DONDERS INSTITUTE

BKI134:
Cognitive psychology
General approaches (part 1)

Noor Seijdel

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Based on previous lectures/slides from Prof. H. Schriefers and Dr. Linda Drijvers

Radboud University Radboudumc

Last Tuesday

– Sign up and earn money as a participant:

https://www.ru.nl/donders/vm-site/proefpersonen/

https://www.ru.nl/fsw/onderzoek/deelnemen-aan-wetenschappelijk-onderzoek/

https://www.mpi.nl/doemee

...other benefits: experience the experiments, 3D scan of your brain, etc.

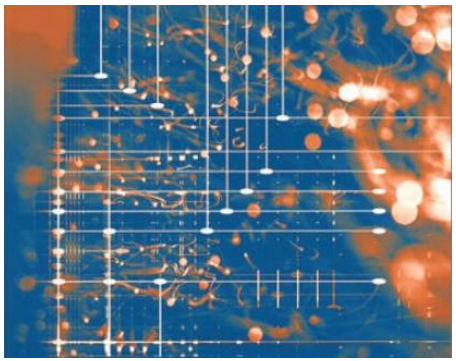
Today

- We started with: some demonstrations / examples
- This session and next session:
  - Approaches to studying cognitive processes (book, chapter 1)

Approaches to study cognitive processes

- Cognitive Psychology:
  - The attempt to uncover the nature of human cognition by observing people's behavior (behavioral experiments, e.g. reaction times)

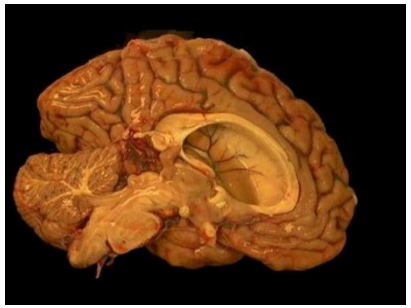
- Computational Cognitive Science
  - The attempt to use computational models to further understanding of human cognition



Approaches to study cognitive processes

- Cognitive Neuroscience:
  - The attempt to use information about behaviour AND the brain to understand human cognition

- Cognitive Neuropsychology:
  - The attempt to understand human cognition by studying patients with brain damage



Today

- **Cognitive psychology**
- **Cognitive neuroscience**
- Cogntive neuropsychology
- Computational cognitive science

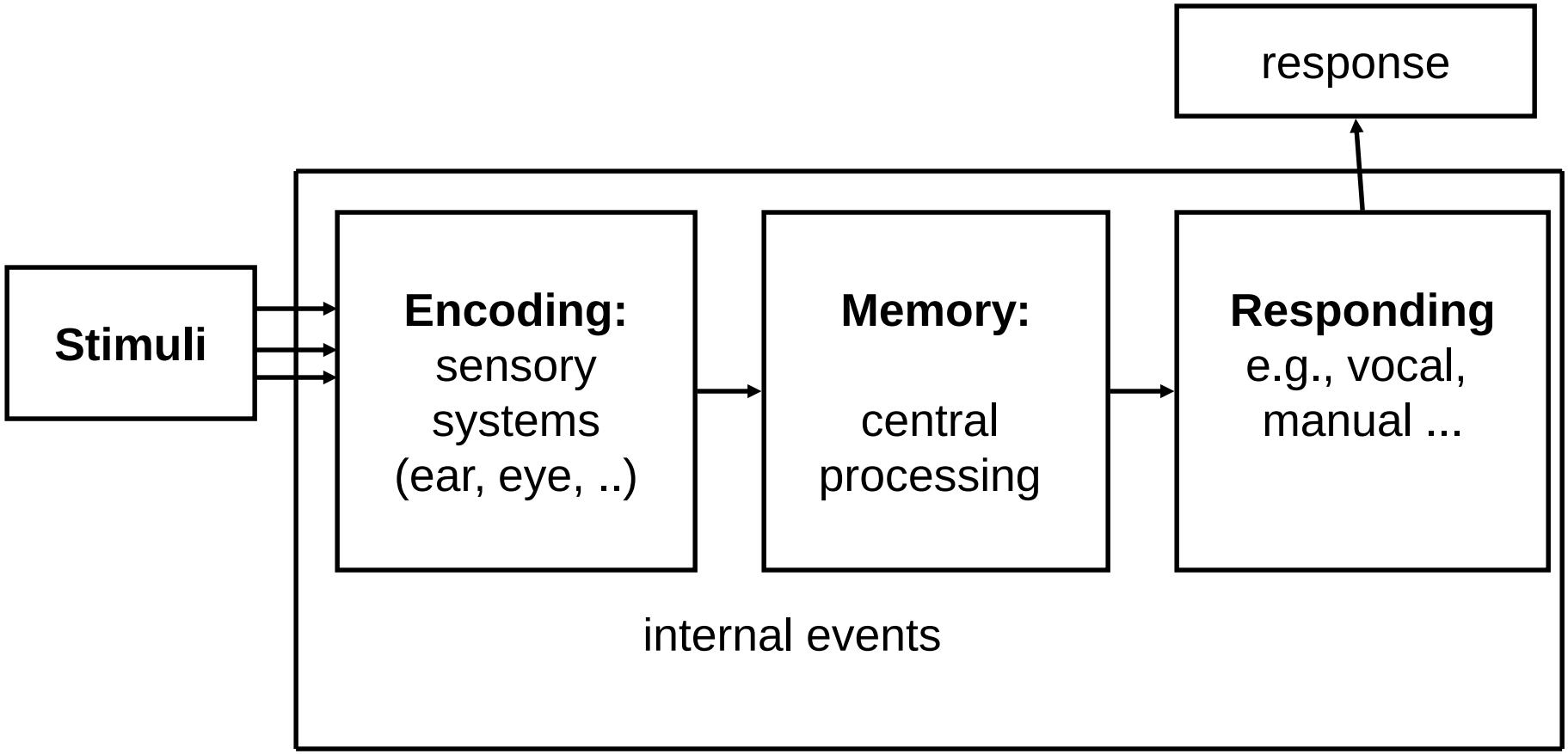
Basic assumptions in cognitive psychology

– information processing (mental processes, cognitive processes) are accessible to scientific empirical / experimental investigation

– human information processing is active, not just passively taking up information and not just forming associations

– mental processes can be inferred from human behavior in carefully controlled (experimental) settings

Information processing models



Experiments: (a) manipulate stimuli, (b) observe response (e.g., reaction time), (c) infer processes in „black box“ / internal events

Inferring cognitive processes from behavior: reaction times

- Cognitive processes take time
- Reaction time: time from a stimulus to a response in a given experimental task
- By comparing reaction times in different tasks, the duration of the component processes can be estimated

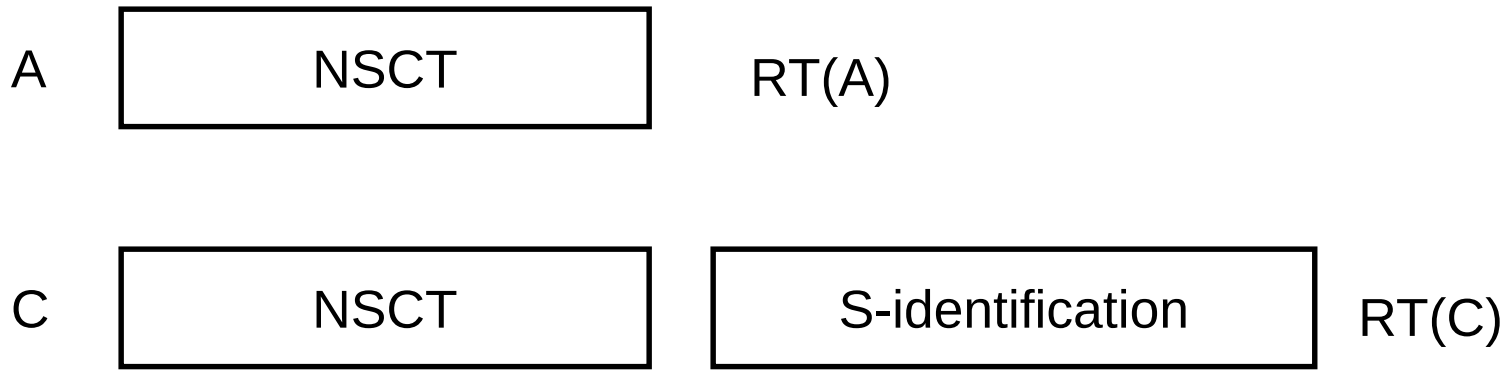
Donders' subtractive method

(S = stimulus, R = response)

