Chapter 1: Intelligent Agents

Lecture Overview

- What is Artificial Intelligence?
- Agents acting in an environment

Learning objectives: at the end of the class, you should be able to

- describe what an intelligent agent is
- identify the goals of Artificial Intelligence
- classify the inputs and the outputs of various agents

What is Artificial Intelligence?

- Artificial Intelligence is the synthesis and analysis of computational agents that act intelligently.
- An agent is something that acts in an environment.
- An agent acts intelligently if:
  - its actions are appropriate for its goals and circumstances
  - it is flexible to changing environments and goals
  - it learns from experience
  - it makes appropriate choices given perceptual and computational limitations

Observing and investigating intelligence

- reflexes
- insticts
- problem solving
- learning
- tool use
- intellectual tasks
- language communication
- creativity
- self-recognition

Reflexes

involuntary and nearly instantaneous movement in response to a stimulus

- can be innate or aquired (conditioning)

Reflexes

- Can intelligence emerge from the interplay of reflexes?
- Is building structure always a sign of intelligent behaviour?

Instincs

Migrating animals: birds, butterflies, mammals, ...

Instincs

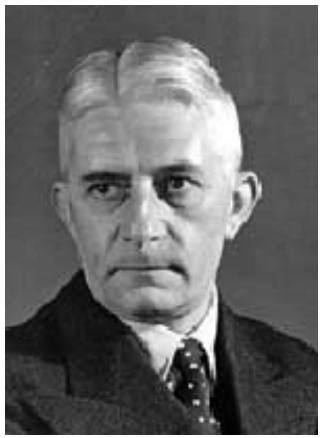
the inherent inclination of a living organism toward a particular complex behavior.

- innate behavior: absence of learning
- eating, nest building, mating, feeding, migration, ...
- no intelligent behaviour, can be counterproductive
- can be overridden by competing instincts or reasoning

Problem solving

Wolfgang Köhler (1887 – 1967)

Intelligenzprüfungen an Anthropoiden (1917)
The Mentality of Apes (1925)



Problem solving

- behaviour is driven by insight, if a goal cannot be reached on a direct and simple path, but a way round is available and chosen.
- distinction between true intelligent results and coincidental success.
  - chance: several independent movements
  - true intelligence: spatially and temporally coherent course without hesitation

Problem solving

Robert Epstein (1953 –)

are pigeons as intelligent as chimpanzees?

Problem solving

Bernd Heinrich (1953 –)

problem solving in ravens

Ethology **111**, 962—976 (2005)

Testing Problem Solving in Ravens: String-Pulling to Reach Food

Bernd Heinrich & Thomas Bugnyar

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Abstract

The aim of our study was to re-examine the acquisition of problem-solving behaviour in ravens: accessing meat suspended from a perch by a string. In contrast to a previous study, here we: (i) controlled for possible effects of fear of the string, competition by dominants, and social learning and (ii) devised a mechanically equivalent but non-intuitive task to test for the possibility of means–end understanding. One-year-old ravens confronted with meat on a string for the first time tried several ways to reach the food. However, five of six birds suddenly performed a coherent sequence of pulling up and stepping on loops of string, essential for solving the problem. Those five birds were also successful in the non-

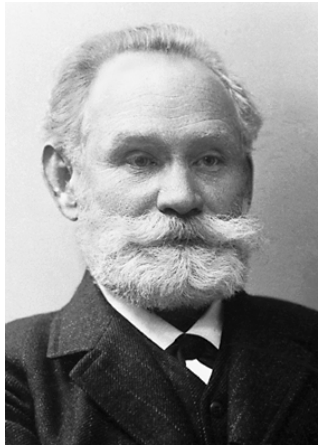
Problem solving

Making the task more challenging ...

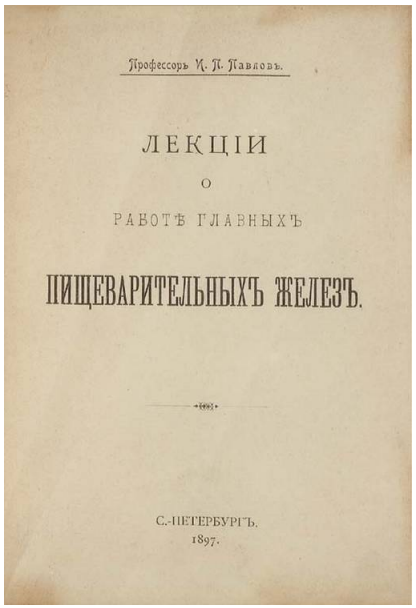
Animals mastered the second task only after they have solved the first one!

