QUANTITATIVE RESEARCH

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COURSE LEARNING OBJECTIVES

- The student is able to:
  - Independently find literature on a specific research topic and conduct systematic literature review
  - Identify qualitative and quantitative research approach and choose between them appropriately
  - Explain qualitative data collection and data analysis approaches
  - Explain quantitative data collection and data analysis approaches
  - Demonstrate ethical approach and research integrity in their own research
  - Identify common threats to quality of research and describe the validity and reliability of their own research
  - Present, both orally and in writing, the research process for a specific research topic, findings, and conclusion in a coherent and concise manner.
  - Write a scientific report covering a specific research topic using academic writing format and required content.

AGENDA

- Quantitative research methods
  - Survey
  - Experiment
- Quantitative data analysis
  - Descriptive statistics
  - Inferential statistics

QUANTITATIVE RESEARCH METHODS

TYPICAL QUANTITATIVE RESEARCH METHODS

- Survey
  - OBS! Survey can be qualitative
- Experiment

SURVEY

SURVEY

- A survey is “an organized method of obtaining data from research participants via **written**, **electronic**, and **oral questioning**, which can be **analyzed to reach conclusions** about the question being investigated within **a sample of the population**” (Buschbacher et al., 2014).
- A survey is not just an instrument for data collection, it is “a **comprehensive system** for collecting information to **describe, compare or explain knowledge, attitudes and behavior**.” (Pfleeger and Kitchenham, 2001).

Hammond, F., Malec, J., Nick, T. and Buschbacher, R. eds., 2014. Handbook for clinical research: design, statistics, and implementation. Demos Medical Publishing.
Pfleeger, S.L. and Kitchenham, B.A., 2001. Principles of survey research: part 1: turning lemons into lemonade. ACM SIGSOFT Software Engineering Notes, 26(6), pp.16-18.

TYPES OF SURVEY

- Supervised
  - The researcher administers the survey together with the participants.
  - Common with telephone survey.
  - Can be one-to-one or in a group.
- Semi-supervised survey
  - The researcher explained the purpose of the survey and work through some example questions, but let the participants provide the information themselves.
- Unsupervised
  - Most common type of survey (web-based, paper-based)
  - The participants answer the questions themselves.

Pfleeger, S.L. and Kitchenham, B.A., 2001. Principles of survey research: part 1: turning lemons into lemonade. ACM SIGSOFT Software Engineering Notes, 26(6), pp.16-18.

TARGET AUDIENCE & SAMPLING

- Target audience (population) - Who do you want to fill out your survey
  - In SE, you may want to focus on people who work with software development.
  - Sample, a representative set of the population
- Sampling approach
  - Probabilistic
    - Random
  - Non-probabilistic
    - Respondents are chosen by the researcher: Convenience, quota, snowballing.

UNIT OF OBSERVATION, UNIT OF ANALYSIS & SEARCH UNIT

- Unit of observation
  - The individuals whom you are interested to elicit information from (e.g., software developers)
- Unit of Analysis
  - The context that the individual is a part of (e.g., software projects that uses Agile).
- Search unit
  - Known group of people, professional forum (Google group, LinkedIn), open source projects
- See some examples from Linåker et al., (2015).

Study	Target Audience	Unit Of Analysis	Unit of Observation	Search Unit	Source of Sampling
[7]	Professionals from ICT companies that worked in finished software projects using OTS components	finished software projects using OTS components	professionals from ICT companies	ICT companies	Databases of ICT companies from Italy, Norway and Germany

J. Linåker, S.M. Sulaman, R. Maiani de Mello, and M. Höst. Guidelines for conducting surveys in software engineering. Technical report, Lund University, 2015.

DESIGN OF THE SURVEY INSTRUMENT

- You need to consider the following (Linåker et al., 2015):
  - Form a team
    - Two heads are better than one, minimise bias
  - Determine what to measure:
    - Descriptive - demographic questions
    - Behavioural - measure change in participants' behaviour
    - Attitudinal - respondents' attitudes and opinion
- Align survey questions with the objective and research question
  - Align the questions with RQs (see Nurdiani et al., 2018)

J. Linåker, S.M. Sulaman, R. Maiani de Mello, and M. Höst. Guidelines for conducting surveys in software engineering. Technical report, Lund University, 2015.
I. Nurdiani, J. Börstler, S. Fricker and K. Petersen, "Usage, Retention, and Abandonment of Agile Practices: A Survey and Interviews Results", In e-Informatica Software Engineering Journal, vol. 13, no. 1, pp. 7–35, 2019.

DESIGN OF THE SURVEY INSTRUMENT

- Questionnaire types
  - Supervised vs unsupervised vs semi-supervised
- Prioritised the important questions in the survey
- Survey question types
  - Closed-ended - participant are given fixed list of response.
  - Open-ended - participant answer the question in their own words

J. Linåker, S. M. Sulaman, R. Maiani de Mello, and M. Höst. Guidelines for conducting surveys in software engineering. Technical report, Lund University, 2015.

OPEN VS CLOSE ENDED QUESTIONS

- Open ended question
  - + Gives the opportunity of gaining richer data
  - - You may find participants who write gibberish.
- Close ended question
  - + More objective (measurable) answer
  - - Richness is limited

DESIGN OF THE SURVEY INSTRUMENT

- Execution method
  - Mail
  - Web-based questionnaire
  - Telephone
  - Face-to-face
- Questionnaire length
  - Keep it short and with minimum effort.
  - Participants should know their progress in completing the survey

RESPONSE RATE & MOTIVATION

- You rely on (kind hearted) volunteers.
- To (hopefully) increase motivation include the following information (Kitchenham and Pfleeger, 2008):
  - “What the purpose of the study is.
  - Why it should be of relevance to them.
  - Why each individual’s participation is important.
  - How and why each participant was chosen.
  - How confidentiality will be preserved.”
- If possible, offer them a benefit.