(FC Donders (1818 – 1889)

- A-task:
  - light "on" (S) ==> button press (R)
  - RT = nervous system conduction time (NSCT)
- B-task
  - blue light "on" (S1) ==> press right (R1)
  - yellow light "on" (S2) ==> press left (R2)
  - RT = NSCT + identification (S1/S2) + response selection (R1/R2)
- C-task
  - blue light "on" (S1) ==> button press
  - yellow light "on" (S2) ==> no button press
  - RT = NSCT + identification (S1 vs S2)

Donders' subtractive method



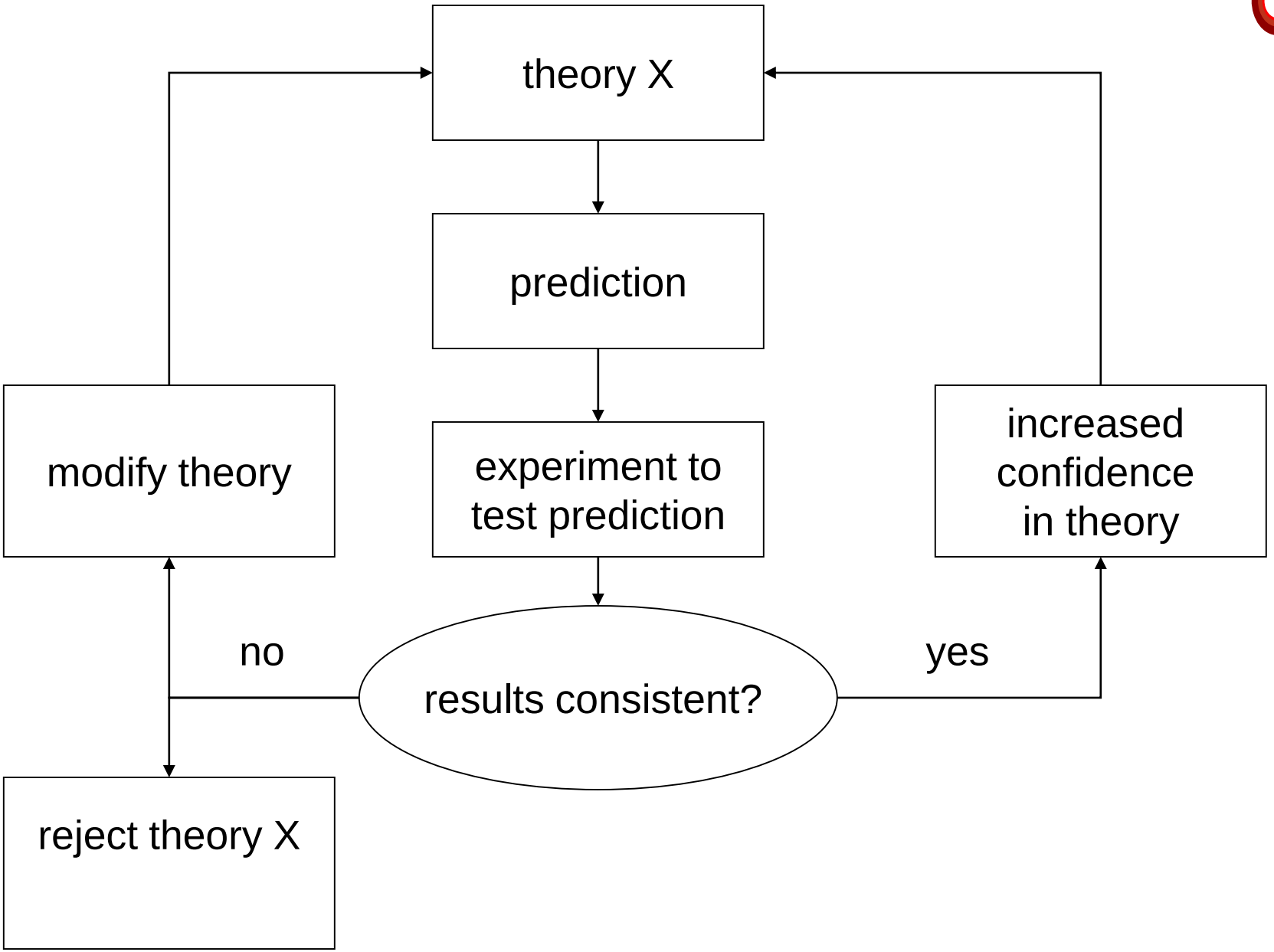
RT(C) - RT(A) = stimulus identification time

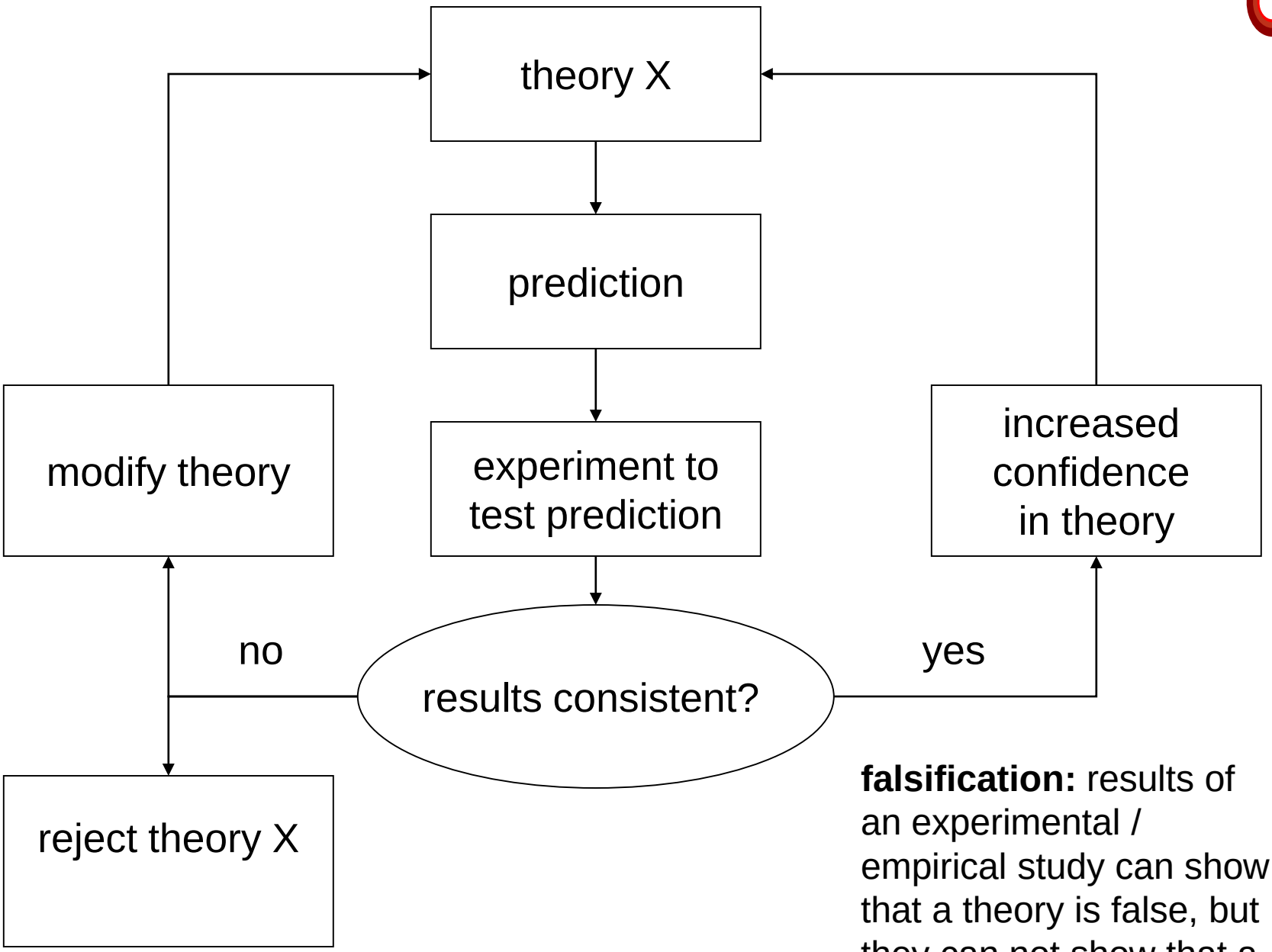
Donders' subtractive method

RT(B) - RT(C) = response selection time

Explanations in cognitive psychology

- Theories and models
  - theory: set of related statements to explain a phenomenon
    - verbal
    - mathematical equations
    - computer program


