

The Impact of Multiple Feature Manifestations on Classification and Inference

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2 important facts about categories

- Multiple feature manifestations
 - Birds → have wings, but each instance of wings is different from one bird to another.
- Interactions with classification and inference
 - People interact with categories by classifying new items and inferring some unknown features of the new item.

Questions:

- How do we derive
 - classification and inference judgments given varying appearance of individual *features*?
- Previous studies show that
 - Handling categories with multiple feature manifestations is very difficult for classification, but not for inference.
- Why?

Goals:

- Contrast
 - classification vs. inference in simplified settings.
- Show that
 - Classification requires \rightarrow concrete exemplars
 - Inference requires \rightarrow abstract summary information
- That's why
 - classification is inappropriate for categories composed of multiple feature instances

Stimuli

A

monek



plaple



Schematic cartoon bugs

5 feature dimensions with binary values.

Horns (long, short)

Head (round, angular)

Body (dotted, striped)

Legs (eight, four)

Tail (short, long)

Category structure

	Monek						Plaple						
	Horns	Head	Body	Legs	Tail	Labels		Horns	Head	Body	Legs	Tail	Labels
M1	1	1	1	1	0	1	P1	0	0	0	0	1	0
M2	1	1	1	0	1	1	P2	0	0	0	1	0	0
M3	1	1	0	1	1	1	P3	0	0	1	0	0	0
M4	1	0	1	1	1	1	P4	0	1	0	0	0	0
M5	0	1	1	1	1	1	P5	1	0	0	0	0	0
M0	1	1	1	1	1	1	P0	0	0	0	0	0	0
Classification Question													
M1	1	1	1	1	0	?							
Inference Question													
M1	?	1	1	1	0	1							

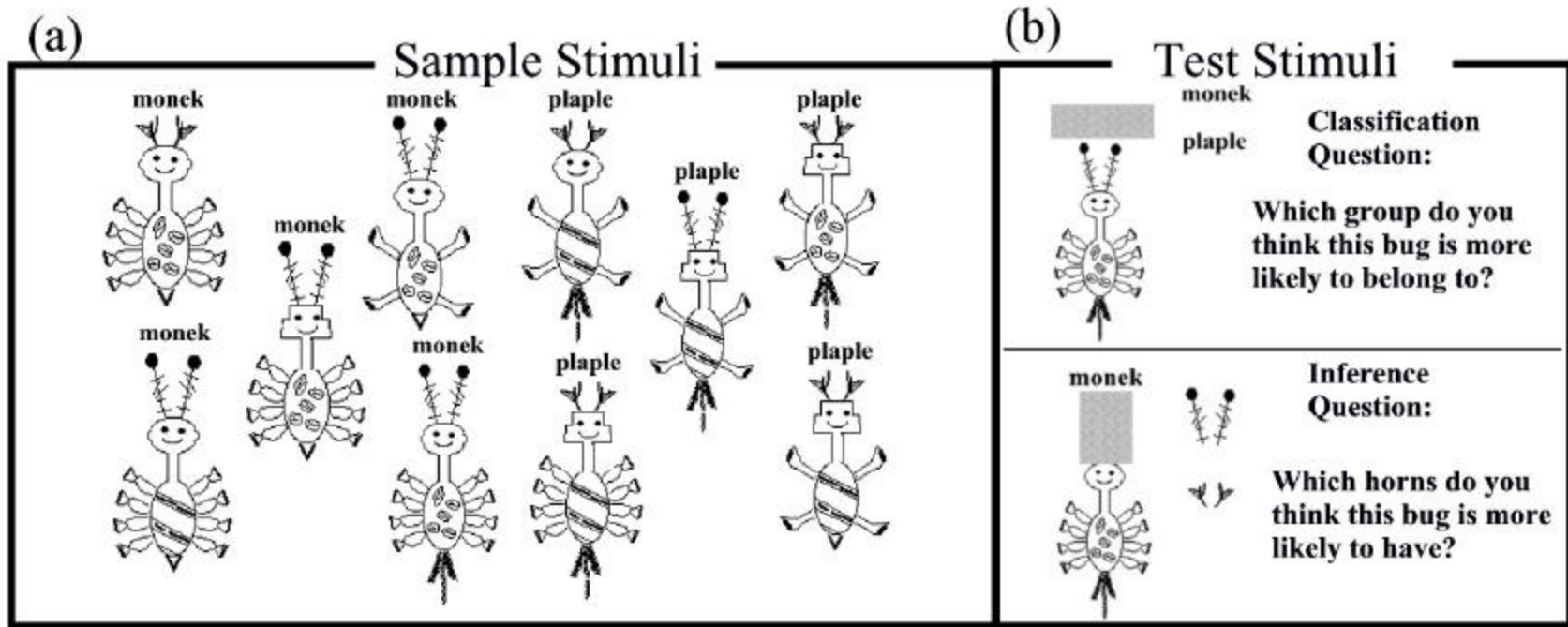
Note. All the stimuli in each category were derived from two prototypes, M0 and P0.

