

# *Cognitive Systems*

Grundlagen der Informationsverarbeitung  
in natürlichen und künstlichen Systemen

2006

Ein 2-semesteriger Kurs ab dem 4. Semester  
von

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# Einführung:

## Was haben wir bisher über Informatik gelernt?

- Theoretische Informatik Prinzipien
  - Automaten, formale Sprachen, Berechenbarkeit, Komplexität
- Praktische Informatik Werkzeuge
  - Imperative, objektorientierte, funktionale Programmierung
  - Datenstrukturen, Algorithmen
- Technische Informatik Hardware
  - Rechnerarchitektur und digitale Schaltungen
  - Betriebssysteme und Nebenläufigkeit
- Informatik und Gesellschaft Wirkung

# Informatik

– ein neuer Weg Menschen kennen zu lernen

- welche Informationsverarbeitungsprinzipien können wir in der Natur vorfinden?
- wie überwinden wir die Berechnungskomplexität?
- welche Software wird eingesetzt?
- welche Schaltkreise?
- von Neumann-Architektur oder hochparallele Prozesse?
- was ist die Wirkung menschlicher Informationsverarbeitungsprozesse auf andere Menschen? – auf die Gesellschaft?

# Menschen

– ein neuer Weg Informatik kennen zu lernen

- welche Anforderungen stellt die Natur an ihre Informationsverarbeitung?
- welche Aufgaben werden in der Natur gelöst?
- was sind die Stärken und die Schwächen natürlicher Informationsverarbeitung?
- was sind die menschlichen Anforderungen an die Informatik?
- was kann die Informatik von natürlicher Informationsverarbeitung lernen?
- kann die Wirkung der Informatik auf Mensch und Gesellschaft verbessert werden?

Science Finds,  
Industry Applies,  
Man Conforms

*Motto of the 1933 Chicago World's Fair*

People Propose,  
Science Studies,  
Technology Conforms

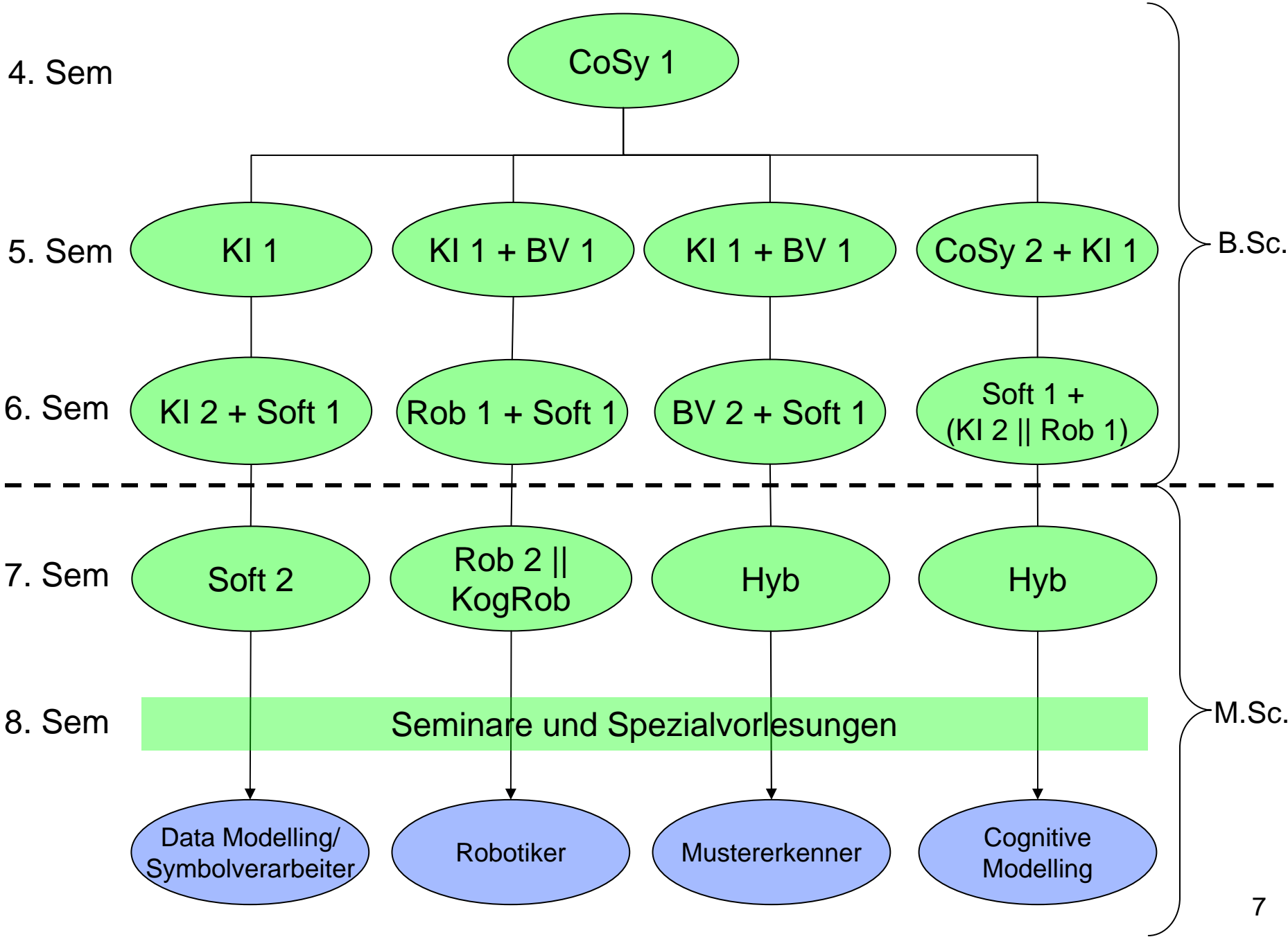
*A person-centered motto for the twenty-first century*

*Don Norman*

# Course Outline

## Cognitive Systems I

- Introduction
- Perception
- Memory and Reasoning
- Learning and Action
- Communication



