COGS500/CMPE489: Cognitive Science

Week 11 – Learning

Adapted from Salah's slides

Overview

- Categories and concepts
- Concept learning
- Logic
- Machine learning

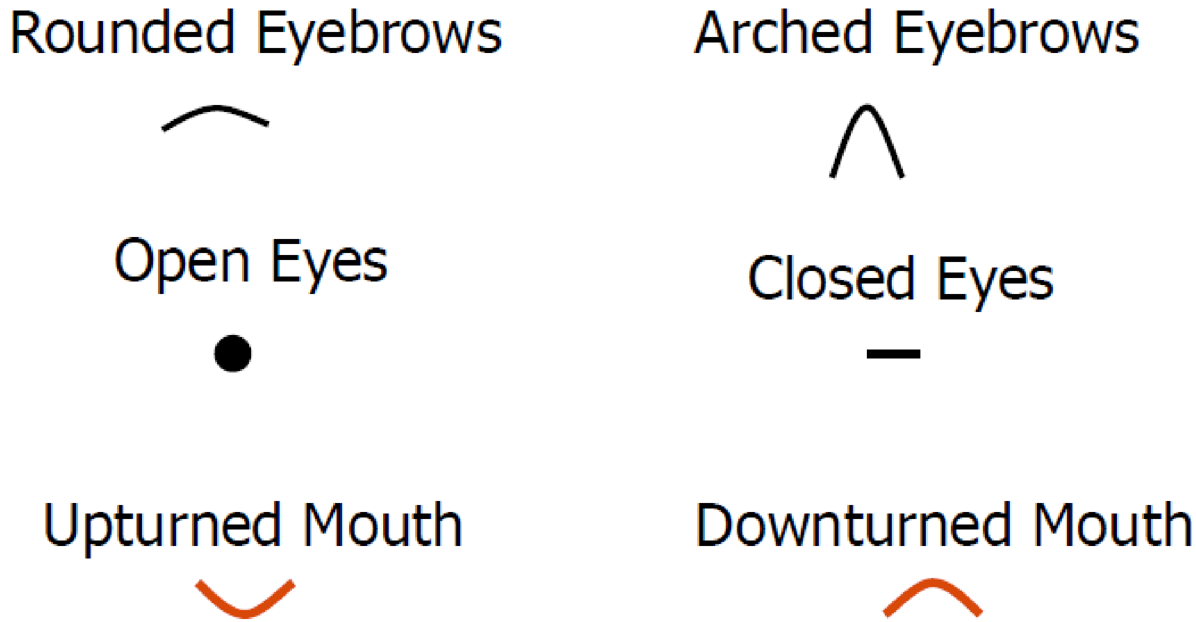
What is learning?

- The acquisition of knowledge or skills through experience, practice, or study, or by being taught.
- Learned information is stored in a cognitive system, and can be re-used.
- How is this information represented?

Categories and concepts

- A category is a class of objects that belong together.
- Concepts are our mental representations of a category.
- Concepts have defining attributes.
  - What do the following concepts have in common? (Barsalau'83)
    - child
    - photo album
    - money

You will be shown a series of faces. Each face consists of a set of attributes:



Your problem: to decide whether each face you'll see is a positive instance of the concept.

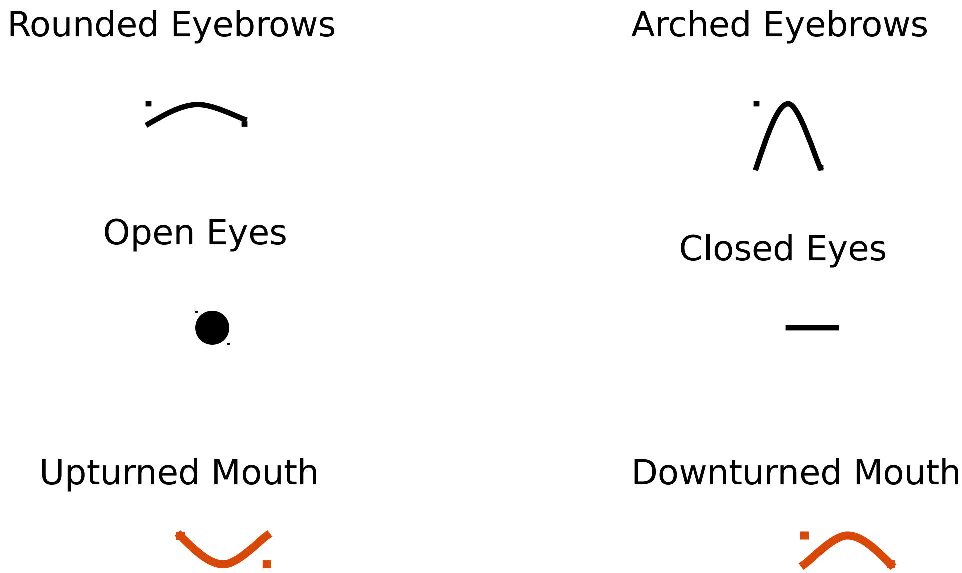
Only one attribute is relevant to solving the problem.

Rounded Eyebrows	Arched Eyebrows
Open Eyes	Closed Eyes
Upturned Mouth	Downturned Mouth

When you see the face (stimulus), respond “Yes” if you think it’s a positive instance or “No” if you think it’s a negative instance.

Learning Concepts

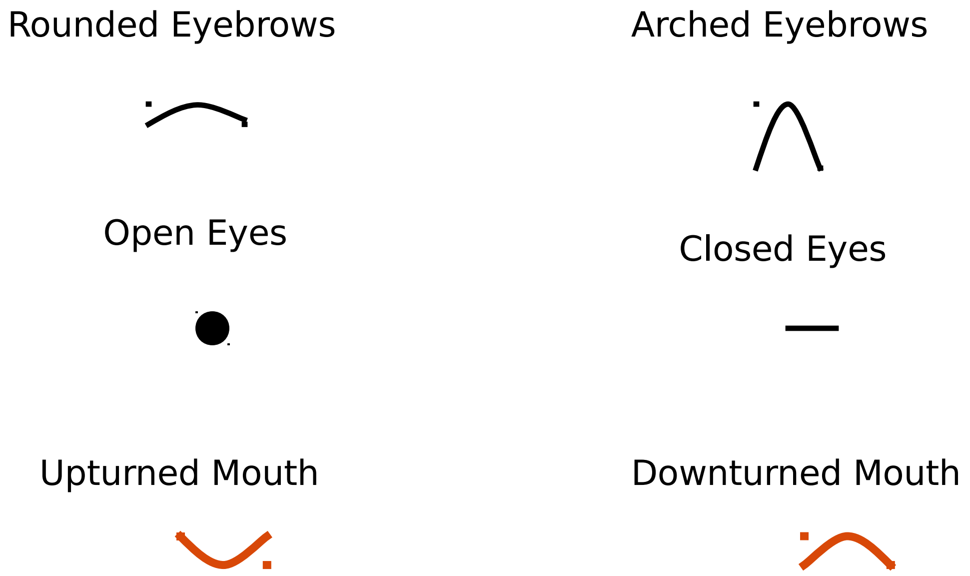
You will be shown a series of faces. Each face consists of a set of attributes:



Your problem: to decide whether each face you'll see is a positive instance of the concept.