Family-
resemblance
structure

Derived from 2
prototypes

(1, 1, 1, 1, 1) and
(0, 0, 0, 0, 0)

Tasks: Classification or Inference



Classification: Ss predicted the category label of a test stimulus based on the samples depicting two categories

Inference: Ss predicted the value of a feature based on the sample depicting two categories

Independent Variable I:

- **Feature-match** : # of matching features between a test stimulus and the sample stimuli
 - 2 levels → high and medium levels of feature match

High

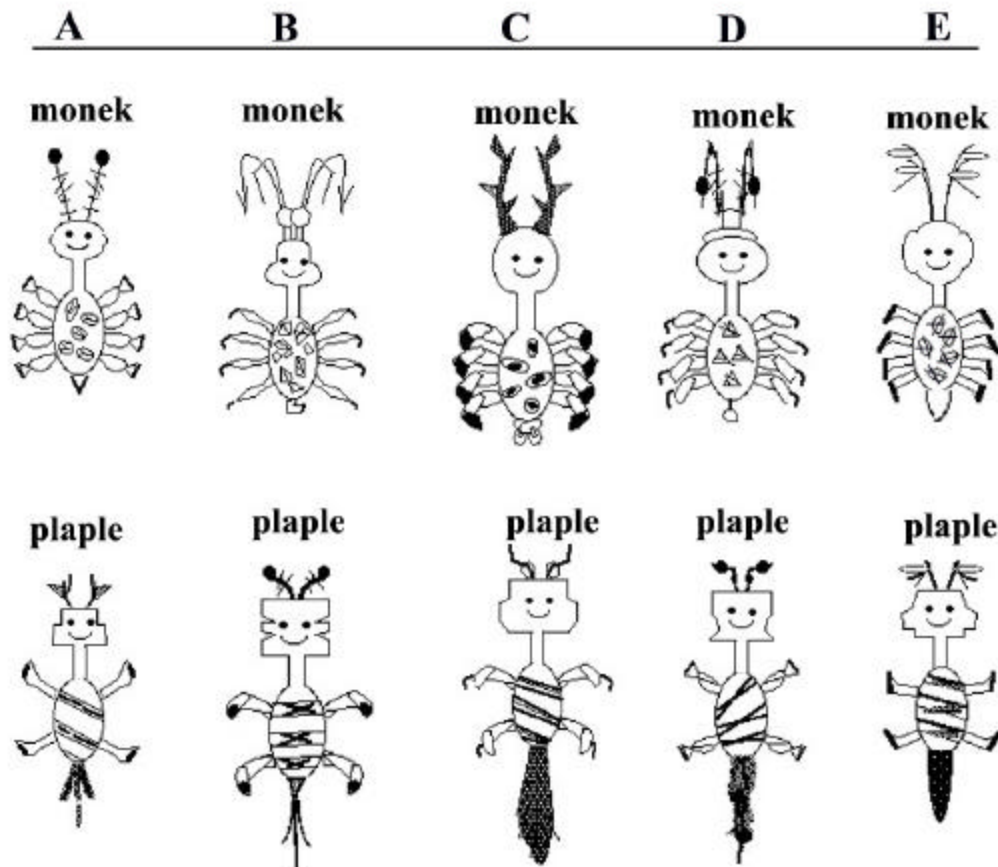
1 1 1 1 1 vs. 1 1 1 1 0

Medium

1 1 1 1 1 vs. 1 1 1 0 0

Monek						Plaple					
Horns	Head	Body	Legs	Tail	Labels	Horns	Head	Body	Legs	Tail	Labels
High-level of feature-match											
1	1	1	1	0	1	0	0	0	0	1	0
1	1	1	0	1	1	0	0	0	1	0	0