# Course Outline

## Cognitive Systems II

- Methods from Psychology, Neuroscience, Informatics
- Cognitive Architectures and Modeling Approaches
- Case Studies in Cognitive Modeling
- Challenges for Cognitive Science

# Course Components

- Weekly plenary lectures - Interaction welcome!
- Bi-weekly writing / programming assignments (in groups)
- Bi-weekly tutorials / presentations and discussions
- Teaching materials:
  - [www.cosy.informatik.uni-bremen.de](http://www.cosy.informatik.uni-bremen.de)
  - => teaching
  - => Cognitive Systems 1
  - [barkowsky@informatik.uni-bremen.de](mailto:barkowsky@informatik.uni-bremen.de)
  - [schultheis@informatik.uni-bremen.de](mailto:schultheis@informatik.uni-bremen.de)
- Office hour Freksa: Friday 2-3pm MZH 5340 / appointment

# Introduction to Cognitive Systems

- (1) Cognition
- (2) Natural vs. Artificial Systems
- (3) System and Environment
- (4) Cognitive Abilities
- (5) Information Processing Paradigm
- (6) Goal of Cognitive Science

# Cognition

“*Cognition*” refers to the principles underlying intelligence and intelligent systems with particular reference to intelligent behavior as computation.

HA Simon & CA Kaplan, Foundations of Cognitive Science, in MI Posner, ed, *Foundations of Cognitive Science*, MIT Press 1991.

# What is Cognitive Science?

*The critical aspect of Cognitive Science is the search for understanding of cognition, be it **real** or **abstract**, **human** or **machine**.*

Donald A. Norman, What is cognitive science?, D. Norman, ed, *Perspectives on cognitive science*, Ablex, NJ 1981.

# Domain of Cognitive Science

Examples:

	<i>real</i>	<i>abstract</i>
<i>human</i>	<i>wayfinding in a city</i>	<i>imagining your next vacations</i>
<i>machine</i>	<i>robot avoiding obstacles</i>	<i>computer planning a trip</i>

# Disciplines of Cognitive Science

	<i>real</i>	<i>abstract</i>
<i>human</i>	psychology anthropology neurosciences	linguistics philosophy logics
<i>machine</i>	artificial intelligence cognitive robotics	informatics mathematics

# Approaches to Cognitive Science

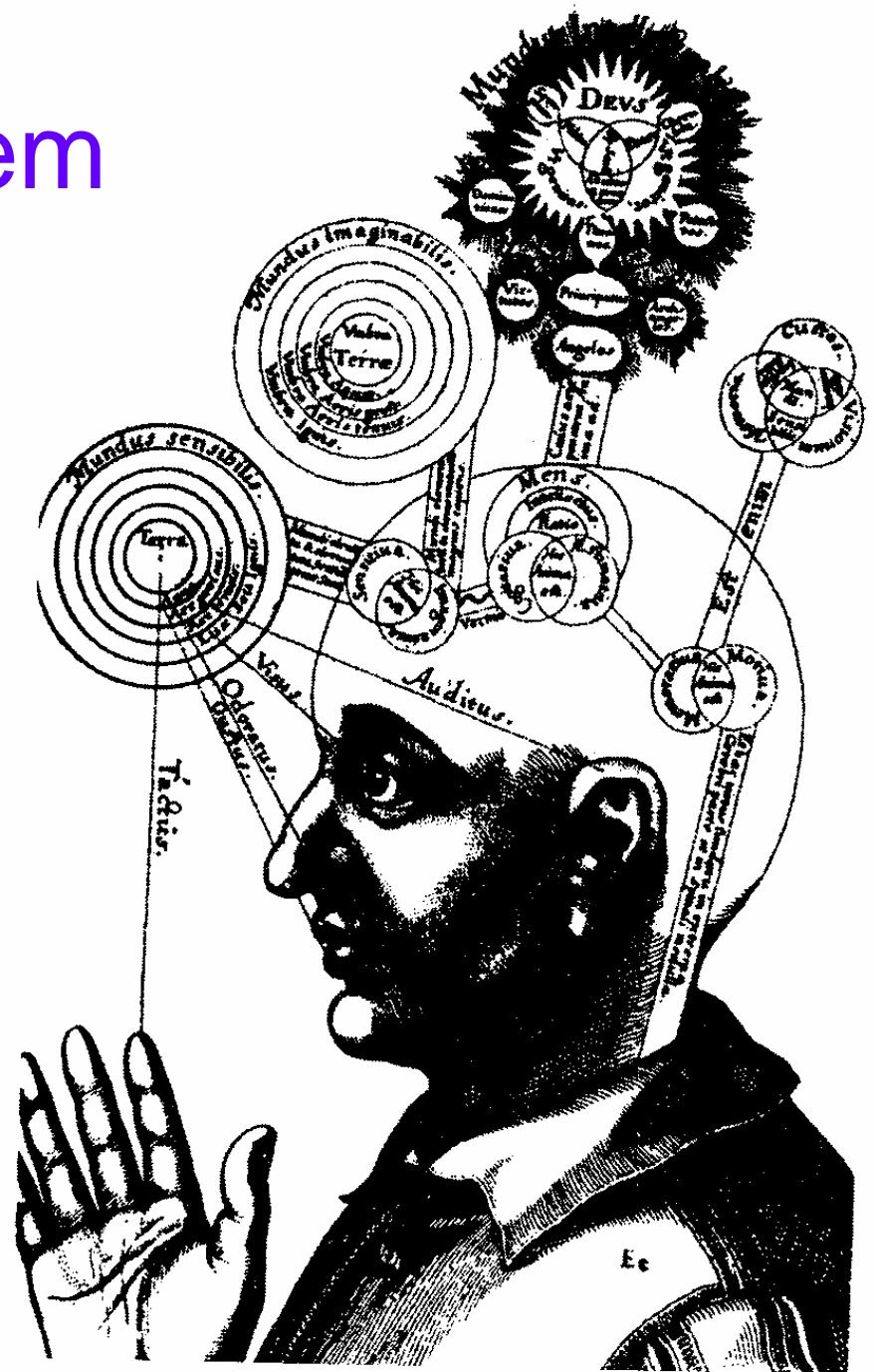
	<i>real</i>	<i>abstract</i>
<i>human</i>	empirical studies	biological models
<i>machine</i>	synthetic constructions	theoretical process models