theory X
prediction
experiment to test prediction
results consistent?
no
yes
modify theory
reject theory X
increased confidence in theory



falsification: results of an experimental / empirical study can show that a theory is false, but they can not show that a theory is „true“

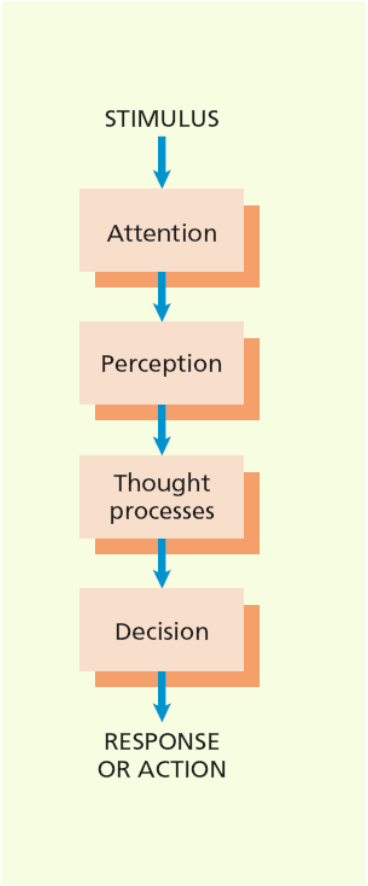
Information processing models

– information is processed through series of processing stages / processing steps

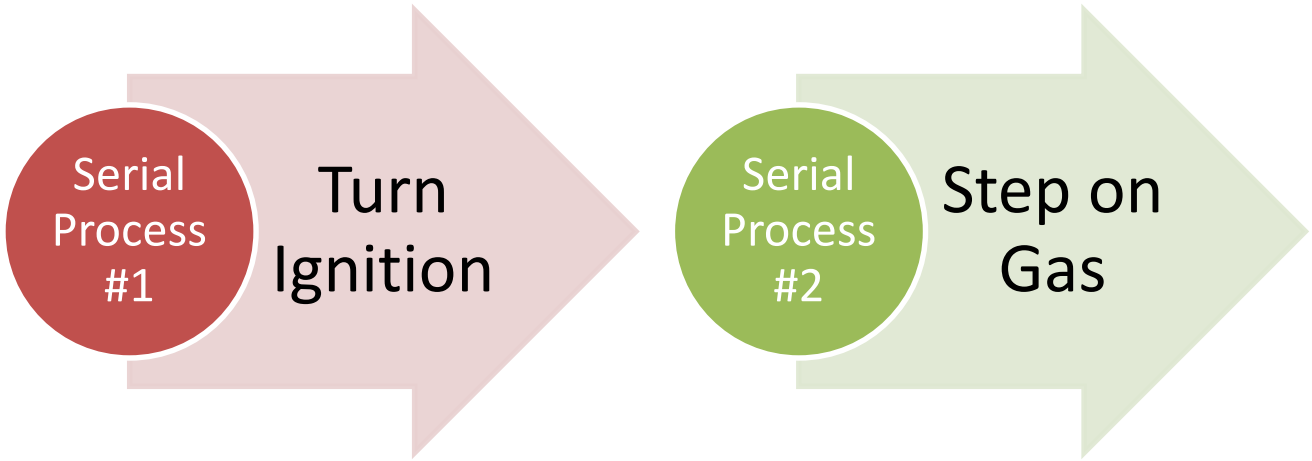
– each stage performs unique special operations on its input information

Information-Processing Approach

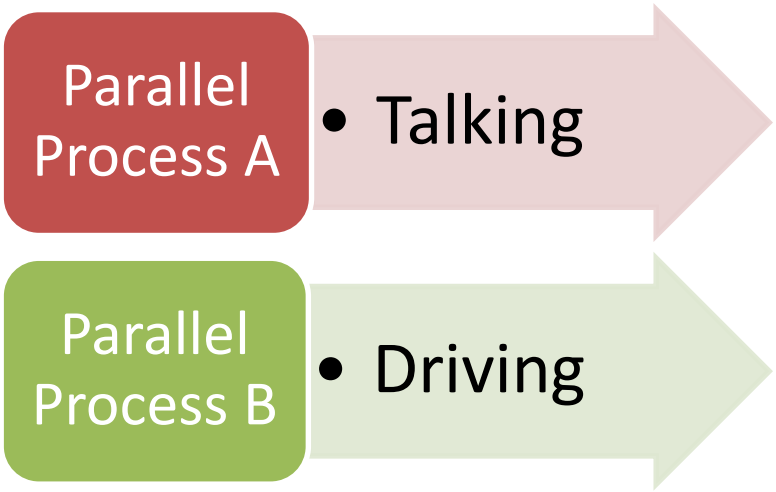
- Major Goal:
  - Specify the processes and structures involved in cognition
- Assumption:
  - Processing in people resembles that in computers



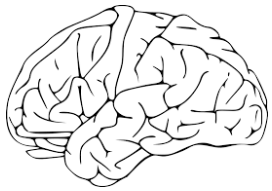
Types of Processing (1): serial processing



Types of Processing (2): parallel processing



Types of Processing (3)



Mind / Brain (e.g. knowledge, past experience, expectation…)

Top-Down Processing

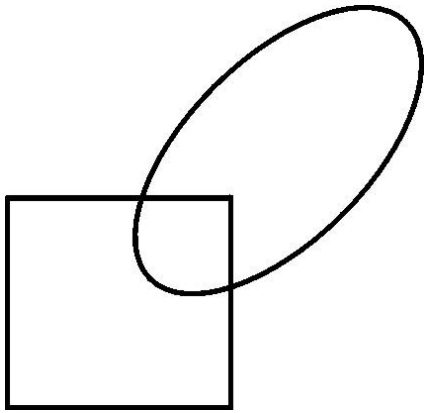
Bottom-Up Processing

External world (stimulus)

Examples

- no top-down influences: knowing a visual illusion does not eliminate the illusion

- top-down influences: knowledge about typical shapes affects interpretation of the visual input



Basic building blocks

- **Independent variable**: the variable that is manipulated by the experimenter
- **Dependent variable:** the variable that is measured by the experimenter

Basic building blocks

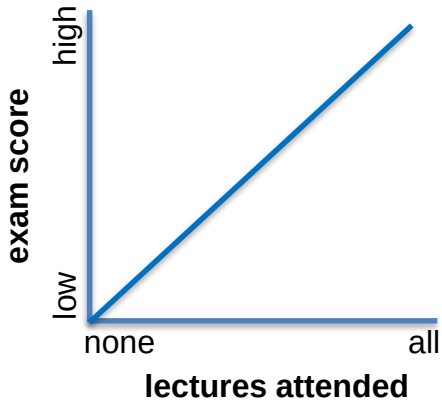
The lecturers of this course want to investigate whether coming to the lectures results in a higher score of the exam.

How? Discuss with your neighbour: what is the *independent* variable? What is the *dependent* variable?