1	1	0	1	1	1	0	0	1	0	0	0
1	0	1	1	1	1	0	1	0	0	0	0
0	1	1	1	1	1	1	0	0	0	0	0
Medium-level of feature-match											
1	1	1	0	0	1	0	0	0	1	1	0
1	1	0	0	1	1	0	0	1	1	0	0
1	0	0	1	1	1	0	1	1	0	0	0
0	0	1	1	1	1	1	1	0	0	0	0
0	1	1	1	0	1	1	0	0	0	1	0

Independent Variable I: Feature-manifestation



The same feature value but different manifestations.

e.g., round head →
Head in A, B, C, D, E are all round but the appearance of each round head is different.

60 stimuli in total

Feature-match

	High	Medium		
Feature-manifestation	Same	10	10	20
	Different	20	20	40
		30	30	60

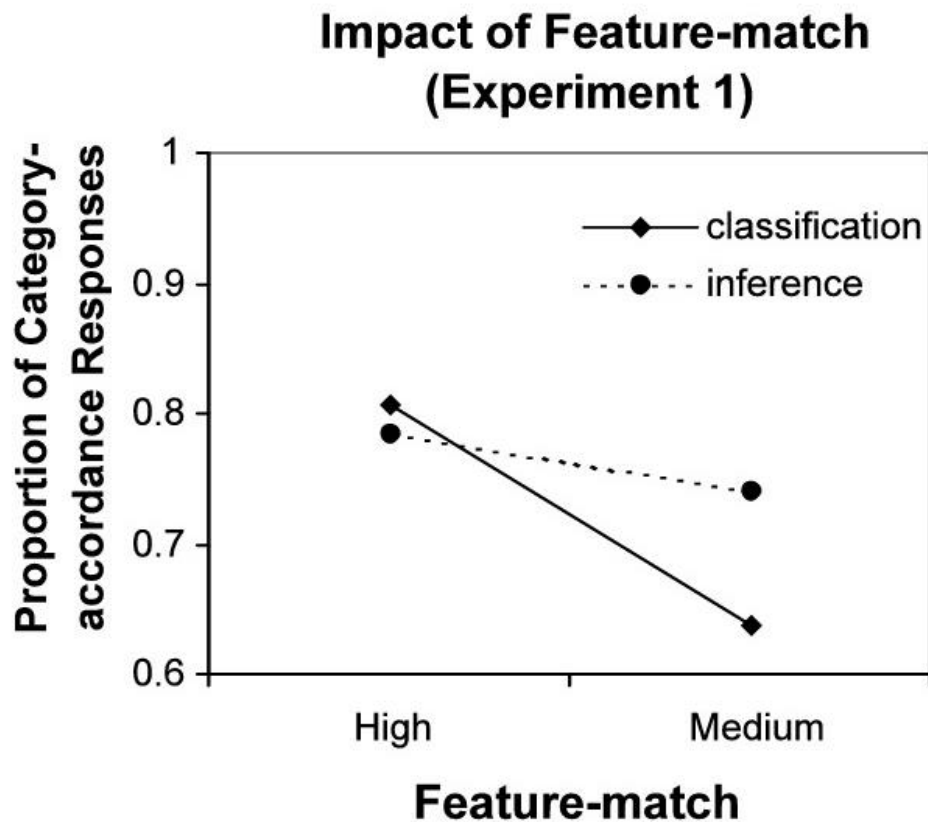
Design:

2 (feature-match – high vs. medium – within-Ss) x

2 (feature-manifestation – same vs. different – within-Ss) x

2(question-type – classification vs. inference – between-Ss)