Conditioning

Iwan Petrowitsch Pawlow (1849 – 1936)



- acquired/learned reflexes
- association learning: direct linking of sensual stimuli
- assumed to be the only type of learning in animals



Imprinting

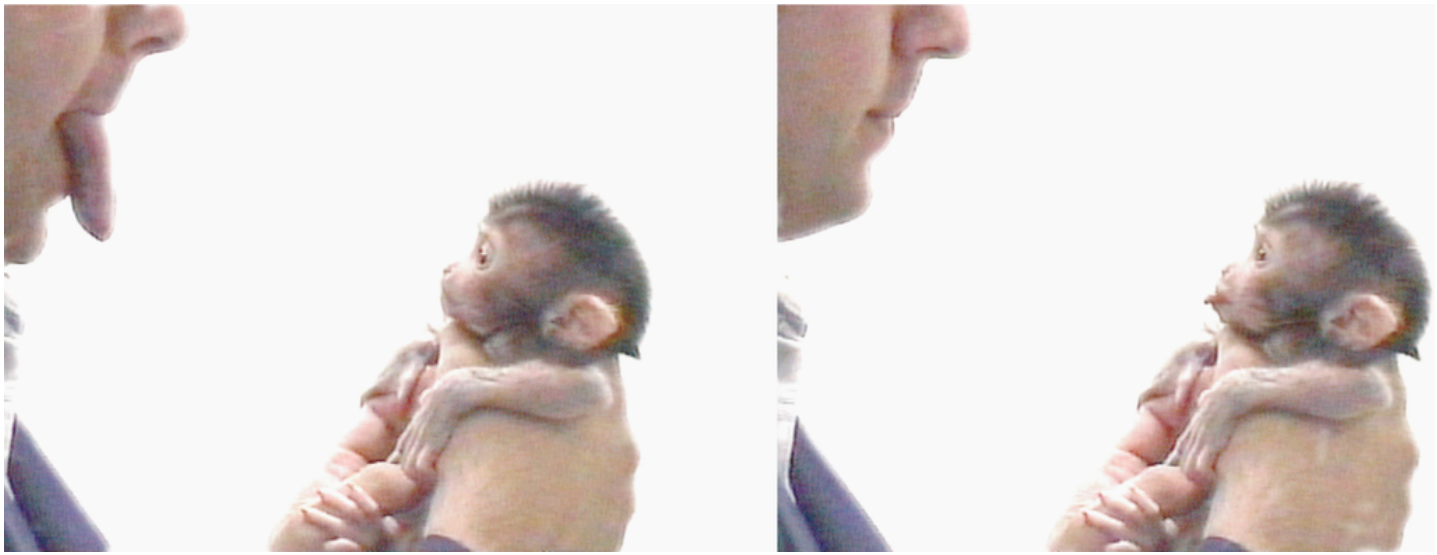
phase-sensitive learning

- rapid
- apparently independent of the consequences of the behavior

Imitation

observing and replicating another individuums behavior

- form of social learning
- leads to the development of traditions and culture
- transfer of information (behaviours, customs, etc.) across generations without the need for genetic inheritance



Imitation

blue tits learned to open sealed milk bottles

1900 – 1945	open milk bottles were dropped at the doorstep
around 1945	sealed milk bottles have been introduced
since 1960	doorstep delivery has been suspended

around 1945	first indiviuals learned to open the seal
around 1950	the whole population of British blue tits had aquired the skill

Imitation

Are blue tits smarter than european robins?

- Only few individuals acquired the skill but not the whole population. Why?

Imitation

Are blue tits smarter than ravens?