B. A. Kitchenham and S. L. Pfleeger, “Personal opinion surveys," in Guide to Advanced Empirical Software Engineering. Springer, 2008, pp. 63-92.

DESIGN OF THE SURVEY INSTRUMENT

- Sequence of survey questions
  - Demographic questions
  - The main questions
  - Filter questions
    - Sensitive question
- Response format
  - Nominal scale (Yes/No/ Don’t know/ Not applicable)
  - Ordinal scale (Agree - Neutral - Disagree)
  - Interval scale (Income, age, experience)

FORMULATING THE SURVEY QUESTIONS (LINÅKER, ETAL., 2015

- Use simple language
- Avoid jargons ()
- Keep it short
- Not ambiguous
- Avoid biased question
- Avoid double barrelled questions
- Don’t use double negatives (not unable)
- Don’t be too demanding
- Don’t ask about things that happened too long ago

SURVEY

EXAMPLE

Development of personal leadership

The scale is:

Too little Just enough Too much
-3 -2 -1 0 +1 +2 +3

	-3	-2	-1	0	+1	+2	+3	I don't know
Secures support from his/her own boss	○	○	○	○	○	○	◉	○
Is flexible in his/her approach to challenges and tasks that arise	○	○	○	○	○	○	◉	○
Seeks out feedback from employees on his/her management practices	○	○	○	○	○	○	◉	○
Assumes the role of leader in stressful situations and in the face of adversity	○	○	○	○	○	○	◉	○

The scale is:

Too little Just enough Too much
-3 -2 -1 0 +1 +2 +3

You have the option of answering “I don't know”. Please use this option if you do not want to answer the question.

EVALUATING SURVEY INSTRUMENTS

Kitchenham and Pfleeger 2008) suggest that you need to check your survey before you deploy your survey,

- How to do it?
  - Piloting
  - A focus group
- Who should help you evaluate?
  - People who might use the results of the survey
  - Representative of your sample population

ADVANTAGES

- A way to gather data from large number of participants
- Relatively cheap and quick.

DISADVANTAGES

- A good survey is hard to design
- Competitive. There are loads of survey out there.

SURVEY

USING PROFESSIONAL FORA AS A WAY TO GATHER DATA

- A trend of using LinkedIn status update, or a post in professional fora as a way to collect data.
- A less strict way to gather data.

SURVEY TOOLS

- SurveyXact (SDU has a license)
  - https://sdunet.dk/da/servicesider/analytics/analyseredskaber/surveyxact
- SosciSurvey
  - Very robust, you can add JS to personalise your survey.
  - Free for non-profit projects.
- SurveyGizmo
  - Free for 100 responses.
  - Basic questions (cannot add logic).