Basic building blocks (example)

– **Independent variable**: Number of lectures that were attended before the exam

– **Dependent variable**: Score on the exam



hypothesis: expected outcome

Another example

- Basic building blocks of an experiment in cognitive psychology
  - Example: Stroop Task
    → Name the color in which the word is written

RED

GREEN

RED

BLUE

YELLOW

– People are faster if the meaning of a color word and the color in which the word is written are **congruent** (i.e., same: **RED**) than when they are **incongruent** (i.e. different: **BLUE**).

Stroop task to exemplify the basic building blocks of an experiment

- Independent variable (factor with levels); also referred to as experimental conditions
  - factor / independent variable: Congruency
  - levels: congruent (RED) versus incongruent (BLUE)
- Dependent variable (= what researcher measures / observes)
  - reaction time (milliseconds)
  - response accuracy („bl ... uh red“)

Stroop task to exemplify the ingredients of an experiment

- Independent variable
  - e.g., congruent versus incongruent
- BUT: Is congruent especially fast? Or incongruent especially slow? Or a bit of both?
  - What do we need to decide this?

Stroop task to exemplify the ingredients of an experiment

- Independent variable
  - e.g., congruent versus incongruent
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  - Some kind of neutral baseline

Stroop task to exemplify the ingredients of an experiment

- Independent variable
  - e.g., congruent versus incongruent
- BUT: Is congruent especially fast? Or incongruent especially slow? Or a bit of both?
  - What do we need to decide this?
  - Some kind of neutral baseline
- E.g.: words in color (TABLE) or something like XXXXX
- Note: what counts as an adequate neutral baseline is often a hotly debated question

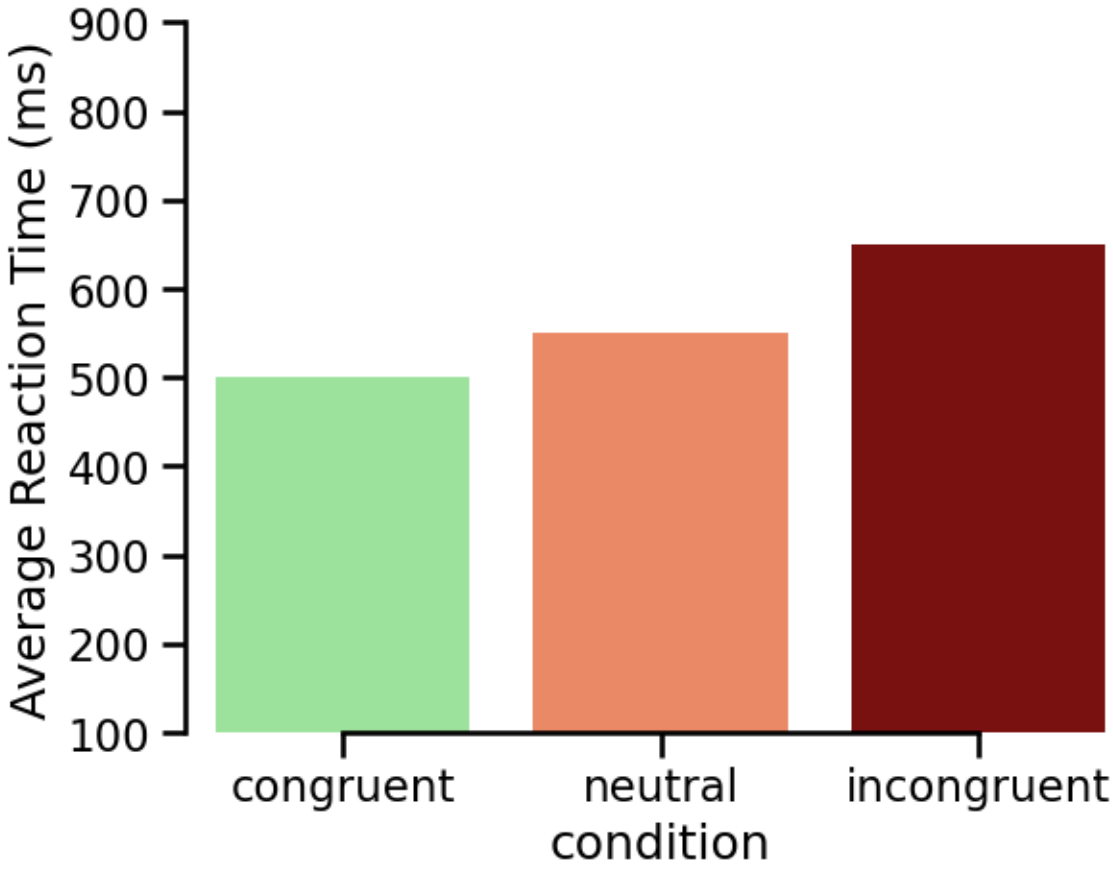
Stroop task to exemplify the ingredients of an experiment

- How do we collect the data / dependent variable?
  - Version 1: per participant one observation in each of the conditions
    - BUT: unpredictable fluctuations in „being focussed on task“ etc within a participant
  - Therefore **we choose version 2**: repeated observations within each condition and each participant; we average RTs across repeated observations in each condition
- We call a single observation a *trial*

Hypothetical results for Stroop-task

- reaction times (RT)
  - RT (congruent) < RT (incongruent)
  - e.g. RT (congruent) = 500 msec (milliseconds)
    RT (incongruent) = 650 msec

Hypothetical results for Stroop-task



Basic building blocks of an experiment: some extensions

- Two independent variables
  - factor 1: congruent versus incongruent
  - factor 2: small vs large font

Ingredients of an experiment: some extensions

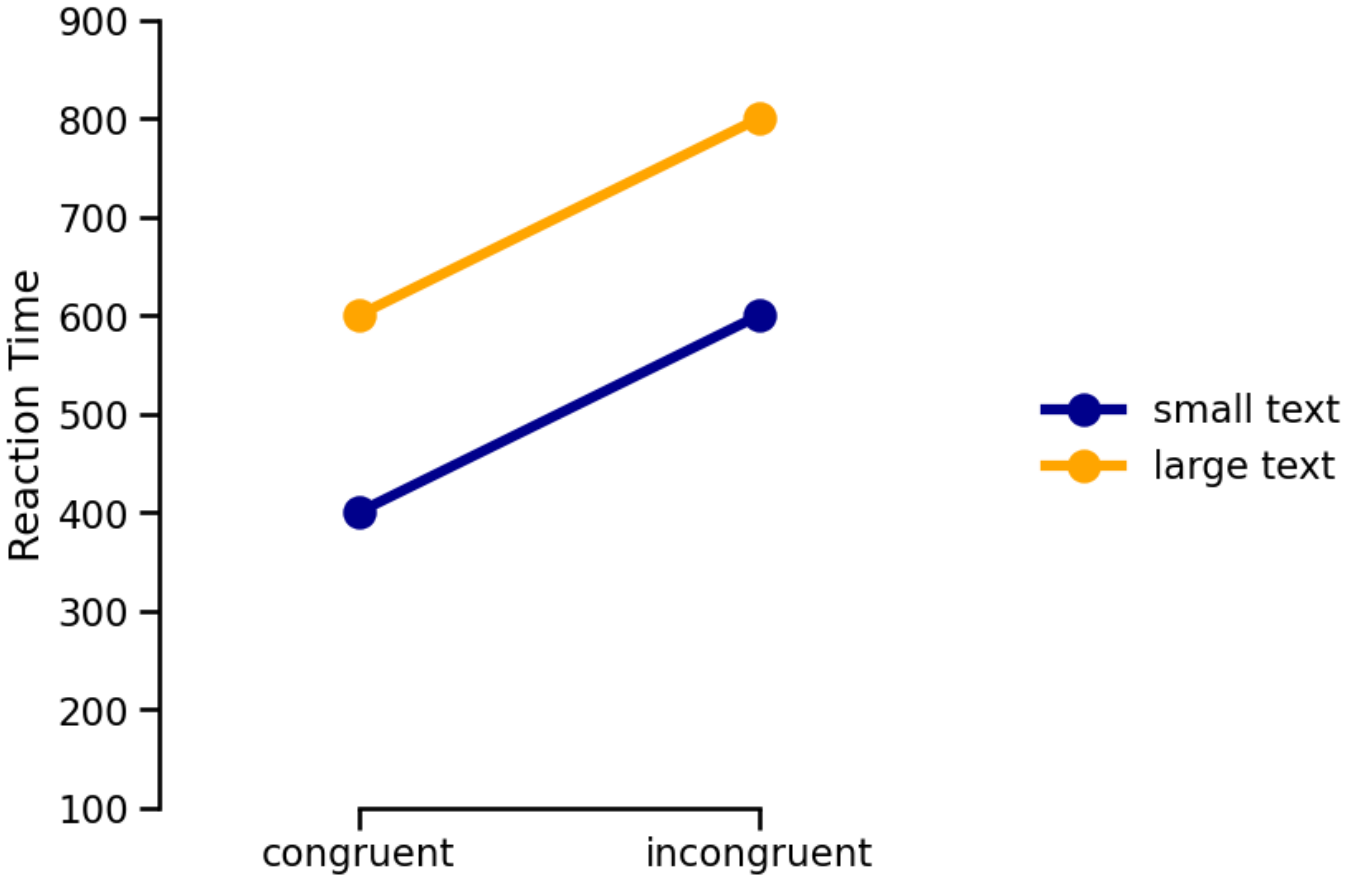
- Two independent variables
  - factor 1: congruent versus incongruent
  - factor 2: small vs large font
- We *cross* two independent variables