Learning Concepts

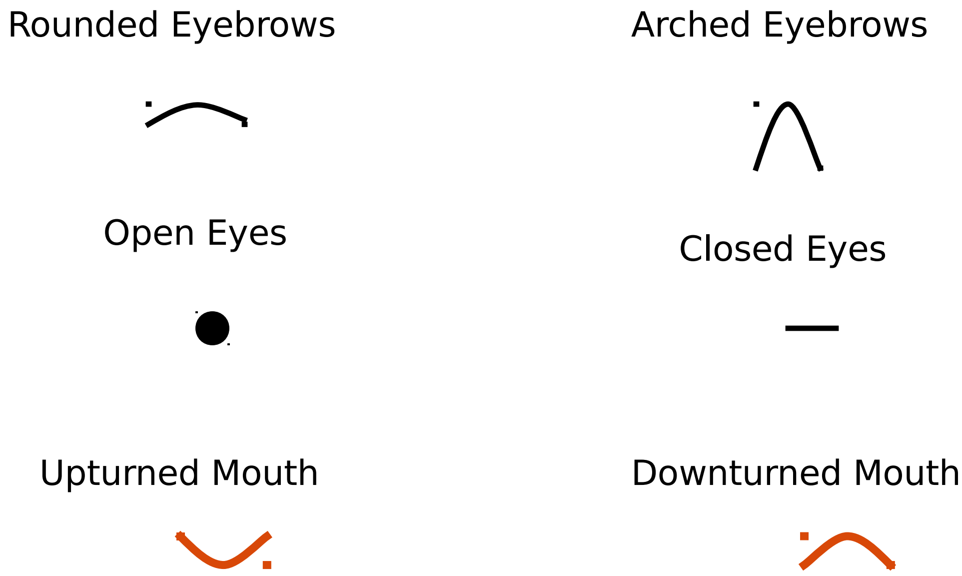
Only one attribute is relevant to solving the problem.



When you see the face (stimulus), respond “Yes” if you think it’s a positive instance or “No” if you think it’s a negative instance.

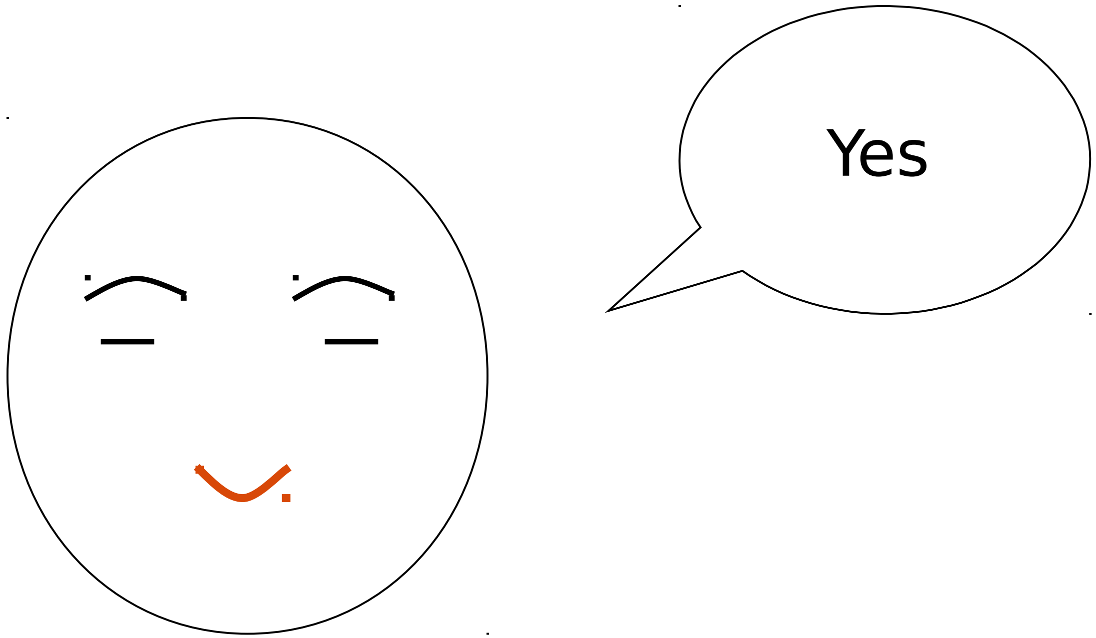
Learning Concepts

After you make your response, you will see the answer.

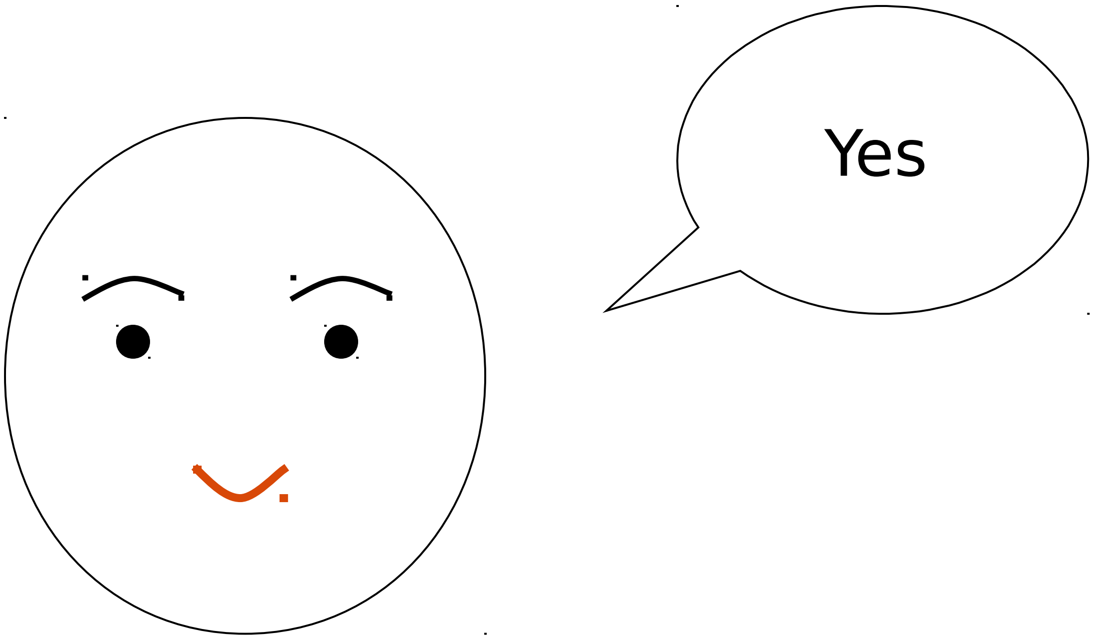


From Matlin, M. (1983) *Cognition*. New York: Holt, Rinehart & Winston.