# Natural vs. Artificial Cognitive Systems

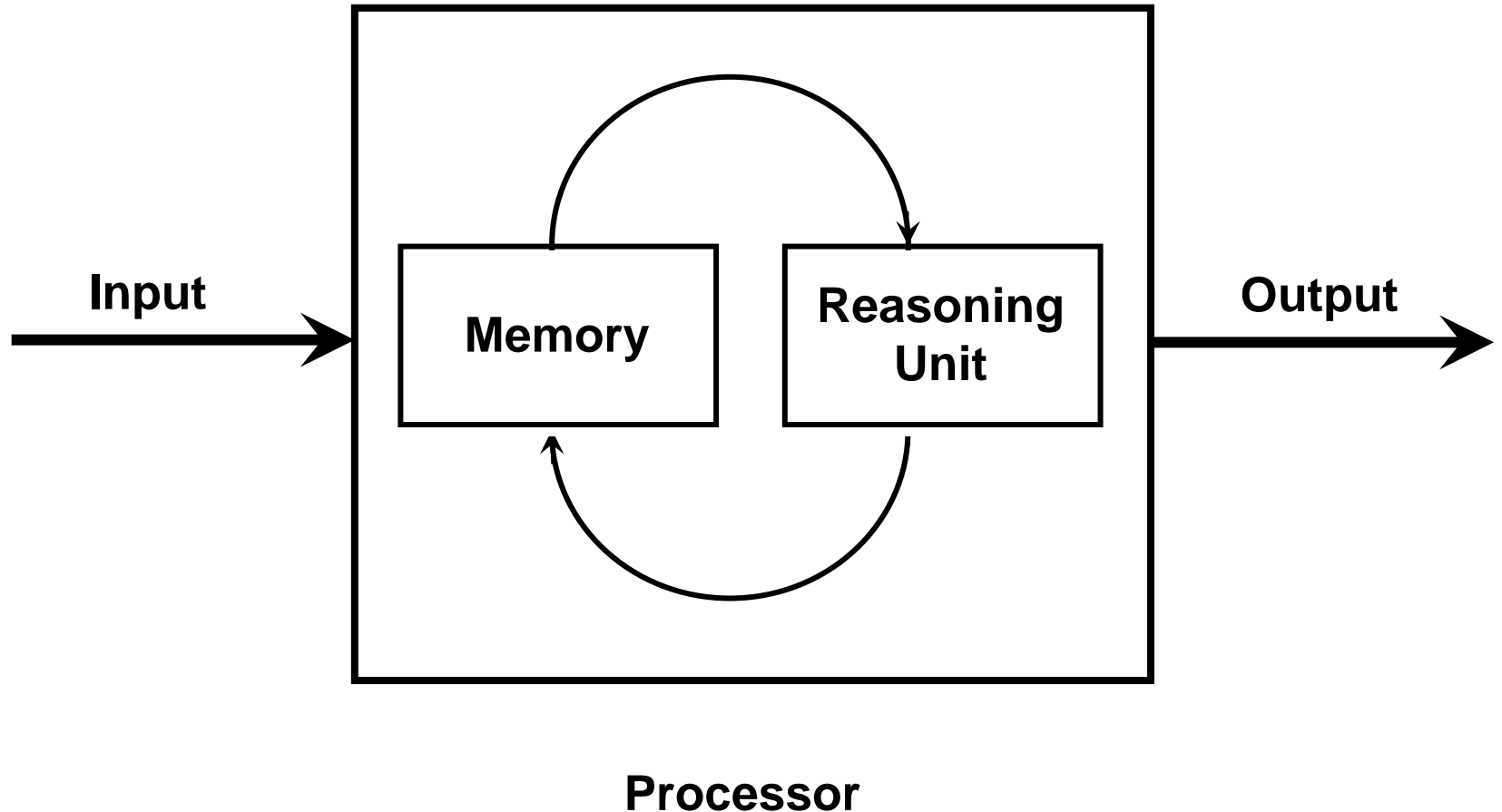
	natural	artificial
calculating	weak	strong
playing games	weak/strong	strong/weak
speaking	strong	improving
planning	pretty good	quite good
perceiving	very strong	specialized
understanding	very strong	weak
arguing	strong	weak
learning	strong	improving
recovery	very strong	weak

# Cognitive System

- sensory organs (afferent)
- thinking organs / memory
- effectors (efferent)



# Cognitive System: Computer Metaphor



# Beyond the Cognitive System

- Source of input
- Manipulation of environment
- Communication with other cognitive systems
- External memories



# Cognitive Abilities

- We will carry out experiments to experience and become aware of specific human cognitive abilities
- Please read the instructions carefully and try to answer the questions for yourselves