Two crossed factors / independent variables with two levels on each factor

	CONGRUENT	INCONGRUENT
SMALL	red	blue
LARGE	red	blue

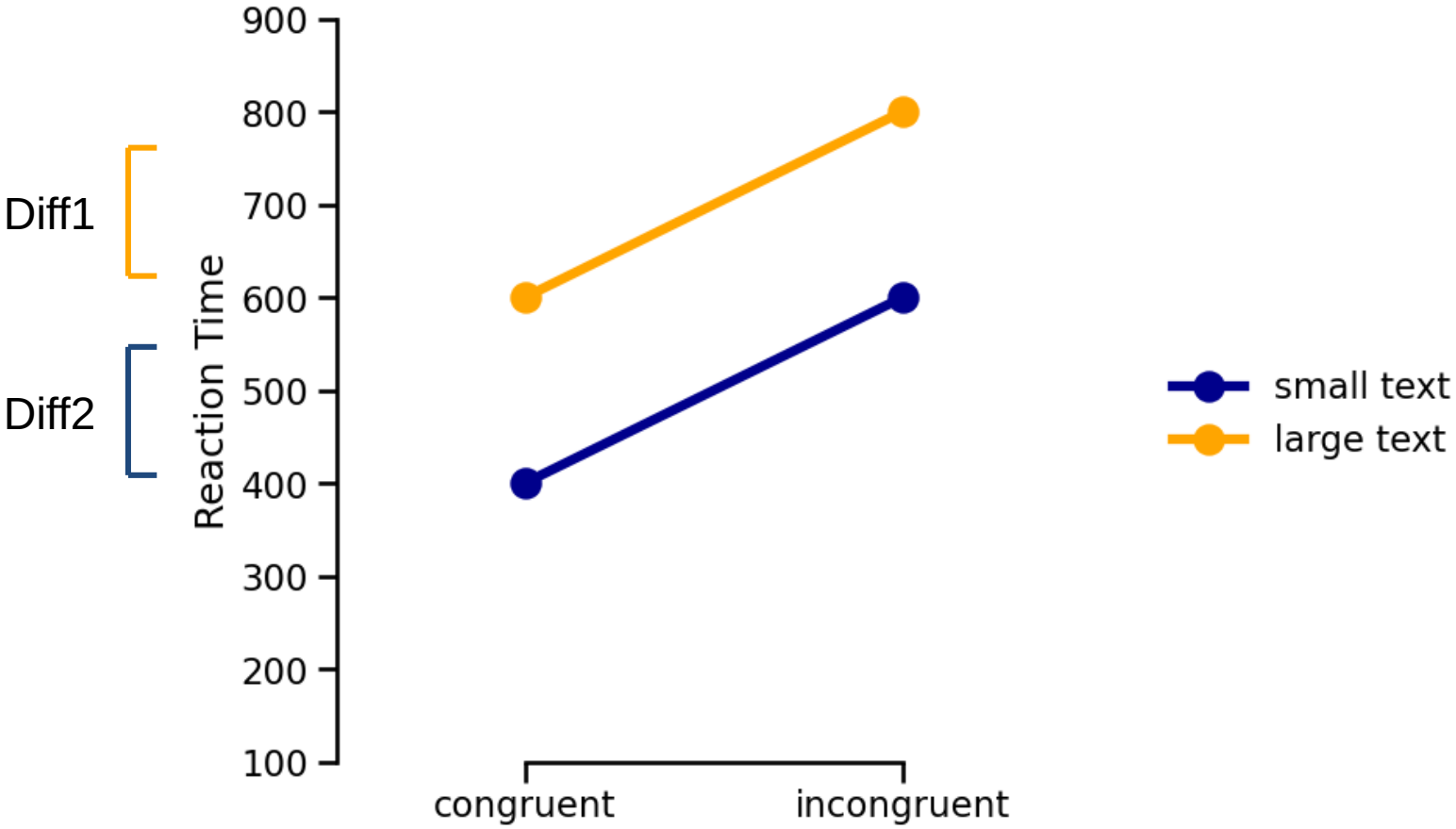
= an experiment with a *two-by-two design*

Additive effects of the two factors



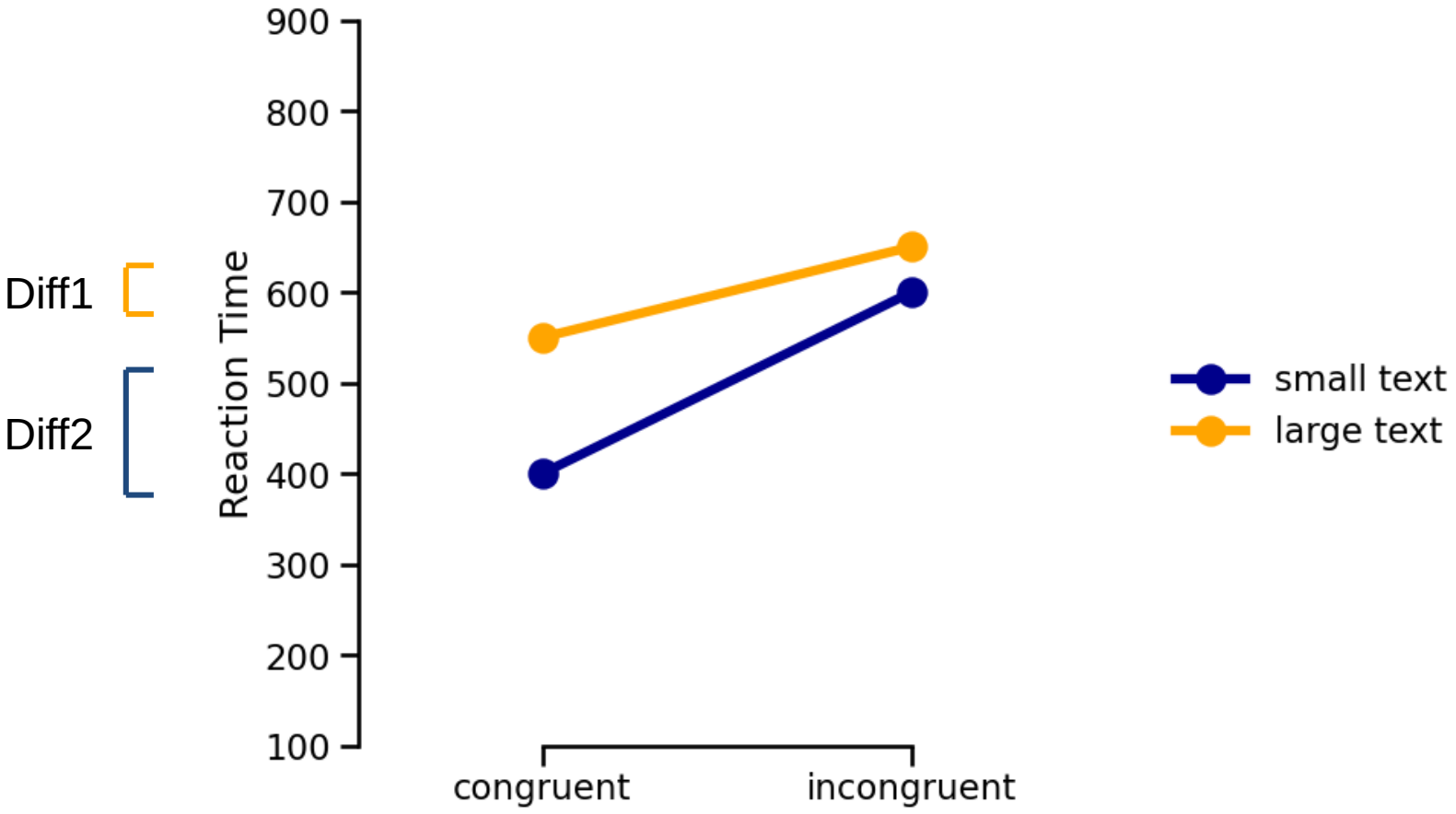
additive effects of small/large and congruent/incongruent: Difference 1 = Difference 2;

