

# Introduction to Cognitive Science and Neuroscientific Methods

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Doorway to Human History

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- What is cognitive science?
- Behavioural study – what is important to design an experiment
- Neuroscientific study – closer look into the brain
- Research topics in cognitive science and examples
- Towards a more interdisciplinary approach

# What is Cognitive Science?

**Interdisciplinary** study of **mind** and **intelligence**

- Intellectual origins – mid 1950

  Development of theories of mind based on complex representations and computational procedures

- Organizational origins – mid 1970s

  Foundation of Cognitive Science Society and the journal Cognitive Science

BUT, humans have been always interested in mind

- Aristotel – 384-322 BC

  Mind is like a clean slate („tabula rasa“)

# Interdisciplinary research field

Which fields are involved in cognitive science? Write here!

Biology

Pedagogy

Psychology

Anthropology

Philosophy

Neurobiology

archaeology

Neuroimaging

Neuroscience

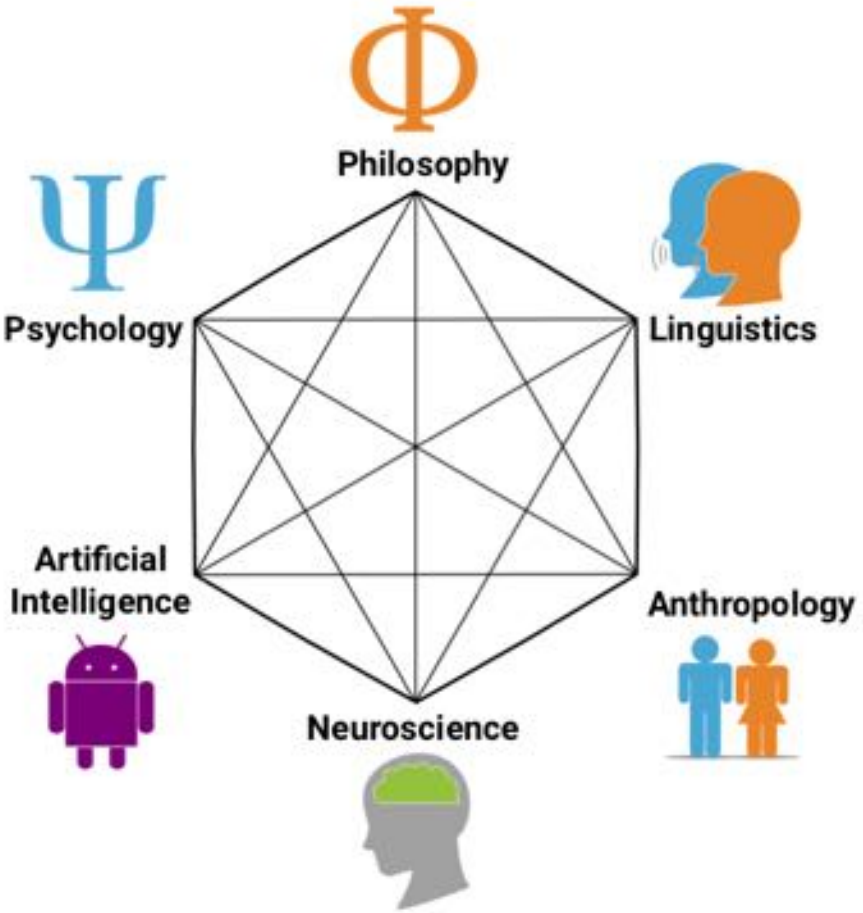
Psycholinguistics

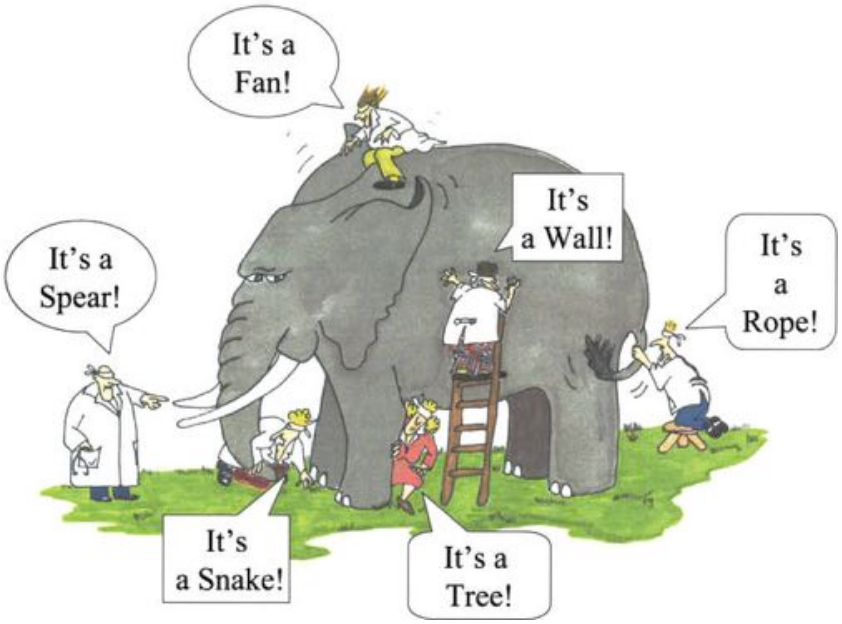
Artificial Intelligence

Sociology

Neurolinguistics

# Interdisciplinary research field



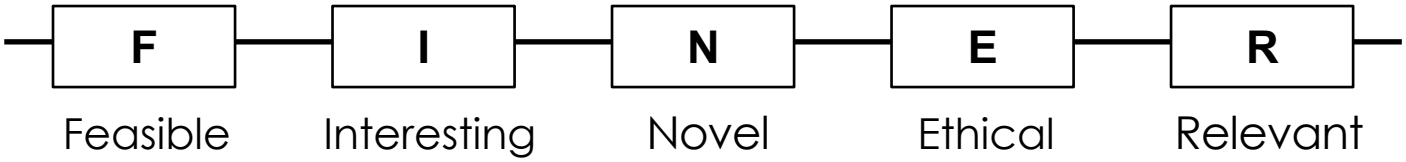

Gardner, H. (1985), P.-M. Daigneault(2013)

# Empirical approach

- Behavioural experiment
- Neuroimaging
- Computer modelling
- Animal study
- (Meta-analysis)

etc…

# Developing a Research Question




- Number of subjects
- Technical expertise
- Affordable
- Manageable in scope

- Intriguing to yourself, peers, and community

- Refute (or confirm) previous findings
- Extend previous findings
- Provide new findings

- In line with the institutional review board

- To scientific knowledge
- To policy
- To future research

# Variables in your design

Independent Variables (IVs)

Variables that you (as the researcher) control.