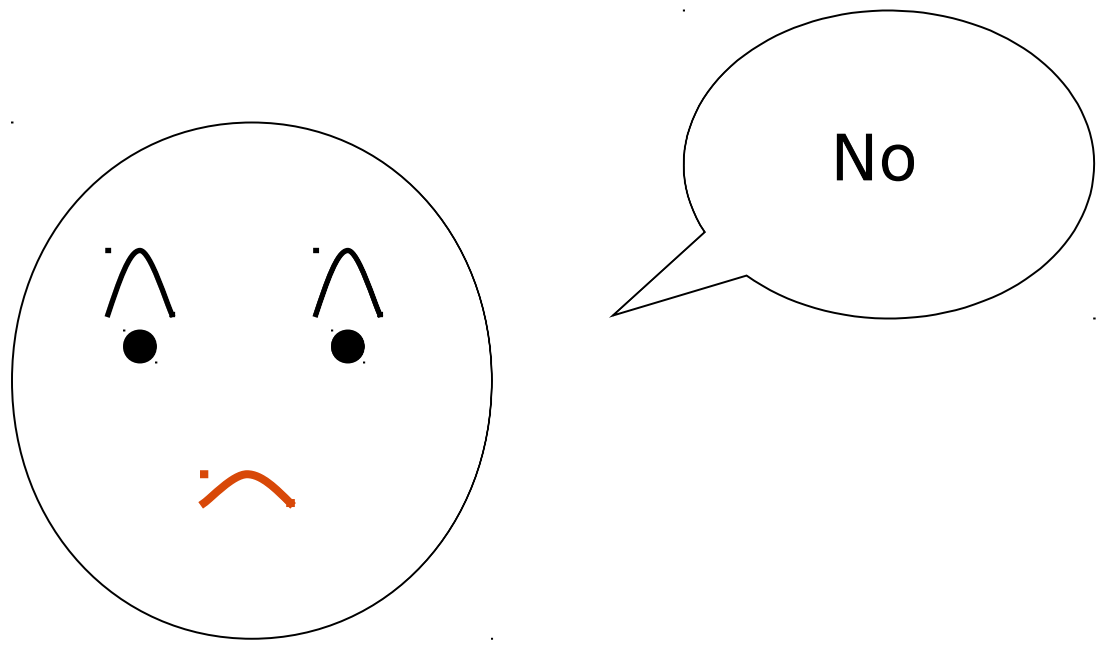
Learning Concepts



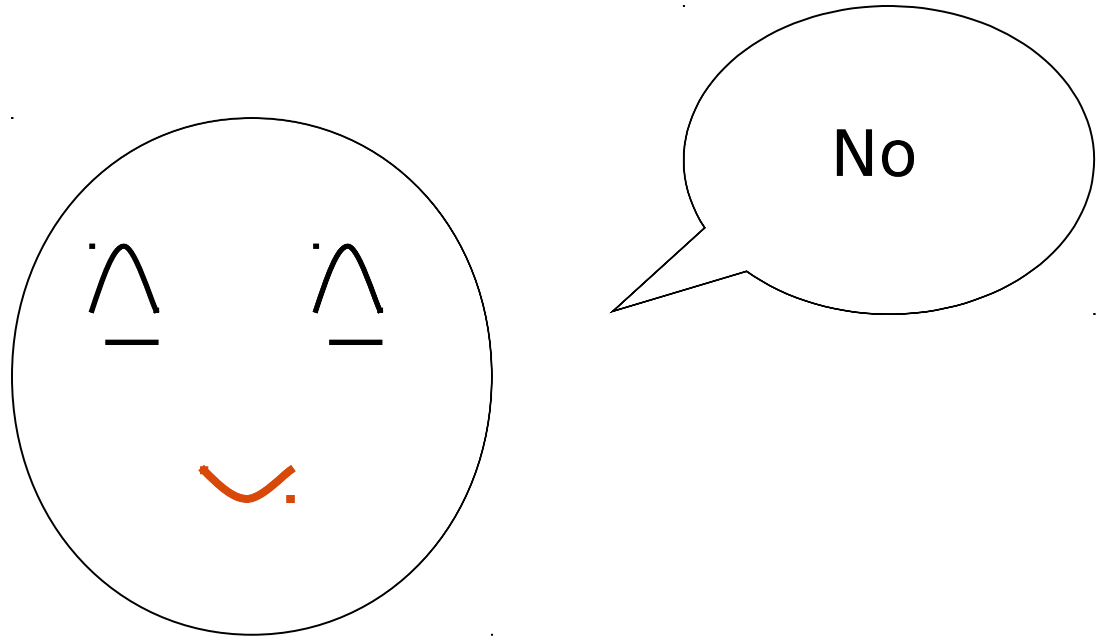
Learning Concepts



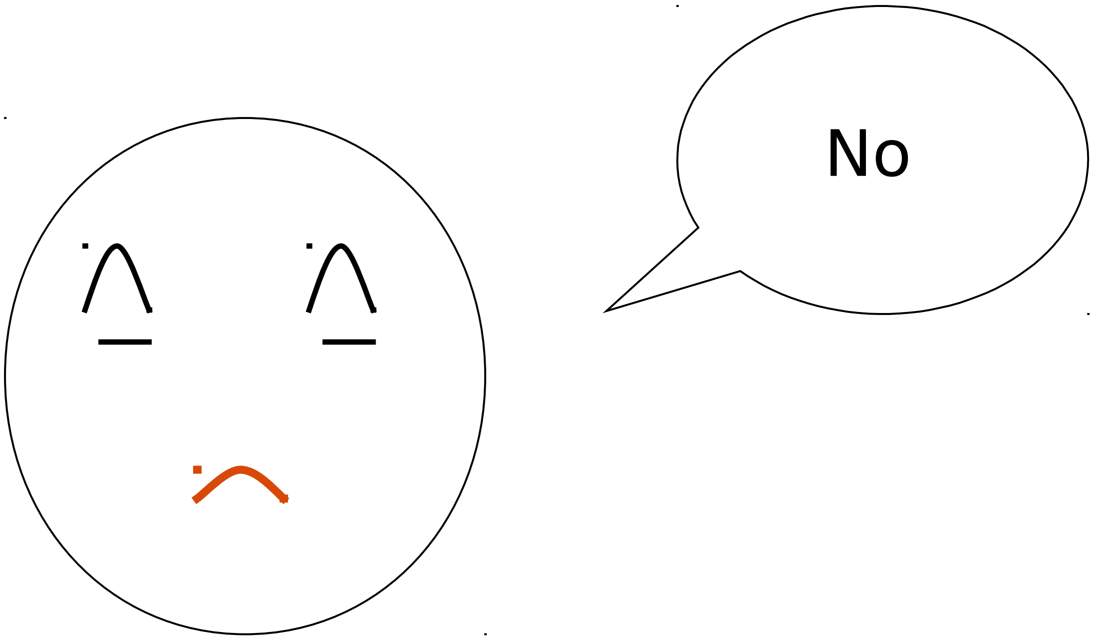
Learning Concepts



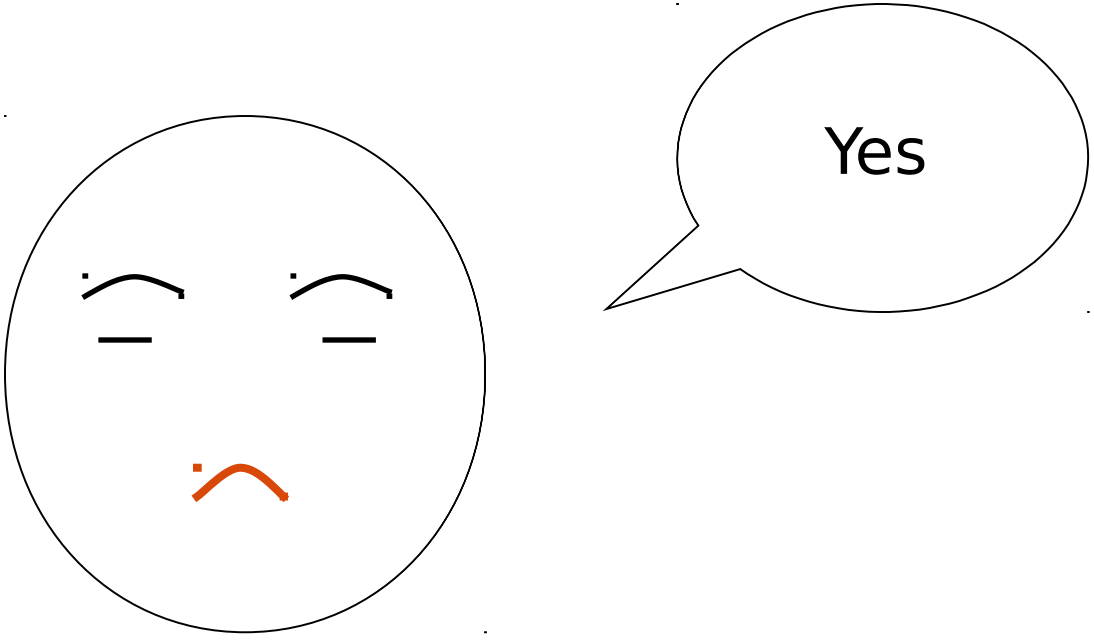
Learning Concepts



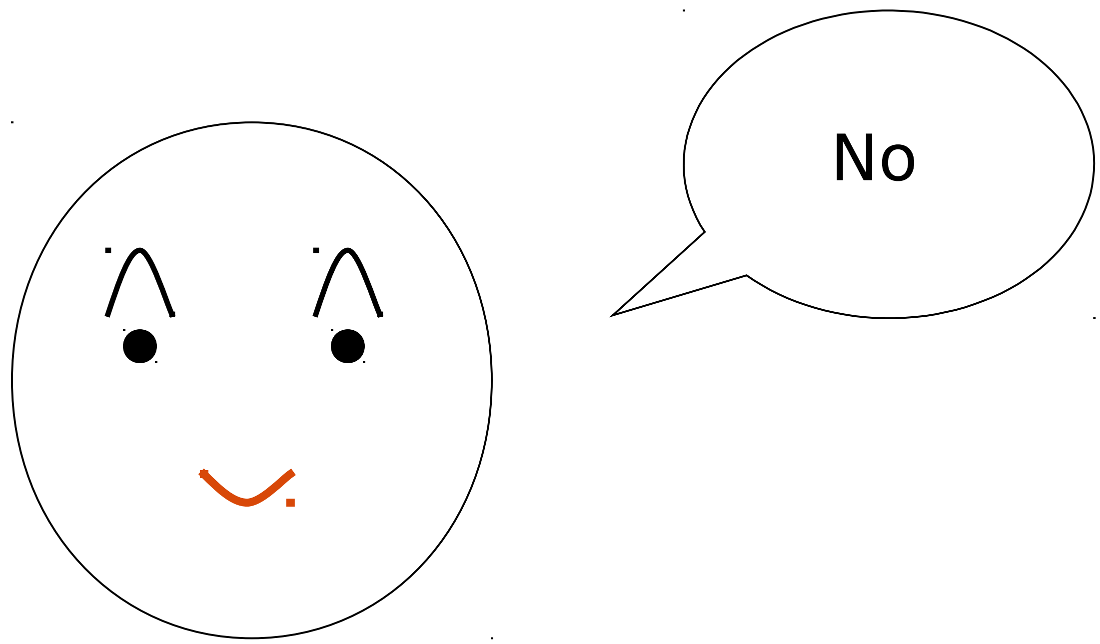
Learning Concepts



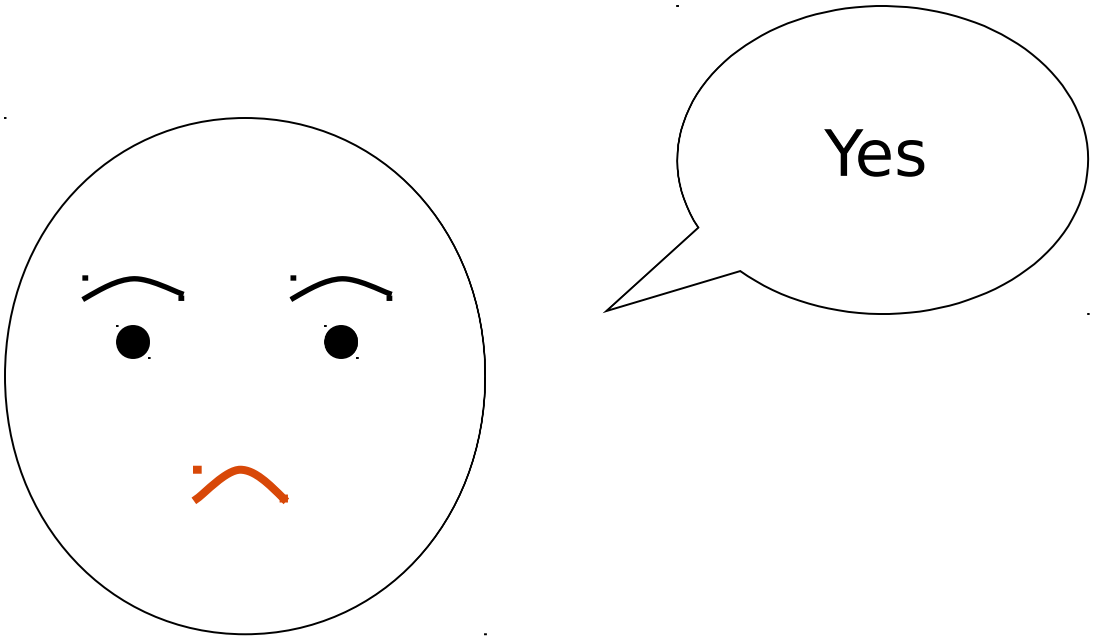
Learning Concepts



Learning Concepts

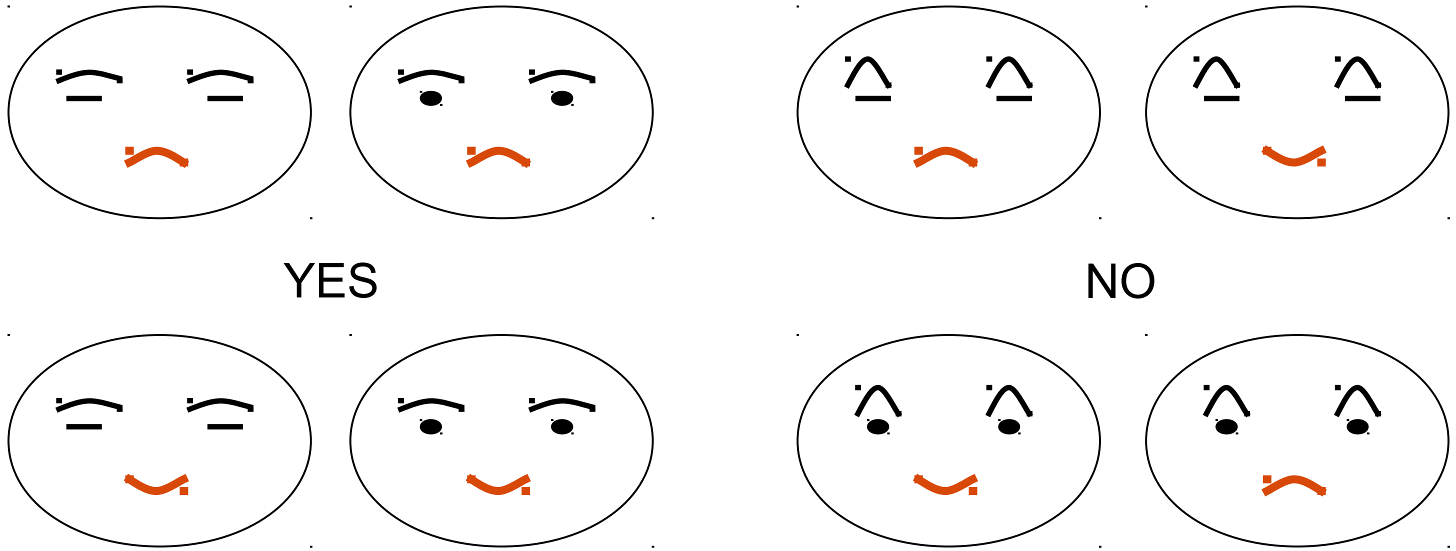


Learning Concepts



And the concept is…

- The concept is “rounded eyebrows.” You can ignore all other attributes of the face and respond correctly to each new stimulus by looking only for the rounded eyebrows.



Representing concepts

The following notation system is used to represent the structure of concepts.

<u>Attributes</u>

These are represented by the letters: **A**, **B**.

<u>Rules</u>

A dash, **-**, means “not”.

A raised dot, •, means “and”; it’s used in “conjunction” rules.

The letter, **v,** means “or”; it’s used in “disjunction” rules.

Concept definitions from Neisser & Weene (1962).

Representing concepts

Level 1 Concepts

Affirmation: **A**

Attribute **A** must be present.

Example: Vertebrate animal—must have a backbone.

Negation: -**A**

Attribute **A** must be absent.

Example: Invertebrate animal—must not have a backbone.

Representing concepts *Level 2 Concepts*

<u>Conjunction</u>: (**A • B)**

Both Attribute **A** and Attribute **B** must be present.

Example: a food that causes an allergic rash. This could be a food (stimulus) that contains both cheese (**A**) and tomatoes **(B**), such as pizza.

 +  = 

<u>Disjunctive Absence</u>: (**–A v –B)**

Either Attribute **A** or Attribute **B**, or both, must be absent. This is the opposite or “complement” of conjunction.

