Informatics 1 Cognitive Science

Lecture 2: Introduction to Cognitive Science

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Slide credits: Frank Mollica, Chris Lucas, Mirella Lapata

Overview

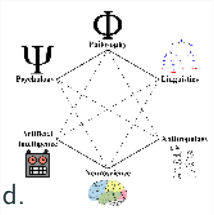
Cognitive Modelling

Cognitive Technology

Is Language a Cognitive Technology?

Recap

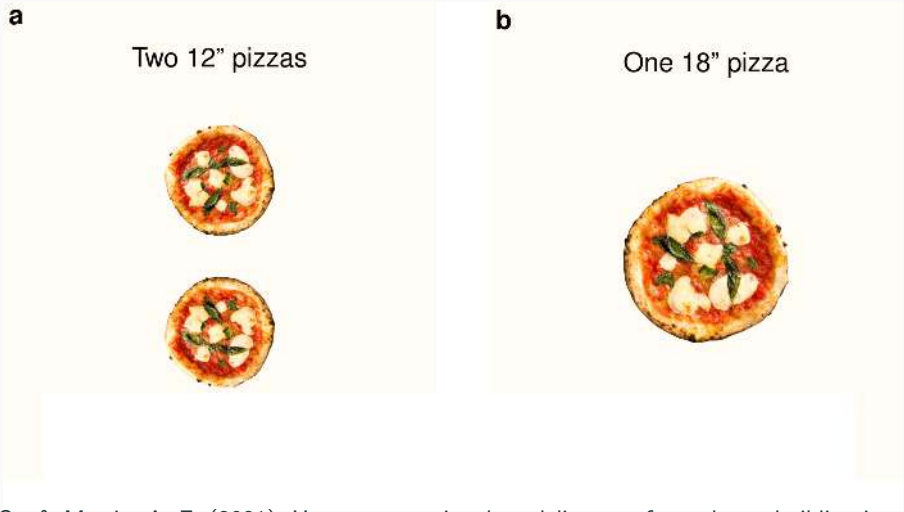
Central to cognitive science are mental representations and processes:



- A mental representation is a description of information in the mind.
- A mental process is a procedure for translating:
  - sensory information into representations;
  - representations into other representations; and
  - representations into actions/behavior.

Computational modeling can be used to *evaluate theories, generate new hypotheses, guide the collection of new data.*

Recap



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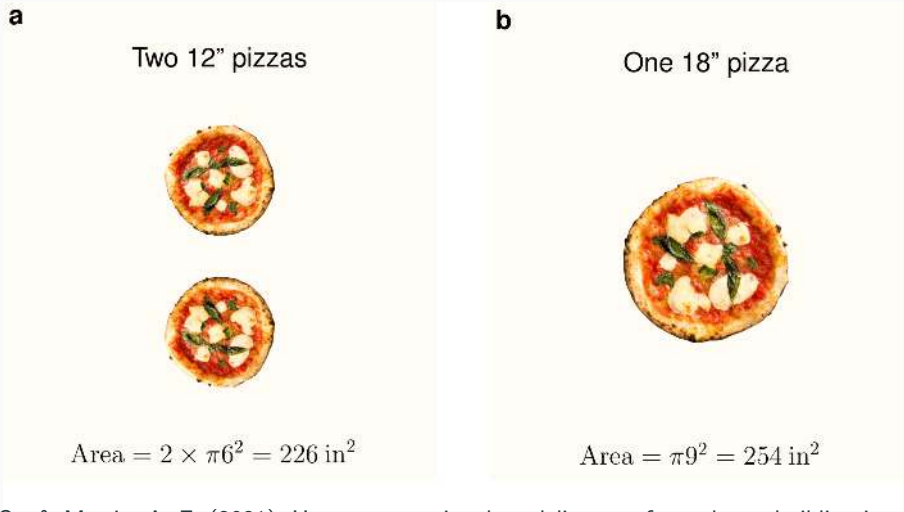
Recap



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A Model of Pizza Selection

The amount of food in a order of N_i pizzas with a radius of R_i is:

$$\Phi_i = N_i \pi R_i^2$$

The function to decide between two orders is:

$$\omega(\Phi_i, \Phi_j) = \begin{cases} i, & \text{if } \Phi_i > \Phi_j \\ j, & \text{otherwise} \end{cases}$$

```
import numpy as np
import math
def food(ds):
return (math.pi * (ds/2)**2).sum()
# Order option a, two 12'' pizzas:
two_pizzas = np.array([12, 12])
# Option b, one 18'' pizza:
one_pizza = np.array([18])
# Decision rule (eq. 2):
print(food(two_pizzas) >
food(one_pizza))
```

Cognitive Modelling

Why Cognitive Modelling?

