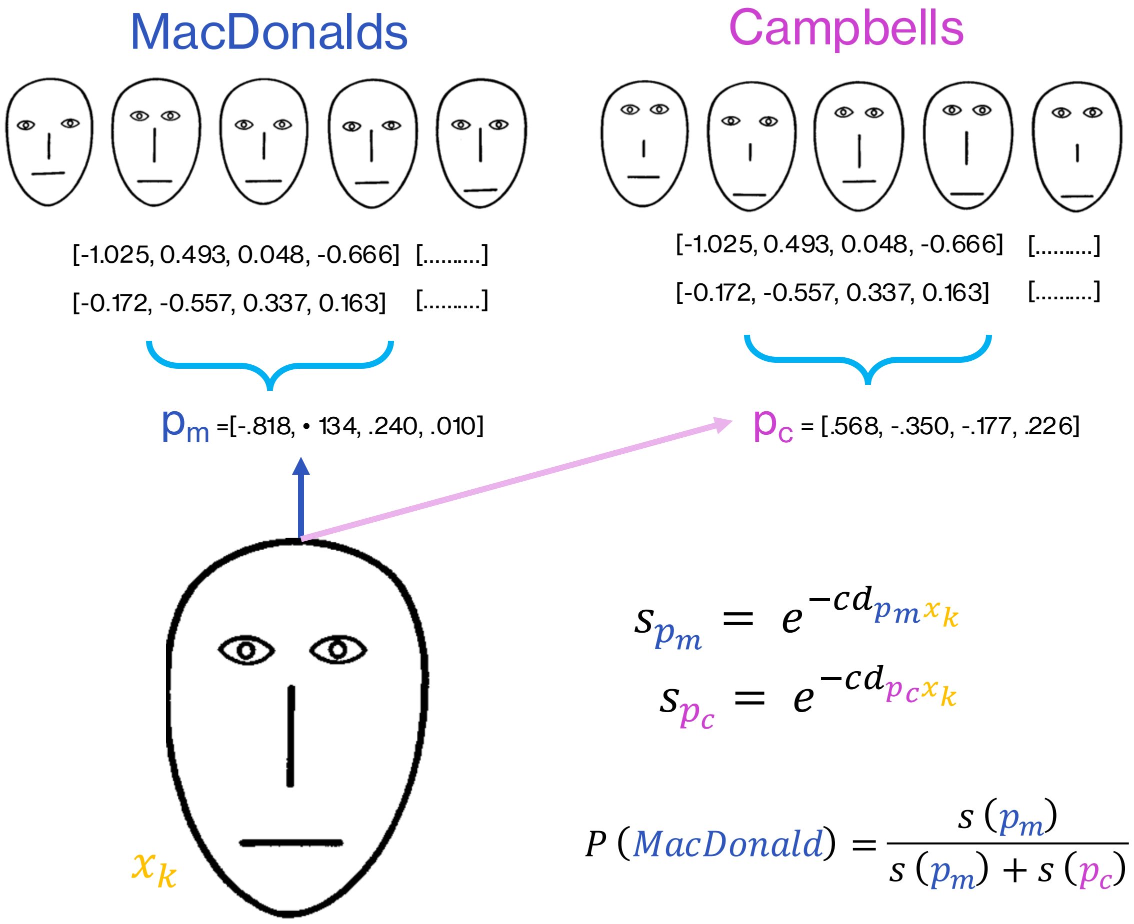
$$s_{ik} = e^{-c d_{ik}}$$

theories of categorization

- prototype theory
  - the concept is a single, abstract representation
  - people create “general” representations of concepts to which new examples are compared
  - these representations may have never actually been encountered
- exemplar theory
  - the concept is a collection of all exemplars
  - people compared the presented item to all previously experienced items to compute “similarity”
  - every exemplar has been actually encountered and stored in memory

prototype model: description

- during training, all exemplars are "averaged" to form a prototype
- during test, the prototypes for each class are activated in proportion to their similarity to the test item
- the probability of responding with one label vs. another depends on whichever prototype is more activated



activity: prototype model

- explore the prototype spreadsheet
- review how the prototype is generated and similarity to the test item is calculated using the prototype
- what decision would you make about this particular test face?