- The linguistic stimuli your participant is given
  Frequency
  Type
- The gender of your participants
- The linguistic units you search for

Dependent Variables (DVs)

Variables that your subject controls.

- Acceptability judgments
- Reaction times
- Amplitudes
- Frequency of occurrence

One often has to operationalize these variables.

# Researchers and experimenters make judgments

In Judgments

- Do you trust the speaker?
- Do you detect some variability/hesitancy in a speaker's response?
- Are your examples non-standard?
- Are there other factors at work in your examples?

In Experiments

- Are your subjects doing the task?
- Is the task sensitive to only the variable of interest?
- Are your item conditions confounded with other factors?

# No Fishing (p-hacking)

Before going forward, you should have a clear testable set of hypotheses.

Often stated, at least implicitly, in terms of your IVs and DVs.

The number of cups of coffee I drink will affect my performance on exams.

I predict the more coffee I drink the better I will do; more coffee, more ingenuity, higher exam scores

# Predictions and Design

Your predictions should guide your design.

Main effect: Only one IV is needed to capture the effect.

Interaction: 2+ IVs are needed to capture the effect.
The number of coffee I drink interacts with my level of hunger, this interaction thereby affecting my performance on the exam

# Design Controls

Limit other sources of variance, i.e. noise (or why we don't just record nature).

- "Norm" your items on known but unimportant variables (via corpora, pre-tests, etc.)
  Length, frequency, complexity, permissibility, etc.
- Randomized presentation
  Avoids context effects.
- Counterbalanced designs
  Each item is tested equally as often, and each subject receives and equal number of items per condition.
- Never leave your subjects to the own devices!
  Give clear instructions about the task and give trial examples.

# A couple of principles to keep in mind

- Formulate a clear question!

  Should have logical, testable, and falsifiable predictions.

- Vary only one variable!

  Vary only the variable of interest, keeping all else constant.

- Handling extraneous variance

  Have a way of dealing with it.

# Empirical approach

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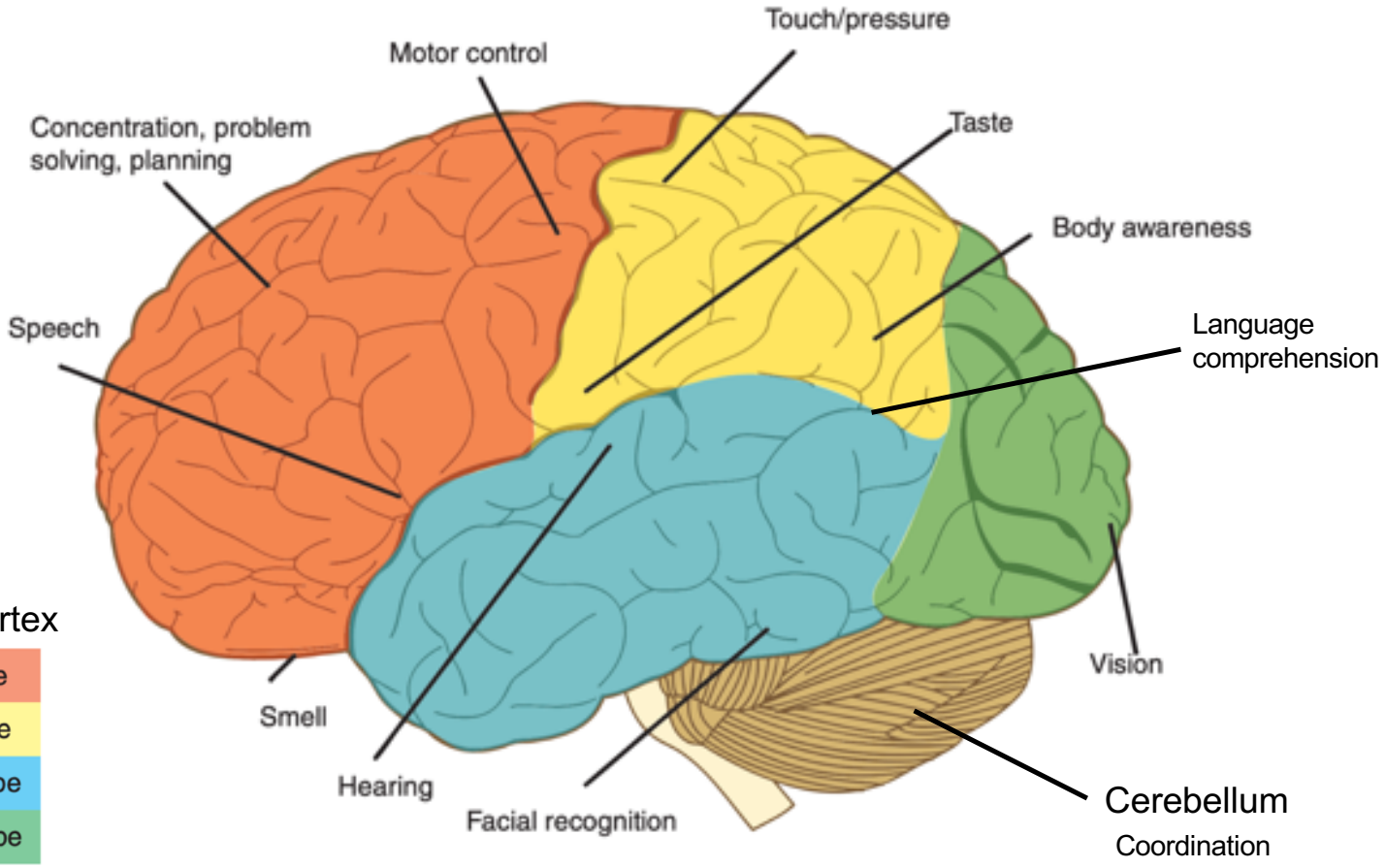
- Neuroimaging
- Computer modelling
- Animal study
- (Meta-analysis)