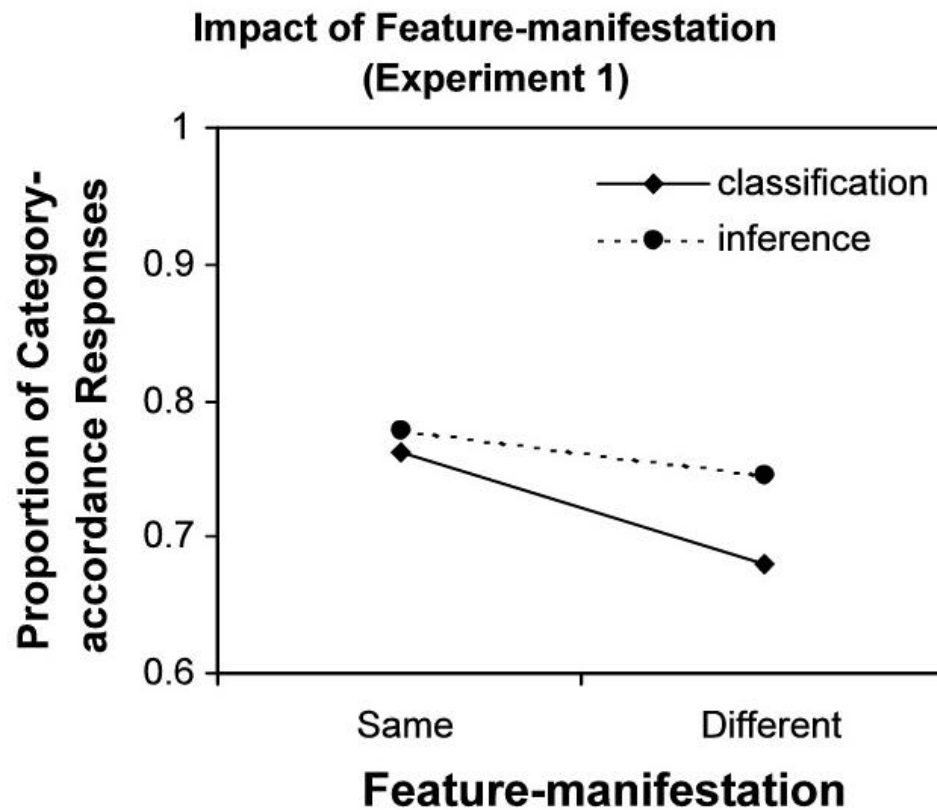
Exp. 1: Results



Interaction: question-type x feature-match

$F(1, 219)=64.7, MSE=0.013, =0.228, p<0.001$

Exp. 1: Results



Interaction: question-type x feature-manifestation

$F(1, 219)=9.5$, $MSE=0.015$,
 $=0.042$, $p<0.01$.

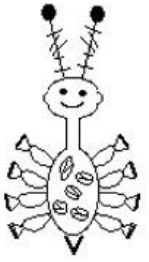
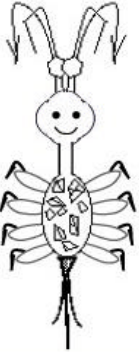
Discussion

- The two variables, feature-match and feature-manifestation, affected classification much more than inference.
 - → Classification makes use of concrete exemplar information more than inference does
 - → Test this idea further in Exp. 2

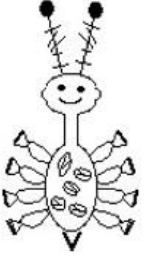

Exp. 2

- Goal:
 - Simplify the experimental setting, and test the difference between classification and inference.
- Modifications
 - Use only one sample stimulus (prototypes of the two categories)
 - Introduce 4 levels of feature-match

Ss received only one sample stimulus (prototype) for each trial.

Sample Stimulus	Test Stimulus
<p data-bbox="325 479 430 511">monek</p> 	<p data-bbox="630 332 1071 479">What is the probability that the bug shown below can belong to the same type, "monek," as the bug shown on the left side?</p> <p data-bbox="798 487 903 519">monek</p> 

Classification task

Sample Stimulus	Test Stimulus
<p data-bbox="283 1136 388 1169">monek</p> 	<p data-bbox="556 990 1176 1120">If the bug shown below belong to the same type, "monek," as the bug shown on the left side, what is the probability that this bug (shown below) can have the horns like these?</p> <p data-bbox="808 1136 913 1169">monek</p> 