EXPERIMENTATION

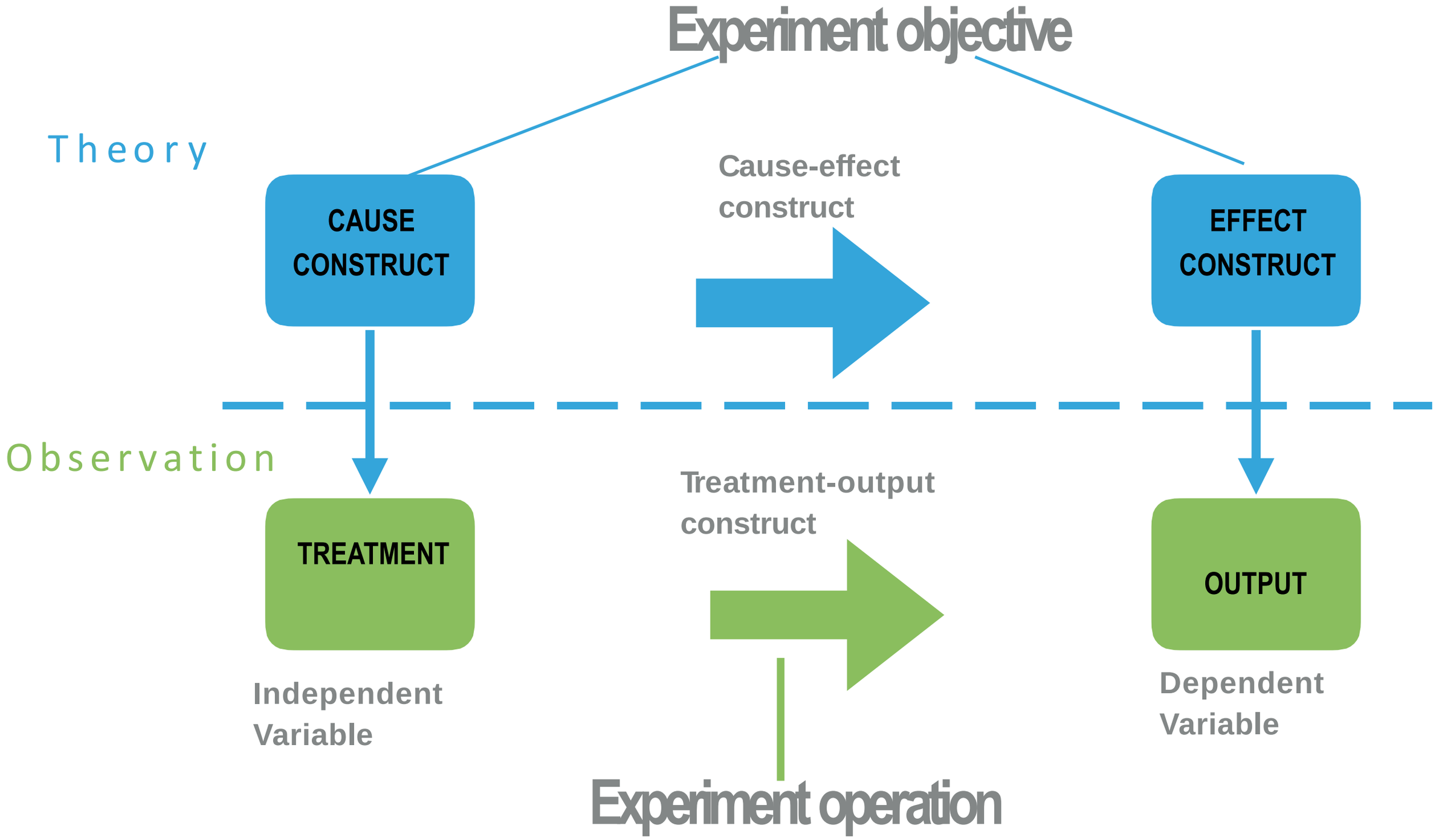
EXPERIMENTS

- Experiment is a “scientific procedure undertaken to make a discovery, test a hypothesis, or demonstrate a known fact.” (Oxford Dictionary).

WHY DO EXPERIMENTATION IN SOFTWARE ENGINEERING????

- Software-intensive organisations want to improve themselves so they adopt process improvement strategies.
- The main reason is to get objective and statistically significant results regarding the improvement of software development.
- Nowadays, experimentation is also becoming industry practice.
  - A/B Testing.

EXPERIMENT PRINCIPLES



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VARIABLES

- A variable is “a characteristic or attribute of an individual or an organisation that can be measured or observed”. (Creswell and Creswell, 2018).

- Types of variable:
  - Independent variable - those that influence the outcome in experimental study. The variable that you control and manipulate
  - Dependent variable - response variable, the variable that you want to observe given the manipulation of the independent variable

TREATMENT, OBJECT, SUBJECT

- **Treatments** are the values of the independent variables that you manipulate in the experiment.
- Treatment can be applied to the combination of objects and subjects.
- **Object** is the artefact/ instrument used in the experiment.
- **Subject** is the participant of the experiment.

TYPES OF EXPERIMENTATION

Controlled Experiment

- Randomisation between treatments and subjects

Quasi-experiment

- When randomisation is not possible.
  - You purposefully group the subjects with the treatments, e.g., you want to make sure there is equal number of experienced developer in the different groups.
- In SE, experiments are often quasi-experiment.

Break (10 min)

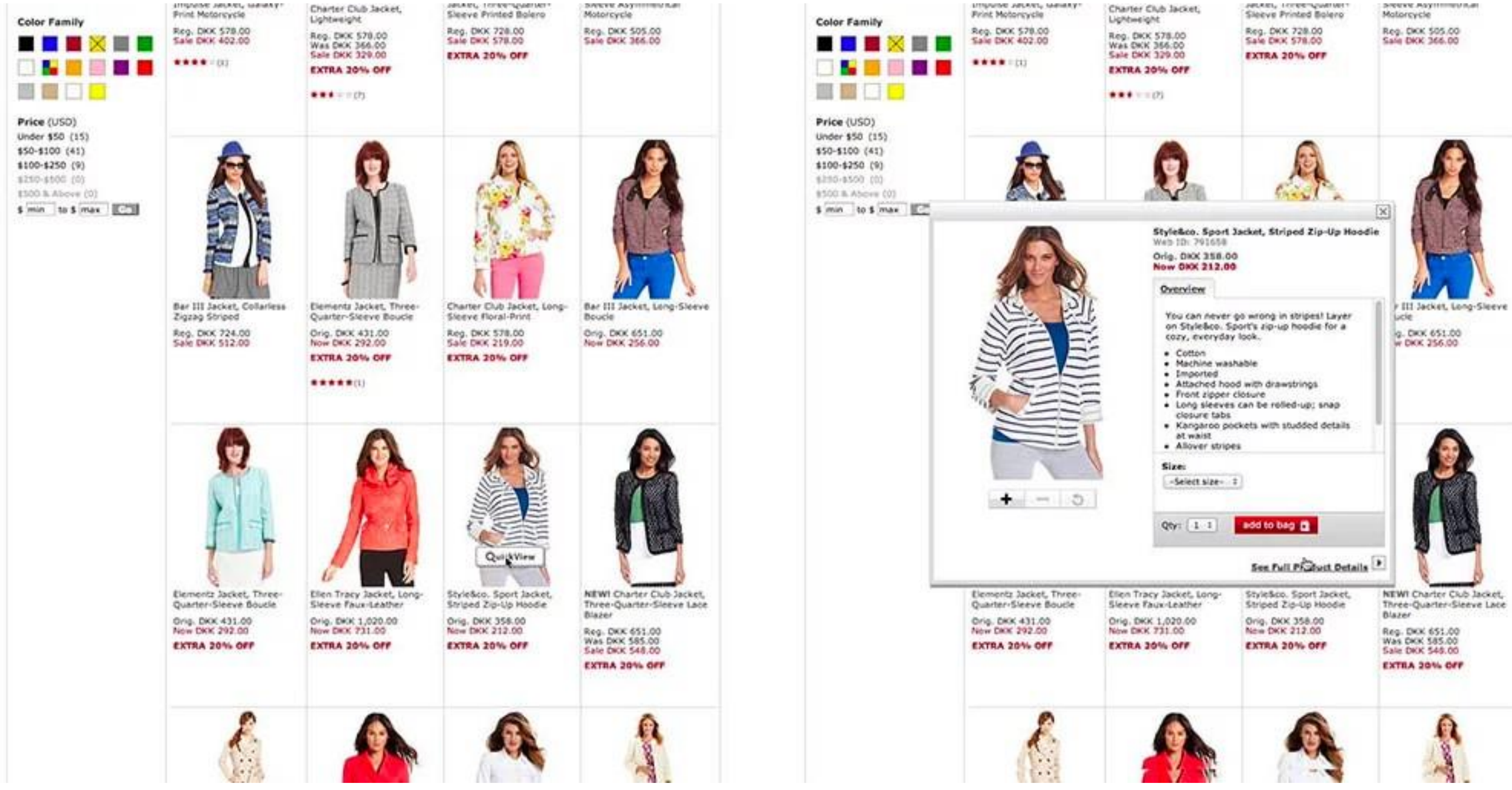
EXAMPLE
QUICKVIEW FOR ECOMMERCE APPLICATION

You work for an e-commerce company and the company wants to increase revenue by improving the user experience of their customers when shopping online. You want to find out if item “quick view” feature would improve user experience and help to increase number of purchased items.

