Introduction to Quantitative Research Methods

A crash course

Outline

- Operationalisation of scientific hypotheses
- Experimental variables
  - Dependent and independent
- Experiment design
  - Within, between, mixed factorial designs
- Data analysis example
  - ANOVA for comparison of means
  - demos

General scientific hypotheses

- Language and action bootstrap cognition
- Embodiment is essential to understand cognition
- Infants have social skills from birth
- Marie Curie ITNs produce better researchers
- The RobotDoc Fellows will become the future leaders in the field of developmental robotics

From general to specific hypothesis (operationalisation)

- The RobotDoc Fellows will become the future leaders in the field of developmental robotics
  - The **membership** of the RobotDoc network will enhance the career perspective of fellows
    - The **participation** to the RobotDoc training workshops will **shorten the time to get a postdoc**
    - The participation to the RobotDoc training workshops will shorten the **time** to get a **permanent position**
    - The participation to the RobotDoc training workshops will result in above average **number of publications**
    - The participation to the RobotDoc training workshops will result in above average **quality of research (journal impact factor)**
    - The participation to the RobotDoc training workshops will result in above average **quality of research (publication citation count)**
    - The participation to the RobotDoc training workshops will result in above average **quality of research (grant income)**
    - The participation to the RobotDoc training workshops will result in researchers with above average academic/industrial **salaries**

From general to specific hypothesis (operationalisation)

- Language and action bootstrap cognition
  - The parallel development of action and language skills improves hierarchical planning capabilities
  - The grounding of language in sensorimotor knowledge bootstraps syntax development
    - The **motor learning** of primitive and hierarchies **speeds up** the acquisition of compositional syntax rule
      - Motor learning = action training vs no action training (control)
      - Syntax performance speeds up (shorter time, lower error, more rules)

Operational Definition

- Operational definition
  - The definition of a general or abstract concept in a **measurable and quantifiable** way (= **variable**)

- **Intelligence** =
  - QI, Memory span test, Non-verbal reasoning
  - Degree qualification grade
  - Number of successful PhD students ☺
- Robot's **language** acquisition =
  - Comprehension test scores (number words or rules, success %, recognition speed...
  - Production, lexicon size, errors,

Experimental variables

- Three different types of variables
  - Independent variables (= factors)
  - Dependent variables
  - Random variables
- Two ways of treating variables
  - Between subject
  - Within subject

Independent Variables (Factors)

- An independent variables (aka factor) is a variable that the **researcher manipulates**

- Typically, they vary between 2 and 5 (levels)
  - Sex (2 levels: M/F)
  - Age (young/old) (12m, 18m, 24m...)
  - Experimental group (2+ levels: control/experimental)
  - Training length (1hour, 2hours, 3hours...)
  - Robot type (1=icub, 2=ecce, 3=asimo ...)

Independent Variables: Treatment

- Treatment of independent variables
  - **Between-subject**: when you compare different conditions in different individuals (subjects)
    - Sex (2 levels: M/F)
    - Age (young/old)
    - Experimental group (e.g. learning effect)
    - Training length (1hour, 2hours, 3hours...)
  - **Within-subject**: When you compare different conditions in the same individual (subject) - aka **repeated measures**
    - Age (12m, 18m, 24m...)
    - Experimental group (e.g. no learning effect)
    - Robot type (1=icub, 2=ecce, 3=asimo ...)

Random variables

- An independent variables that the **researcher does not control directly**, but needs to be considered in the experiment
  - Not considered in the design, but needs to be aware of
    - M/F: choose only female participants ... if you think that sex might possibly influence your experiment but you cannot easily find a balance of F/M participants
    - Random assignment to groups

Dependent variables

- An variable that the **researcher measures** during the experiment
  - Any quantifiable measure of performance
  - Number of errors
  - Learning success (percentage, points....)
  - Intelligence/QI
  - Number of words learned
  - Memory span
  - Results in test
  - ....