etc…

# Brain regions and functions

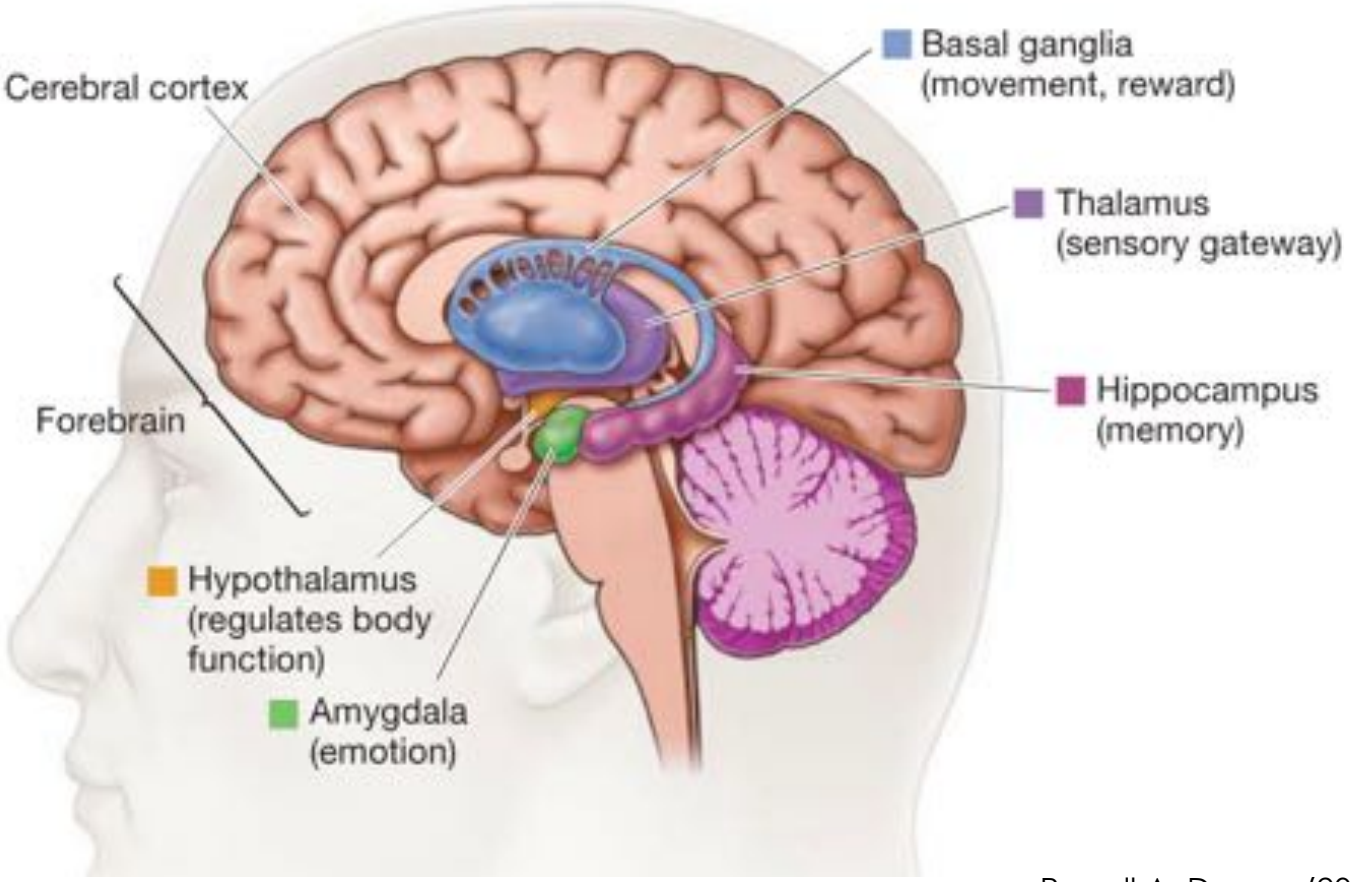



Cerebral Cortex

- Frontal lobe
- Parietal lobe
- Temporal lobe
- Occipital Lobe

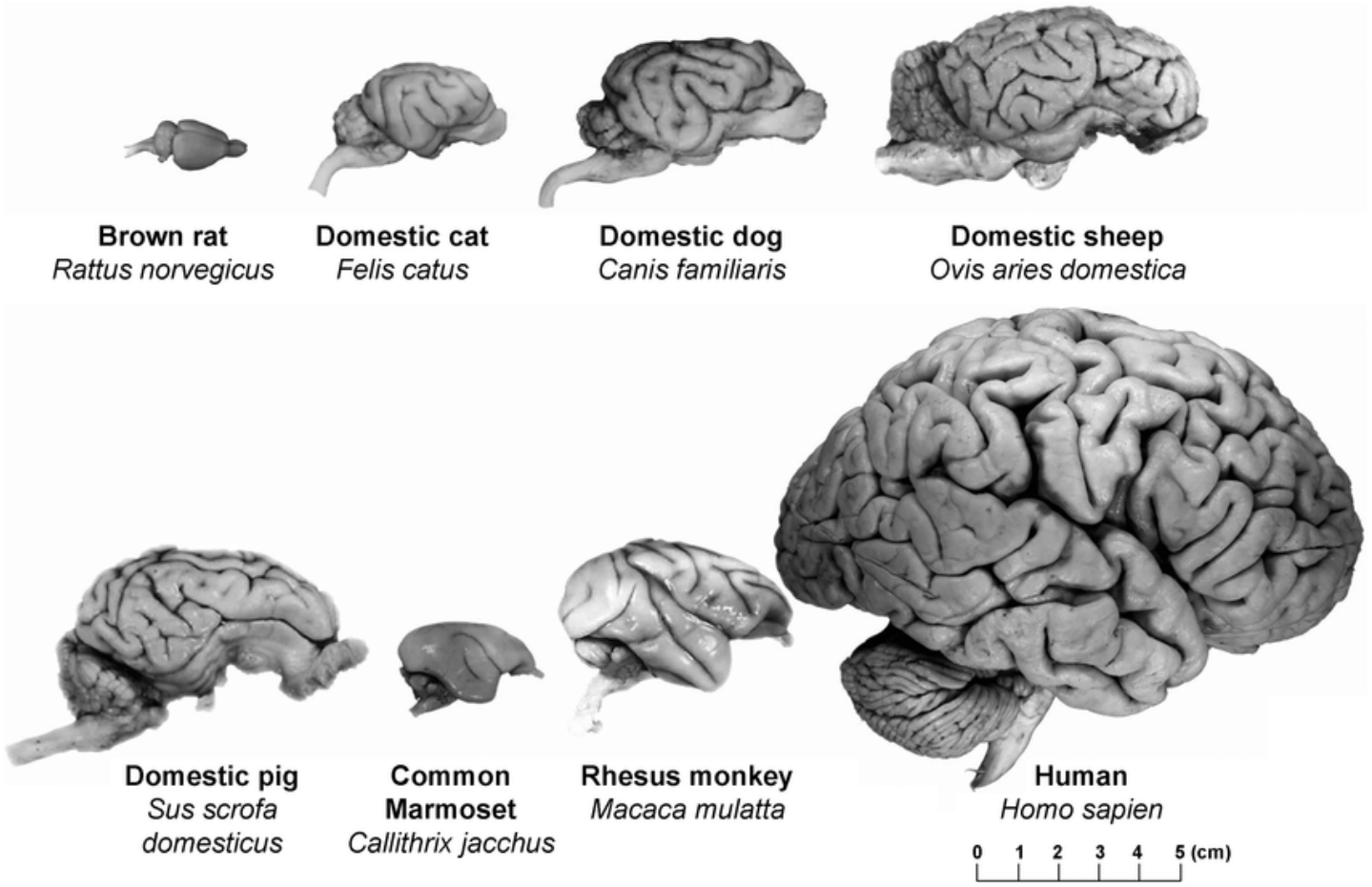
A. Obenaus (2017)

# Brain regions and functions



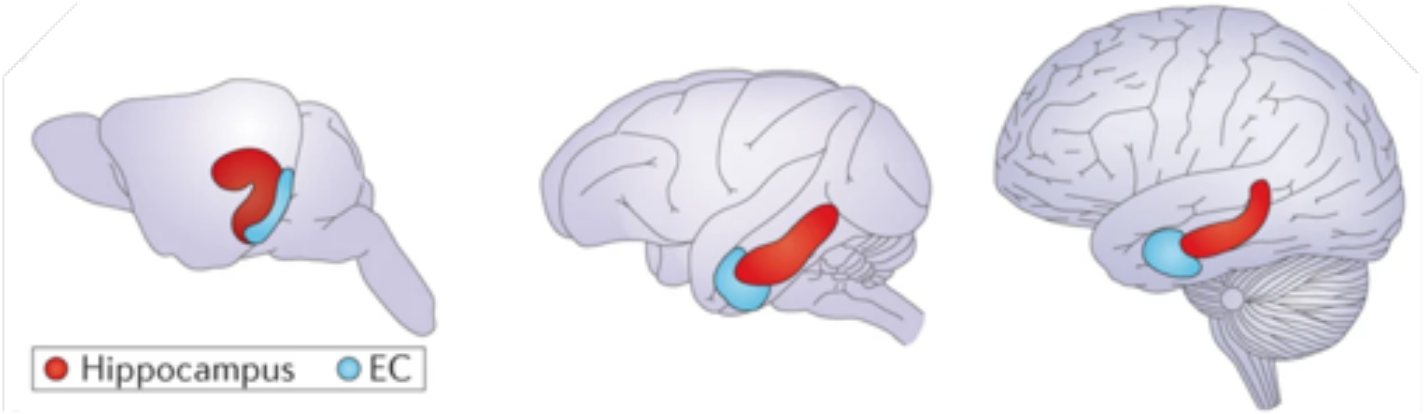

Russell A. Dewey (2017)

# Human-animal comparison




A. J. Sorby-Adams et al. (2017)

# Human-animal comparison




Rat Monkey Human

B. A. Strange et al. (2014)

# Neuroscientific methods
## – closer look into the brain

Invasive imaging

- Stereoelectroencephalography (SEEG)
- Electrocorticography (ECoG)
- Positron Emission Tomography (PET)
- Single Photon Emission Computed Tomography (SPECT)

# Neuroscientific methods
## – closer look into the brain

Non-invasive imaging

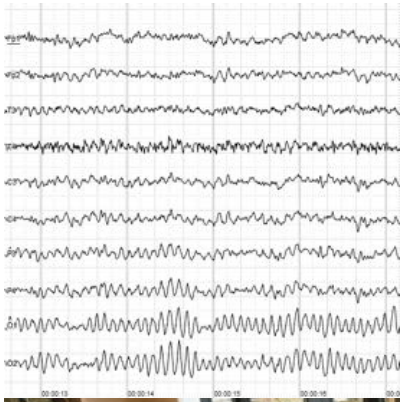
- Electroencephalogram (EEG)
- Magnetoencephalography (MEG)
- Magnetic Resonance Imaging (MRI)
- Near-infrared spectroscopy (NIRS)