Does this example make sense to LE&GD students????

Ja eller Nej

EXAMPLE- QUICKVIEW FOR ECOMMERCE APPLICATION



EXPERIMENT PROCESS

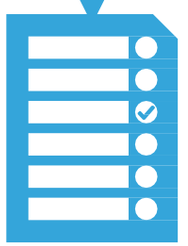
EXPERIMENT SCOPING

EXPERIMENT PLANNING

EXPERIMENT OPERATION

ANALYSIS & INTERPRETATION

PRESENTATION & PACKAGE



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EXPERIMENT SCOPING

- The goal of the experiment needs to be defined.

- Goal template:

Analyse <Objects of study> : What is studied?

For the purpose of <Purpose>: What is the intention?

With respect to their <Quality focus> : Which effect is studied?

From the point of view of <Perspective> : Whose view?

In the context of: <Context>: Where is the study conducted?

EXPERIMENT SCOPING

- The goal of the experiment needs to be defined.
- Goal template:

Analyse “Quick view” and “no quick view” product browsing

For the purpose of comparing their impacts

With respect to number of purchased items

From the point of view of the sales and marketing

In the context of the websites’ end users

EXPERIMENT PROCESS

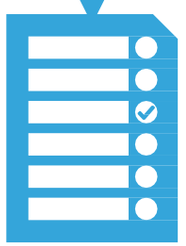
EXPERIMENT SCOPING

EXPERIMENT PLANNING

EXPERIMENT OPERATION

ANALYSIS & INTERPRETATION

PRESENTATION & PACKAGE



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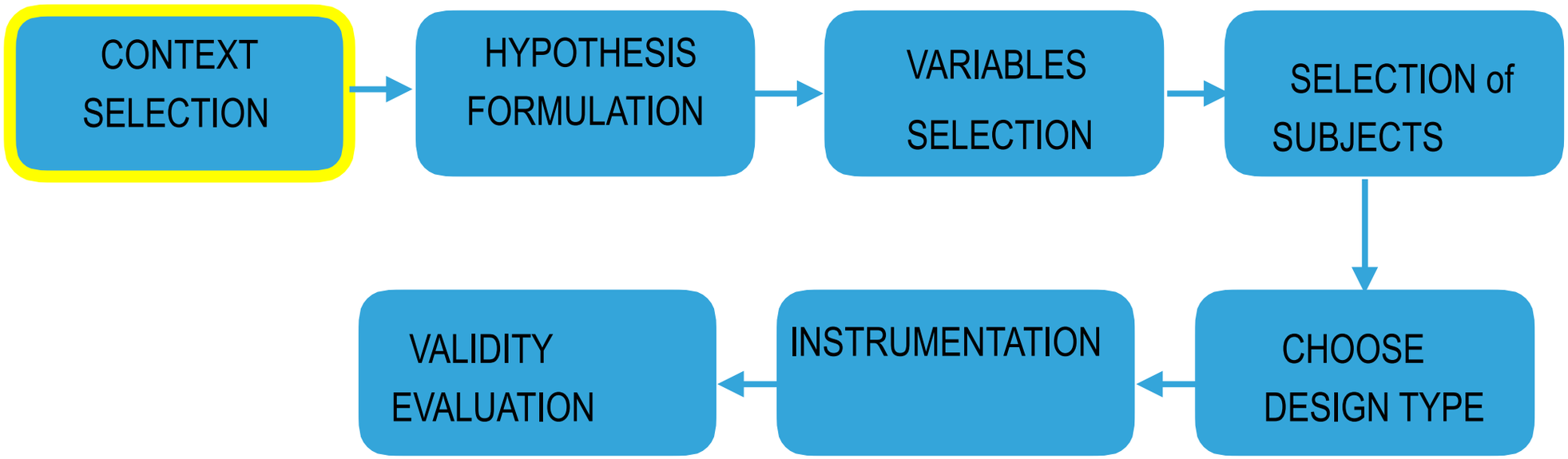
EXPERIMENT PLANNING



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CONTEXT SELECTION

- Offline vs Online
- Student vs practitioners (e.g., personas vs actual customers)
- Toy vs real problems
- Specific vs general (e.g., specific demographic vs anyone).