Additive effects of the two factors



additive effects of small/large and congruent/incongruent: Difference 1 = Difference 2;

Interaction of the two factors



interaction = difference between differences: Diff 1 < Diff 2

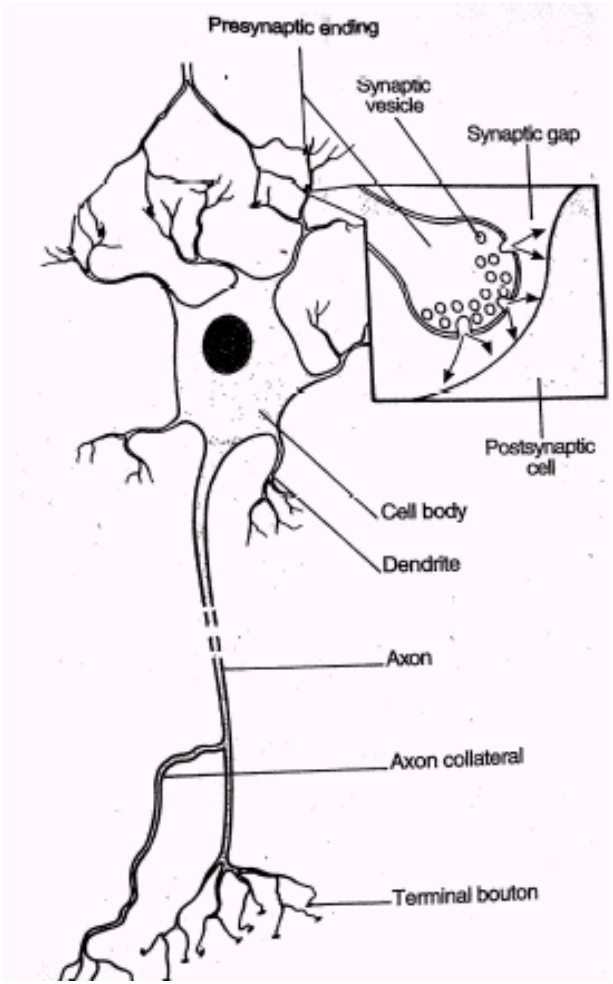
Today

- Approaches to studying cognitive processes (book, chapter 1)
  - **Cognitive psychology**
  - **Cognitive neuroscience**
  - Cogntive neuropsychology
  - Computational cognitive science

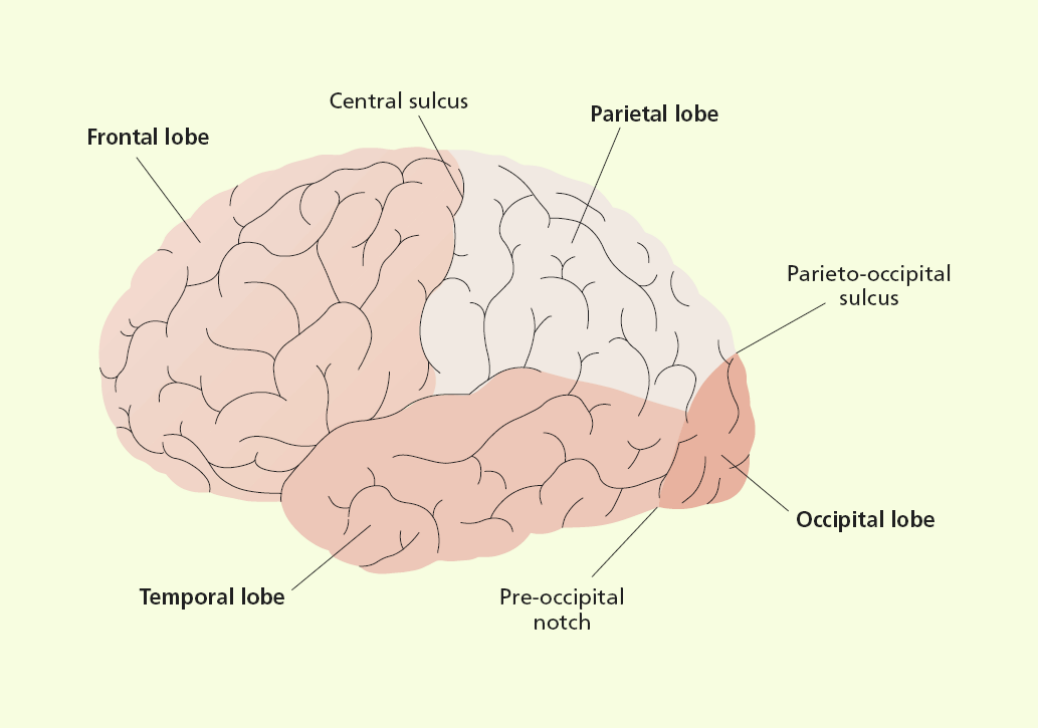
Cognitive Neuroscience

The attempt to use information about behaviour AND the brain to understand human cognition

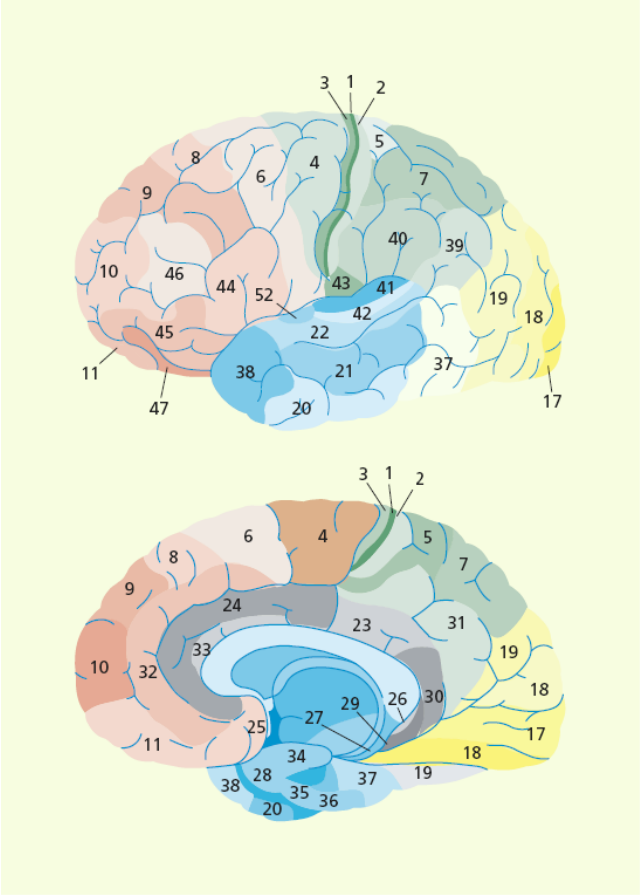
The basic building blocks of the brain are neurons