The string pulling experiment again:

- Every individual developed its own solution strategy
- No transfer of skills between individuals
- One raven didn't master the task even though it was able to observe the other ones pulling the meat

Tool use

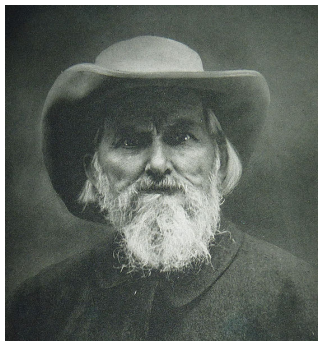
Jane Goodall (1934 –)

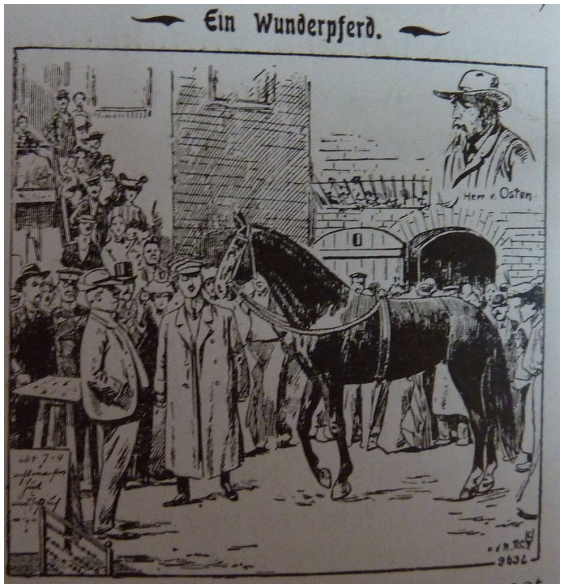
Tool-Using and Aimed Throwing in a Community of Free-Living Chimpanzees (1964)

Intellectual tasks

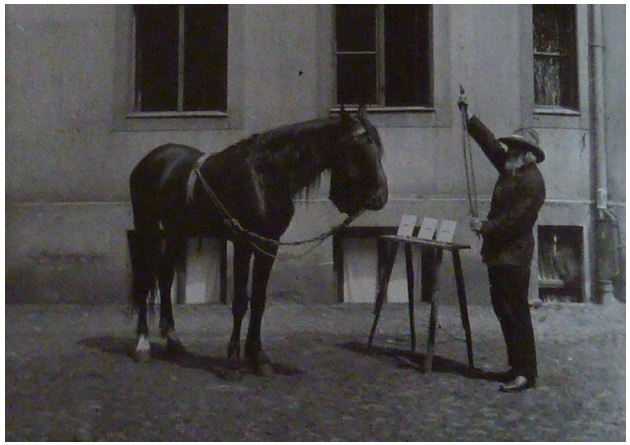
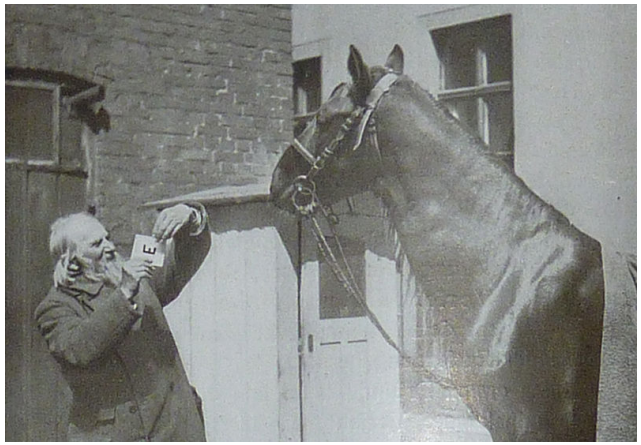
Der kluge Hans (1895 – 1916 ?)