CONTEXT SELECTION

Analyse “Quick view” and “no quick view” product browsing

For the purpose of comparing their impacts

With respect to number of purchased items

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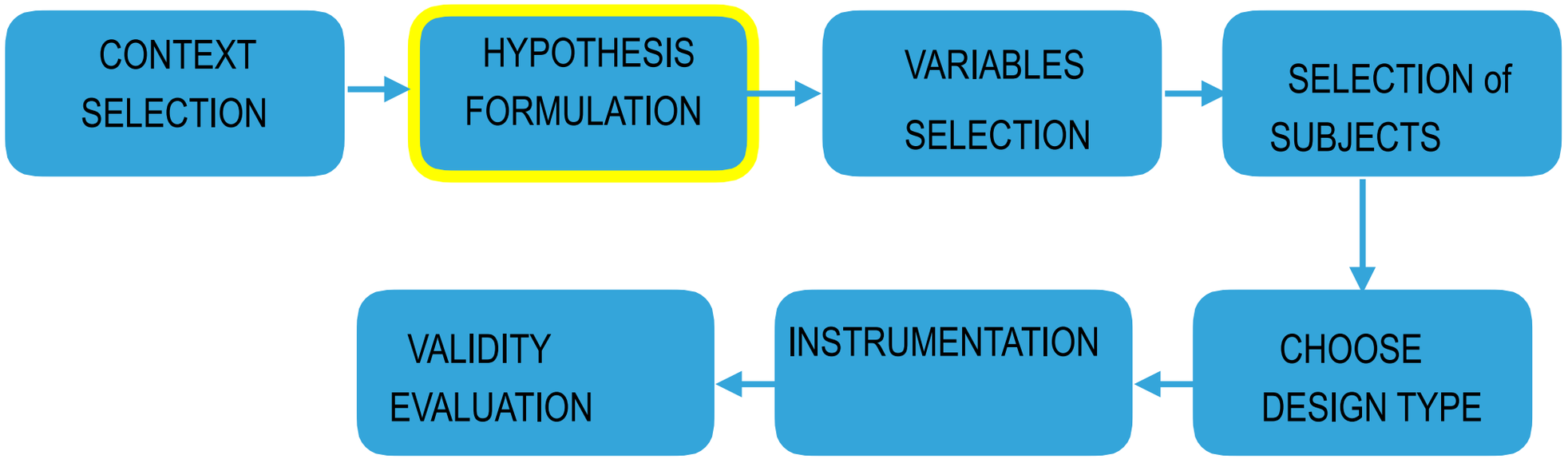
EXPERIMENT PLANNING



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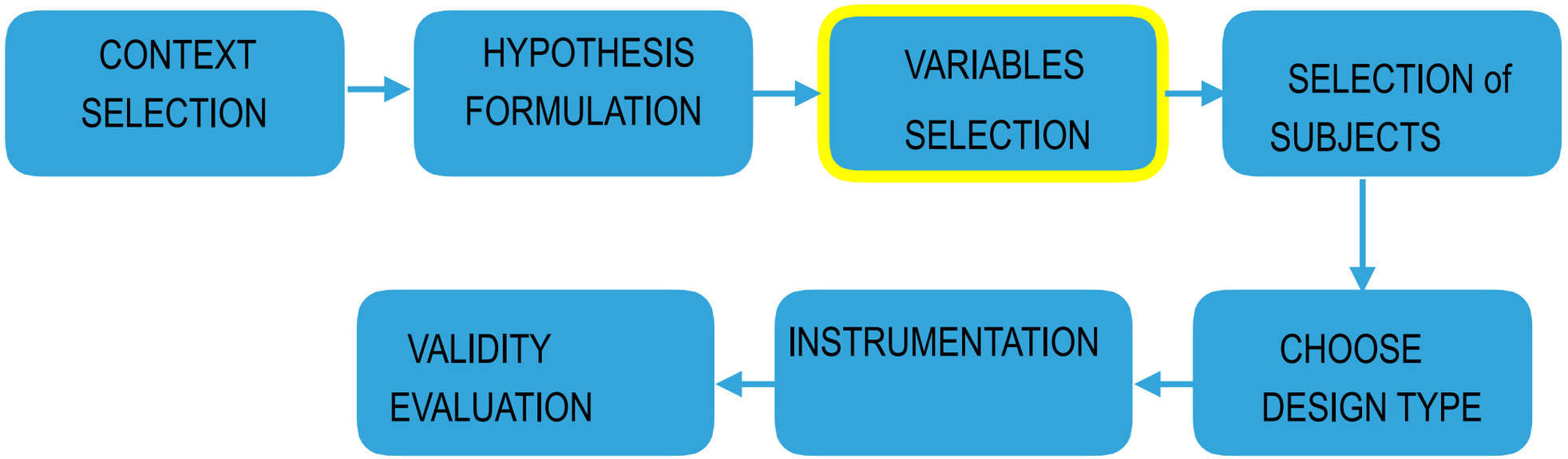
HYPOTHSIS FORMULATION

- Null hypothesis - there is no underlying trends.
  - No difference in number of sales between “quick view” and “no quick view” browsing feature.
- Alternative hypothesis - favour the rejection of the null hypothesis.
  - There is a difference in number of sales between “quick view" and “no quick view” browsing feature.

RISKS IN HYPOTHESIS TESTING

- Type I error
  - Statistical test suggests that there is a difference between the treatments, when there is actually no difference (False positive).
- Type II error
  - Statistical test suggest there is no difference between the treatments, where there is actually a difference (False negative).