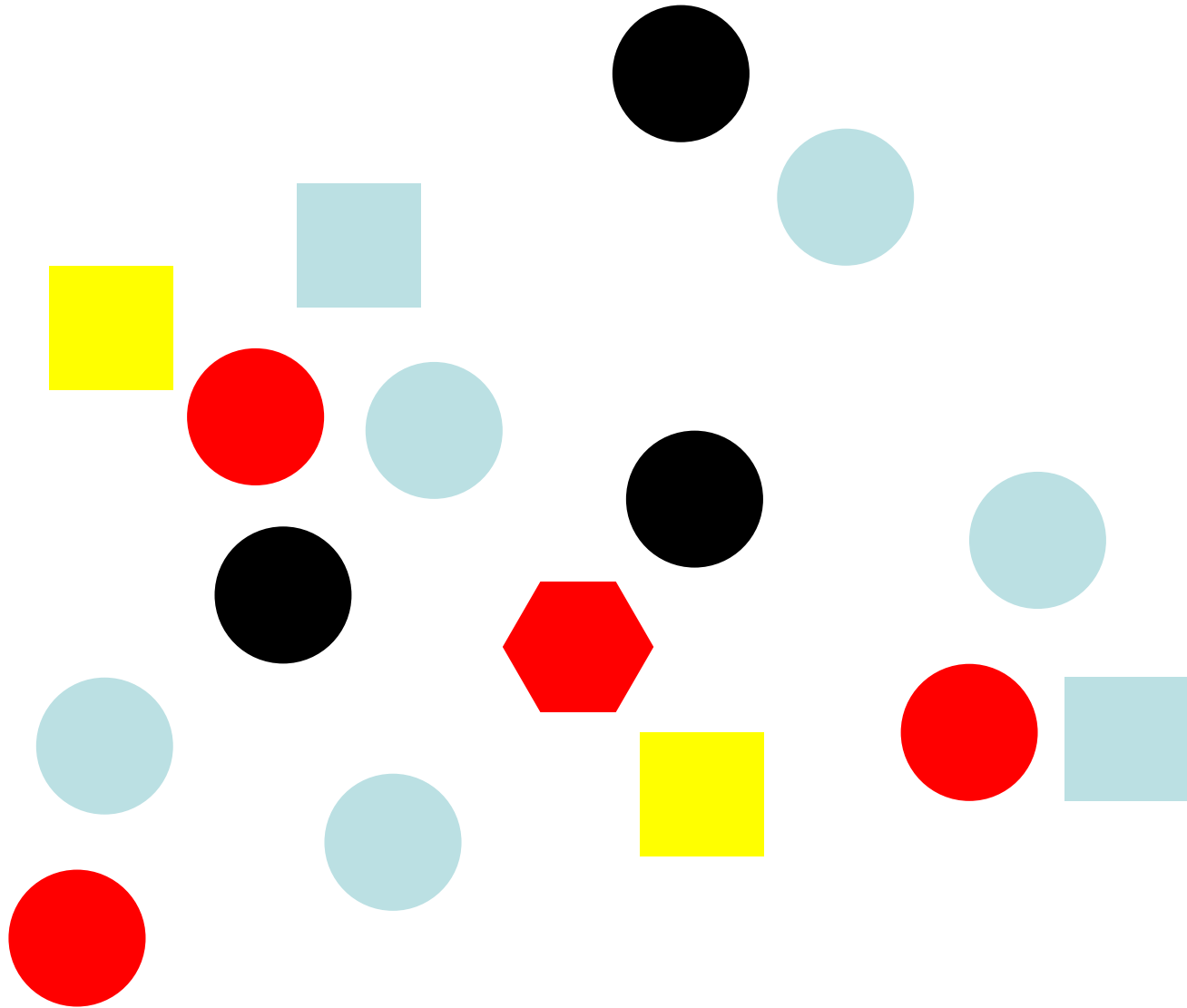
# Cognitive Abilities (1)

- Ability to detect and interpret sensory stimuli

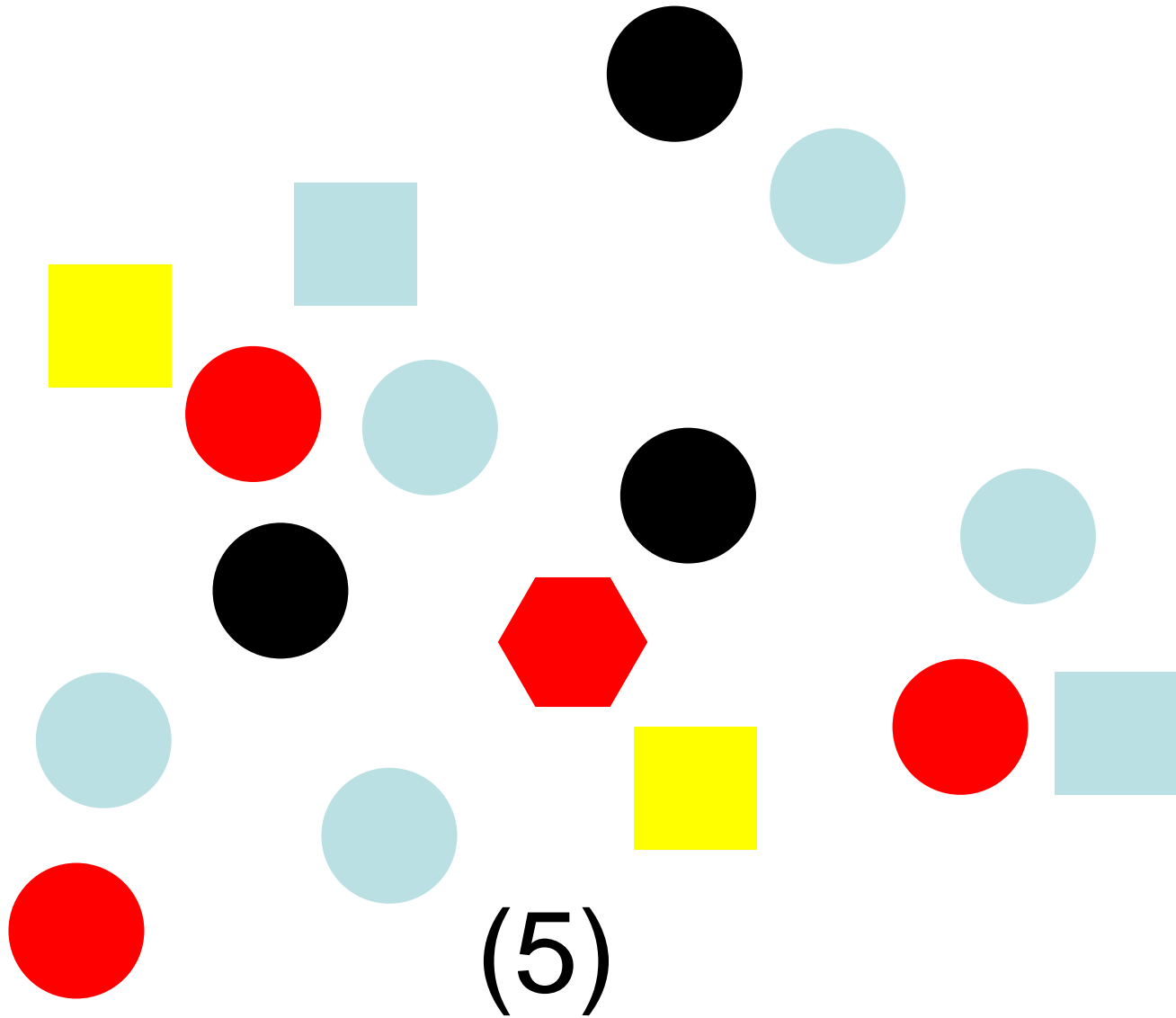
Example:

On the following slide you will see for a short period of time a number of colored geometric objects. Detect as fast as possible how many light blue circles there are.

ready?



your  
answer?