Brain stimulation

- Transcranial magnetic stimulation (TMS)

# Electroencephalogram (EEG)

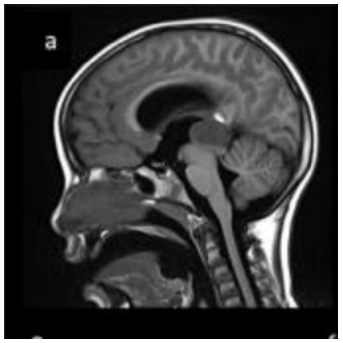
- Record neuroelectrical impulses (brain waves) within the brain across the scalp
- Advantages:
  - High temporal resolution
  - Low cost
  - Portable
- Disadvantages:
  - Low spatial resolution
  - High noise ratio



https://team.inria.fr/potioc/

# Magnetic Resonance Imaging (MRI)

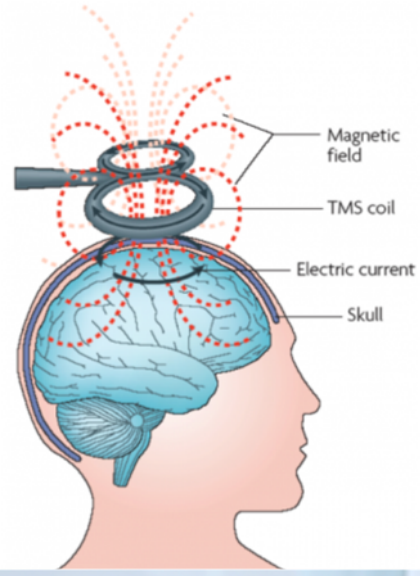
- Structural MPI (MPI/sMRI)
  Measure the energy from proton spin change caused by strong magnetic field and radiofrequency pulse
- Functional MPI (fMRI)
  Measure blood-oxygen-level-dependent (BOLD): different magnetic property of oxy- and deoxyhemoglobin
- Advantages:
  - High spatial resolution
- Disadvantages:
  - Low temporal resolution (fMRI)
  - possible claustrophobia
  - very loud
  - high weight and cost




A. M. Granados et al. (2017)

# Transcranial magnetic stimulation (TMS)

- Non-invasive form of brain stimulation
- Stimulate nerve cells in the brain with strong magnetic fields
- Activate/inactivate certain area of the brain



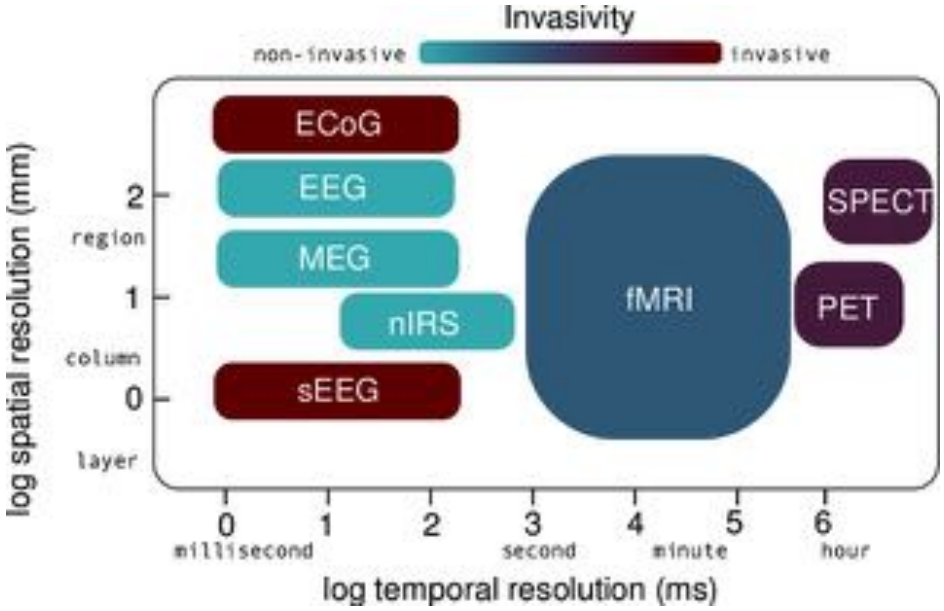

medbriefnamibia.com

# Which method is best?

There is no best of best. Find better fit to your research question.

Consider:

- Temporal resolution
- Spatial resolution
- Invasivity
- Cost
- Portability




F.Pedregosa (2015)

# What you can study about in cognitive science?

- Learning and memory
- Reasoning
- Decision making
- Dreaming and consciousness
- Perception
- Emotion
- Language
- Communication

and more…

# Variance in linguistic research

## Continuous

- Frequency counts

How frequently does a particular word occur in CELEX?

- Reaction time data

How much time does it take for a participant to make a lexical decision?

- Amplitude data

How does amplitude change across formant boundaries?

## Categorical data

- Acceptability judgement

Is this sentence acceptable?

- Gender

Record people at a department store to see their production of some consonant

# Causes for linguistic variance

Subject effects

- Cognitive/memory limitations
- Attention limitations
- Perceptual limitations
- Motor limitations
- Dialect differences

Item effects

- Contextual effects
- How salient are alternatives?

"Noise"

You are incredibly hungry when you come for the experiment.