EXPERIMENT PLANNING



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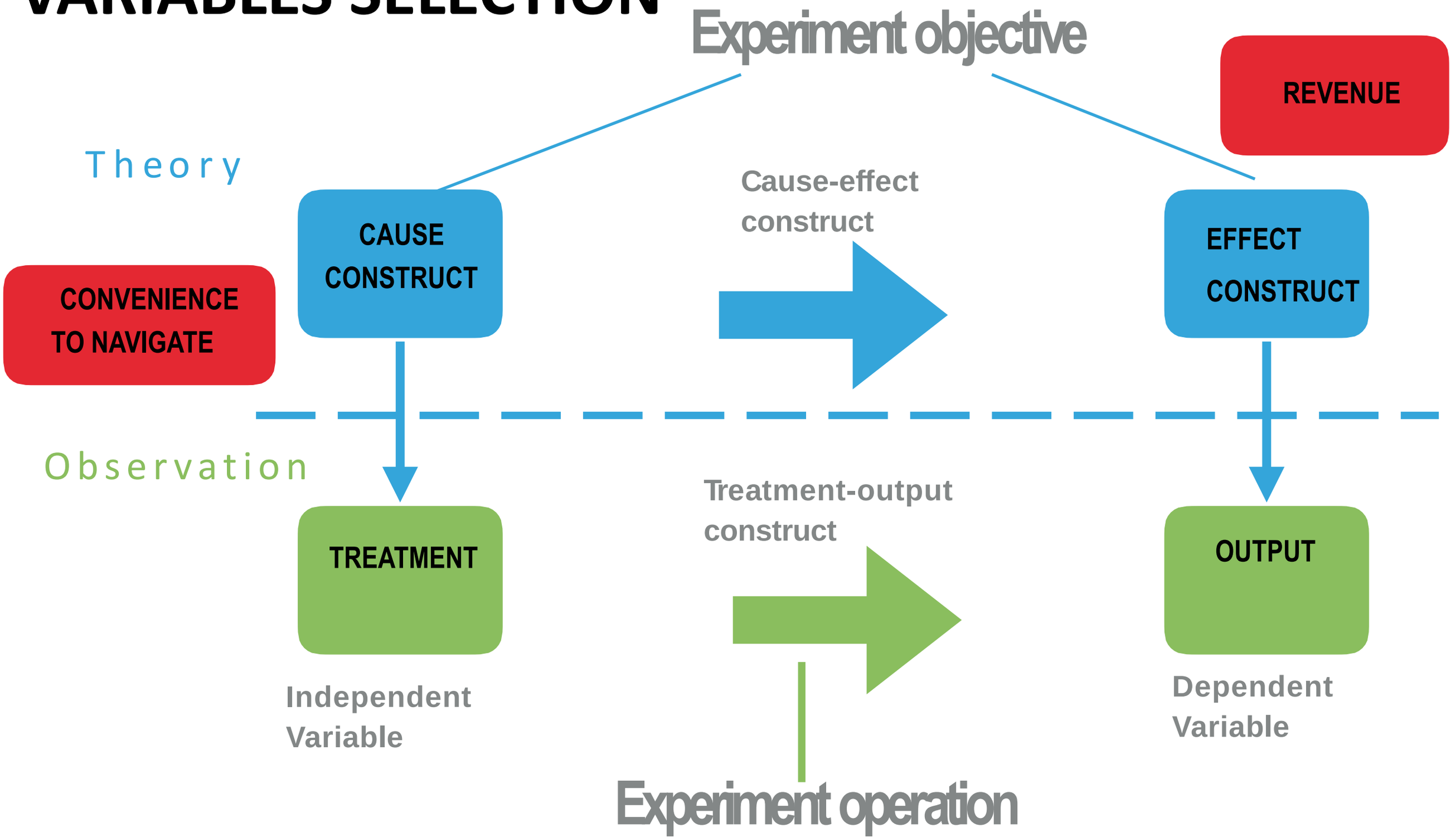
EXPERIMENT PLANNING

VARIABLES SELECTION



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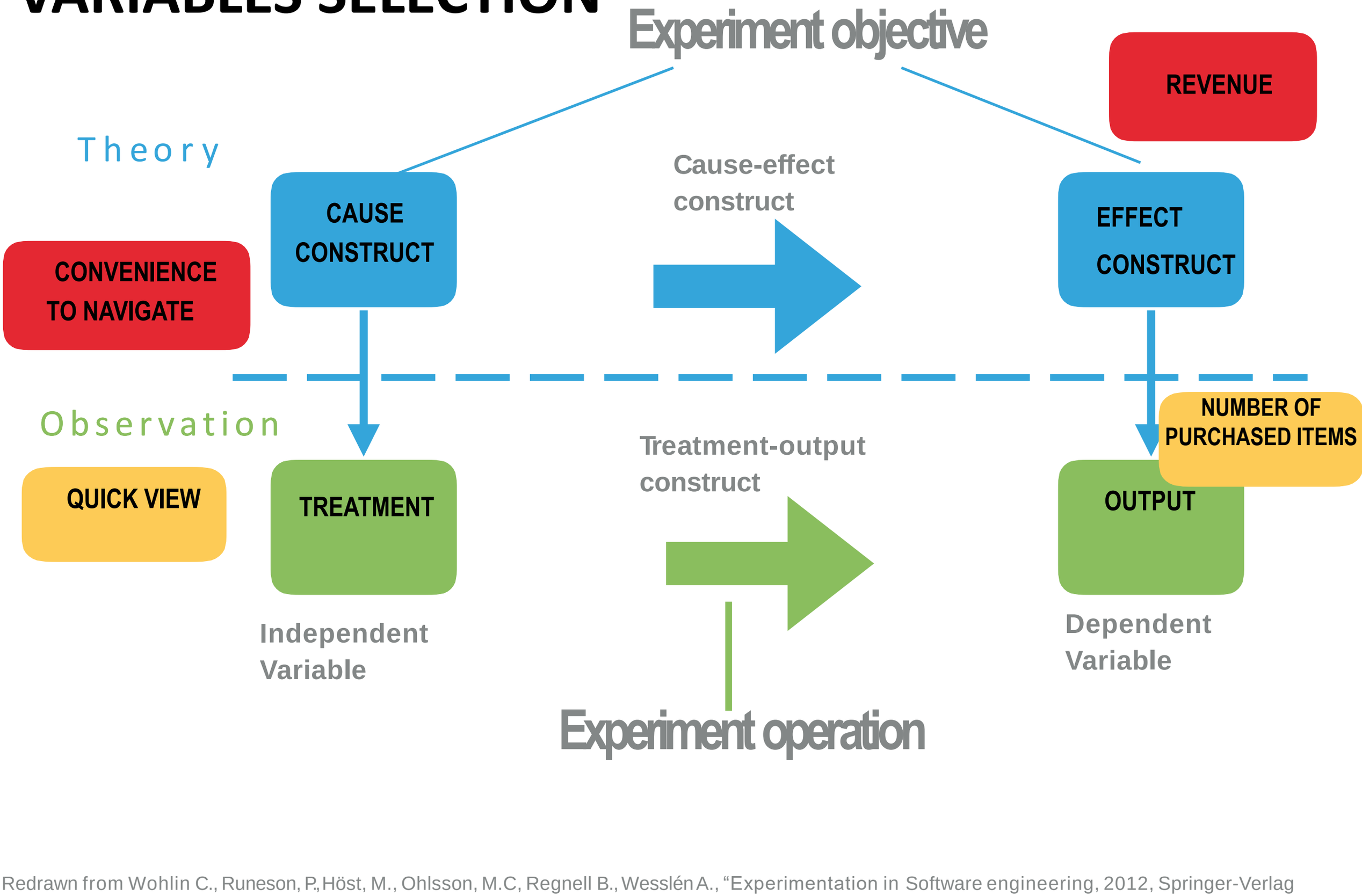
EXPERIMENT PLANNING