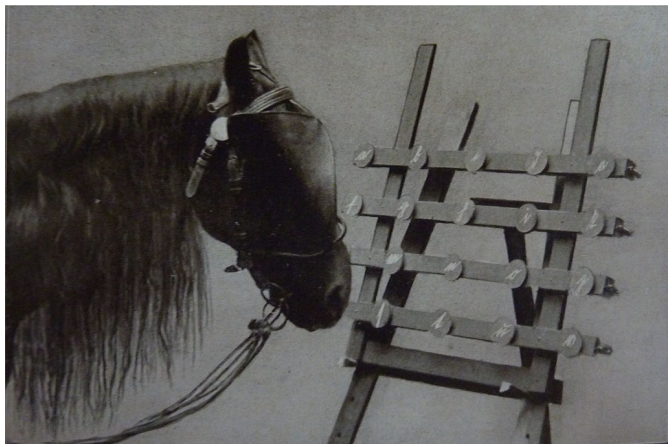
- Orlow-Traber
- owner: Wilhelm von Osten (1838 – 1909)
- ability to count and calculate
  and to distinguish simple concepts





Intellectual tasks

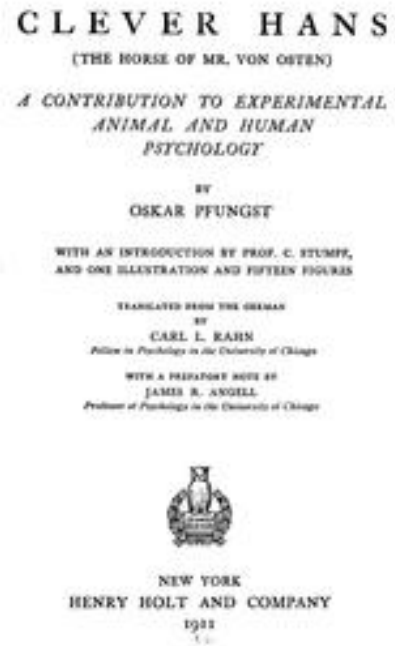




Has Hans been intelligent?

- Hans commission (1904): no manipulation found

Intellectual tasks

Oskar Pfungst (1874 – 1933)


CLEVER HANS

(THE HORSE OF MR. VON OSTEN)

A CONTRIBUTION TO EXPERIMENTAL ANIMAL AND HUMAN PSYCHOLOGY

BY

OSKAR PFUNGST

WITH AN INTRODUCTION BY PROF. C. STUMPF, AND ONE ILLUSTRATION AND FIFTEEN FIGURES

TRANSLATED FROM THE GERMAN BY CARL L. RAHN

Fellow in Psychology in the University of Chicago

WITH A PREFATORY NOTE BY JAMES R. ANGELL

Professor of Psychology in the University of Chicago

NEW YORK

HENRY HOLT AND COMPANY

1911

Rigorous testing:

- Isolating horse and questioner from spectators
- Using questioners other than the horse's master
- Blindfolding the horse
- Using questions, where the questioner didn't know the answer

Intellectual tasks

- Hans could get the correct answer even if not von Osten was asking
- horse must have seen the questioner
- questioner had to know what the answer was
- von Osten knew the answer $\rightarrow$ 89% correct
- von Osten did not know the answer $\rightarrow$ only 6% correct
- the questioner's posture and facial expression changed as the horse's taps approached the right answer
- the changes were consistent with an increase in tension
- the tension was released when the horse made the final, correct tap

Intellectual tasks

Confirming the findings by inverse experiments:

- cues from the audience are sufficiently reliable

$\Rightarrow$ the Clever Hans effect

Intellectual tasks

Irene Pepperberg (1949 –)

Teaching numerical concepts to parrots

- counting (up to seven)
- simple inferences on numbers
- cardinal vs. ordinal numbers
- the notion of zero

Cognition 125 (2012) 219–232

Contents lists available at SciVerse ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Grey parrot number acquisition: The inference of cardinal value from ordinal position on the numeral list

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ARTICLE INFO

Article history:
Received 4 September 2011
Revised 24 June 2012
Accepted 4 July 2012
Available online 9 August 2012

Keywords:
Animal cognition
Parrot cognition
Nonhuman numerical competence
Successor function

ABSTRACT

A Grey parrot (*Psittacus erithacus*) had previously been taught to use English count words ("one" through "sih" [six]) to label sets of one to six individual items (Pepperberg, 1994). He had also been taught to use the same count words to label the Arabic numerals 1 through 6. Without training, he inferred the relationship between the Arabic numerals and the sets of objects (Pepperberg, 2006b). In the present study, he was then trained to label vocally the Arabic numerals 7 and 8 ("sih-none", "eight", respectively) and to order these Arabic numerals with respect to the numeral 6. He subsequently inferred the ordinality of 7 and 8 with respect to the smaller numerals and he inferred use of the appropriate label for the cardinal values of seven and eight items. These data suggest that he constructed the cardinal meanings of "seven" ("sih–none") and "eight" from his knowledge

