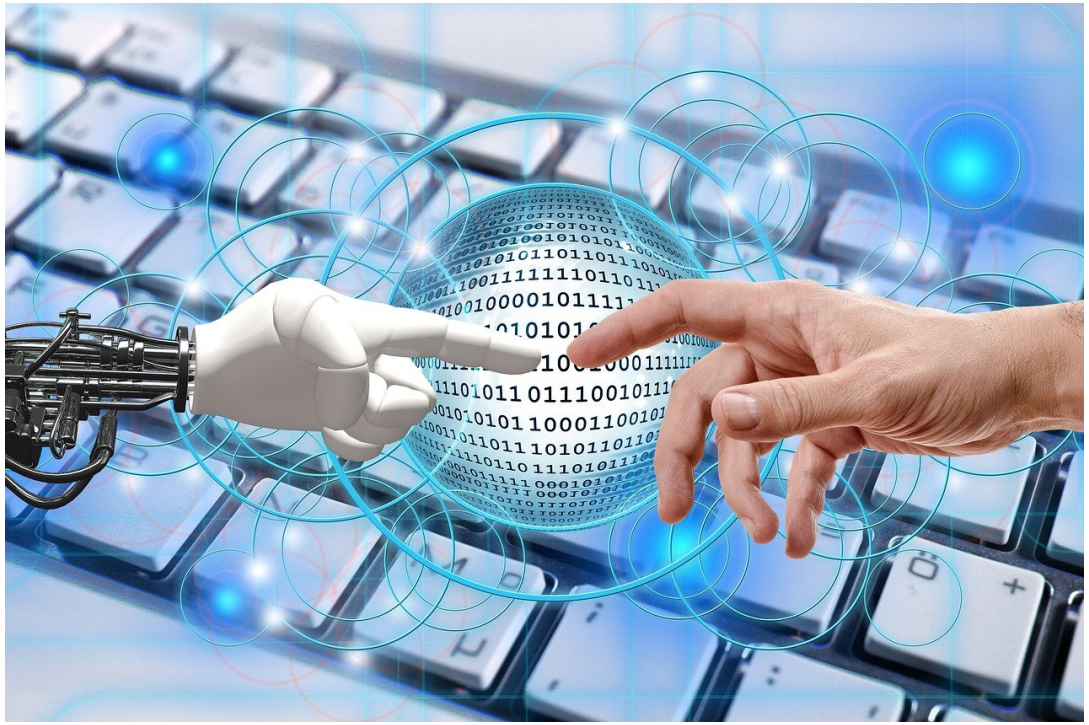
# Conducting Human-Robot Interaction Experiments



Prof. Dr. Teena Hassan
teena.hassan@h-brs.de

Department of Computer Science
Hochschule Bonn-Rhein-Sieg
Sankt Augustin

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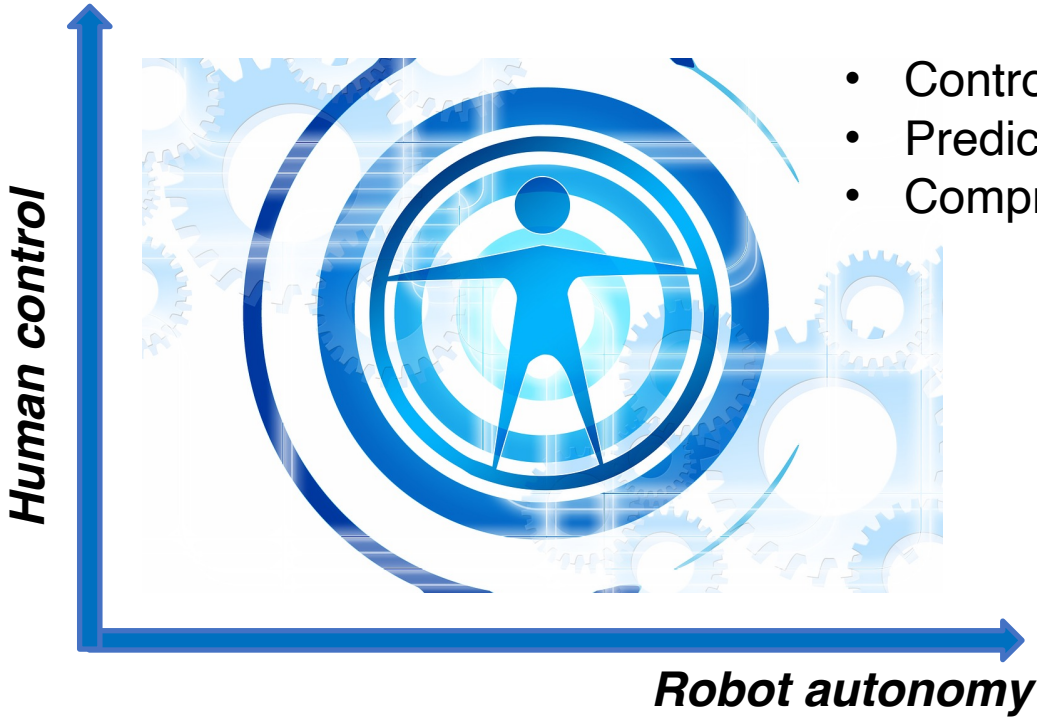
# Learning Goals

- At the end of today's lecture, you will be able to:
  1. Explain the **need for hypothesis-driven experimental research** in Human Robot Interaction (HRI).
  2. Describe the **stages** involved in hypothesis-driven experimental research.
  3. Illustrate with the help of an example, how **hypotheses are formulated** from research questions.
  4. Explain the **“full cycle”** of research.

# Recap: Human-Centered Robotics

- The human factor is crucial for the success of robotics.
- The human is now at the center of human-robot interaction.




- Controllable
- Predictable
- Comprehensible

Ben Shneiderman (2020) Human-Centered Artificial Intelligence: Reliable, Safe & Trustworthy, International Journal of Human–Computer Interaction.

- Not enough to build robots that work from a technical point of view.
- **Prove the impact of robots on the humans they are meant to serve.**
  - Through rigorous, reproducible experiments

# Hypothesis-driven Experiments in HRI

- Investigate and make inferences about the impact of robots on humans.
  - Which design is perceived as **safer** and **more trusted**?
  - Is a robot tutor **more effective** than a human tutor?
  - Are the emotions expressed by the robot **believable**?
  - Do the explanations given by the robot **improve understandability**?

Technical design

Human factor

# Primary Reference

- Guy Hoffman and Xuan Zhao. 2020. A Primer for Conducting Experiments in Human Robot Interaction ACM Trans. Hum. Robot Interact . 10, 1, Article 6 (October 2020), 31 pages https://doi.org/10.1145/3412374

- Your reading assignment for last week!