VARIABLES SELECTION



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EXPERIMENT PLANNING

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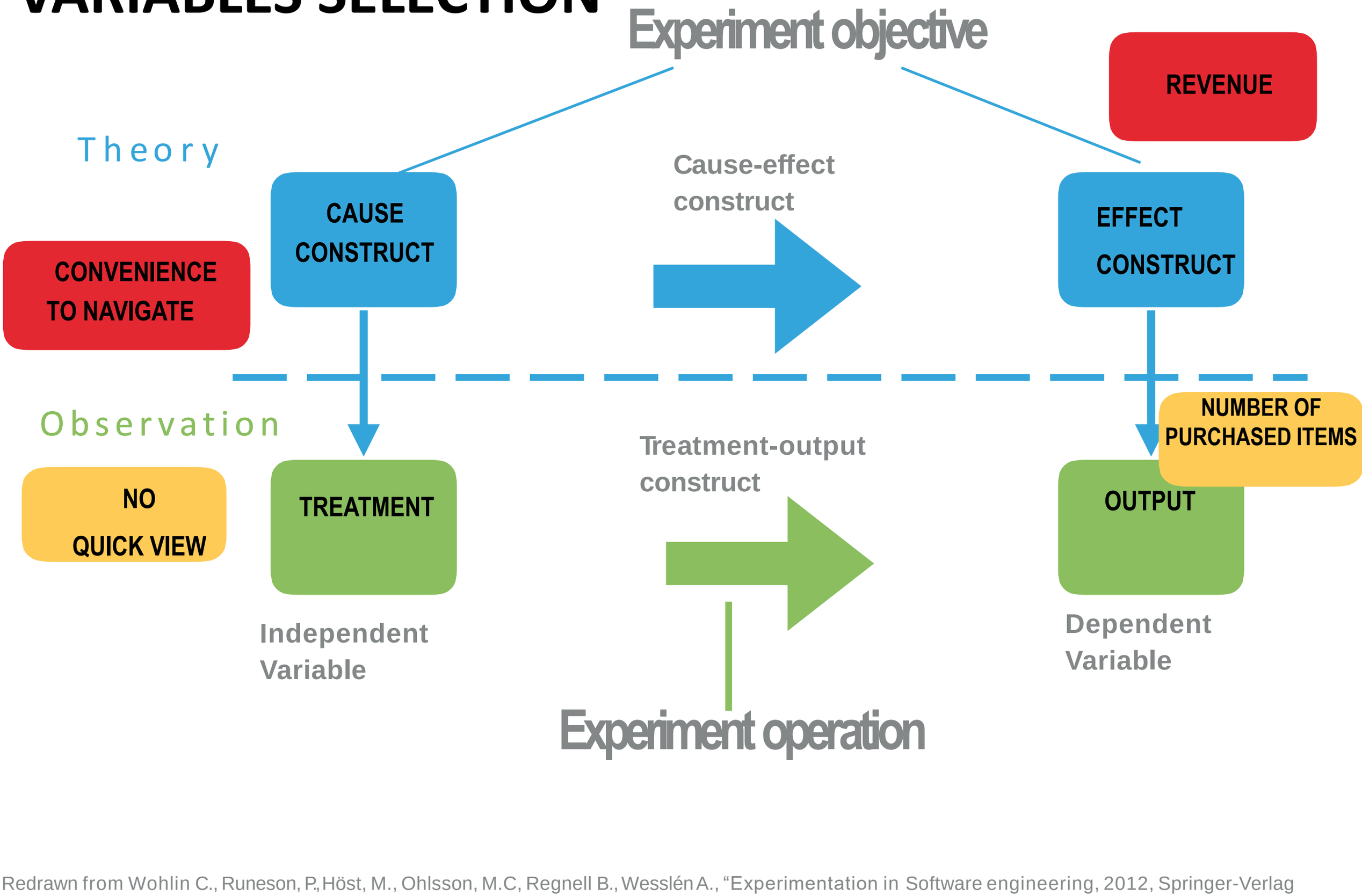