type	Face	class	eye_separation	mouth_height	eye_height	nose_length
training	1	MacDonald	10	6	11	3
training	2	MacDonald	11	4	12	4
training	3	MacDonald	15	3	11	6
		MACDONALD_PROTOTYPE	12	4.333333333	11.33333333	4.333333333
		TEST	9.5	2.5	13	2
		DISTANCE	4.222953153			
		SIMILARITY	0.1210590814			
		ACTIVATION_MACDONALD	0.1210590814			
		P(MACDONALD)	0.9988762844			

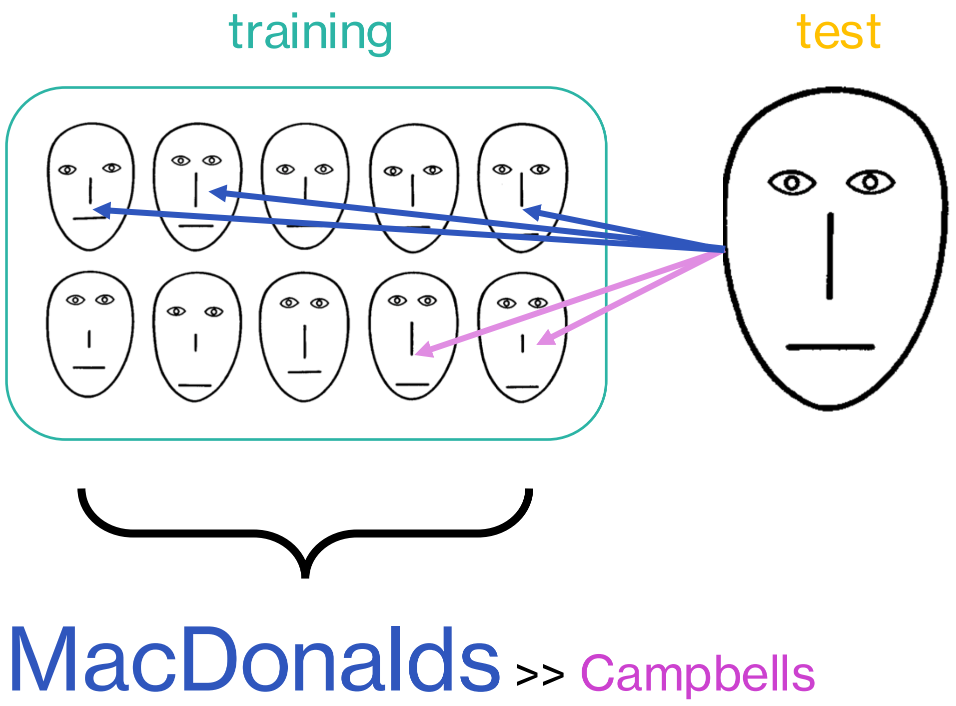
type	Face	class	eye_separation	mouth_height	eye_height	nose_length
training	4	Campbell	6	10	2	9
training	5	Campbell	4	11	3	11
training	6	Campbell	3	15	4.0000000	16.0000000
		CAMPBELL_PROTOTYPE	4.333333333	12	3	12
		TEST	9.5	2.5	13	2
		DISTANCE	17.80293359			
		SIMILARITY	0.000136189018			
		ACTIVATION_CAMPBELL	0.000136189018			
		P(CAMPBELL)	0.00112371562			

theories of categorization

- prototype theory
  - the concept is a single, abstract representation
  - people create “general” representations of concepts to which new examples are compared
- exemplar theory
  - the concept is a collection of all exemplars
  - people compared the presented item to all previously experienced items to compute “similarity”