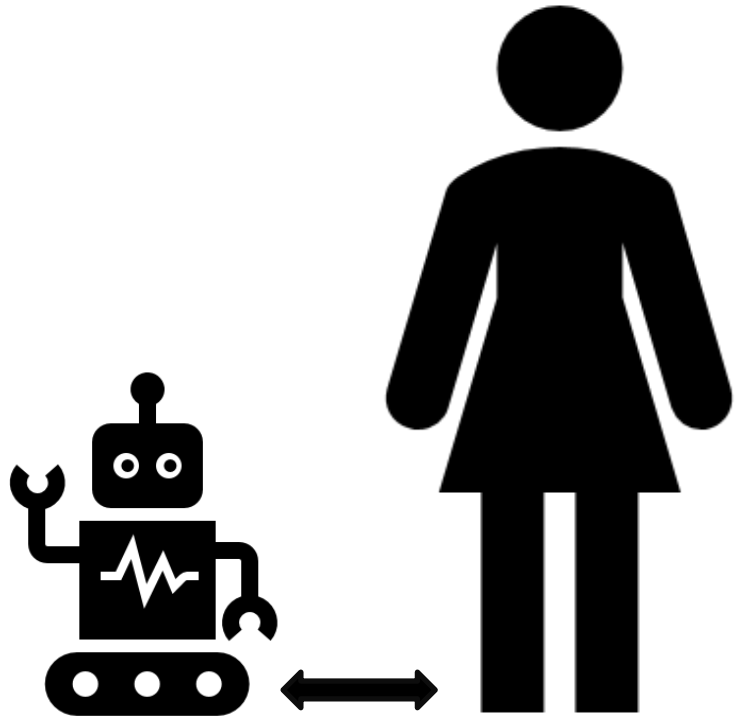
# HRI – An Example Scenario

- You have a robot that can walk alongside humans.

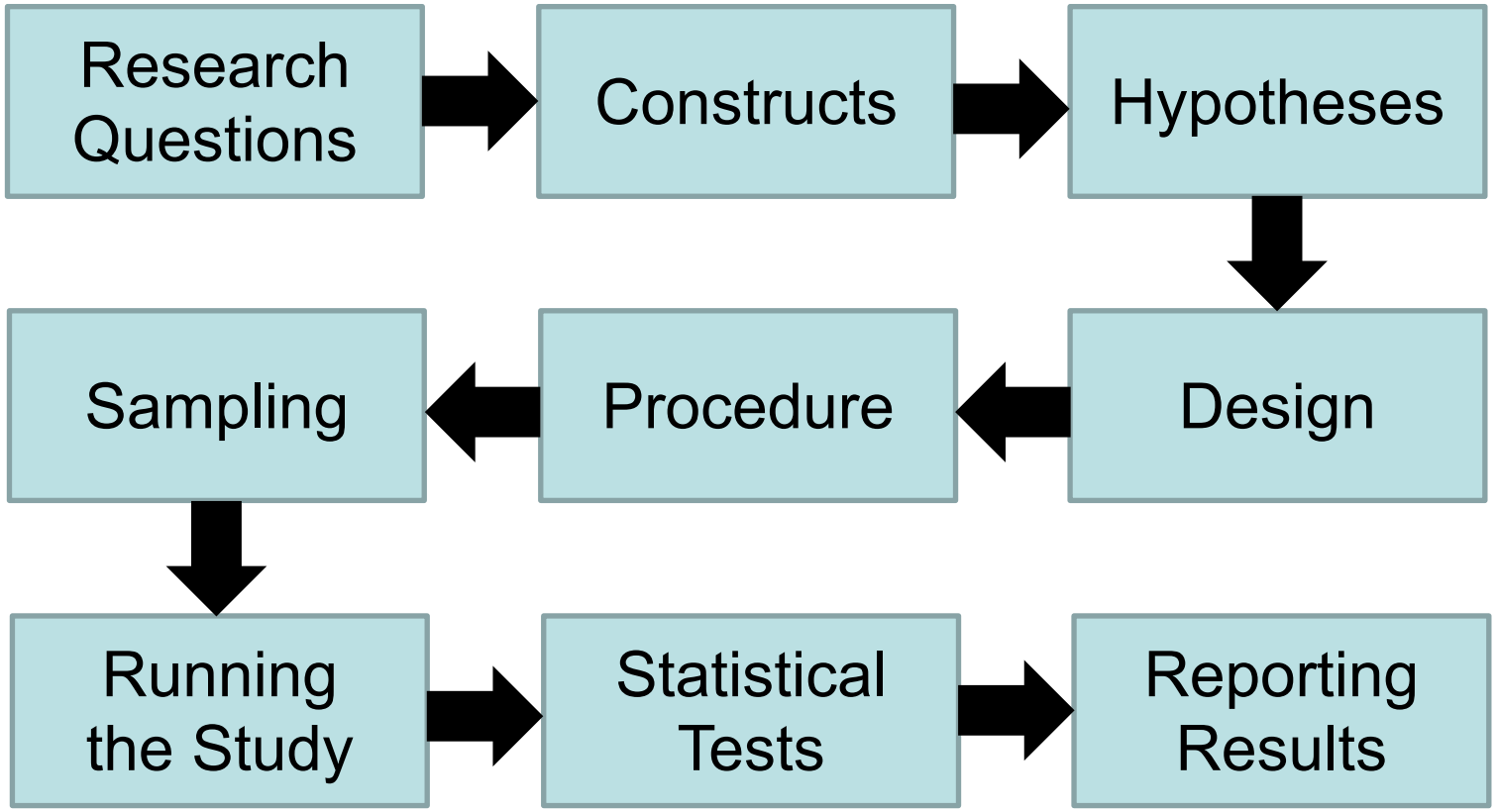
- Motivated by findings on how humans walk alongside humans:

  - A novel, human-aware, navigation algorithm that can **adapt the robot's path according to the movement patterns of the human**.