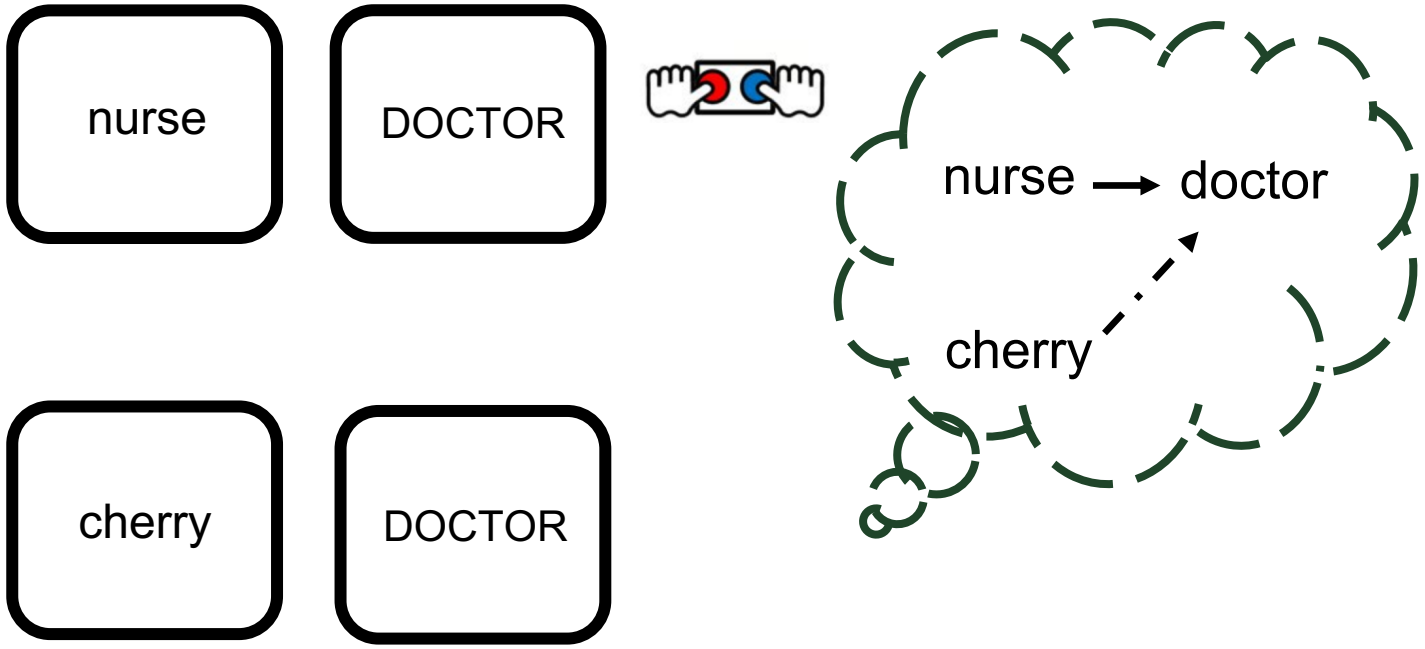
nurse

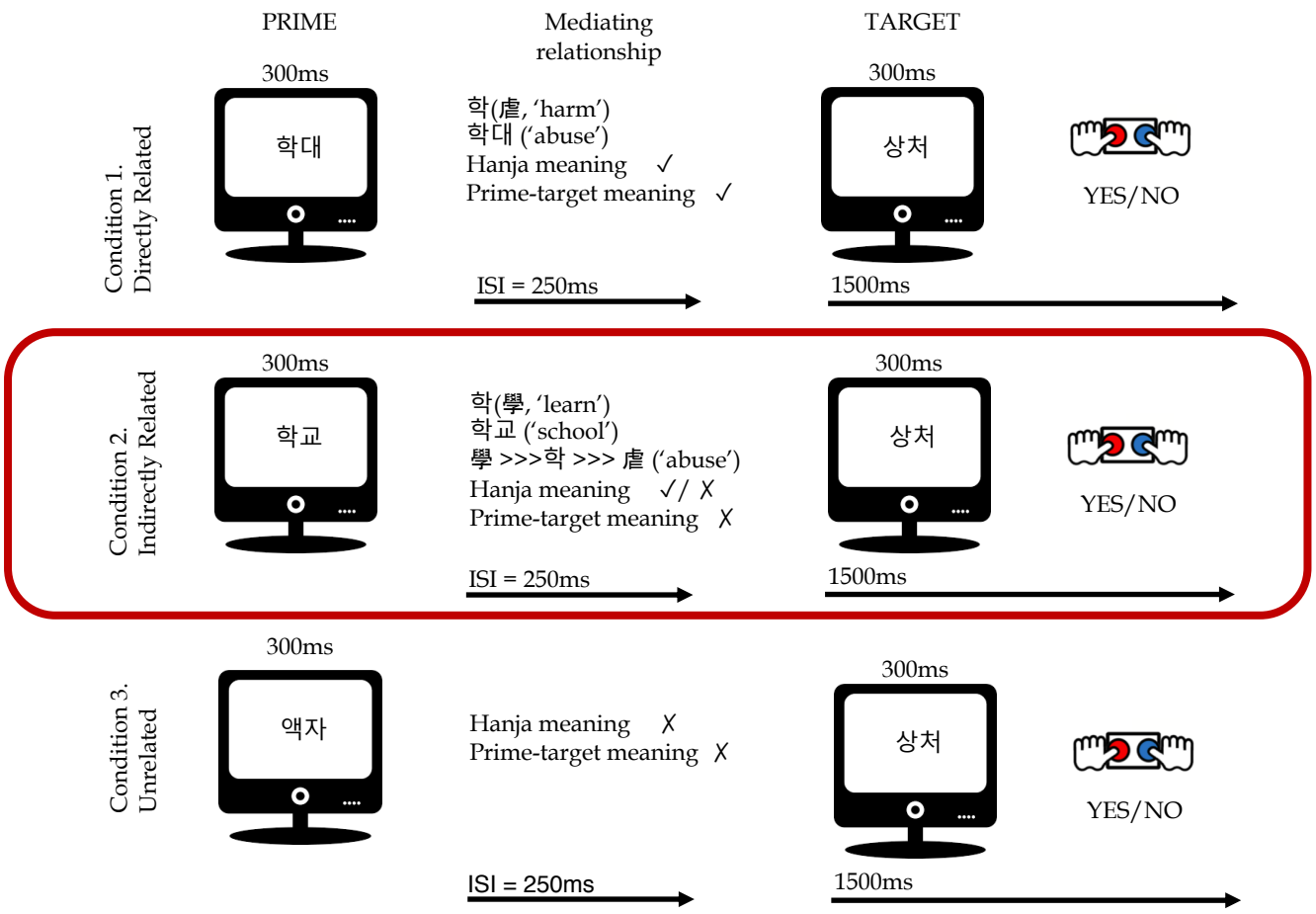
DOCTOR

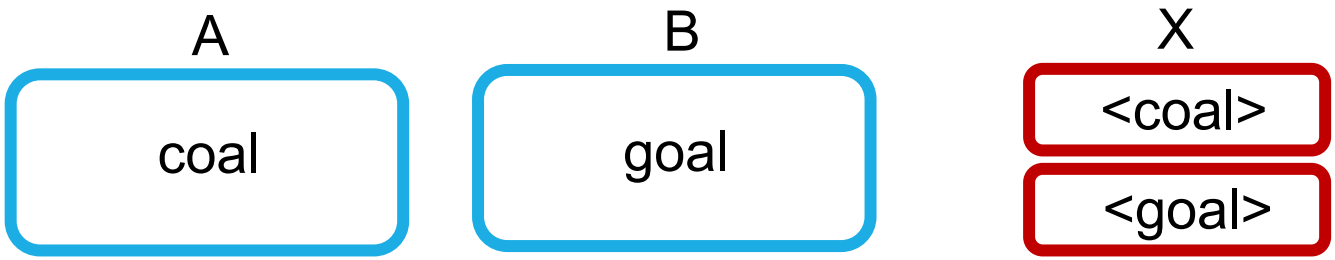
cherry

# TIGER

# Lexical decision




PRIME
Mediating relationship
TARGET
Condition 1. Directly Related
300ms
학대
학(虐, 'harm')
학대 ('abuse')
Hanja meaning ✓
Prime-target meaning ✓
300ms
상처
YES/NO
ISI = 250ms
1500ms
Condition 2. Indirectly Related
300ms
학교
학(學, 'learn')
학교 ('school')
學 >>>학 >>> 虐 ('abuse')
Hanja meaning ✓/ ✗
Prime-target meaning ✗
300ms
상처
YES/NO
ISI = 250ms
1500ms
Condition 3. Unrelated
300ms
액자
Hanja meaning ✗
Prime-target meaning ✗
300ms
상처
YES/NO
ISI = 250ms
1500ms