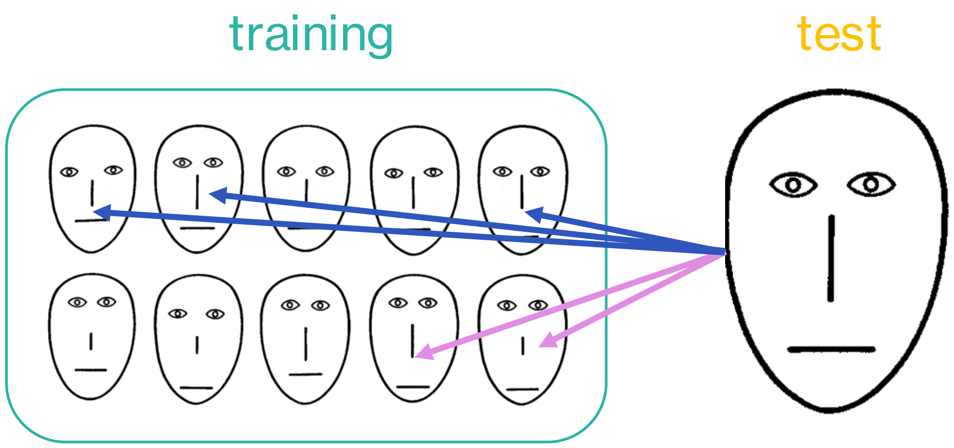
exemplar model: description

- during training, people store individual examples into memory
- during test, the training items are activated in proportion to their similarity to the test item
- the probability of responding with one label (MacDonald) vs. another (Campbell) depends on the sum of these activations



exemplar model: test

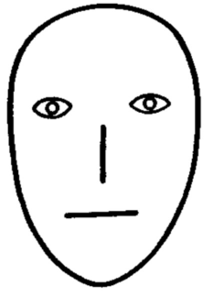
- when a new item (x_k) is presented, each training item is activated in proportion to its similarity to the test item



exemplar model: similarity

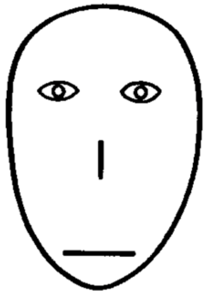
- explore the exemplar spreadsheet
- report back which face has the highest and lowest similarity to the test item
- exemplar x_i is activated in proportion to its similarity to test item x_k

x_i



[-1.025, 0.493, 0.048, -0.666]

TEST (x_k)



[-0.172, -0.557, 0.337, 0.163]

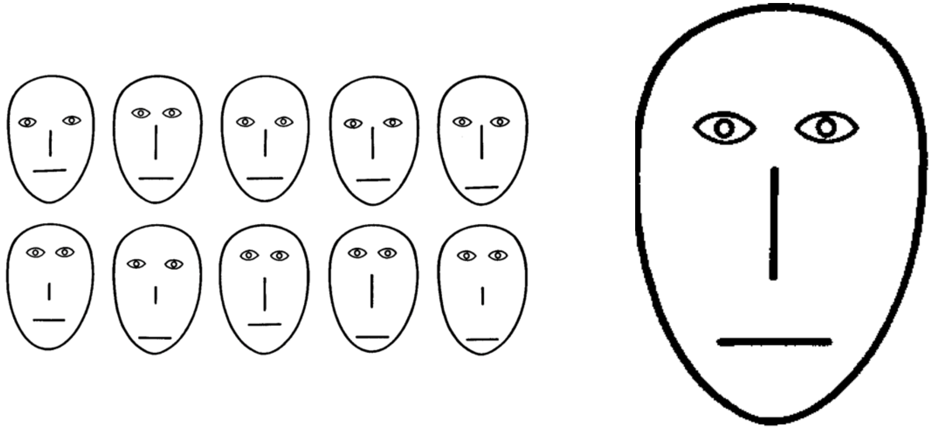
type	Face	class	eye_separation	mouth_height	distance_from_TEST	similarity_to_TEST	SumActivation-M	P(MacDonald)
training	1	MacDonald	10	6	3.535533906	0.1707137754	0.580147939	0.9616191218
training	2	MacDonald	11	4	2.121320344	0.3462271655	**SumActivation-C**	**P(Campbell)**
training	3	MacDonald	15	3	5.522680509	0.06320699811	0.02315530843	0.03838087816
training	4	Campbell	6	10	8.276472679	0.01595095879		
training	5	Campbell	4	11	10.12422837	0.006332158012		
training	6	Campbell	3	15	14.0890028	0.0008721916276		
TEST	TEST	UNKNOWN	9.5	2.5	0	1		

$$d_{ik} = \sqrt[2]{\sum_m |x_{im} - x_{km}|^2}$$

$$s_{ik} = e^{-cd_{ik}}$$

exemplar model: test

- when a new item (x_k) is presented, each training item is activated in proportion to its similarity to the test item
- activations of each exemplar in a class are added up to produce total activation for the class
- the probability of classifying the new test item is determined by whichever class has higher total activation



$$activation\,(MacDonald) = \sum_{k \in MacDonald} s_{ik}$$

$$activation\,(Campbell) = \sum_{k \in Campbell} s_{ik}$$

$$P\,(MacDonald) = \frac{activation\,(MacDonald)}{activation\,(MacDonald) + activation\,(Campbell)}$$

reviewing the evidence

- both exemplar and prototype models have a proposal for how a classification decision may be reached, i.e., they can predict classification decisions given a set of examples and a new test item
  - they are both process/computational models
- we also have a large dataset of classification decisions from human participants who did this experiment
- how can we compare the two models?

exemplar vs. prototype model?