Inference task

Stimuli & Design

- 40 stimuli for 4 levels of feature-match
 - 10 high, 10 medium, 10 low, and 10 inconsistent questions
 - All stimuli had different manifestations from the sample stimuli
- Design
 - 4 (feature-match – high, medium, low, inconsistent – within-Ss) x
 - 4(question-type – classification vs. inference – between-Ss)

Sample Stimulus					
Horns	Head	Body	Legs	Tail	Label
1	1	1	1	1	1

Feature-match

Test Stimulus						
	Horns	Head	Body	Legs	Tail	Label
<i>High</i>	1	1	1	1	0	<i>?/1</i>
	<i>?/1</i>	1	1	1	0	1
	Horns	Head	Body	Legs	Tail	Label
<i>Medium</i>	1	1	1	0	0	<i>?/1</i>
	<i>?/1</i>	1	1	0	0	1
	Horns	Head	Body	Legs	Tail	Label
<i>Low</i>	1	1	0	0	0	<i>?/1</i>
	<i>?/1</i>	1	0	0	0	1



Inconsistent questions

Sample Stimulus					
Horns	Head	Body	Legs	Tail	Label
1	1	1	1	1	1



Test Stimulus						
	Horns	Head	Body	Legs	Tail	Label
Inconsistent-	1	1	1	1	1	?/0
Question	1	1	1	1	?/0	1

Inconsistent questions ask the question inconsistent with the values shown in the sample.

Inconsistent questions

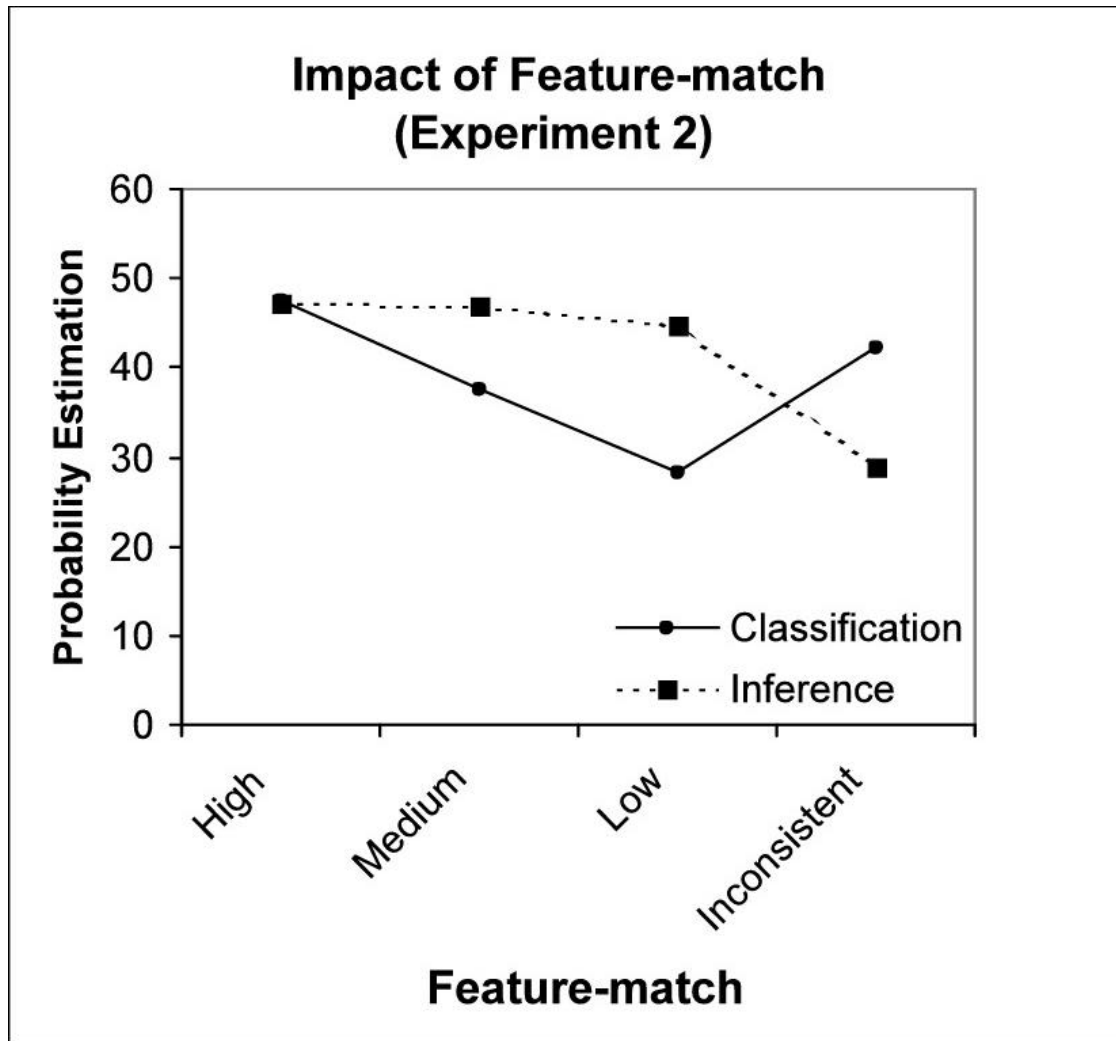
Sample Stimulus	Test Stimulus
<p>monek</p> 	<p>What is the probability that the bug shown below can belong to the same type, "plaple," as the bug shown on the left side?</p> <p>plaple</p> 