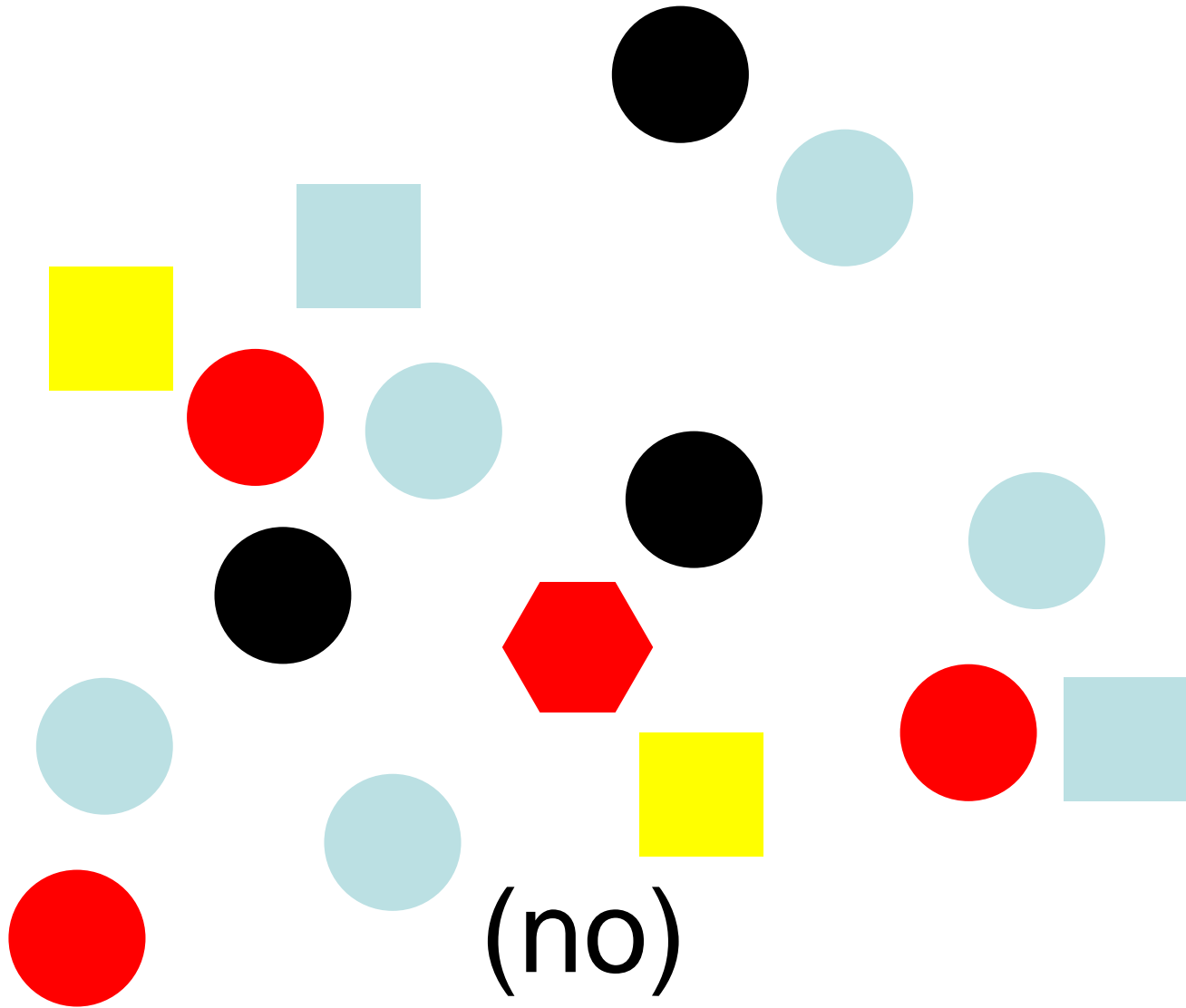
# Cognitive Abilities (2)

- Ability to detect and interpret sensory stimuli
- Tendency to focus on certain sensory stimuli and to disregard others

Example:

Was there a yellow hexagon among the colored geometric objects?

your  
answer?