Experimental Design (Factorial)

- The exact definition of the **different experimental conditions** due to the cross/combination of the independent variables (factors)
- Design types
  - One-way between-subject
  - One-way (repeated) within-subject
  - Factorial full between-subject
  - Factorial full within-subject (repeated measures only)
  - Factorial mixed design (some within, some between)

One-Way Between-Subject Design

- One between-subject independent variables
  - ROBOT type with 3 levels (icub, ecce, asimo) – *between*
- Two dependent variables
  - understanding test score, production test score
- Factorial design: 3 (one-way)

	score
Icub	Mean of understanding score
Ecce	Mean of understanding score
asimo	Mean of understanding score

	score
Icub	Mean of production score
Ecce	Mean of production score
Asimo	Mean of production score

One-Way Within-Subject Design

- One repeated independent variables
  - AGE of robot with 3 levels (1month, 2m, 3m) - *within*
- Two dependent variables
  - understanding test score, production test score
- Factorial design: 3 (one-way)

	score
1-month old	Mean of understanding score
2-month old	Mean of understanding score
3-month-old	Mean of understanding score

	score
1-month old	Mean of production score
2-month old	Mean of production score
3-month old	Mean of production score

Factorial Full Between-Subject Design

- Two between-subject independent variables
  - ROBOT type with 2 levels (icub, ecce) - *between*
  - TRAINING experience with 2 levels (no-training, training) - *between*
- One dependent variable: test score
- Factorial design: 2 x 2

	No-training	Training
icub	Mean of test score	Mean of test score
ecce	Mean of test score	Mean of test score

Factorial Full Within-Subject Design

- Two repeated independent variables
  - AGE of robot with 3 levels (1month, 2m, 3m) - *within*
  - TRAINING experience with 2 levels (pre, post) - *within*
- One dependent variable: test score
- Factorial design: 3 x 2

	1 month old	2 month old	3 month old
Pre	Mean of test score	Mean of test score	Mean of test score
Post	Mean of test score	Mean of test score	Mean of test score

Mixed Design

- Two independent variables
  - ROBOT type with 3 levels (icub, ecce, asimo) - *between*
  - TRAINING experience with 2 levels (pre, post) - *within*
- One dependent variable: test score
- Factorial design: 3 x 2

	Pre-training	Post-taining
icub	Mean of test score	Mean of test score
ecce	Mean of test score	Mean of test score
asimo	Mean of test score	Mean of test score

Analysis of results: Comparison of means with ANOVA

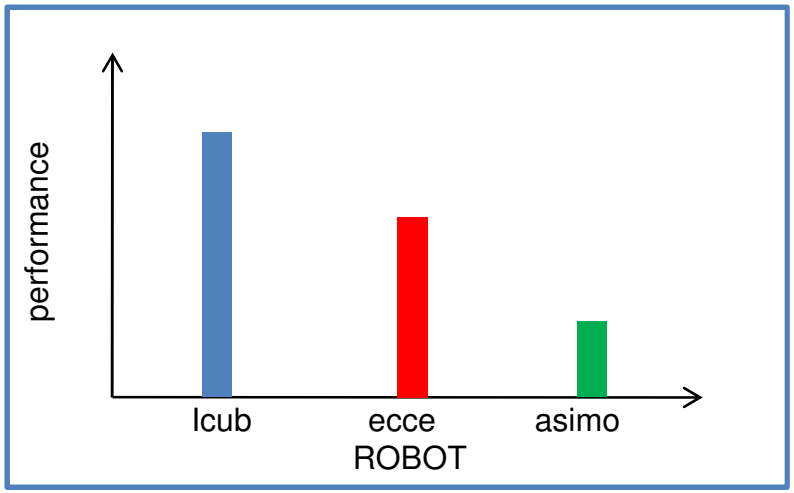
- ANOVA: ANalysis Of Variance
  - Statistical comparison of means in different conditions
- Main factors
  - Compare ROBOT's performance: icub vs ecce vs asimo
  - Compare TRAINING performance: pre vs post
- Interaction
  - Compare TRAINING x ROBOT interaction conditions

	Pre-training	Post-taining
icub	Mean of test score	Mean of test score
ecce	Mean of test score	Mean of test score
asimo	Mean of test score	Mean of test score

ANOVA DEMO: ONE WAY (BETWEEN)

- Independent variables
  - ROBOT type with 3 levels (icub, ecce, asimo) – *between*
- One-way design: 3