Classification task

Sample Stimulus	Test Stimulus
<p>monek</p> 	<p>If the bug shown below belong to the same type, "monek," as the bug shown on the left side, what is the probability that this bug (shown below) can have the tail like these?</p> <p>monek</p> 

Inference task

Results



Interaction effect:

$F(3, 252)=31.7,$

$MSE=115.3,$

$=0.274, p<0.001$

Fitting GCM (Nosofsky & Zaki, 2002) to the data from Exp. 1 and 2

Exp. 1

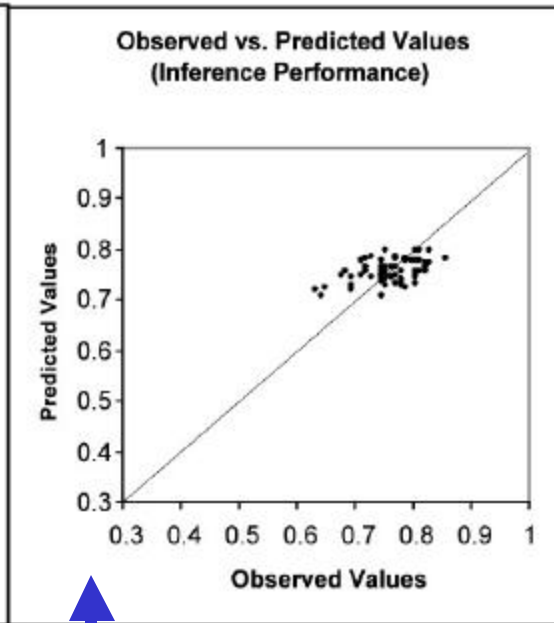
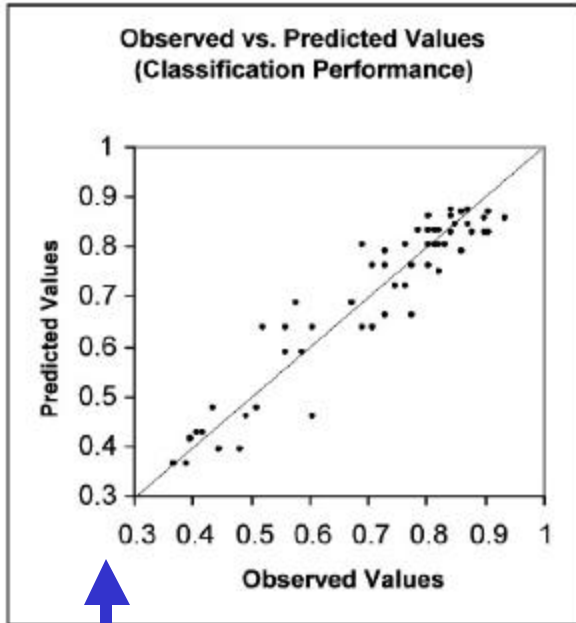
$$P(A | i) = \frac{[\sum_{j \in Ca} sim(j, i)]^g}{[\sum_{j \in Ca} sim(j, i)]^g + [\sum_{j \in Cb} sim(j, i)]^g}$$