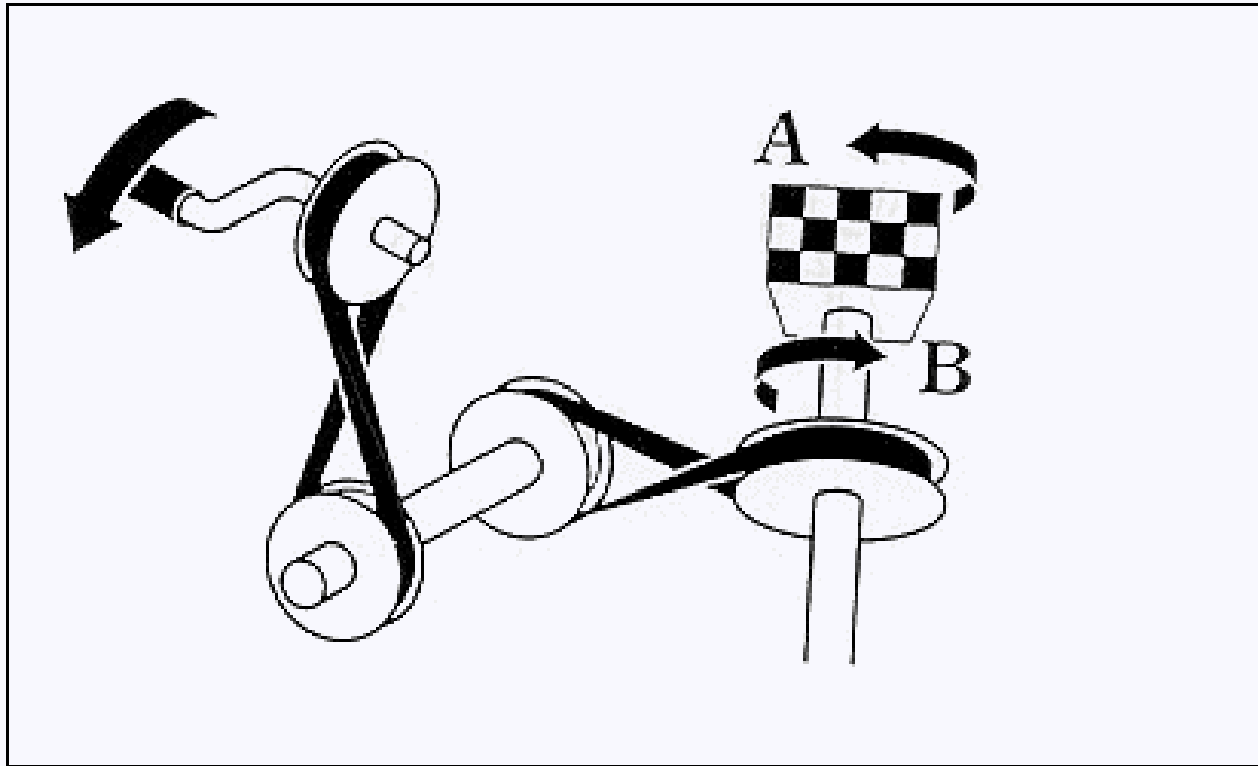


# Cognitive Abilities (3)

- Ability to detect and interpret sensory stimuli
- Tendency to focus on certain sensory stimuli and to disregard others
- **Detailed knowledge of the physical characteristics of the environment**

Example ...





If the handle is turned as shown, in which direction will the box move:  
A or B?

(by Mary Hegarty)

# Cognitive Abilities (4)

- Tendency to focus on certain sensory stimuli and to disregard others
- Detailed knowledge of the physical characteristics of the environment
- Ability to extract parts of complex events and to integrate them into a schema that gives meaning to the episode

## Example ...



# Cognitive Abilities (5)

- Detailed knowledge of the physical characteristics of the environment
- Ability to extract parts of complex events and to integrate them into a schema that gives meaning to the episode
- **Ability to extract meaning from letters and words**

Examples ...

THE

CAT

Jim observed the hunter  
with the binoculars

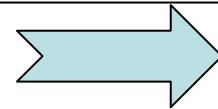
He was just about  
to pull the trigger

He was looking  
for the deer.

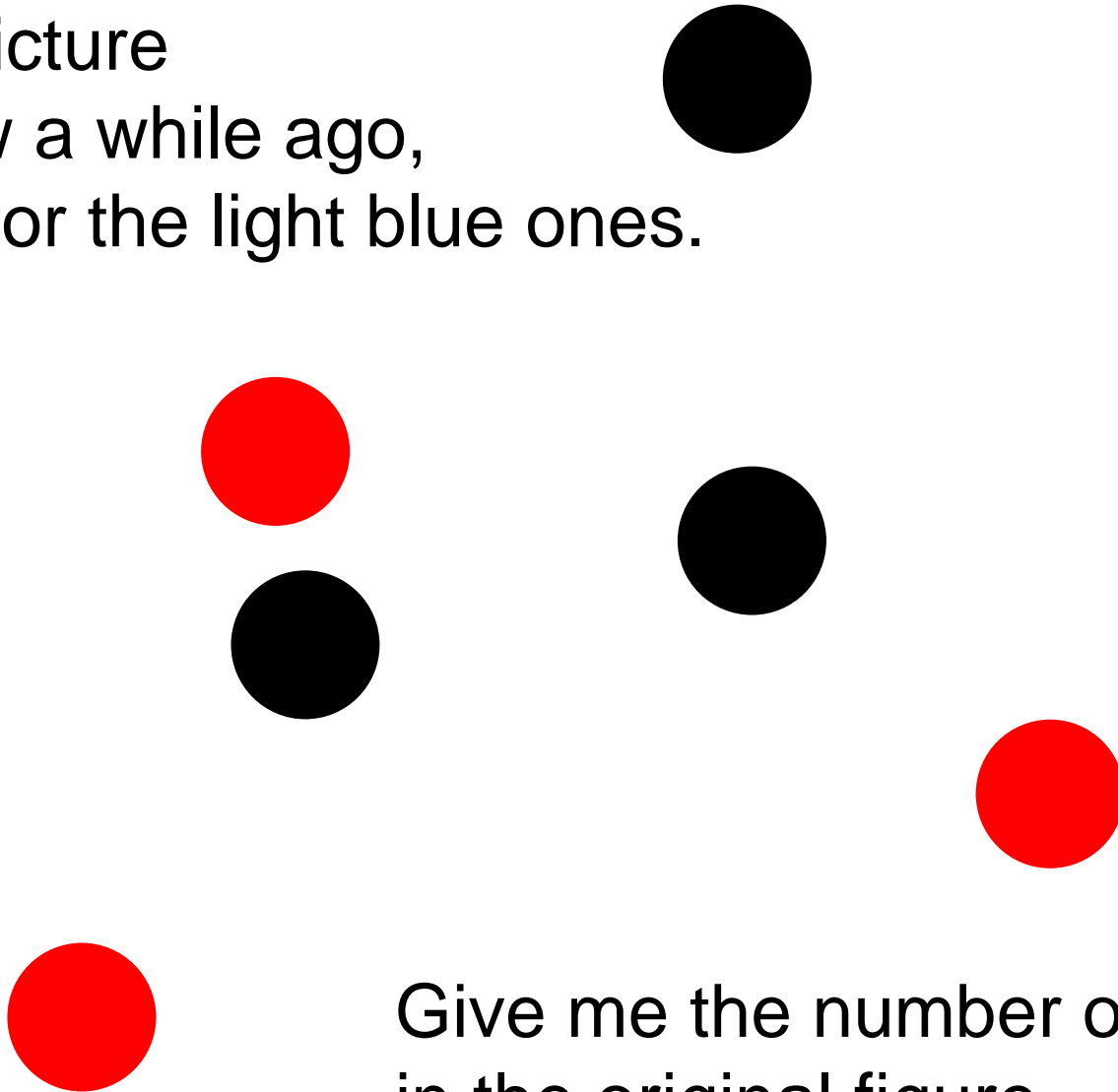
# Cognitive Abilities (6)

- Ability to extract parts of complex events and to integrate them into a schema that gives meaning to the episode
- Ability to extract meaning from letters and words
- Capacity to retain explicit knowledge and to integrate it into an ongoing sequence

Example ...