# Do we really need to run experiments?

Not necessarily.

- Experiments are messy.
- Fewer opportunities for replication.
- Even in experiments, there is an inevitable degree of subjectivity.

# Generalizations

What makes a good theory?

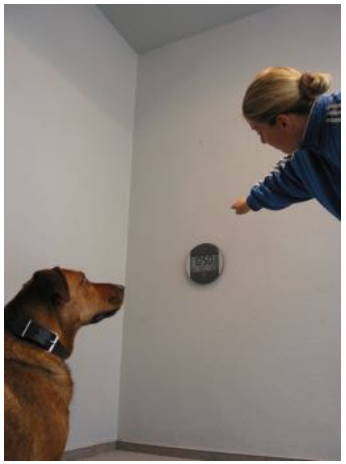
- Do not stipulate a solution
- Look for generalizations and deeper principles.

What might our results say about the structure of the mental lexicon?

A lot, but now we know that semantic relatedness has a significant effect.

# DogLab – topics

## Special skills?



Communication

Cooperation

Smell & Cognition

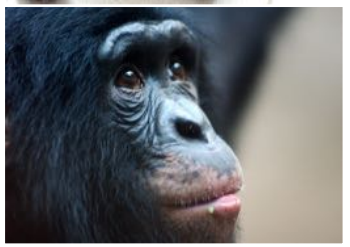
## Common skills?