Exp. 2

$$P(A | i) = \frac{[\sum_{j \in Ca} sim(j, i)]^g}{[\sum_{j \in Ca} sim(j, i)]^g + [\sum_{j \in Cb} sim(j, i)]^g + mc}$$

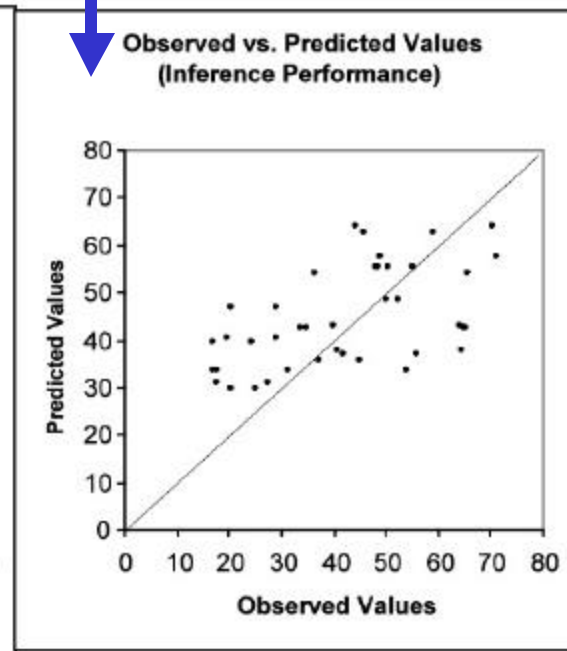
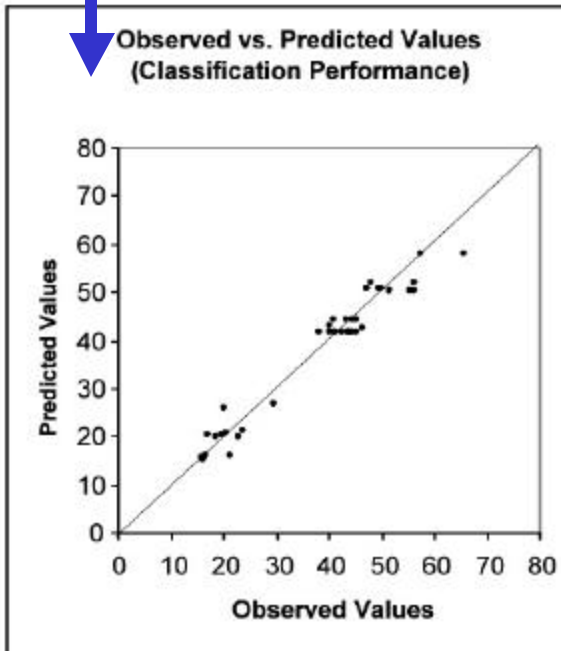
$$sim_{ij} = \exp(-c \times d_{ij}^r)$$

$$d_{ij} = \sum_{m=1}^M w_m |h \times x_{im} - x_{jm}|$$



Classification data

Inference data



Exp. 1

% explained:

Classification = 88.9%

Inference = 23.9%

Exp. 2

% explained:



Classification = 95.0%



Inference = 26.0%

Discussion

- GCM was able to account for classification data very well.
- GCM failed to account fro inference data.
 - What makes classification and inference different?
- Hypothesis
 - Category labels and category features are two different things. That's why classification and inference is different.