*Example from (Hoffman & Zhao, 2020)*



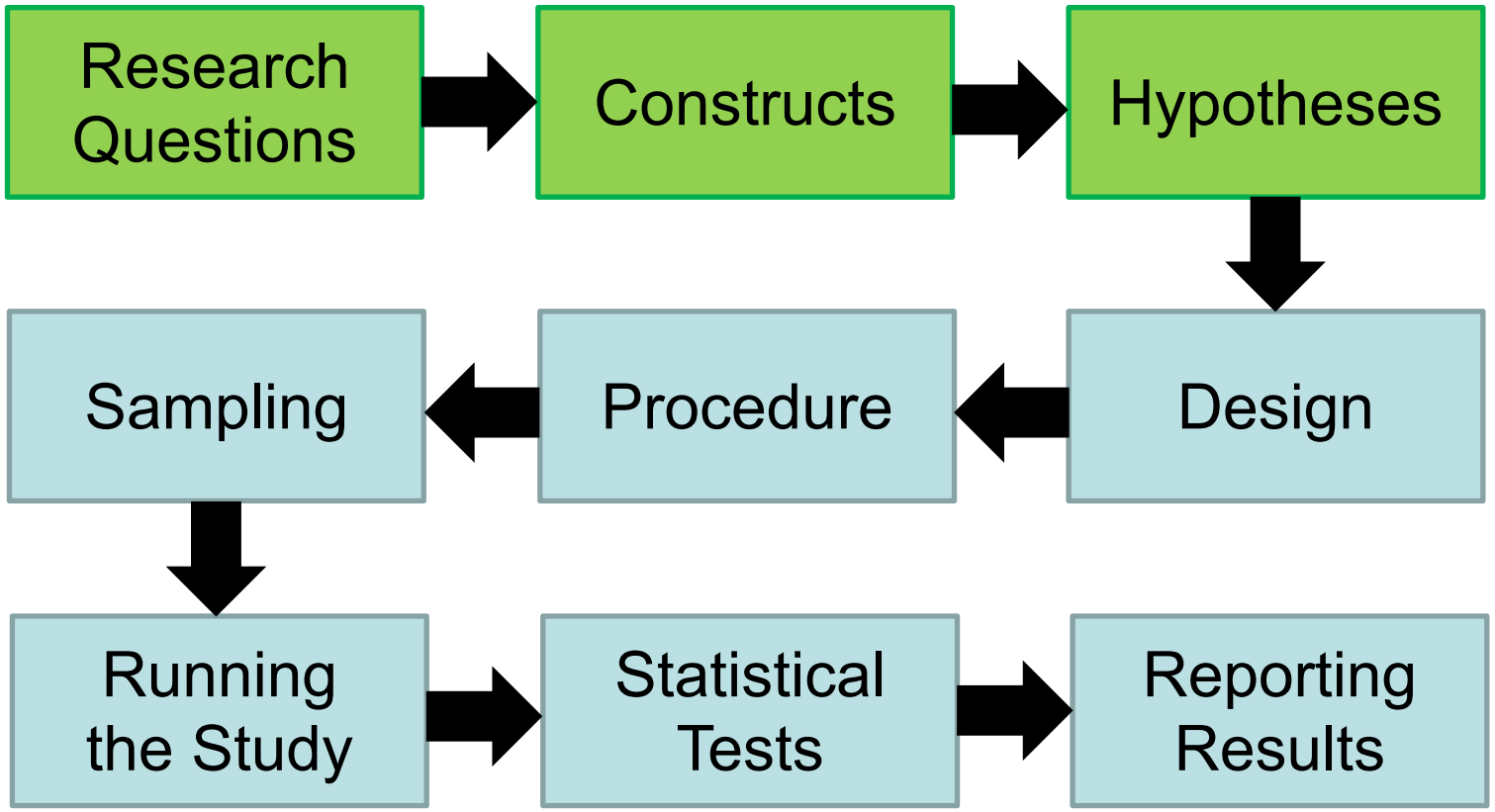
# Hypothesis-Driven Experimental Research




(Hoffman & Zhao, 2020)

RCHDPro SaRuStRe

# Hypothesis-Driven Experimental Research




(Hoffman & Zhao, 2020)

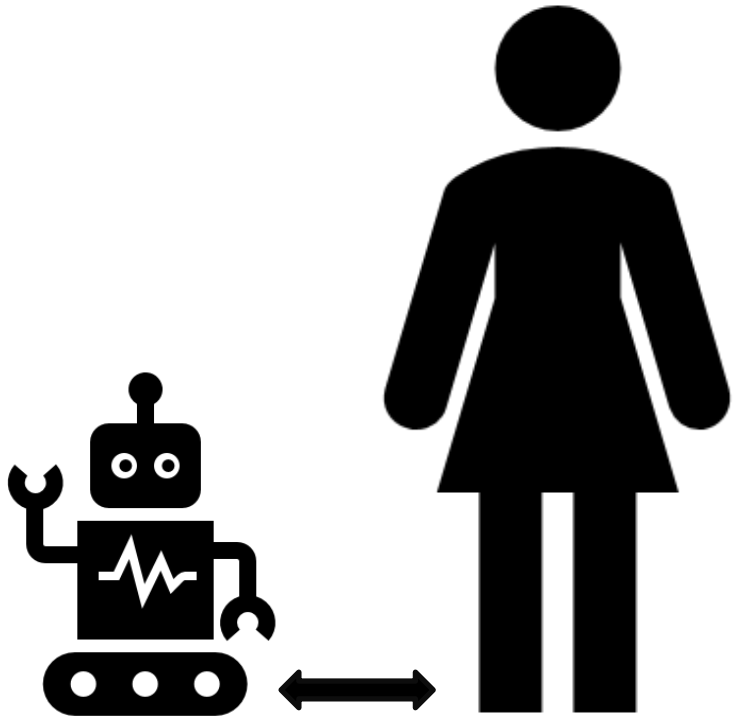
# Identify Research Questions

- **Define research questions** based on theoretical foundations, previous experiments.

- Research questions:
  1. "To what extent, if any, will a human-adaptive path algorithm make people **trust** the robot to accompany them? "

  2. "Do people feel **safe** walking with a robot running the new algorithm?"

*Example from (Hoffman & Zhao, 2020)*

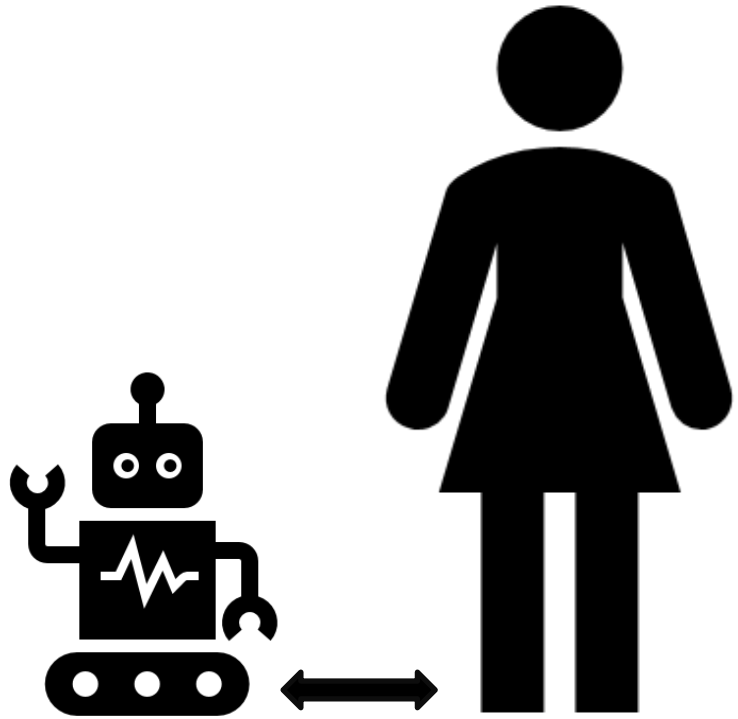


# Identify Constructs

- **Identify the constructs** (theoretical / abstract concepts) that are central to the research questions.