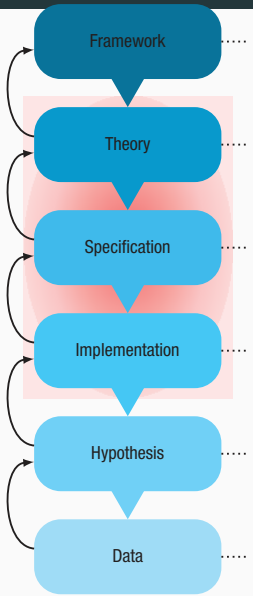
According to Guest and Martin, computational modeling:

- takes a verbal description and formalizes it to make it implementable
- forces us to make a theory explicit and to specify its scope, its assumptions and its computational repercussions
- improves theories by uncovering aspects that are not well specified or ambiguous
- stops us from atheoretically testing hypotheses
- allows us to systematically compare theories and generate new hypotheses

Cognitive modeling is a multi-step process.

What is Cognitive Modelling?

Guest and Martin analyze this process as:



What is Cognitive Modelling?

A framework is a conceptual system of building blocks for creating simulations of complex psychological systems. A framework is typically described using natural language or diagrams.

A theory is a scientific proposition—described by natural language, mathematics, logic, diagrams—that introduces causal relations with the aim of describing, explaining, or predicting a set of phenomena.

A specification is a formal description of a system to be implemented based on a theory. It provides a means of discriminating between theory-relevant claims and theory-irrelevant auxiliary assumptions. It constraints the space of possible computational models.

What is Cognitive Modelling?

An implementation is an instantiation of a model created using anything from physical materials, e.g., a scale model or software.

A hypothesis is a narrow testable statement. Hypotheses in psychology focus on properties of the world that can be measured and evaluated by collecting data and running inferential statistics. Any sentence that is directly testable by statistical means can be a hypothesis.

Data are observations collected from the "real world" or from a computational model.

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Let's look at an example for language acquisition (more in week 2).

What is Cognitive Modelling?

Data

"I eated the cheerios."

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Hypothesis

The child will say "eated" more than "ate."

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def past_tense(verb): return verb + 'ed'
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The child makes the past tense by adding "-ed" to any verb.

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Theory

Words and Rules

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Words and Rules

Framework

Sympol Manipulation vs. Neural Networks

What is Cognitive Modelling?

Framework

Productivity & Reuse vs Connectionism

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Implementation

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Hypothesis

The child will say "seeed" more than "saw."

The child will say "helped" more than "helpen."

What is Cognitive Modelling?

Time for a short quiz on Wooclap!

https://app.wooclap.com/REGEPQ

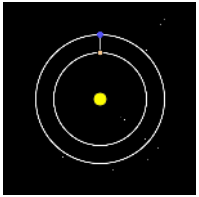
Cognitive Technology

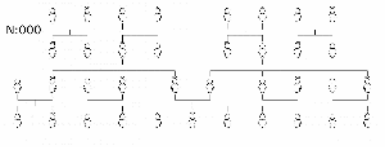
Innate Instincts vs Cognitive Gadgets

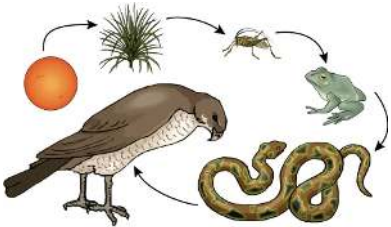
Heyes' (2019) theory of "cognitive gagets":

- psychologist have previously posited a set of innate cognitive instincts: imitation, mind reading, language, etc.
- however, the evidence for the innateness of these cognitive abilities is increasingly disputed
- we can instead assume that they are the result of general learning mechanisms
- what is learned is culturally transmitted cognitive technologies (cognitive gadgets); examples include navigation, food chains, kinship systems
- cultural transition happens through interaction and communication
- is language itself a cognitive technology?

What is a Cognitive Technology?