Example: a non-allergenic food. It lacks cheese, or tomatoes, or both, such as a cheeseburger or a salad with tomatoes.

Representing concepts

Level 2
Concepts"

<u>Disjunction</u>: (**A v B)**

Either **A** or **B**, or both, must be present.

Example: an allergenic food that involves the same attributes as before—cheese (**A**) and tomatoes (**B**)—but either one alone can cause a rash, as well as both ingredients combined. So with this rule you would have to avoid cheeseburgers as well as pizza.

Representing concepts

Level 2
Concepts

Conjunctive Absence (**-A • -B**)

Both **A** and **B** must be absent. This is the complement of disjunction. All the negative instances with conjunction become positive instances with conjunctive absence.

Example: a non-allergenic food, if the allergy involves the disjunctive rule. Any food that lacks both tomatoes and cheese would be OK to eat.

Representing concepts

Level 2
Concepts

<u>Exclusion</u> (**A • -B**)

A must be present and **B** must be absent.

Example: eligible to vote; person is a citizen (**A**) and is not a felon (**B**).

<u>Implication</u> (**-A v B**)

If **A** is present, **B** must be present also. If **A** is absent, then it doesn't matter if **B** is present or absent. This is the complement of exclusion. All the negative instances under exclusion are positive instances under implication.

Example: *in*eligible to vote; if person is not a citizen (-**A**), it doesn't matter whether they are a felon (**B**). If they are a citizen (**A**), then they must be a felon.

Representing concepts

Level 3 Concepts

Level 3 rules involve relationships between pairs of attributes rather than individual attributes.

<u>Either/Or</u> (**A • -B**) v (**-A • B**)