Physical Cognition

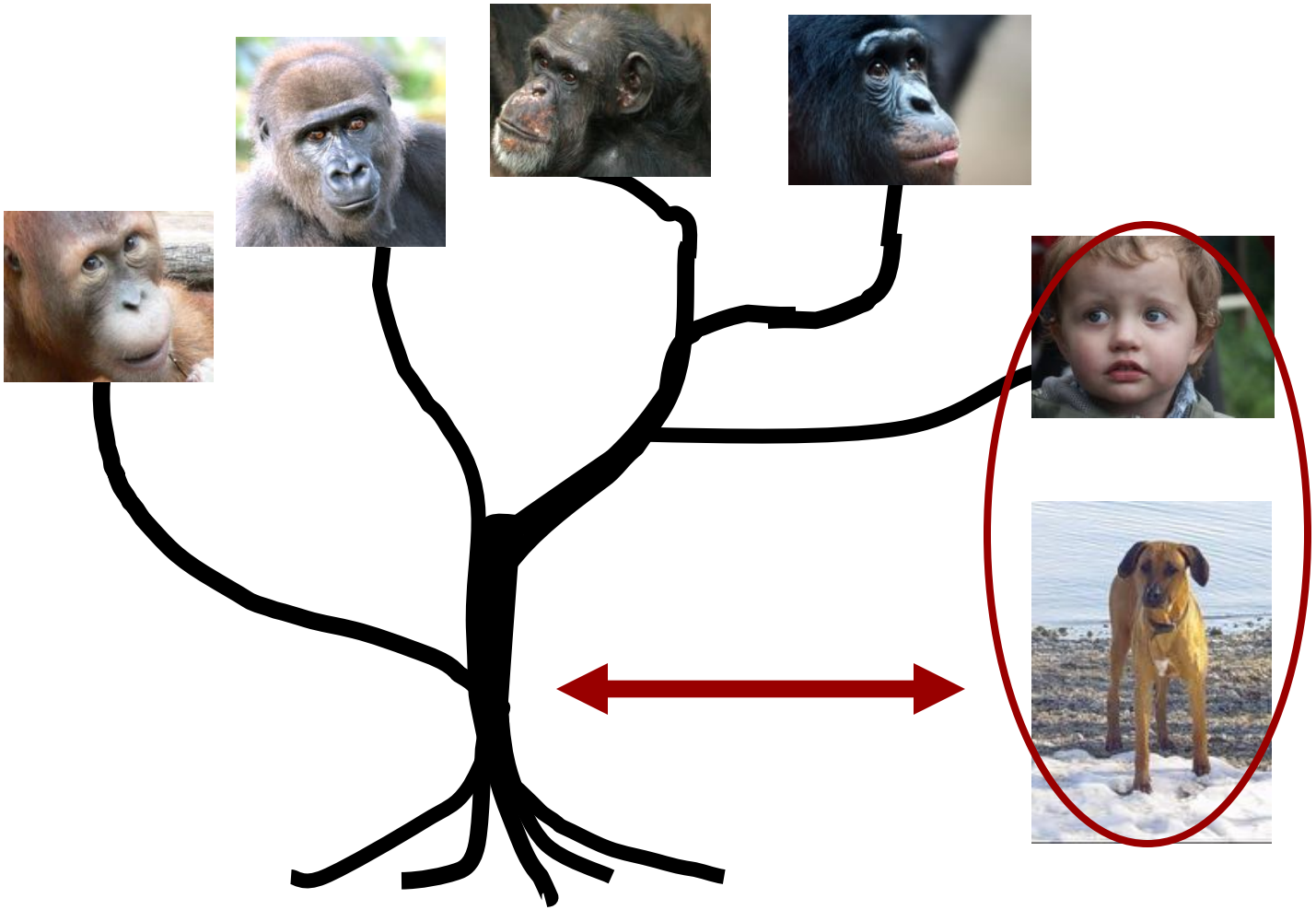
Meta-Cognition

Social Learning

Perspective-taking



# DogLab



# DogLab

# DogLab in Jena

- Database with more than 200 family dogs
- Studies without owners (usually), owners are informed after the study
- Reward: food and/or toy

# DogLab in Jena

Max Planck Institute for the Science of Human History, DogStudies
Kahlaische Strasse 10, 07745 Jena, Germany

Web: http://doglab.shh.mpg.de/dog-cognition.php

# Voice perception

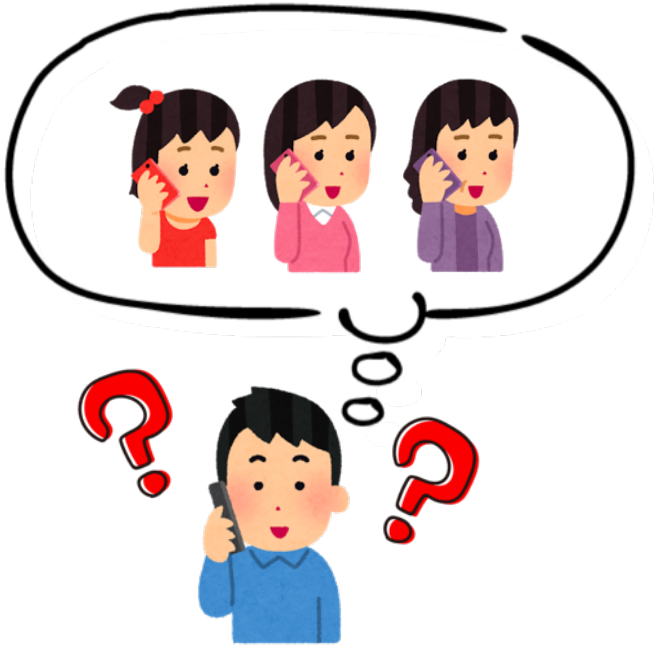
- Content of Speech
- Emotion
- Individual difference

  (gender, age, personality…)

What feature makes individual difference in voice?

# Speaker identification

Mistake the speaker on the phone



Family members have similar faces

Do they have similar **voices**?

@irasutoya.com, https://fundamentalists.fandom.com/wiki/Keller_Family

# Kinship recognition in voice

Which of the pairs is/are siblings?

Pair A

Pair B

Pair C

Pair D

# Kinship recognition in voice

Which of the pairs is/are siblings?

Non-twin siblings

Non-related

Monozygotic twins

Dizygotic twins

# Towards a more interdisciplinary approach

- What are the individual contributions of quantitative and qualitative studies?
- Methodological issue(s) to consider:
  - Sampling from a (largely) WEIRD* population
    - Why might researchers gravitate towards WEIRD participants?
    - What problems might arise from a biased group selection?
  - Sampling from less WEIRD populations?
    - One (less than ideal) solution …
    - Can you think of other ways to help mitigate this issue?
  - Are we really capturing phenomena occurring in the wild?
  - How do we reconcile capturing variance while maintaining clean and manageable data?
- What are some outstanding questions you see that have yet to be tackled in the field of cognitive science? What might be an appropriate method to investigate this question? Your turn!

*Western, Educated, Industrialized, Rich, and Democratic

# Remember:

- Making precise predictions
  Ask a clear question with clear, testable, and falsifiable predictions – this will guide your research.

- Experiments, Statistics, and Norms
  Do not run experiments because all your friends are running experiments.
  Choose the right method to probe your research question.
  Control for as much as possible, keep as much constant to eliminate confounds.

- Generalizations
  Look for deeper principles, stating the phenomenal pattern you are investigating is not the same.

- Interdisciplinary approach
  Be aware of the issues and limitations of existing methods.
  Creativity leads you to new ways to explore.