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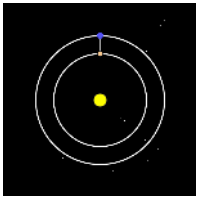
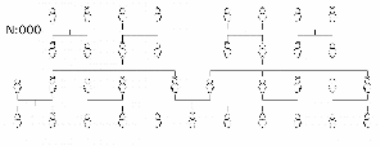
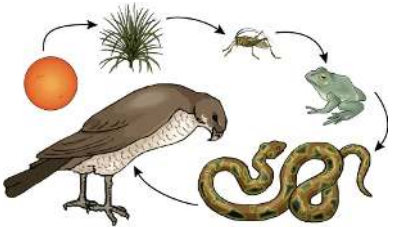




Language

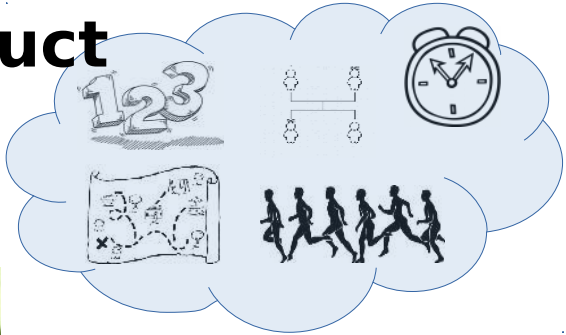


What is a Cognitive Technology?

What is a Cognitive Technology?

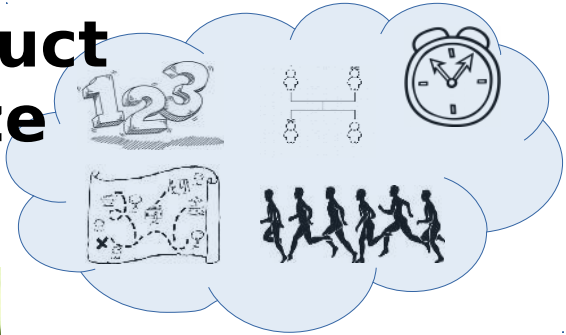
“Three koalas”

Construct



“Three koalas”

Construct
Utilize



What is a Cognitive Technology?

We humans have created not just physical machines . . . but also mental machines; mechanisms of thought, embodied in our nervous systems, that enable our minds to go further, faster, and in different directions than the minds of any other animals . . . They are "gadgets," rather than "instincts" because, like many physical devices, they are products of cultural rather than genetic evolution. New cognitive mechanisms—different ways of thinking—have emerged, not by genetic mutation, but by innovations in cognitive development. (Heyes, 2019, p. 1)

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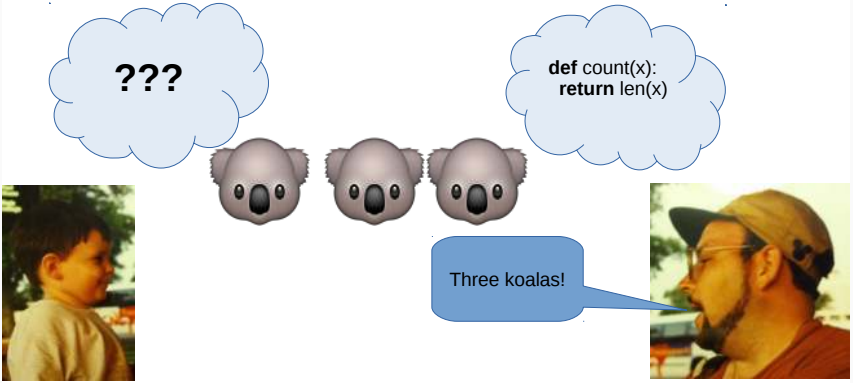

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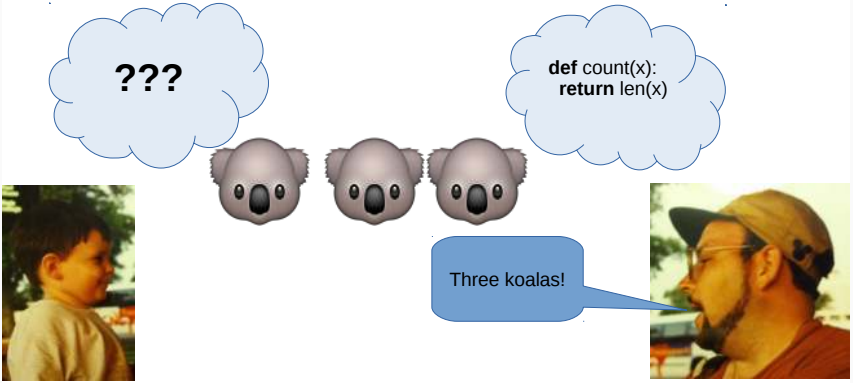

- Cognitive technology: the representations and processes
- Cognitive artifact: the linguistic signal
- Environment: the koalas and the teacher

What is a Cognitive Technology?