This slide shows all circles  
of the picture  
you saw a while ago,  
except for the light blue ones.

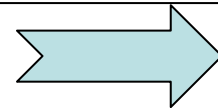


Give me the number of circles  
in the original figure.

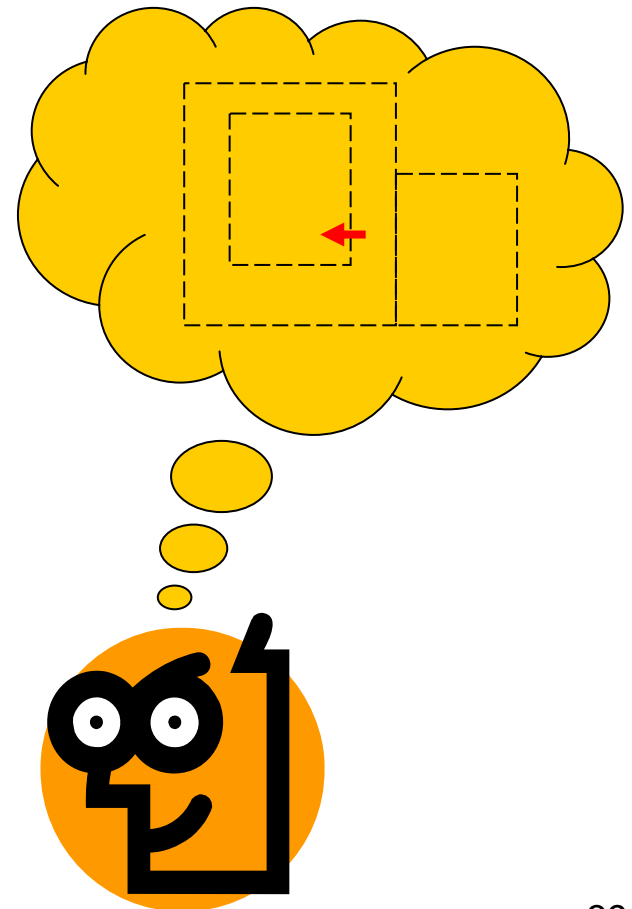
# Cognitive Abilities (7)

- Ability to extract meaning from letters and words
- Capacity to retain explicit knowledge and to integrate it into an ongoing sequence
- Ability to form an image of a “cognitive map”

For example ...



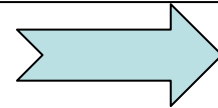
You may know that the room MZH 1400 is located roughly in the center of the first floor of the building and that it is surrounded by a hall. Imagine what the corresponding floor plan might look like...



# Cognitive Abilities (8)

- Capacity to retain explicit knowledge and to integrate it into an ongoing sequence
- Ability to form an image of a “cognitive map”
- **Understanding the role of another person**

For example ...



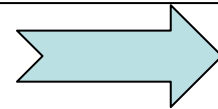
“When you approach me from the entrance, please bear to your left.”

She must be very sad about the loss.

# Cognitive Abilities (9)

- Ability to form an image of a “cognitive map”
- Understanding the role of another person
- Ability to use “memory tricks” to aid in recall of information

For example ...



Memorize the PO Box # of Universität Bremen:

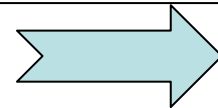
33 04 40

330 440

# Cognitive Abilities (10)

- Understanding the role of another person
- Ability to use “memory tricks” to aid in recall of information
- **Tendency to store linguistic information in a general form**

For example ...



Can you recall the last task regarding the colored objects I presented?

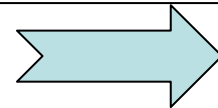
The task was:

“Give me the number of circles in the original figure.”

# Cognitive Abilities (11)

- Ability to use “memory tricks” to aid in recall of information
- Tendency to store linguistic information in a general form
- **Ability to solve a problem**

For example ...



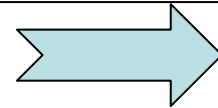
# Missionaries and Cannibals Problem

- Three missionaries and three cannibals want to cross a river from side A to side B.
  - They have a boat that holds no more than two persons at a time.
  - The life of the missionaries is endangered when the cannibals outnumber the missionaries at any location.
- ¿ How can the six gentlemen safely cross the river?

# Cognitive Abilities (12)

- Tendency to store linguistic information in a general form
- Ability to solve a problem
- **General ability to act in a sensible way**

For example ...

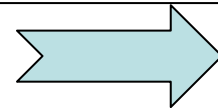




# Cognitive Abilities (13)

- Ability to solve a problem
- General ability to act in a meaningful way
- Translation of a high-level instruction into a complex motor response

For example ...



“Quickly run up the stairs, please.”

# Cognitive Abilities (14)

- General ability to act in a meaningful way
- Translation of a high-level instruction into a complex motor response
- Ability to recall quickly from long-term memory specific information that is immediately applicable to the present situation

For example ...

What are your parents' names  
and dates of birth? ...