1. Human-adaptive movement of robot (C1)
2. Trust of human in the robot (C2)
3. Human's feeling of safety (C3)

(Hoffman & Zhao, 2020)



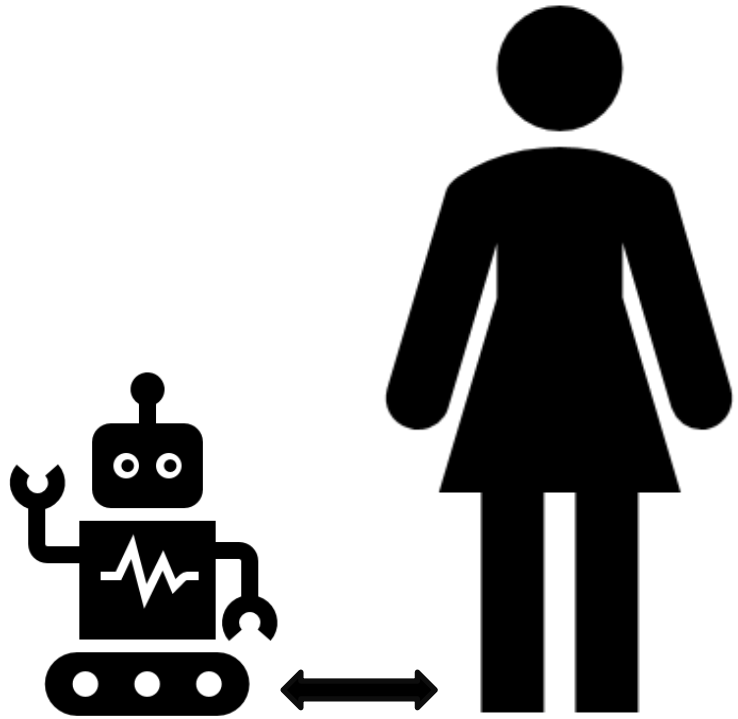
# Formulate Hypotheses

- Formulate hypotheses about the **relationship between constructs**.
  - Causal versus correlation

- Formulate hypotheses before running the study.
- Otherwise it is an exploratory study.

- Always compare against a baseline.

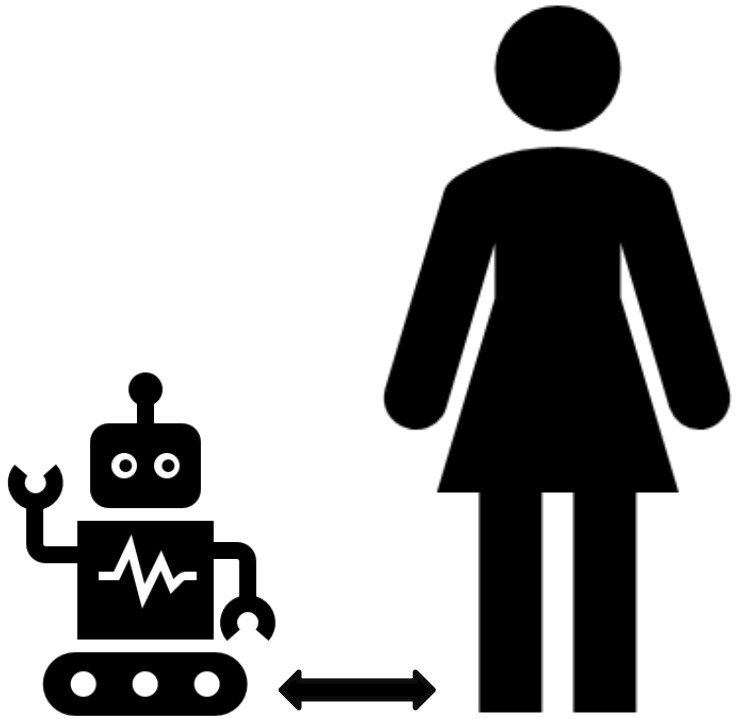
(Hoffman & Zhao, 2020)



# Formulate Hypotheses

- One example hypothesis:
  - H1: Links C1 and C2 causally.
    - Users trust (C2) the robot with the human-adaptive movement (C1) more than a robot that walks along a straight-line path to goal.

C1 is predictor (discrete).
C2 is outcome.



What is the baseline here?