Either **A** or **B** must be present, but both cannot be present together. This is different from disjunction (Level 2). In disjunction, **A** or **B** must be present, but both can be present together.

Example: the “negative product rule” in math. When you multiply two numbers together, you will get a negative product if one of the numbers is negative but not if both numbers are negative.

Representing concepts

Level 3 Concepts

<u>Negative Product Rule</u>

Let **A** and **B** represent positive numbers, for example:

A = 9 **B** = 6

(**A** • **-B**) v (**-A** • **B**)

9 X **–**6 = **-**54

-9 X 6 = **-**54

-9 X **–**6 = **+**54

Representing concepts

Level 3
Concepts

Both/Neither (**A • B**) v (**-A • -B**)

Both A and B must be present, or neither must be present. This is the complement of the either/or rule.

Example: the “positive product rule” in math. When you multiply two numbers together, you will get a positive product if both numbers are positive or neither number is positive.

Representing concepts

Level 3 Concepts

Positive Product Rule

Let **A** and **B** represent positive numbers, for example:

A = 9 **B** = 6

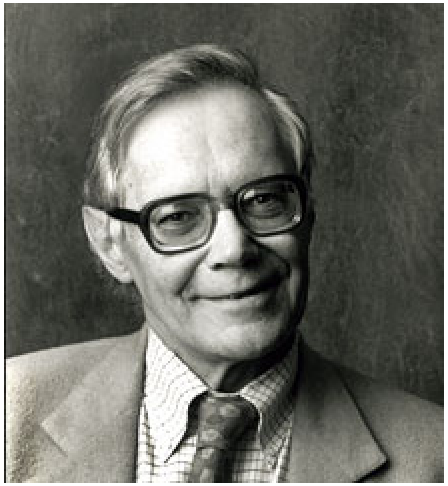
(**A** • **B**) v (**-A** • **-B**)

9 X 6 = **+**54

-9 X **-**6 = **+**54

-9 X 6 = **-**54

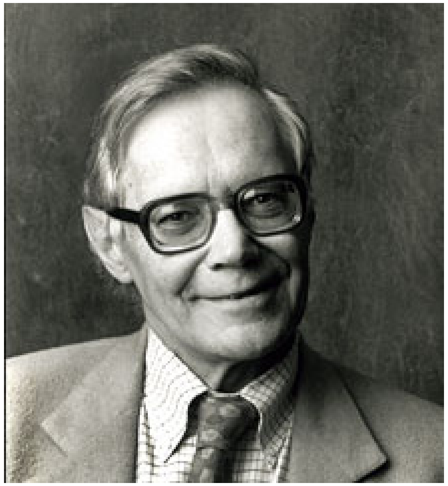
Learning concepts



Neisser and Weene (1962) measured the difficulty of learning concepts at each level of complexity. On each trial, they showed subjects an index card on which four letters were written.

Then??

Learning concepts



Neisser and Weene (1962) measured the difficulty of learning concepts at each level of complexity. On each trial, they showed subjects an index card on which four letters were written.