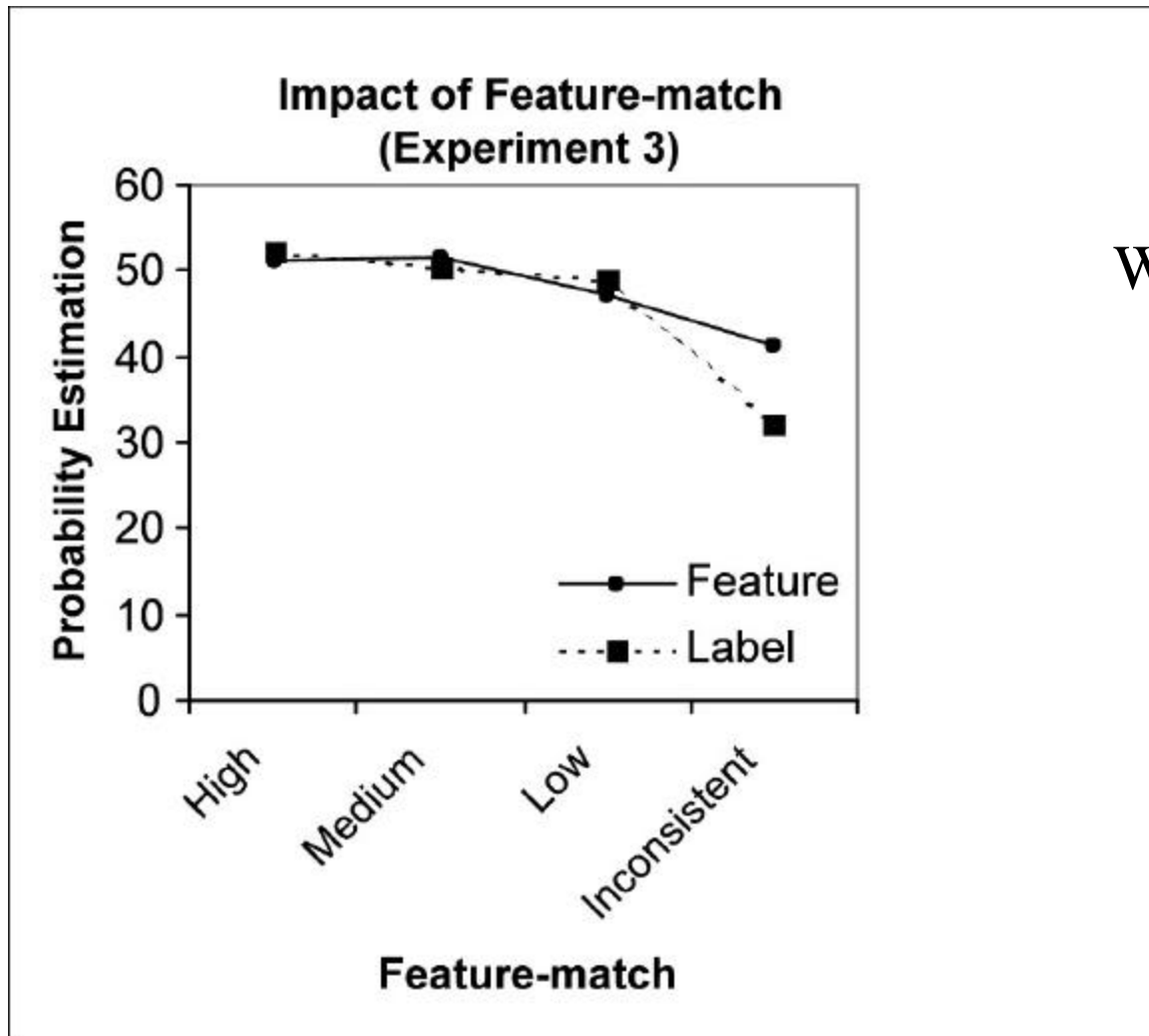
Contrast 2 inference conditions

<p>Sample Stimulus</p> <p>monek</p> 	<p>Test Stimulus</p> <p>If the bug shown below belong to the same type, "monek," as the bug shown on the left side, what is the probability that this bug (shown below) can have the horns like these?</p> <p>monek</p> 
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<p>Sample Stimulus</p> 	<p>Test Stimulus</p> <p>If the bug shown below has the same wings as the bug shown on the left side, what is the probability that this bug (shown below) can have the horns like these?</p> 
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- The category label was replaced with a new feature, wings

Results



When category labels were present, Ss were less likely to endorse inconsistent feature values.

Why?

Category labels force Ss to assume that members in a category have features in common.

Interaction: Question type x feature match

$F(3, 453)=12.1, MSE=80.0, =0.134, p<0.001.$

$t(151)=2.77, d=0.45, p<0.05$

General Discussion

- Why is classification learning inappropriate for categories composed of multiple feature instances?
 - Because classification heavily relies on concrete exemplar matching.
- What are the implications of this finding?
 - People employ fundamentally different decision strategies to make classifications and inferences.
- What is important about this distinction?
 - Categories with multiple feature instances cannot be learned by classification alone.

References

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