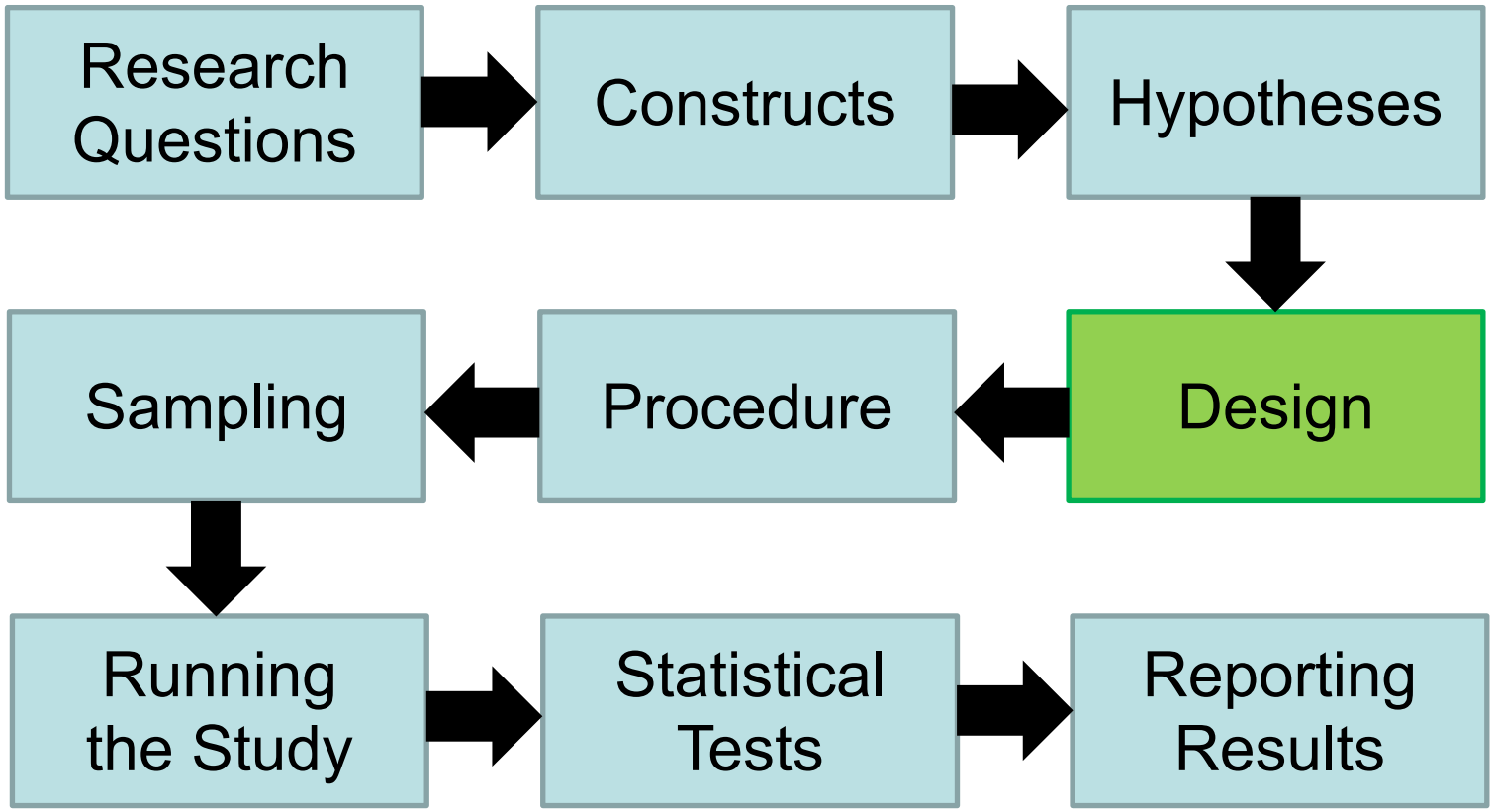
(Hoffman & Zhao, 2020)

# Higher-Order Relationships

- How and why?
  - Mediation analysis
  - Safety mediates trust?

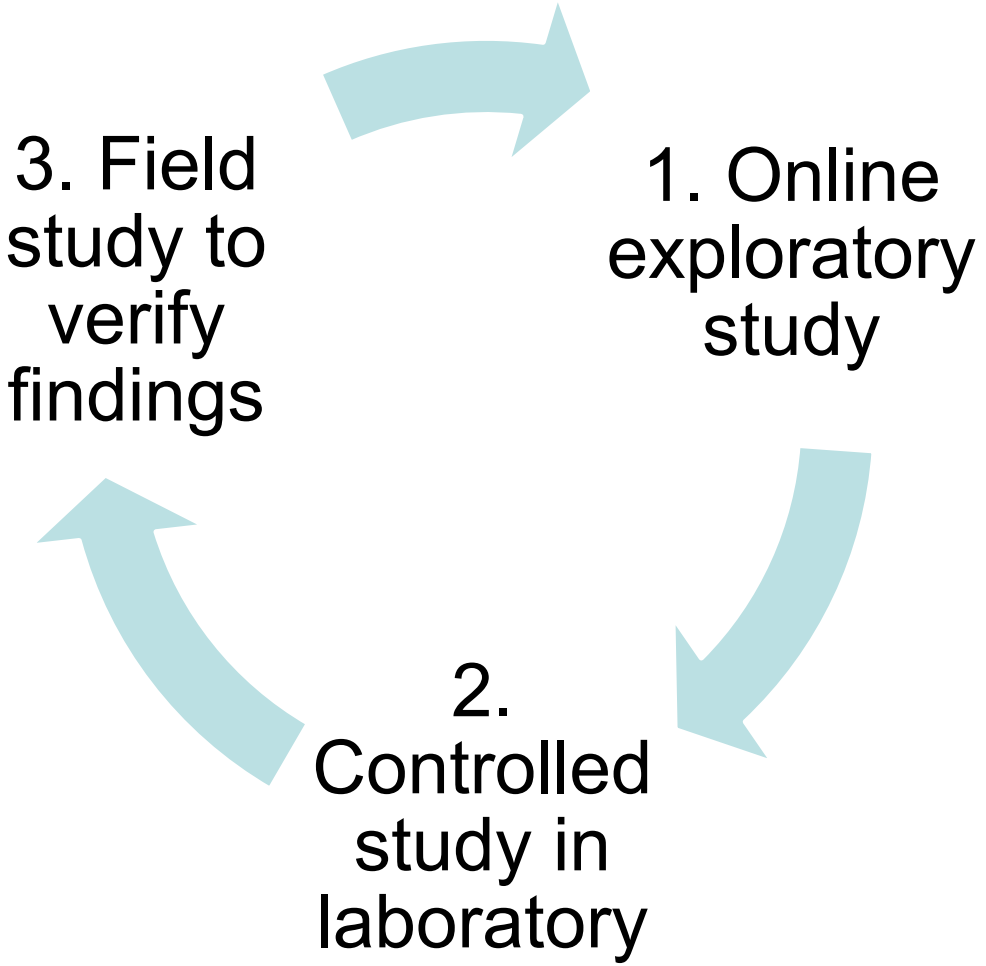
- For whom, when, where?
  - Moderation analysis
  - Dog ownership affects trust levels?

# Hypothesis-Driven Experimental Research




(Hoffman & Zhao, 2020)

# Designing Study: Full-Cycle Research




Chad R. Mortensen and Robert B. Cialdini. 2010. Full-cycle social psychology for theory and application. *Soc. Pers. Psychol. Compass* 4, 1 (2010), 53–63.

# Designing Study

| Field | Laboratory | Online |
|---|---|---|
| • Close to reality<br>• Good external and ecological validity | • Easy to control the variables<br>• Less influence of confounding variables | • Low cost<br>• Easy to find participants<br>• More diversity |
| • ~~Confounding~~ Unexpected variables affect the internal validity | • Ecological and external validity could be poor. | • Difficult to control environment<br>• Experience levels differ<br>• No real interaction possible |

# Designing Study

Operationalise constructs into variables that can be manipulated or measured.