In each of the four positions on the card, one of five letters could appear: **J**, **Q**, **V**, **X**, **Z**. For example, they could have J J J J, V X Q J, Z Q Z X. There were 625 possible combinations.

Subjects were told that no more than two letters were relevant to any concept and the order (position) of the letters was irrelevant.

Learning concepts - cards

When a card was shown, subjects pushed a switch UP if they thought it was a positive instance, and pushed it DOWN if they thought it was a negative instance.

Cards were presented until the subjects reached a criterion of mastery: 25 consecutive trials with at least 24 correct answers.

Learning concepts

Presence of **X** (Level 1)

Positive Instances	Negative Instances
X J J J	Q J J J
J J X J	J J Z J
Q V Z X	Q V Z V
V X Q J	V J Q J

Learning concepts

Conjunction of **X** and **Z** (Level 2)

Positive Instances	Negative Instances
X V J Z	V V J Z
Z X Q X	J V Q X
Z Q X Z	Q Q Q Q
Z Z Z X	Z Z Z J

Learning concepts

Disjunction of **X** and **Z** (Level 2)

Positive Instances	Negative Instances
X J Q Z	V J Q V
V Q V Z	V Q V J
Z X V Z	Q Q Q Q
J V X J	V V V J

Learning concepts

Either **X** or **Z** (Level 3)

Positive Instances	Negative Instances
X J Q V	X Z J Q
V Q V Z	X Q V Z
Z J V Z	Q Q Q Q
J V X J	V V V J

Learning concepts

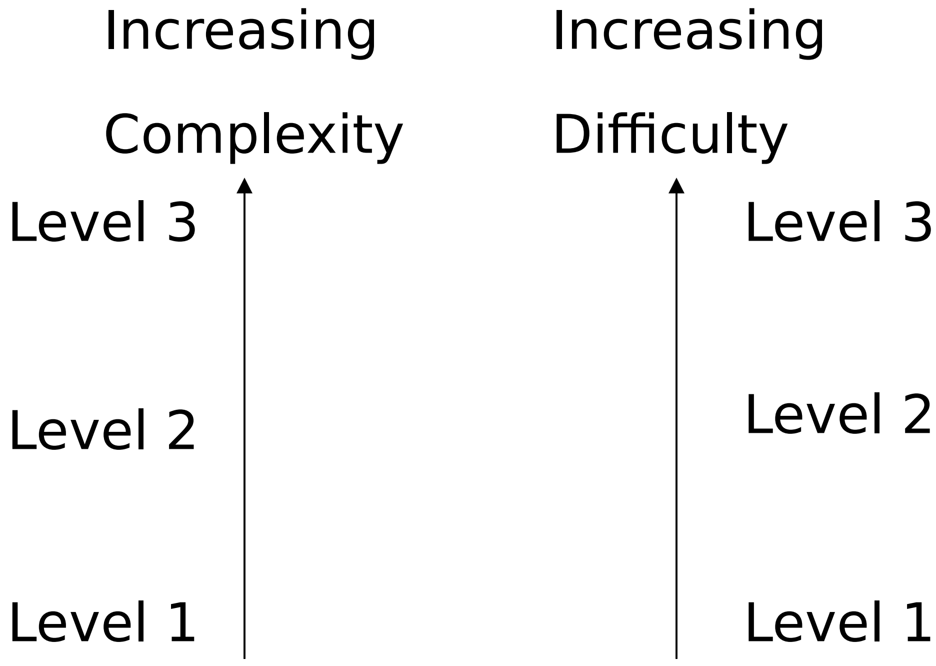
Trials to Criterion for Different Types of Problems

Type of Concept	Cycle 1		Cycle 2	
	Median	Q_1/Q_3	Median	Q_1/Q_3
Level I				
Presence (A)	11.0	3.0/22.0	4.0	1.0/12.0
Absence (—A)	7.0	2.0/21.5	1.5	0.0/ 3.0
Level II				
Conjunction (A·B)	13.0	6.0/43.5	18.0	4.5/50.5
Disjunction (AvB)	21.0	8.0/46.0	24.0	7.5/29.5
Exclusion (A·—B)	28.0	14.0/51.0	17.0	2.5/30.5
Disjunctive absence (—Av—B)	50.0	25.0/ ∞	23.0	9.5/37.5
Conjunctive absence (—A·—B)	29.0	17.0/61.0	8.0	3.0/18.0
Implication (—AvB)	∞	57.5/ ∞	19.5	9.0/59.0
Level III				
Either/or (A·—B)v(—A·B)	68.0	47.5/ ∞	41.5	22.5/ ∞
Both/neither (A·B)v(—A·—B)	∞	54.5/ ∞	53.5	38.0/ ∞

Learning concepts

Results

Results were measured in terms of trials to criterion. The more trials subjects needed to reach the criterion, the more difficult it was to learn the concept.



Learning concepts

Logical complexity and psychological difficulty were correlated. However, complexity was not the only factor determining the difficulty of learning a concept.

Within a level, concepts differed in difficulty even though they were equal in complexity.

Generally, rules that required …… were learned faster than rules that required …..

Learning concepts

Logical complexity and psychological difficulty were correlated. However, complexity was not the only factor determining the difficulty of learning a concept.

Within a level, concepts differed in difficulty even though they were equal in complexity.

Generally, rules that required the absence of attributes (like negation) were learned faster than rules that required the presence of attributes (like affirmation).

Learning concepts

The kinds of concepts we learn through everyday experience often do not have a single set of defining attributes. These are called natural concepts. The kinds of concepts studied by Neisser & Weene that have a single set of defining attributes are called artificial concepts.

Artificial concepts are deliberately created, like the qualifications for voting or getting a driver's license.

Natural concepts are based on individual experience and people may disagree on whether a stimulus is a positive instance of a category.   It's not a question of logic.

Learning concepts

For example, what do all vehicles have in common? Would you say “wheels?” Then how would you categorize a raft; is it a positive or negative instance? Or an elevator? Or a horse?

There is a lot of evidence that when we learn a natural concept we form a “**prototype**”, a kind of picture of the most typical positive instance.

When deciding whether to call a stimulus a positive instance, we compare all its attributes to those of the prototype. The greater the overlap, the more typical the stimulus is seen to be.

Another view is that we remember specific examples, or “**exemplars**,” of the category rather than some ideal prototype.

Learning concepts

Whatever the process, nonhuman species as well as humans are capable of forming complex natural concepts. Pigeons have been trained to identify such varied concepts as trees, people, and buildings.

This is done though discrimination training. You intermittently reinforce key-pecking responses when a picture of a positive instance is shown but not a negative instance. After hundreds of examples, pigeons will respond appropriately when new examples are shown: They peck faster when they see a positive instance than a negative instance.