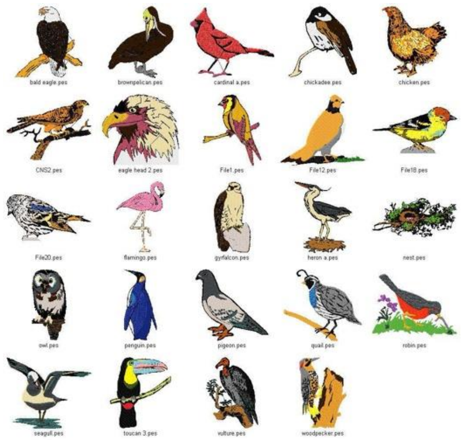
- the exemplar model performed *better* than the prototype model in predicting human classification decisions

Table 3
Maximum Likelihood Parameters and Summary Fits, Experiment 1B

Model	Parameters									Fits		
	σ	c	w_1	w_2	w_3	w_4	x_c	b	M_7	SSE	% Var	$-\ln L$
All-subjects analyses												
Context												
Classification	.267[a]	1.077[a]	.15	.15	.29	.41		.173	1.464[a]	.097	96.5	129.2
Recognition	.267[a]	1.077[a]	.13	.56	.23	.08	5.322		1.464[a]	.076	95.4	119.2
Prototype												
Classification	.186[a]	.777[a]	.16	.14	.40	.30		.044	1.123[a]	.175	93.7	181.0
Recognition	.186[a]	.777[a]	.25	.55	.12	.07	1.231		1.123[a]	.182	89.0	156.0