# Cognitive Abilities (15)

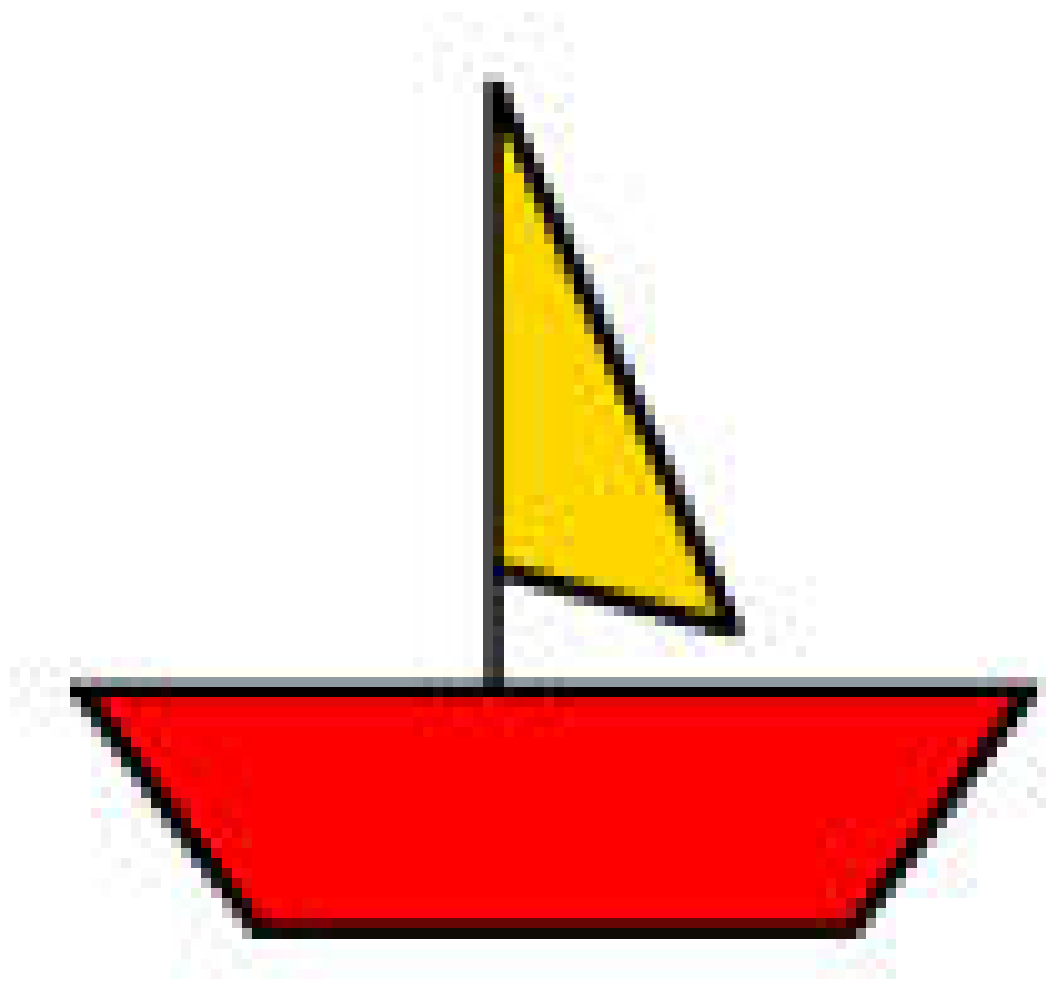
- Translation of a high-level instruction into a complex motor response
- Ability to recall quickly from long-term memory specific information that is immediately applicable to the present situation
- **Ability to translate visual events into spoken language**

For example ...

Describe what happened in the movie you saw a couple of minutes ago ...

# Cognitive Abilities (16)

- Ability to recall quickly from long-term memory specific information that is immediately applicable to the present situation
- Ability to translate visual events into spoken language
- **Knowledge that objects have a specific name**



# Cognitive Abilities (17)

- Ability to translate visual events into spoken language
- Knowledge that objects have a specific name
- **Inability to perform perfectly**

# Inability to Perform Perfectly

- In a complex open world it is impossible to guarantee perfect solutions
- We need ways to discover imperfections
- We need ways to recover from imperfections

# Information Processing Paradigm

## Assumptions:

- Cognition can be understood as a sequence of stages
- At each stage unique processes operate on incoming information
- Each stage receives information from preceding stages and then performs its unique function

# Internal Representations

- Environmental information is transformed into neurological structures and meaningful symbols (internal representation)
- This representation is processed in connection with other internally available information about the world (knowledge)
- The result is transformed into actions on the environment

# Retrospect: Behaviorism

- Animals (including people) act according to stimulus-response (S-R) patterns
- Behaviorism studied responses to stimuli
- Methods for studying internal processes adequately were not available
- Internal mental operations and structures (e.g. attention, consciousness, memory, thinking) were not studied for about fifty years

# The Cognitive Revolution

- Edward C. Tolman conducted experiments whose outcome could not be explained by simple S-R patterns
- He showed that rats appear to build up an internal representation of their environment to find food in a clever way
- Interest began to focus on attention, memory, pattern recognition, images, semantic organization, language processes, thinking, consciousness, emotion, ...

# The Advent of the Computer

- 50 years ago: Computers were recognized to be suitable for general symbol processing
- Computer Metaphor of the Mind
- 1956: Dartmouth Conference. The birth of “Artificial Intelligence”
- New methods for the study of internal representations and memory became available

# The Physical Symbol System Hypothesis (PSSH)

- Fundamental thesis of Cognitive Science:

*A physical symbol system has the necessary and sufficient means for general intelligent action.*

Herbert A. Simon & Alan Newell

- Brains and computers are symbol systems.

# Symbol Manipulation = Information Processing

- Information is processed by syntactic operations on formal symbols
- Synthesis of syntactic operations allows to form more abstract symbols (concepts)
- Meaning emerges from syntactic operations

# Key Questions

- What are the stages at which information is processed?
- In what form is information represented in the human mind?

# Goal of Cognitive Science

*The hope is that Cognitive Science will lead to a better understanding of the human mind, of teaching and learning, of mental abilities and of the development of intelligent devices that can augment human capabilities in important and constructive ways.*

Donald A. Norman, What is cognitive science?, in D. Norman, ed, *Perspectives on cognitive science*, Ablex, NJ 1981.

# Next week

- Information processing in neurons and neural structures
- Shannon's Theory of Communication (Information theory)