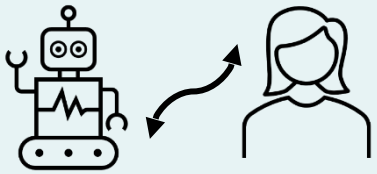
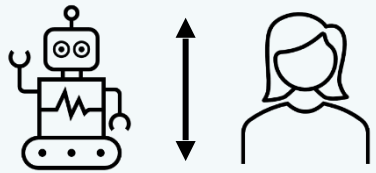
For H1:

1. Human-adaptive movement of robot (C1)
   - Conditions tested in the experiment
     → Independent variable

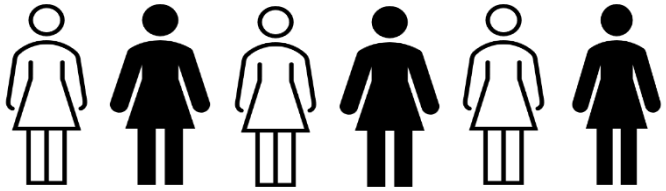
2. Trust of human in the robot (C2)
   - Subjective: Questionnaires
   - Objective: Behaviour
     → Dependent variables

# Designing Study

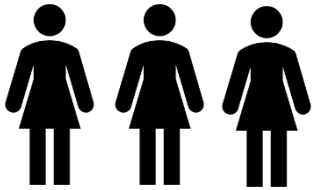
- How many conditions should each subject (samples from a population) be exposed to?

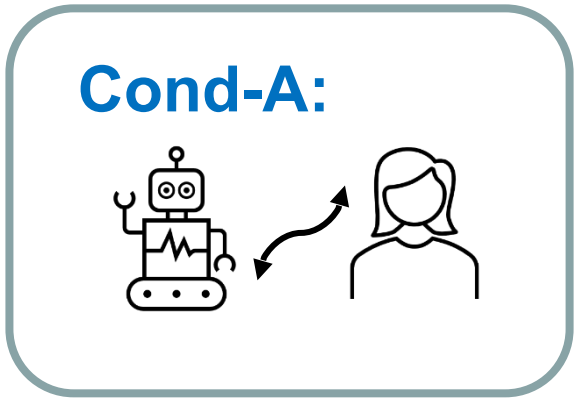
| Condition | Description | Icon |
|---|---|---|
| **Cond-A** | **Robot performs human-adaptive movement** |  |
| **Cond-B** | **Robot moves along straight-line path** |  |

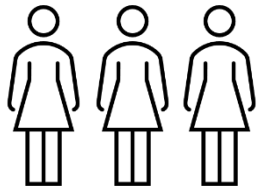
# Within-Subjects Design

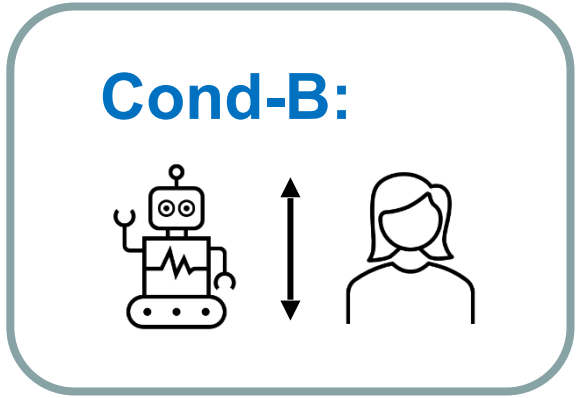



# Between-Subjects Design

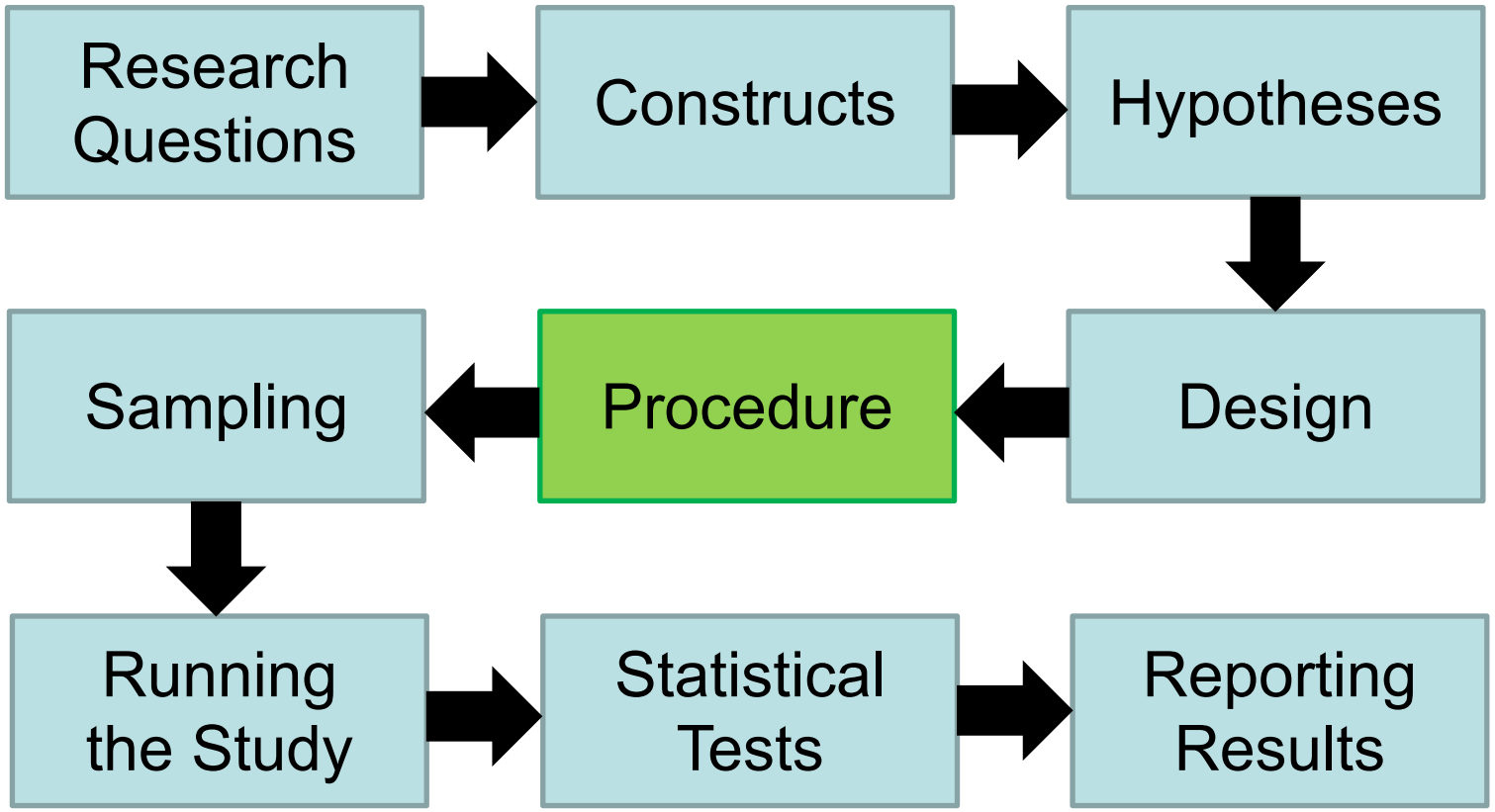






# Hypothesis-Driven Experimental Research




(Hoffman & Zhao, 2020)