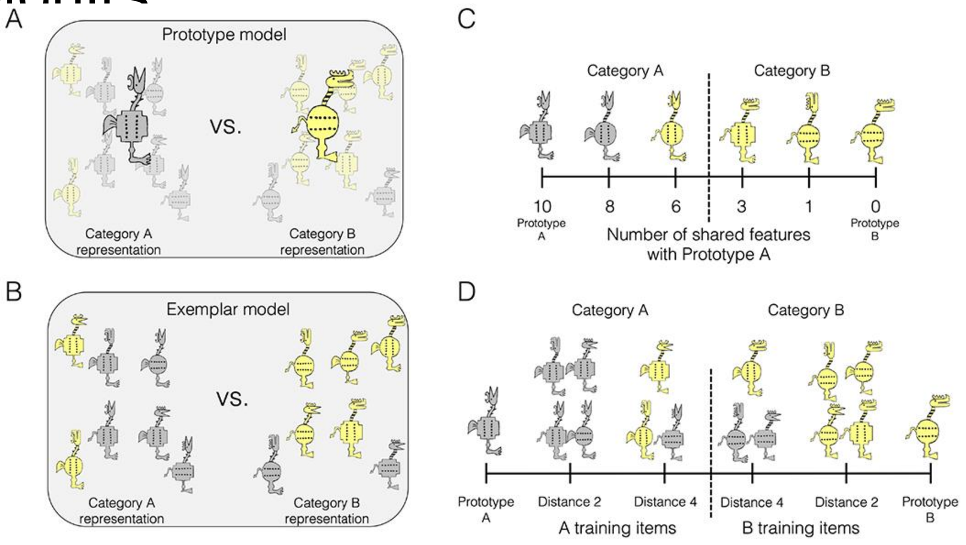
other types of categories

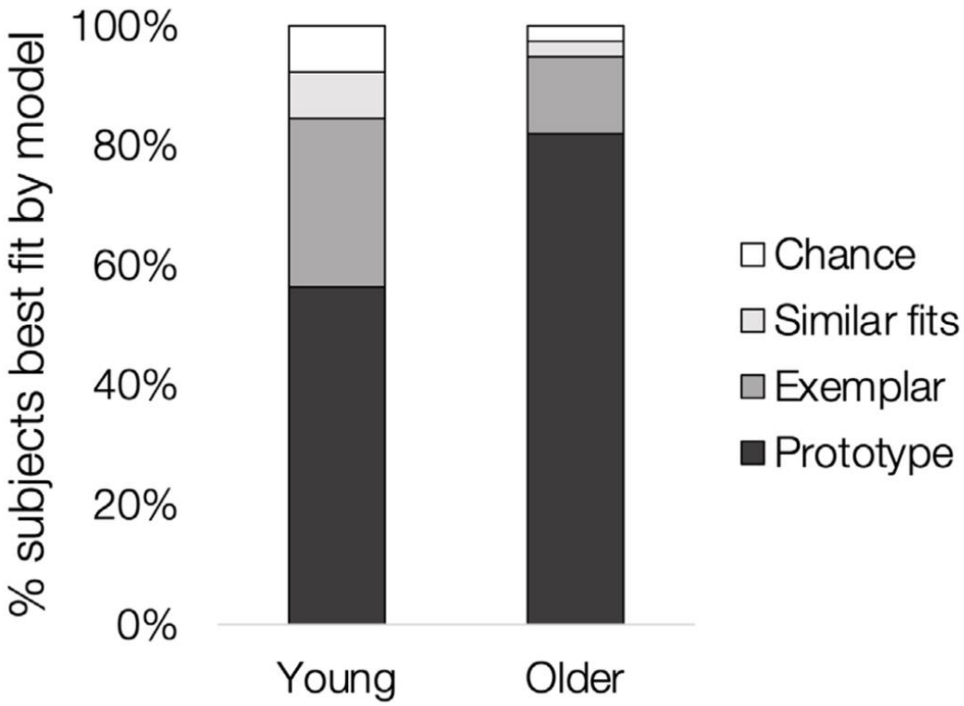
- taxonomic / hierarchical categories
- thematic categories
- ad hoc categories



categorization and aging

- older adults relied to a greater degree on generalized (prototype) category representations than young adults





paper

exemplar vs prototype learners

Policy Insights from the
Behavioral and Brain Sciences
2019, Vol. 6(1) 21–28

DOI: 10.1177/2372732218814861
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SAGE

Recommendations From Cognitive Psychology for Enhancing the Teaching of Natural-Science Categories

Robert M. Nosofsky[1] and Mark A. McDaniel[2]

Abstract

Because of their complex structures, many natural-science categories are difficult to learn. Yet achieving accuracy in classification is crucial to scientific inference and reasoning. Thus, an emerging theme in cognitive-psychology and cognitive-science research has been to investigate better ways to instruct about categories. This article briefly reviews major findings that will help inform policies for teaching categories in the science classroom. Many of the examples come from our specific project that examines teaching rock classifications in the geologic sciences. This project uses formal models of human category learning—developed in cognitive psychology—to search for optimal teaching procedures. The model-suggested category-teaching procedures often lead to better learning outcomes than do alternative procedures motivated by teachers' and students' intuitive judgments. In addition to reviewing these enhanced procedures for teaching natural-science categories, the article points to recent broader efforts for fostering collaborations between cognitive-science researchers and education researchers.

exemplar models & instance theory

- exemplar models are derived from a process-oriented theory of memory and cognition, “instance theory”
- instance theory uses a general framework for cognitive processing, where ‘instances’ are defined, encoded, and retrieved
- the framework has been applied beyond memory processes, to account for many phenomena such as associative learning, language, eyewitness identification, etc.