Natural language communication

- Alex the grey parrot
- Washoe the chimp
- Koko the gorilla
- Nim Chimpsky

Alex the grey parrot

Irene Pepperberg (1949 –)
Alex (1976 – 2007)

Alex the grey parrot

MAN	Come on, what is it?
ALEX	Keychain.
I.P.	Good birdie. Good parrot. What is it?
ALEX	Rock.
MAN	Good boy.
I.P.	Yeah, good birdie. Alex, what toy?
ALEX	Nail.
I.P.	Nail, that's right. You're a good birdie. You're a very good boy.
MAN	What toy?
ALEX	Truck.
I.P.	That's right.
MAN	You're a very good birdie.
I.P.	Tell me what color. What color?
ALEX	Yellow.
I.P.	Yellow, that's right.
MAN	What matter?
ALEX	Wood.
MAN	Good. That's right. Very good.
I.P.	How many? Good boy. How many?
ALEX	Two.
I.P.	Good parrot. Good boy. One. Two.

Alex the grey parrot

I.P.	Can you tell me what's different? What's different?
ALEX	Color.
I.P.	Good boy. All right. What same? What same?
ALEX	Shape.
I.P.	Good boy, good birdie. What color bigger? You know. What color bigger?
ALEX	Yellow.
I.P.	Good boy. Good birdie.
I.P.	Look. What matter four-corner blue?
DENISE	What matter four-corner blue?
ALEX	Wood.
DENISE	That's a good boy. You're right.

Alex the grey parrot

After 19 years of training:

- 200/500 lexical items (active/passive)
- basic language understanding and language production capabilities
- different dimensions of object descriptions (color, shape, material, ...)
- complex object descriptions: *four-corner wood*
- refusal to cooperate; rejection of food or toys

Washoe the chimp

Allen Gardner (1930 –)
Beatrice Gardner (1934 – 1995)
Washoe (1965 – 2007)

Teaching American Sign Language

- raised like a child
- private trailer with living and cooking areas
- learned 350 words of ASL
- taught her adopted son Loulis some ASL
- invention of new sign combinations:
  $swan = water + bird$
- simple verb-noun combinations
- no conditioning, no rewards

Koko the gorilla

Francine (Penny) Patterson (1947 –)
Ronald Cohn (?)
Koko (1971 –)

- production: 1000 signs, comprehension: 2000 signs
- learning or conditioning?
- invention of new sign combinations: *ring* = *finger* + *bracelet*
- no sentences, but adjectives, nouns and noun phrases
- rewards if answer is somehow ok: *apple* is *apple* or *red*

Nim Chimpsky

Herbert S. Terrace

Nim Chimpsky (1973 – 2000)

- not "raised like a child"
- learned 150 signs
- but Terrace concluded that this was not natural language
  - mean length of 20000 recorded responses only 1.2
  - no correlation between lexical growth and structural complexity

Nim Chimpsky

strong criticism of the experimental methodology

- apes remained passive
- interpretation of responses is up to the experimenter
- human language capabilities are projected onto the ape
- often the response of the ape was preceded by an (unvoluntary) similar movement of the experimenter (250 ms earlier)

Creativity

Music playing robots

Creativity

Painting elephants

Creativity

Desmond Morris (1928 –)
Painting chimpanzees

Self-recognition

Does the animal recognize itself as an acting agent?

$\Rightarrow$ mirror test

Passing the test:

Humans (at age 18 months or older), Bonobos, Chimpanzees, Orangutans, Gorillas (Koko!), Bottlenose dolphins, Orcas, Elephants, European Magpies (the only non-mammal)

Conclusions

- intelligence is a composite property
  - different kinds of intelligence
- intelligence is a graded notion
  - cognitive tasks with different degrees of difficulty
- intelligence is a highly subjective notion
  - contradictory interpretations of observations are quite common
- danger of "anthropo"morphization
  - objective investigation methods required
- studying intelligence requires systematic analysis
  - no conclusions can be drawn from isolated observations