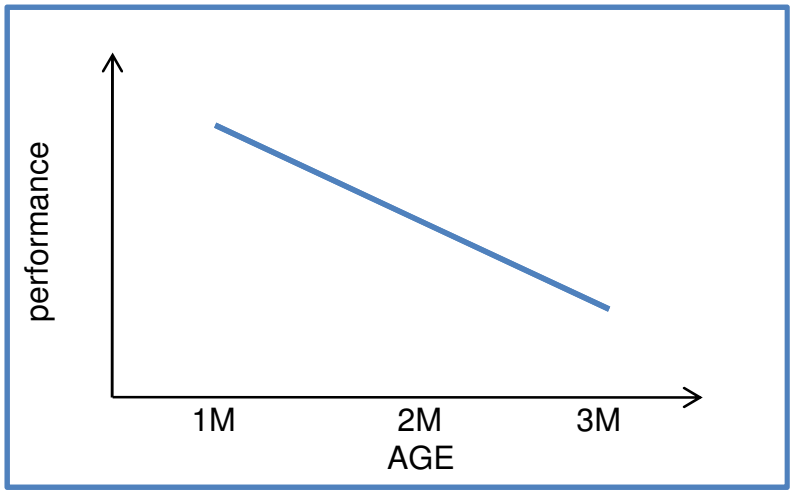
	score
Icub	Mean of understanding score
Ecce	Mean of understanding score
asimo	Mean of understanding score



ANOVA DEMO: ONE WAY (WITHIN)

- Repeated independent variables
  - ROBOT type with 3 levels (icub, ecce, asimo) – *between*
- One-way design: 3

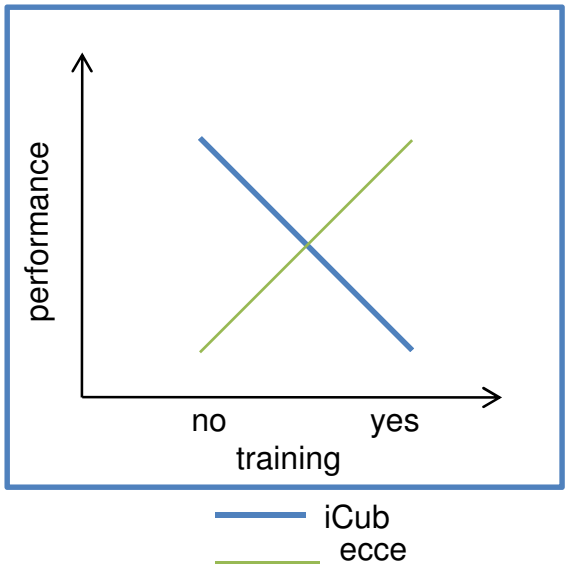
	score
1-month old	Mean of understanding score
2-month old	Mean of understanding score
3-month-old	Mean of understanding score



ANOVA DEMO: 2x2 BETWEEN

- Independent variables
  - ROBOT type with 2 levels (icub, ecce) - *between*
  - TRAINING experience with 2 levels (no-training, training) - *between*
- Factorial design: 2 x 2

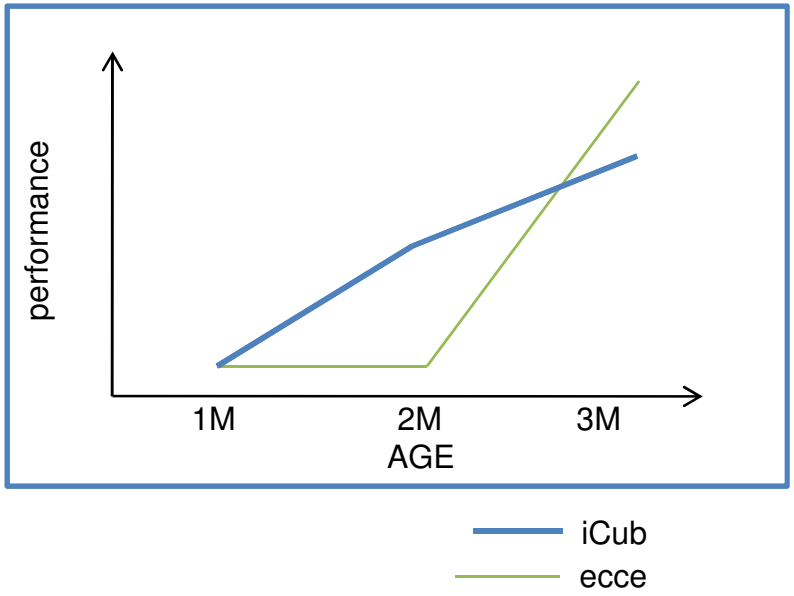
	No-training	Training
icub	Mean of test score	Mean of test score
ecce	Mean of test score	Mean of test score