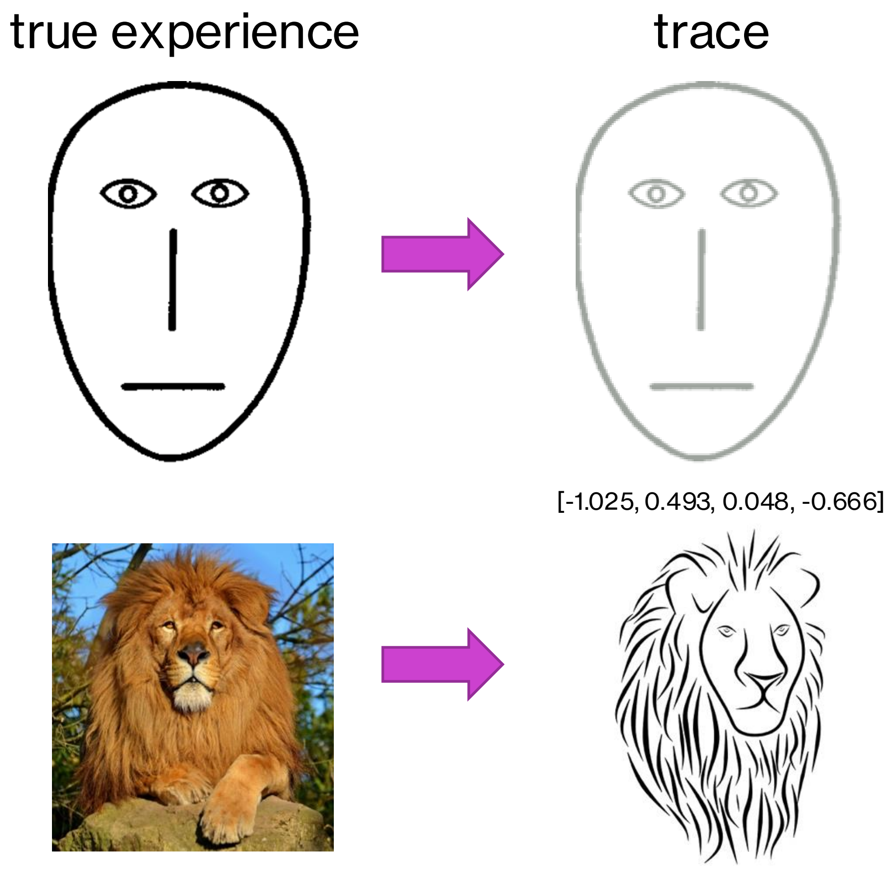
Instance theory as a domain-general framework for cognitive psychology

Randall K. Jamieson, Brendan T. Johns, John R. Vokey and Michael N. Jones

Abstract | The dominant view in cognitive psychology is that memory includes several distinct and separate systems including episodic memory, semantic memory and associative learning, each with a different set of representations, explanatory principles and mechanisms. In opposition to that trend, there is a renewed effort to reconcile those distinctions in favour of a cohesive and integrative account of memory. According to instance theory, humans store individual experiences in episodic memory and general-level and semantic knowledge such as categories, word meanings and associations emerge during retrieval. In this Perspective, we review applications of instance theory from the domains of remembering, language and associative learning. We conclude that instance theory is a productive candidate for a general theory of cognition and we propose avenues for future work that extends instance theory into the domain of cognitive computing, builds hybrid instance models and builds bridges to cognitive neuroscience.

instance theory: key assumptions

- all experiences are encoded as “traces” in memory, and capacity for traces is very larger / unlimited
- “traces” can capture many different aspects or properties of an experience
- retrieval is driven by the overlap between the current experience and its similarity to traces of previous experiences



MINERVA 2

- MINERVA 2 (Hintzman, 1984; 1986; 1988) is a computational model of memory based on instance theory
- MINERVA 2 has been applied more broadly to cognitive phenomena
  - associative learning (Jamieson et al., 2010)
  - semantic memory (Jamieson et al., 2018)
  - sequence learning (Jamieson & Mewhort, 2009)
  - false memory (Arndt, 1998)