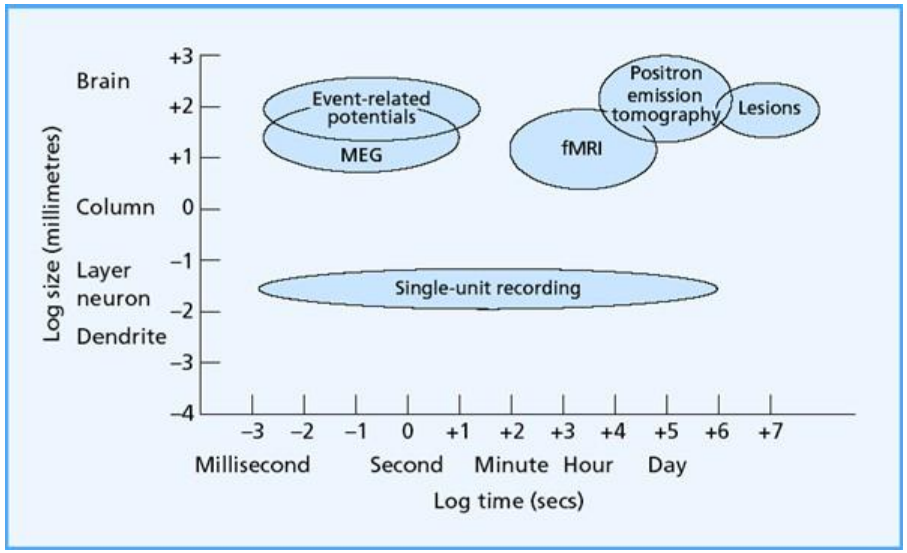
The Cerebral Cortex



The Brodmann Areas



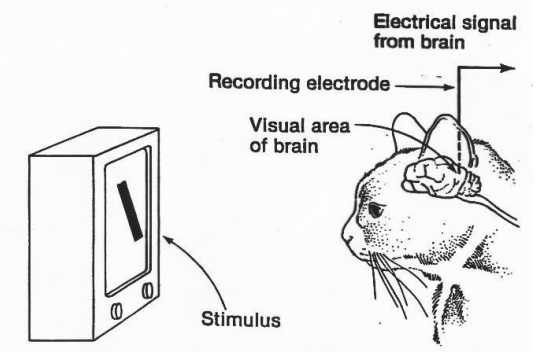
Techniques to study brain functioning

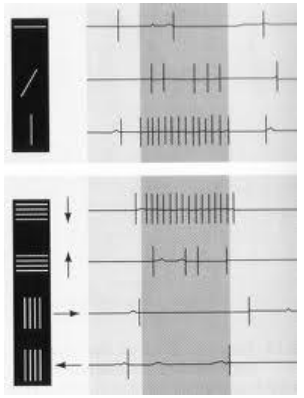


Single-Unit Recordings

Technique

- Micro-electrode inserted into the brain
- Records activity from a (set of) single neurons
- Example:
  - Hubel and Wiesel (1969; 1972) primary visual cortex
- Extraordinarily high temporal and spatial resolution





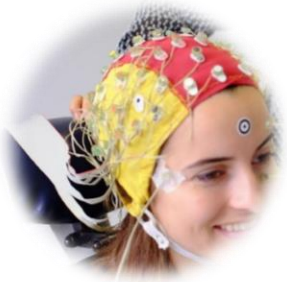
Single-Unit Recordings

Limitations

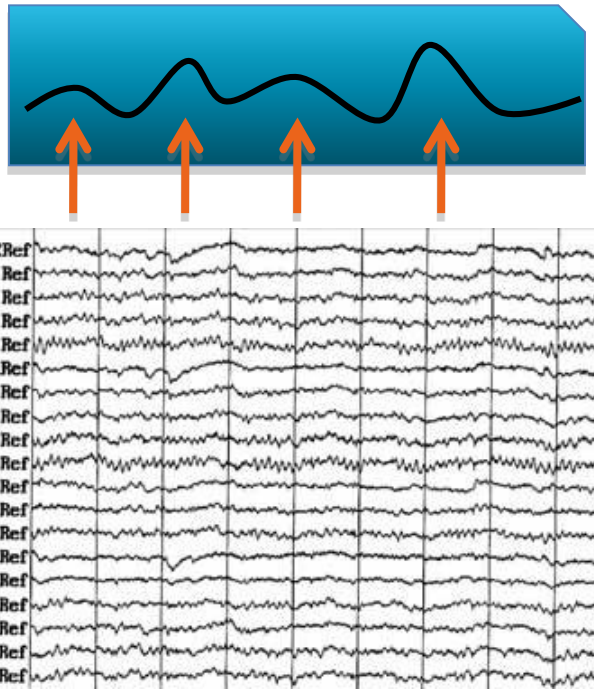
- Highly invasive
  - Requires surgery
  - Damages cells along the electrode's path
- Expensive
- Many higher cognitive activities involve far larger populations of neurons that aren't in the domain of this technique

Event Related Potentials (ERPs)

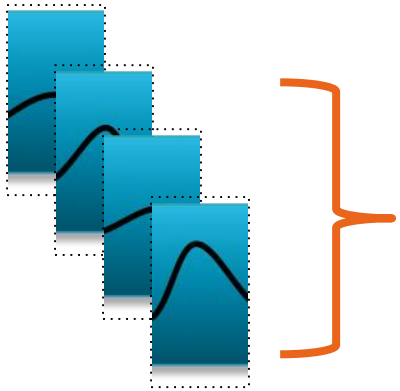
1) Electrical activity on the scalp is recorded during repeated events, stimulus onset marked



Continuous EEG



2) The brain waves are then segmented and averaged

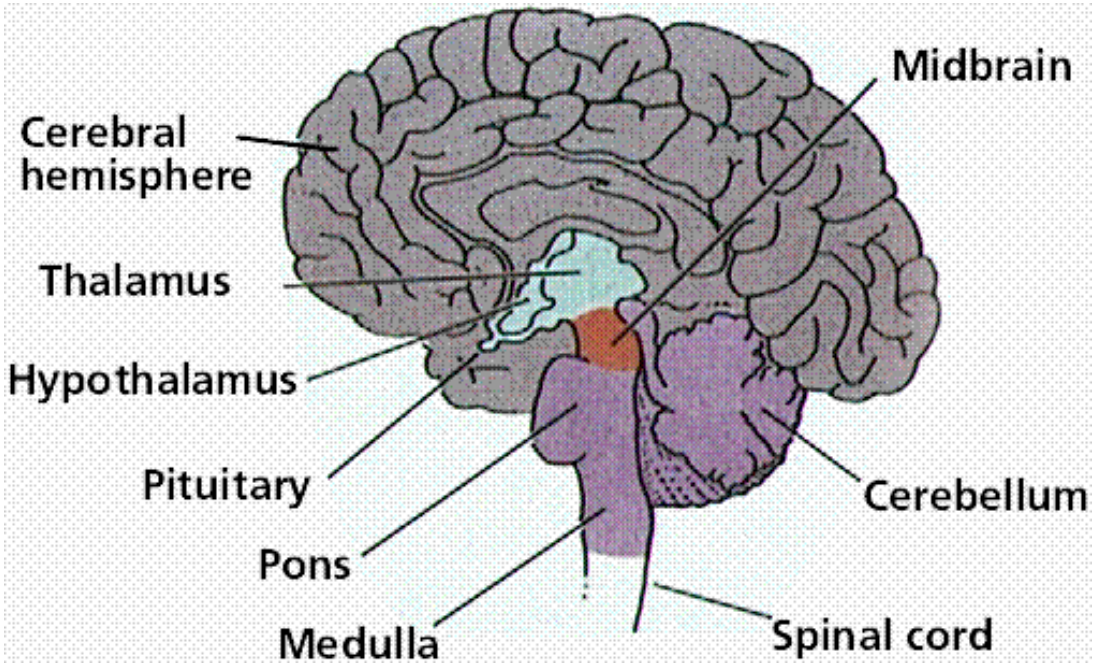


Averaged ERP component

Event Related Potentials (ERPs)