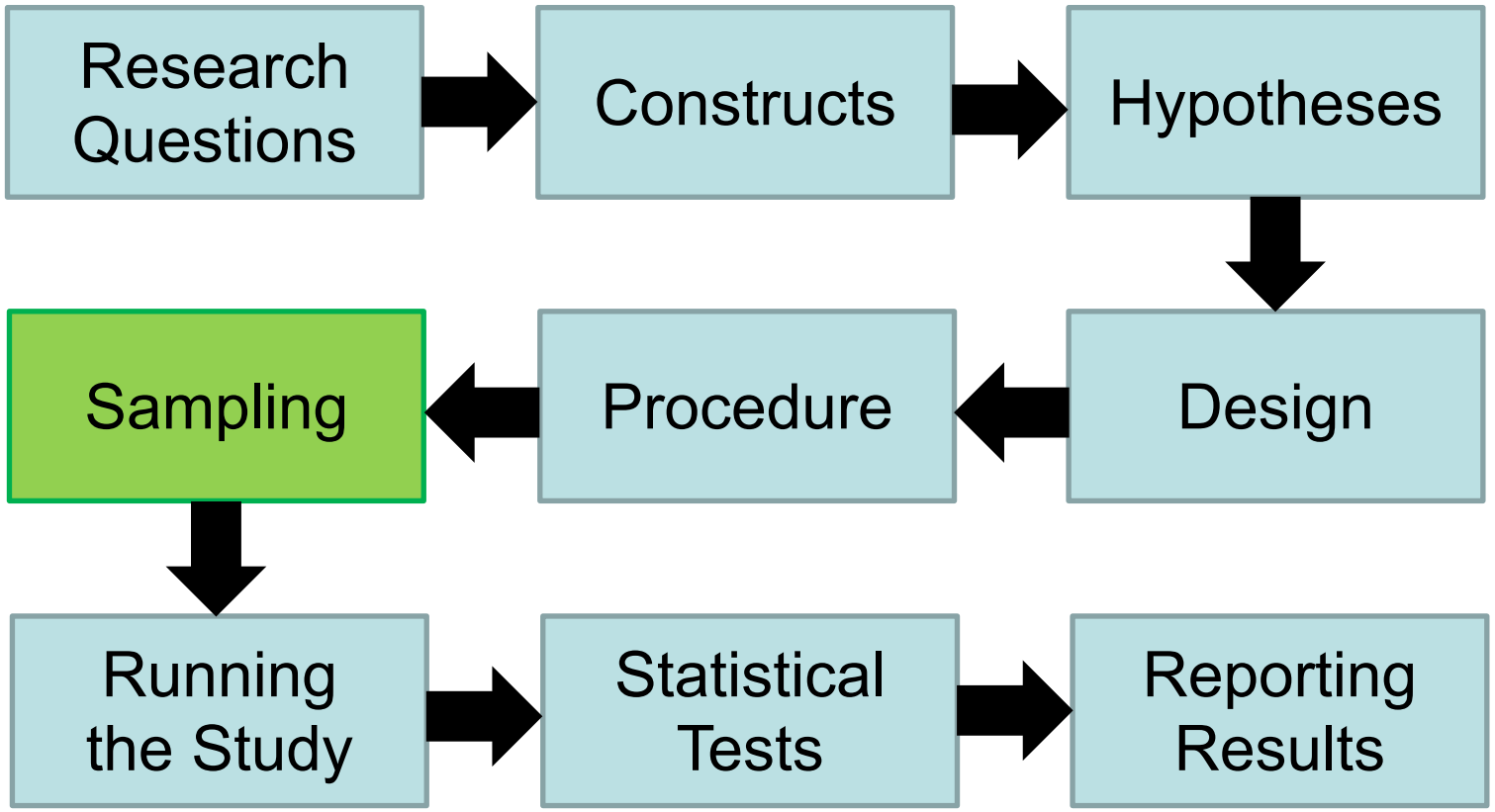
# Think-Pair-Share: 5 Mins

Let us look at the second research question:

"Do people feel **safe** walking with a robot running the new algorithm?"

1. Identify the constructs
2. Formulate a hypothesis
3. Operationalise the constructs
4. How would you design the study? Why?

# Hypothesis-Driven Experimental Research

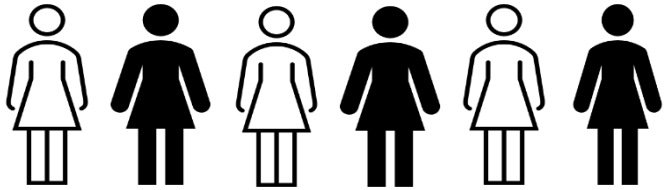



(Hoffman & Zhao, 2020)

# Make a Guess...

➢Which design would require more samples to achieve the same statistical power?

A. Within-subjects design

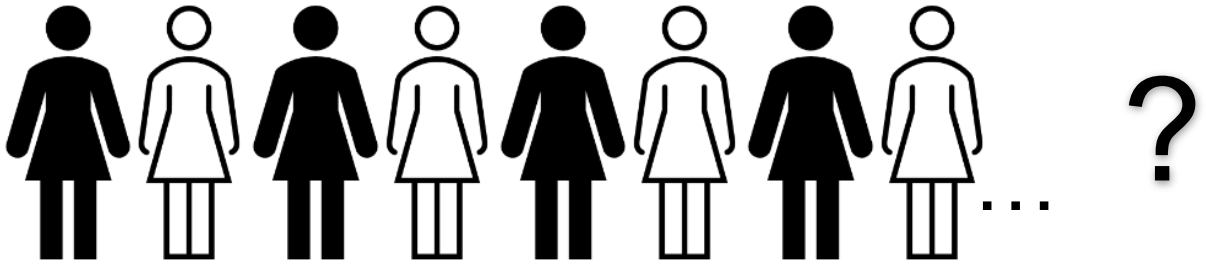


B. Between-subjects design

A ⟨ B

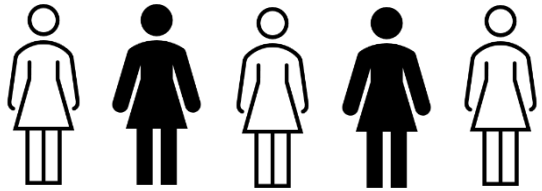
# How Many Samples are Enough?