Our organized knowledge about the world

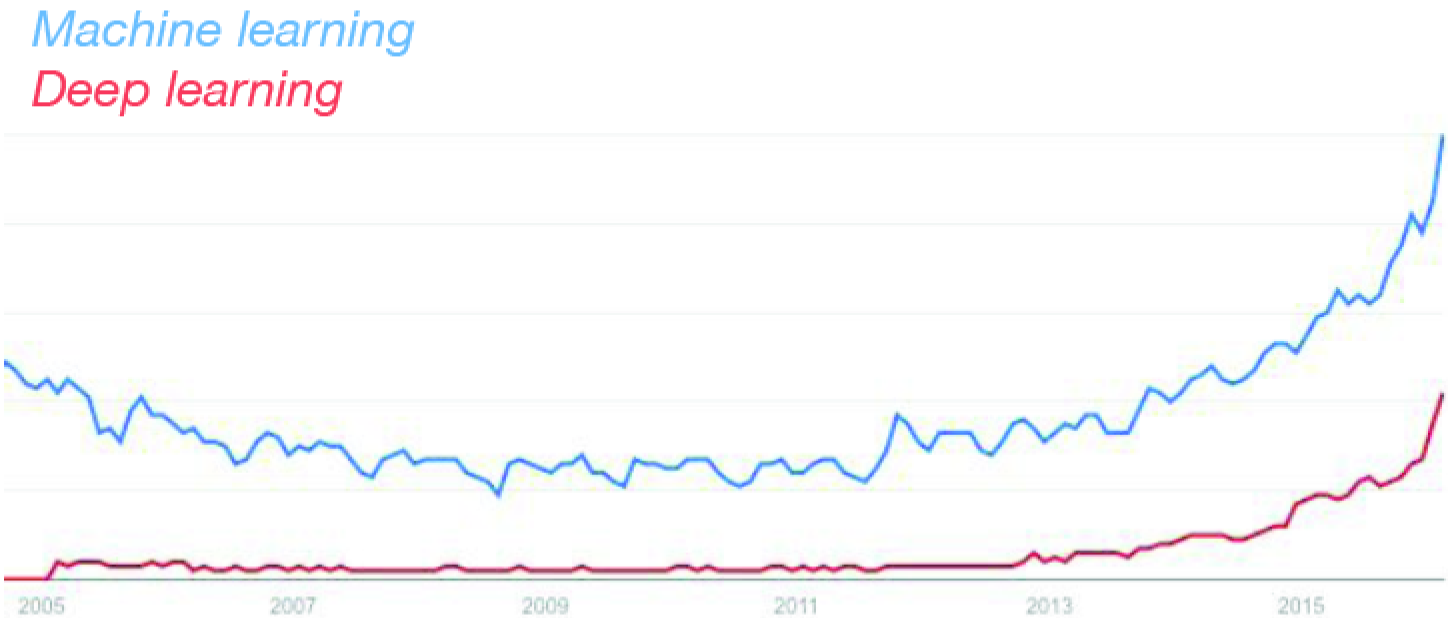
- Whether an object in the grocery is an apple
  - Feature comparison model: list of necessary features - such as color, size and shape
  - Prototype approach: compare it with the most idealized apple
  - Exemplar approach: compare it with specific examples of apples (golden, stark, gala)
  - Network model: Interconnections among related items: apple related to other items which are red, seed-bearing and pear.

MACHINE LEARNING

Why "Learn" ?

- Machine learning is programming computers to optimize a performance criterion using example data or past experience.
- There is no need to "learn" to calculate payroll
- Learning is used when:
  - Human expertise does not exist (navigating on Mars),
  - Humans are unable to explain their expertise (speech recognition)
  - Solution changes in time (routing on a computer network)
  - Solution needs to be adapted to particular cases (user biometrics)

Google Trends



What We Talk About When We Talk About "Learning"

- Learning general models from a data of particular examples
- Data is cheap and abundant (data warehouses, data marts); knowledge is expensive and scarce.
- Example in retail: Customer transactions to consumer behavior:

  People who bought "Blink" also bought "Outliers" (www.amazon.com)
- Build a model that is *a good and useful approximation* to the data.

What is Machine Learning?

- Optimize a performance criterion using example data or past experience.
- Role of Statistics: Inference from a sample
- Role of Computer science: Efficient algorithms to
  - Solve the optimization problem
  - Representing and evaluating the model for inference

Applications

- Association
- Supervised Learning
  - Classification
  - Regression
- Unsupervised Learning
- Reinforcement Learning

Learning Associations

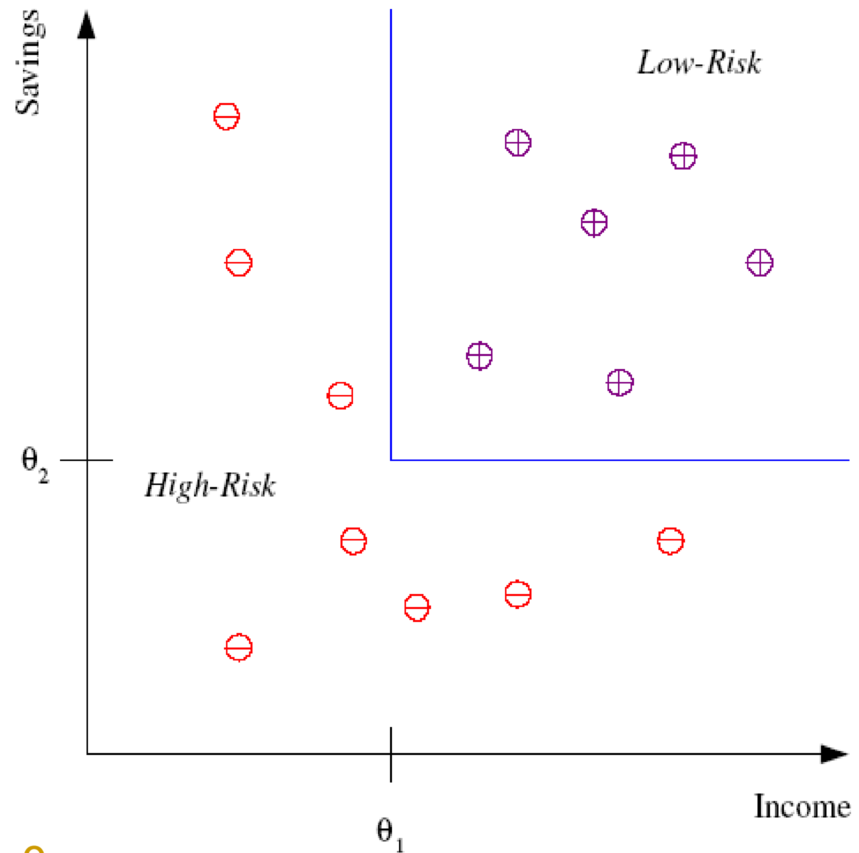
- Basket analysis:

  $P(Y \mid X)$ probability that somebody who buys X also buys Y where X and Y are products/services.