ANOVA DEMO: 2x3 MIXED

- Independent variables
  - ROBOT type with 2 levels (icub, ecce) – *between*
  - AGE of robot with 3 levels (1M, 2M, 3M) – *within*
- Factorial design: 2 x 3

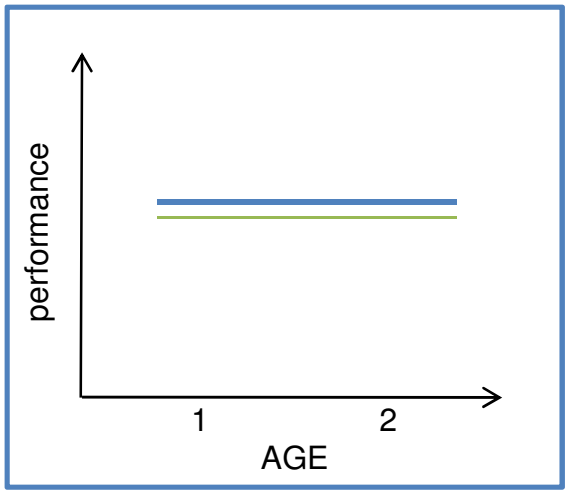
	1 month old	2 month old	3 month old
icub	Mean of test score	Mean of test score	Mean of test score
ecce	Mean of test score	Mean of test score	Mean of test score