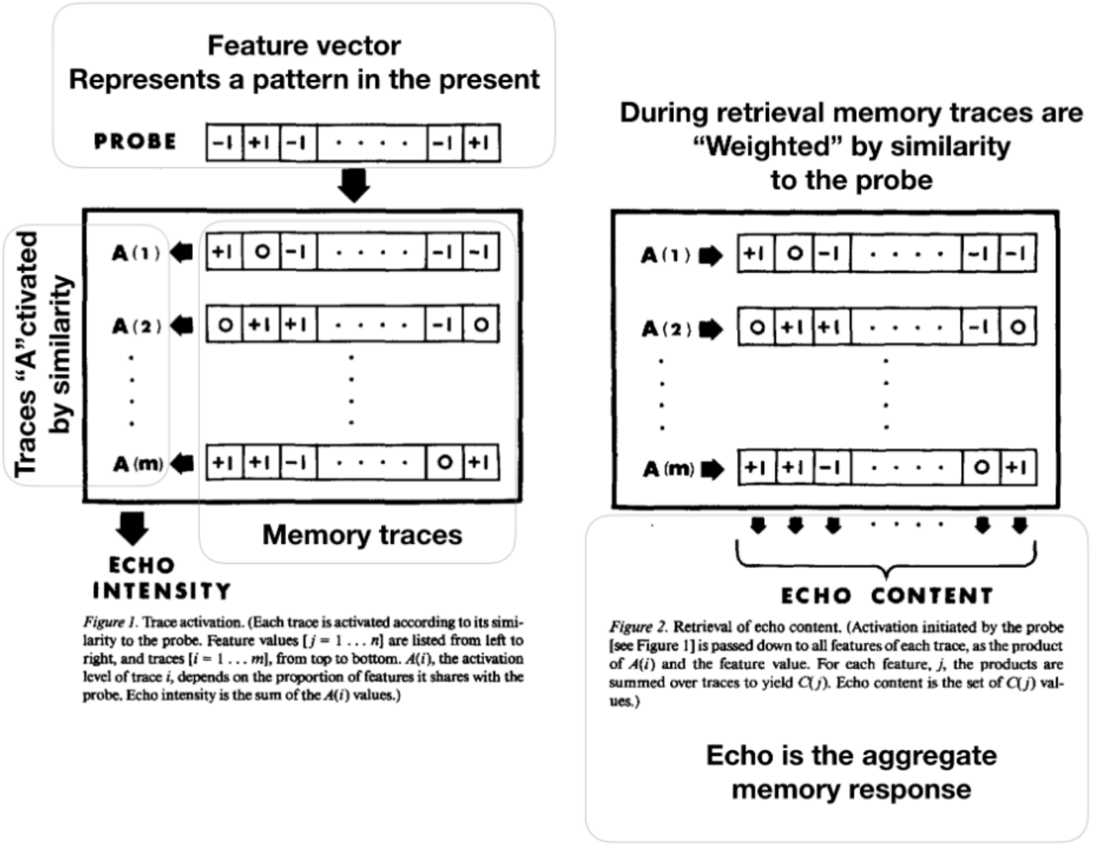


Figure 1. Trace activation. (Each trace is activated according to its similarity to the probe. Feature values [$j = 1 \ldots n$] are listed from left to right, and traces [$i = 1 \ldots m$], from top to bottom. $A(i)$, the activation level of trace i, depends on the proportion of features it shares with the probe. Echo intensity is the sum of the $A(i)$ values.)

Figure 2. Retrieval of echo content. (Activation initiated by the probe [see Figure 1] is passed down to all features of each trace, as the product of $A(i)$ and the feature value. For each feature, j, the products are summed over traces to yield $C(j)$. Echo content is the set of $C(j)$ values.)

instance theory: limitations

- rule-based categorization
- hierarchical knowledge/processing?
- inferences/induction
- capacity limitations and levels of analysis

Is there an exemplar theory of concepts?

Gregory L. Murphy

Psychonomic Bulletin & Review **23**, 1035–1042 (2016) | Cite this article

Abstract

It is common to describe two main theories of concepts: prototype theories, which rely on some form of summary description of a category, and exemplar theories, which claim that concepts are represented as remembered category instances. This article reviews a number of important phenomena in the psychology of concepts, arguing that they have no proposed exemplar explanation. In some of these cases, it is difficult to see how an exemplar theory would be adequate. The article concludes that exemplars are certainly important in some categorization judgments and in category-learning experiments, but that there is no exemplar theory of human concepts in a broad sense.

alternative domain-general models

- the appeal of instance theory is its broader application to more than one instance/facet of cognition
- however, this is *one* theory: other such theories exist that do not rely on exemplar storage and retrieval mechanisms
  - domain-specific models
  - error-driven models (more next week: language!)
  - inferential models (social cognition week)

next class

- Dr. Channing Hambric

Here are the to-do's for the week:

- Week 5 Exit Ticket (due Thursday)
- Week 5 Quiz (due Sunday)
- Project Milestone 2 (SPARK) (due Monday)
- Post any lingering questions here
- Extra credit opportunities:
  - Submit Exra Credit Questions (1 point for 8 submissions)
  - Submit Optional Meme Submission (1 point for winners!)