- Very crucial question in empirical research.
- How many samples are needed to draw scientifically sound conclusions?



## Power Analysis

Simply put, a **statistically sound** method to determine **the sample size** and **power** of an experiment.



Sample size

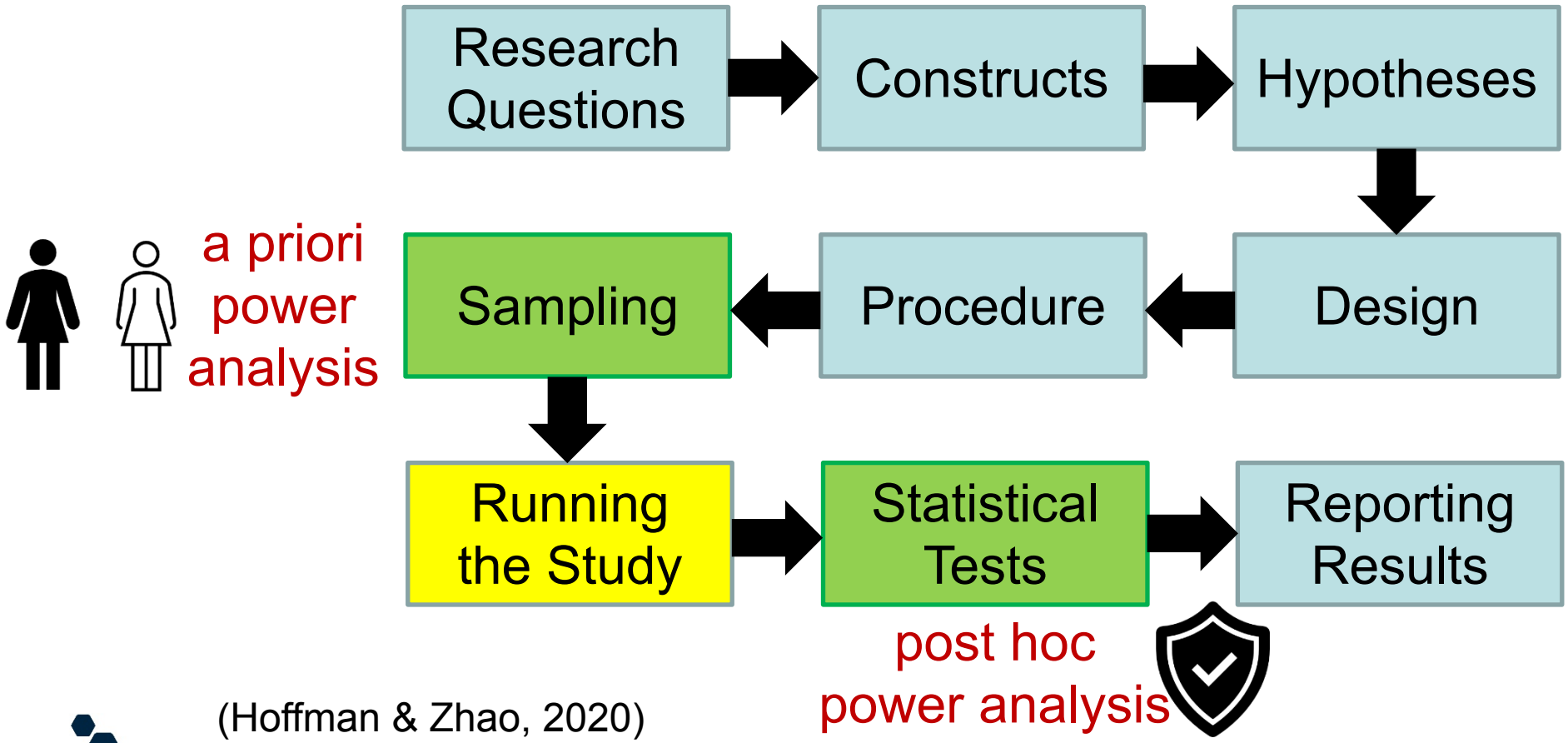
Power

# Why is Power Analysis Important in HRI?

- Humans are **unpredictable** and **exhibit variability** in their behavior.
  - Inter- and intrapersonal variability
- When we conduct an experiment:
  - How can we be sure that the **effects that we observed are meaningful** and not noise?
- **We should perform a priori and post hoc power analyses.**

(Bartlett et al., 2022)

# Hypothesis-driven Experimental Research




(Hoffman & Zhao, 2020)

# Think-Pair-Share: 20 Mins

In the state-of-the-art paper that you chose to read from the HRI conferences/journals, extract the following information:

Alternatively: Design an HRI experiment in the project that you are currently working on.

1. List the research question(s).
2. Identify the constructs.
3. Identify the hypothesis and explain how the constructs are linked in the hypothesis.
4. What is the baseline in the hypothesis?
5. How are the constructs operationalised?
6. How is the study designed?

# Conclusion

- In this lecture, you learned to:
  1. Explain the **need for hypothesis-driven experimental research** in Human Robot Interaction (HRI).
  2. Describe the **stages** involved in hypothesis-driven experimental research.
  3. Illustrate with the help of an example, how **hypotheses are formulated** from research questions.
  4. Explain the **“full cycle”** of research.

# References


- Guy Hoffman and Xuan Zhao. 2020. **A Primer for Conducting Experiments in Human–Robot Interaction**. ACM Trans. Hum.-Robot Interact. 10, 1, Article 6 (October 2020), 31 pages. https://doi.org/10.1145/3412374

- Madeleine E. Bartlett, C. E. R. Edmunds, Tony Belpaeme, and Serge Thill. 2022. **Have I Got the Power? Analysing and Reporting Statistical Power in HRI.** *J. Hum.-Robot Interact.* 11, 2, Article 16 (June 2022), 16 pages. https://doi.org/10.1145/3495246

- Chad R. Mortensen and Robert B. Cialdini. 2010. Full-cycle social psychology for theory and application. *Soc. Pers. Psychol. Compass* 4, 1 (2010), 53–63.

# Next Session

- Lecture on “Power Analysis" and “Introduction to Statistical Tests and Visualisations”
  - Thursday, 27.06.2024 at 9 am
  - In: B060, Grantham Allee 20, 53757 Sankt Augustin