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Is Language a Cognitive Technology?

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A human language is a system of remarkable complexity. To come to know a human language would be an extraordinary intellectual achievement for a creature not specifically designed to accomplish this task. A normal child acquires this knowledge on relatively slight exposure and without specific training. He can then quite effortlessly make use of an intricate structure of specific rules and guiding principles to convey his thoughts and feelings to others, arousing in them novel ideas and subtle perceptions and judgments. (Chomsky, 1975, p. 4)

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A few potential sources of evidence to consider:

- Genetic and neuroscientific evidence
- Animal communication
- Linguistic universals and diversity
- Acquisition: critical periods

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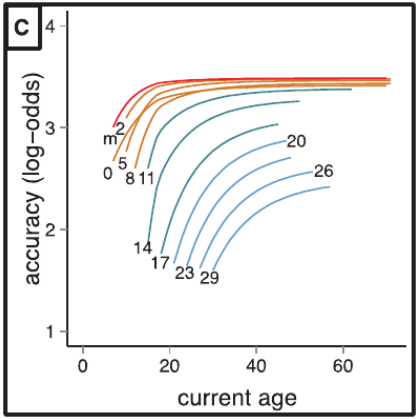
Is Language a Cognitive Technology?

There is a critical period in development during which a language can be acquired like a native speaker.

- child vs. adult language learning
- native vs. non-native speakers
- age of immigration and language ability
- arrive before age 6 $\rightarrow$ generally pass as native speakers
- arrive after puberty $\rightarrow$ generally do not pass as native speakers
- Evidence: "feral children", "wolf children", "attic children"
- Wild boy of Aveyron, *L'enfant sauvage* by François Truffaut

Is Language a Cognitive Technology?



Red: monolinguals; orange: age of exposure: 0–9 years old;

green: AoE 10–19; blue: AoE 20–30.

A critical period for second language acquisition: Evidence from 2/3 million English speakers, J.K. Hartshorne, J.B. Tenenbaum, S. Pinker. Cognition 177 (2018), 263–277.

Is Language a Cognitive Technology?

Genie

- Was tied to her potty chair for 13 years by her dad
- Only words she knew: *stop it* and *no more*
- Could she manage to learn language?

  https://isle.hanover.edu/isle2/Ch12Speech/Ch12Genie.html

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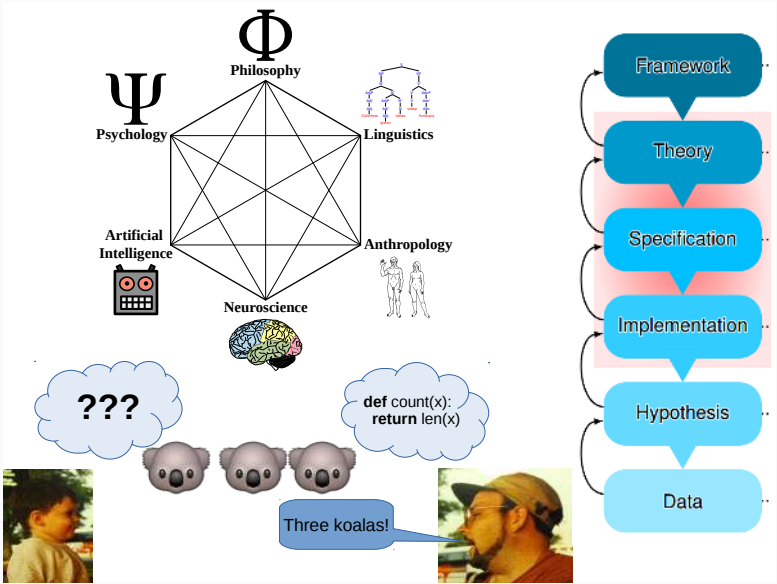
- Genie learned many words but not syntax!
- Amount of language learned after critical period seems limited.
- Difficult to disentangle linguistic from other forms of deprivation.

Summary


Philosophy
Psychology
Linguistics
Artificial Intelligence
Anthropology
Neuroscience
???
def count(x):
return len(x)
Three koalas!
Framework
Theory
Specification
Implementation
Hypothesis
Data