  Example: P (chips | beer) = 0.7

Classification

- Example: Credit scoring
- Differentiating between low-risk and high-risk customers from their *income* and *savings*



Discriminant: IF *income* > θ_1 AND *savings* > θ_2

THEN low-risk ELSE high-risk

Face recognition

Training examples of a person

Test images

ORL dataset,
AT&T Laboratories, Cambridge UK

Regression

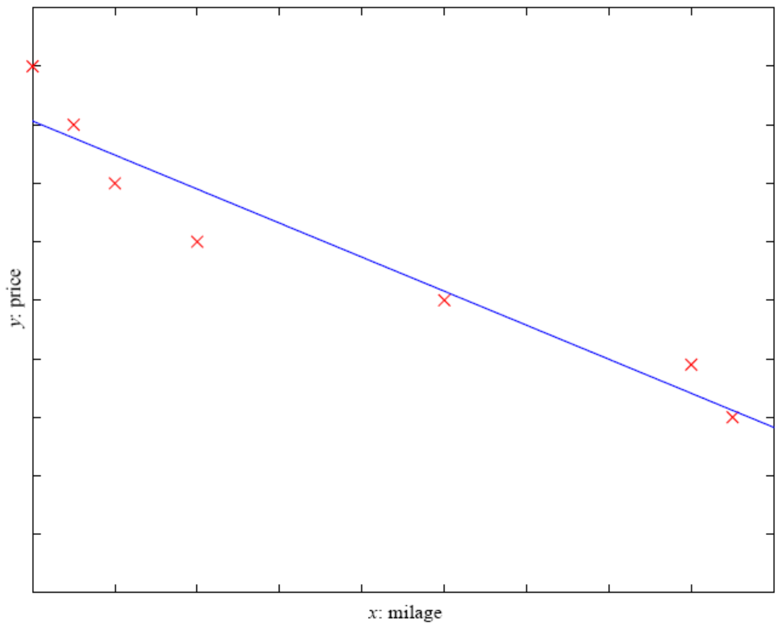
- Example: Price of a used car
- x : car attributes

  y : price

  $$y = g(x \mid \theta)$$

  $g(\,)$ model,

  θ parameters



Supervised Learning: Uses

- Prediction of future cases: Use the rule to predict the output for future inputs
- Knowledge extraction: The rule is easy to understand
- Compression: The rule is simpler than the data it explains
- Outlier detection: Exceptions that are not covered by the rule, e.g., fraud

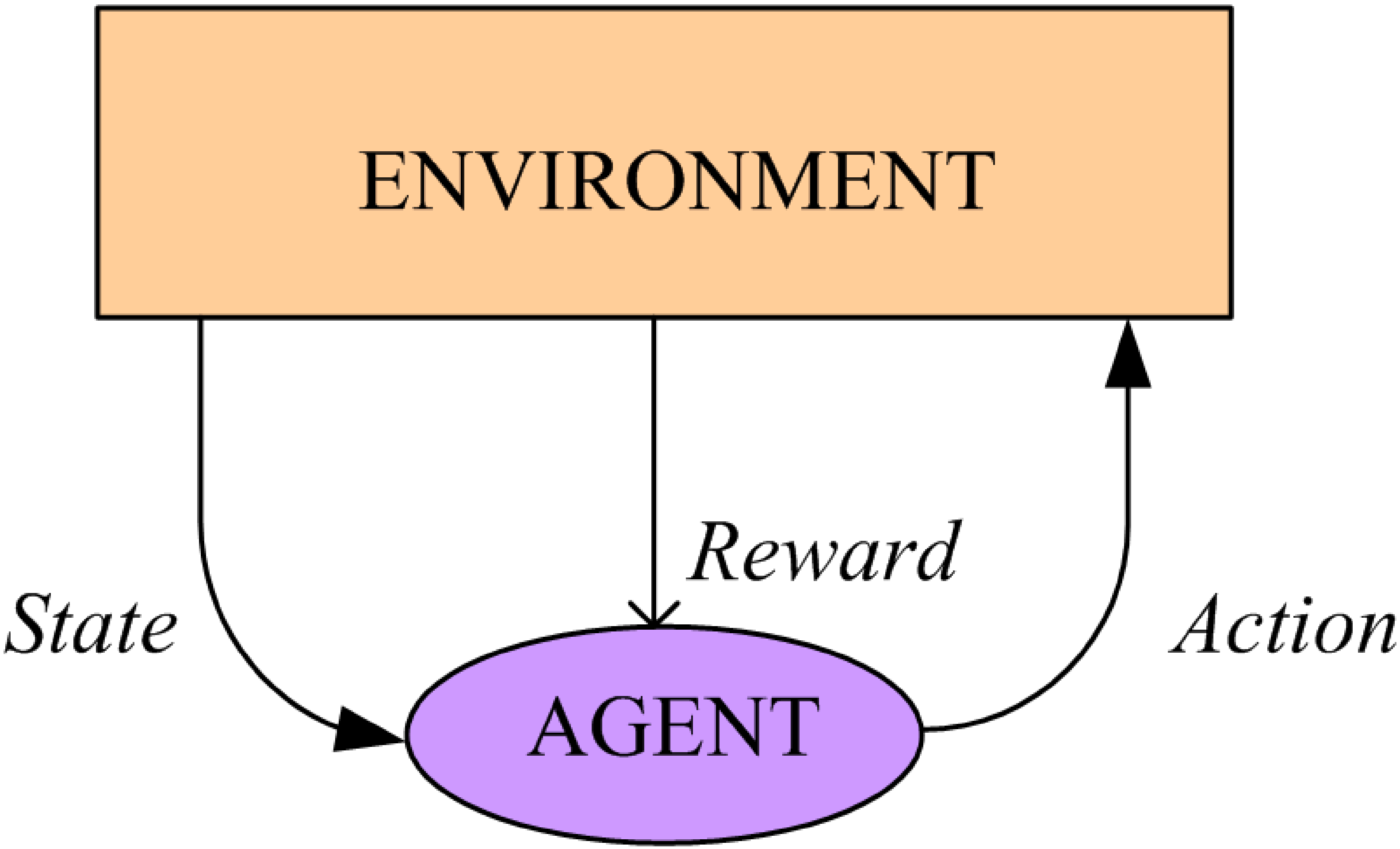
Unsupervised Learning

- Learning “what normally happens”
- No output
- Clustering: Grouping similar instances
- Example applications
  - Customer segmentation in CRM
  - Image compression: Color quantization
  - Bioinformatics: Learning motifs

Reinforcement Learning

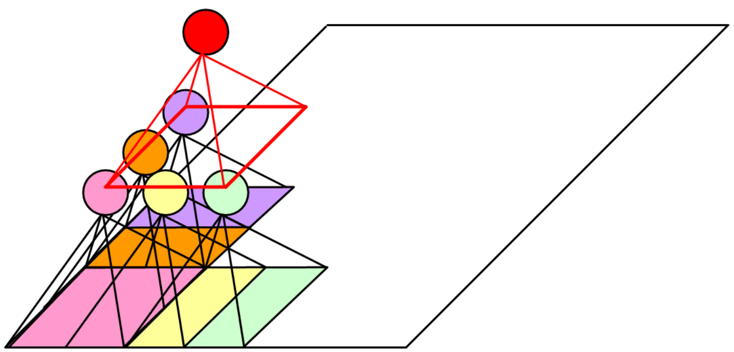
- Learning a policy: A sequence of outputs
- No supervised output but delayed reward
- Credit assignment problem
- Game playing
- Robot in a maze
- Multiple agents, partial observability, ...

Reinforcement Learning



Summary

- Different types of learning
  - Association
  - Supervised Learning
    - Classification
    - Regression
  - Unsupervised Learning
  - Reinforcement Learning
- Biologically plausible machine learning?



Any questions???

Quiz

- Rosenblatt's perceptrons (or Mcculloch Pitts neurons)
  - are (not?) classifiers because
  - are (not?) regressors because
  - are (not?) reinforcement learners because
  - are (not?) supervised learners because
  - are (not?) unsupervised learners because

References

- Douglas Navarick – Learning and Memory.
- Matlin, Cognition, Chapter 8.
- E. Alpaydın, Intro. to Machine Learning