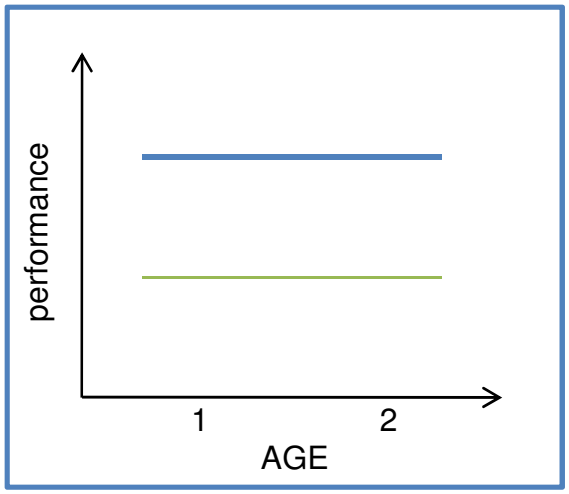
iCub

ecce

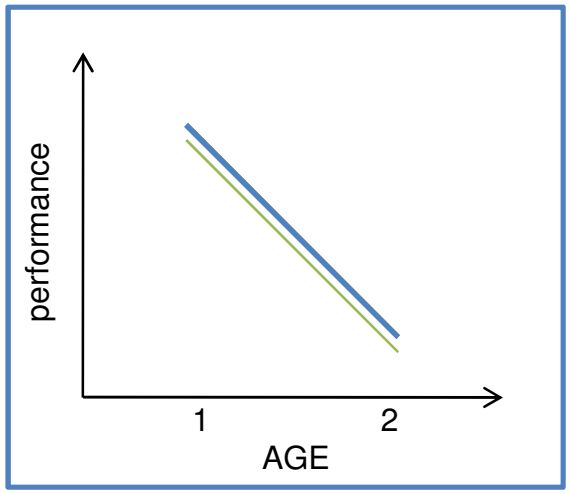
Overview of 2x2 **manova** results



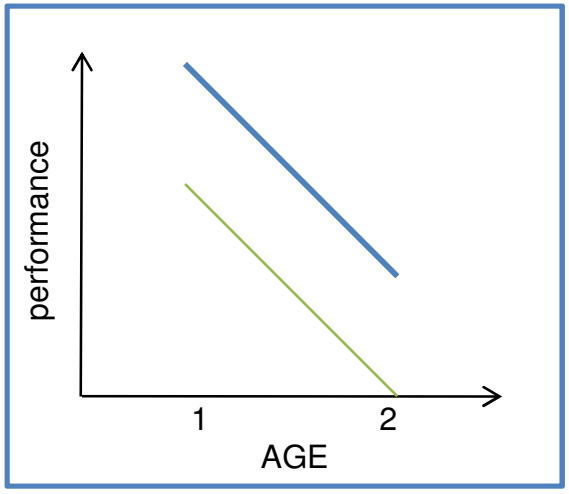
nothing significant



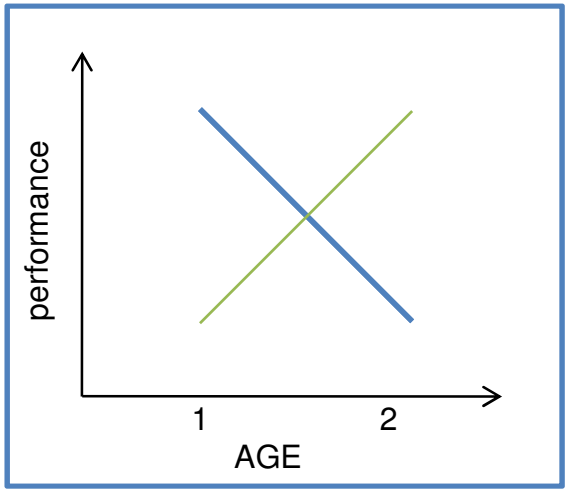
ROBOT significant

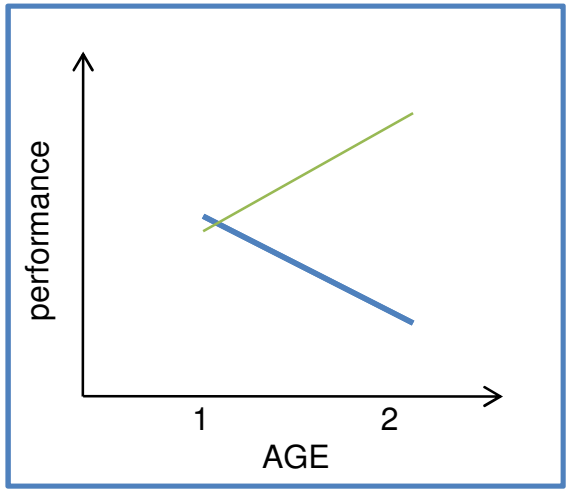


AGE significant



ROBOT , AGE significant



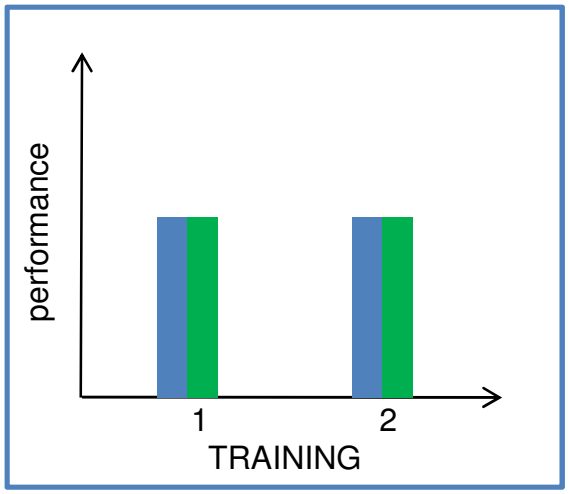


ROBOTxAGE significant interaction

iCub

ecce

Overview of 2x2 **anova** results



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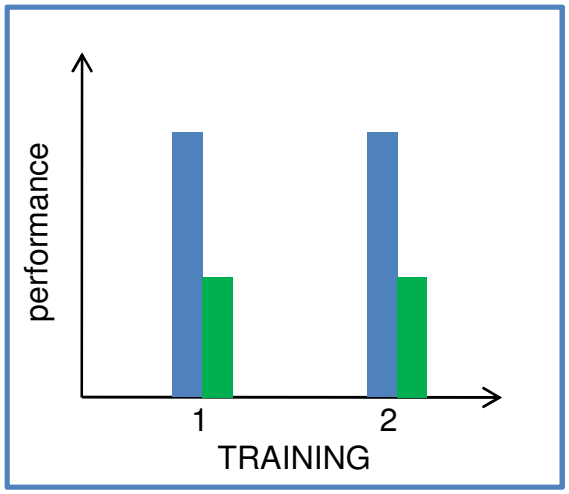
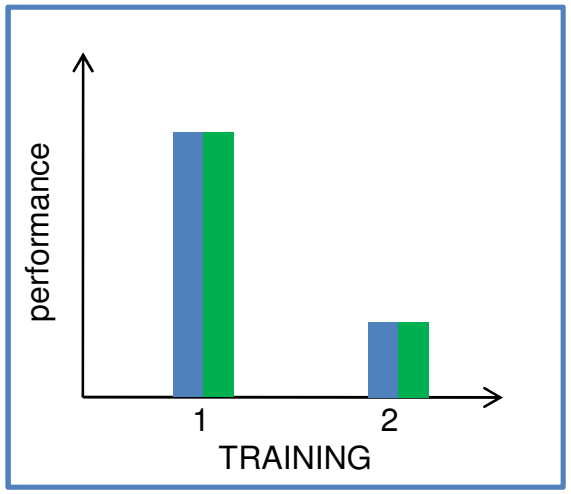
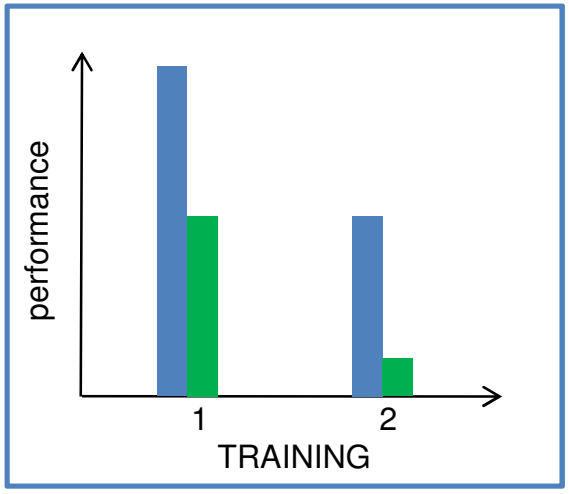


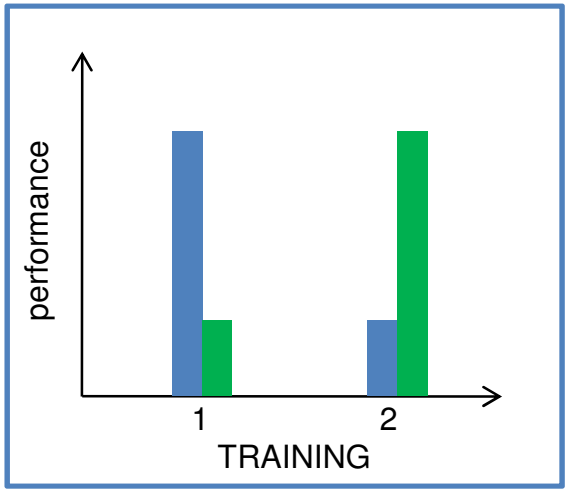
ROBOT significant

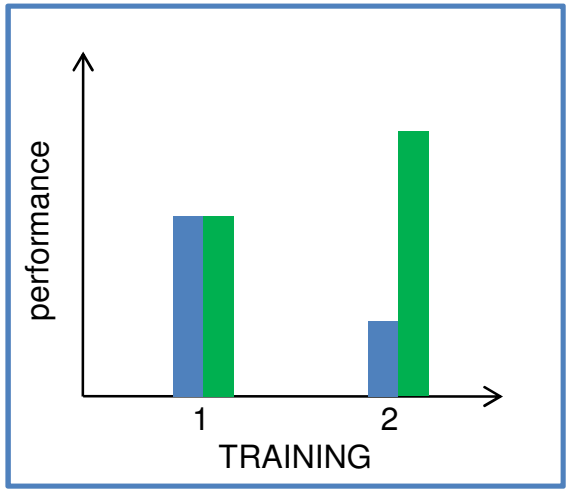


AGE significant



ROBOT , AGE significant





ROBOTxAGE significant interaction

More than just anovas

- T-test
  - Two compare 2 means only
    (equivalent to one-way anova with 2 levels)
- Correlations
  - Between many pairs of dependent variables
  - When the independent variables would have too many levels
- Chi square
  - To compare distribution of frequencies
- Factor analysis (ICA)
  - To reduce many (>>2) dependent variables to few (~2/3) combined factors
- ....

Take home message

- Plan experiment in advance
- Make explicit experimental design
- Always run pilot experiment(s)
- Read experimental literature to see which experimental designs are commonly used and which analysis methods
- Innovate literature tradition (with courage and caution)