Limitations

- Limited spatial resolution, but high temporal resolution
- Requires many trials
- Skull and brain tissue distort electrical fields
- Largely blind to subcortical activity


Midbrain
Cerebral hemisphere
Thalamus
Hypothalamus
Pituitary
Cerebellum
Pons
Medulla
Spinal cord

Magneto-Encephalography (MEG)

Technique

– Measures the magnetic fields produced by the brain's electrical activity

– Provides high temporal resolution and moderate spatial resolution (better spatial resolution than EEG)

– ((right thumb rule: an electric current in direction of right thumb induces a magnetic field "in direction" of the other fingers))

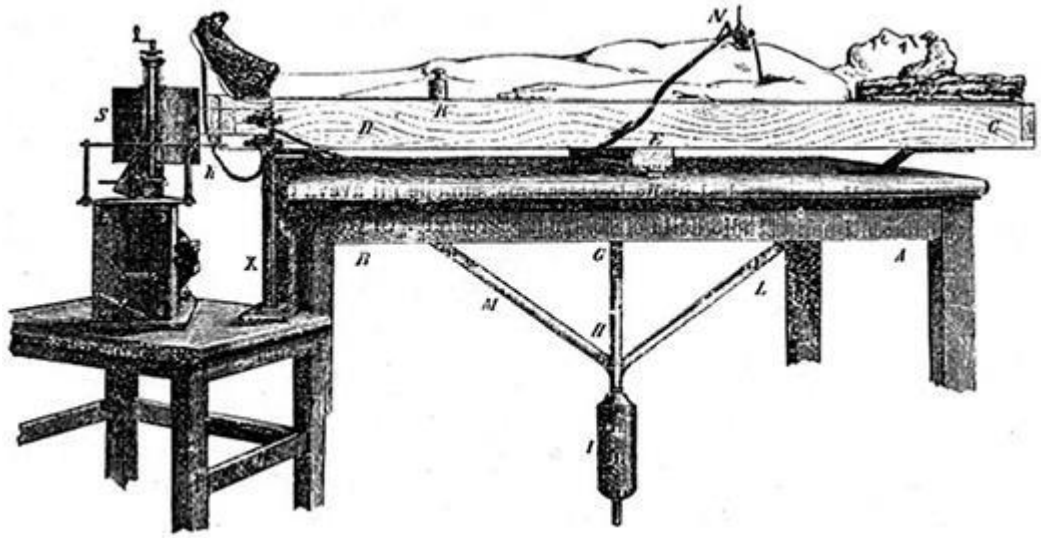
Limitations

– Expensive

– Requires the participant to maintain a potentially uncomfortable body position for long durations

Functional Magnetic Resonance Imaging (fMRI)

Mosso's balance



Angelo Mosso (1846-1910)

Functional Magnetic Resonance Imaging (fMRI)

- fMRI provides a non-invasive, indirect measure of ~*brain activity*

- Event-Related fMRI:
  - Blood (hemoglobin) carries oxygen (O2)
  - More O2 uptake in active regions of the brain
  - Compare O2 uptake for different tasks in different regions of the brain
  - Classical fMRI approach: compare O2 uptake for, e.g., two experimental tasks
  - similar to Donders´ subtraction method

Functional Magnetic Resonance Imaging (fMRI)

Limitations

– More expensive than EEG
– Poor temporal resolution (6−8s)
– Provides only an indirect measure of brain activity
– Noise from the scanner can be distracting
– May be uncomfortable
– Participants must remain still, limiting response types and experiment duration

Techniques to study brain functioning

EEG

(electroencephalography)

- event-related potentials
- oscillations

\+ high temporal resolution, relatively 'cheap'

- requires many trials, largely blind to subcortical activity

MEG

(magnetoencephalography)

- event-related fields
- oscillations

\+ high temporal resolution, good spatial resolution

- expensive, participant cannot move, cannot have a dental wire

fMRI (functional magnetic resonance imaging)

- haemodynamic response
- (blood oxygenation)

\+ excellent spatial resolution

- poor temporal resolution, expensive

TMS (transcranial magnetic stimulation)

- depolarization or hyperpolarization in the neurons of the brain

\+ might show causal involvement of brain areas in process

- Sometimes uncomfortable for participant

The trade-off between temporal and spatial resolution

- High temporal resolution (e.g., EEG, MEG) goes with low spatial resolution
- High spatial resolution (fMRI) goes with low temporal resolution
  - spatial resolution: in which area / part of the brain
  - temporal resolution: when in time (e.g., after stimulus onset)

Cognitive neuroscience: evaluation

+ Great variety of techniques offering excellent temporal or spatial resolution
+ Some techniques allow for causal inferences (e.g. TMS)
+ Rich data permit assessment of integrated brain processing as well as specialised functioning
+ Resolution of complex theoretical issues

Cognitive neuroscience: evaluation

- Functional neuroimaging techniques provide correlational data
- Most studies are underpowered and there are a lot of false positives
- Brain functioning is very complex
- Difficulty in relating brain activity to psychological processes
- Much over-interpretation of data involving reverse inferencing

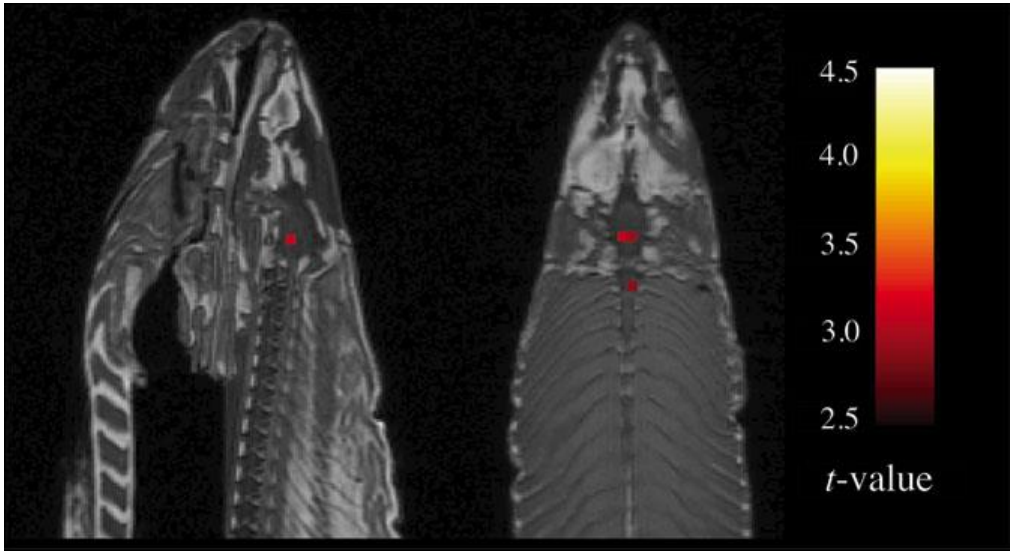
Much overinterpretation

METHODS

Subject. One mature Atlantic Salmon (Salmo salar) participated in the fMRI study. The salmon was approximately 18 inches long, weighed 3.8 lbs, and was not alive at the time of scanning.

Task. The task administered to the salmon involved completing an open-ended mentalizing task. The salmon was shown a series of photographs depicting human individuals in social situations with a specified emotional valence. The salmon was asked to determine what emotion the individual in the photo must have been experiencing.

Design. Stimuli were presented in a block design with each photo presented for 10 seconds followed by 12 seconds of rest. A total of 15 photos were displayed. Total scan time was 5.5 minutes.


4.5
4.0
3.5
3.0
2.5
t-value

Next week

- Approaches to studying cognitive processes
  - Cognitive psychology
  - Cognitive neuroscience
  - **Cognitive neuropsychology**
  - **Computational cognitive science**