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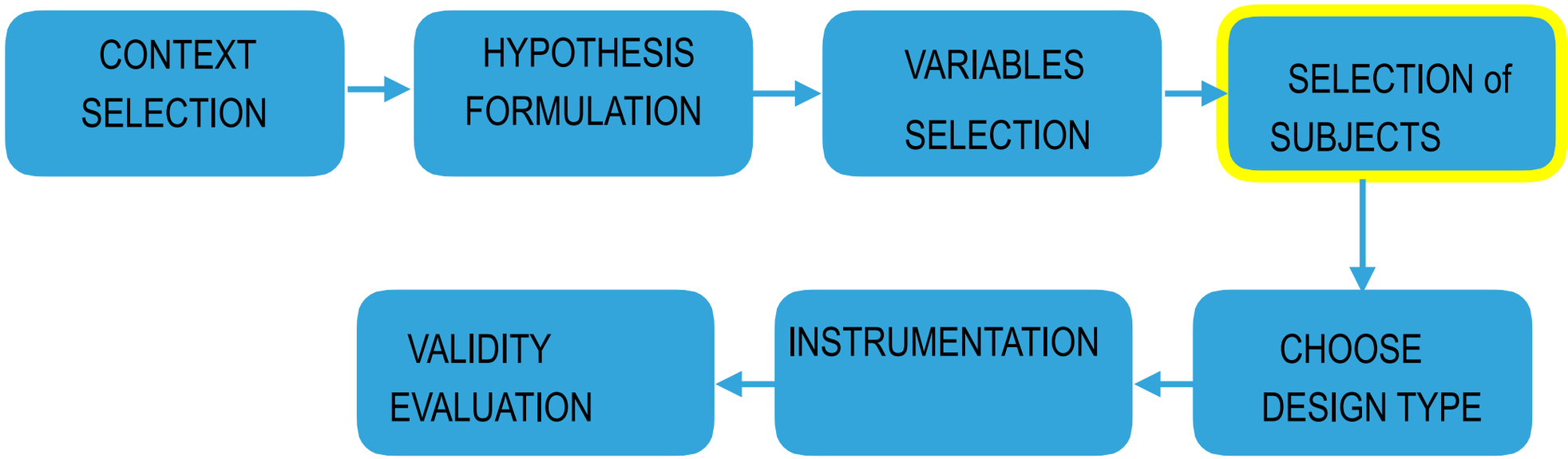
EXPERIMENT PLANNING



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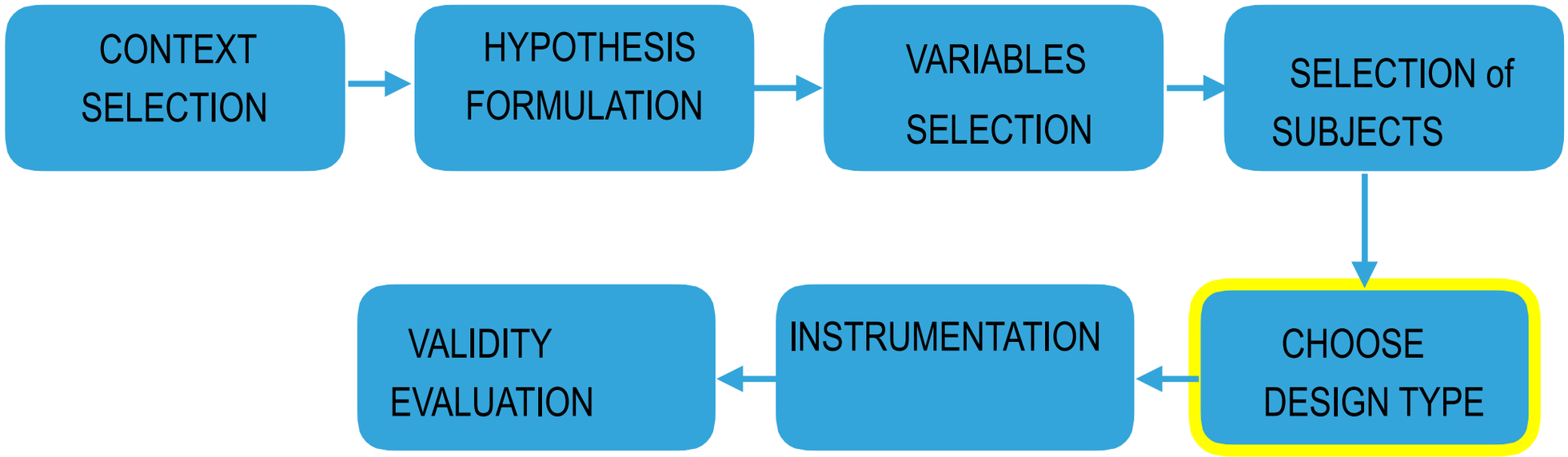
SELECTION OF SUBJECTS

- **Probabilistic**
  - Random sampling - subjects are selected from a list of the population at random.
  - Stratified random sampling - population is separated into groups (strata) and random samples are taken from each group
- **Non probabilistic**
  - Convenience sampling - the nearest people willing to participate

EXPERIMENT PLANNING



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CHOICE OF EXPERIMENT DESIGN

- General principles:
  - Randomisation - pick subjects at random
  - Blocking - Eliminate undesired effect of a factor.
    - For example, your participants have different experience. You should divide the participants into blocks, experienced and less experienced.
- Balancing - Each treatment has equal number of subjects and contains subjects from each block.

EXAMPLE: EXPERIMENT DESIGN

- Treatments: “quick view” and “no quick view”
- Subjects:
  - Experienced: Subject 1, Subject 3
  - Less experienced: Subject 2, Subject 4

Subject	Quick View	No quick view
1	X	
2	X	
3		X
4		X

EXAMPLE: EXPERIMENT DESIGN

- Treatments: “quick view” and “no quick view”
- Subjects:
  - Experienced: Subject 1, Subject 3
  - Less experienced: Subject 2, Subject 4

BLOCKS

Subject	Quick View	No quick view
1	X	
2	X	
3		X
4		X

EXAMPLE: EXPERIMENT DESIGN

- Treatments: “quick view” and “no quick view”
- Subjects:
  - Experienced: Subject 1, Subject 3
  - Less experienced: Subject 2, Subject 4

BLOCKS

Subject	Quick View	No quick view
1	X	
2	X	
3		X
4		X

BALANCING

SUBJECT ASSIGNMENT TO TREATMENT

- Between subjects
  - One subject one treatment
- Within subjects
  - One subject two (or more) treatments.

BETWEEN SUBJECTS

Subject	Quick View	No quick view
1	X	
2	X	
3		X
4		X

WITHIN SUBJECTS

Subject	Quick View	No quick view
1	1	2
2	1	2
3	2	1
4	2	1

WITHIN SUBJECTS

Subject	Quick View	No quick view
1	1	2
2	1	2
3	2	1
4	2	1

MIXING UP THE ORDERING OF THE TREATMENTS IS IMPORTANT TO MINIMISE LEARNING EFFECT

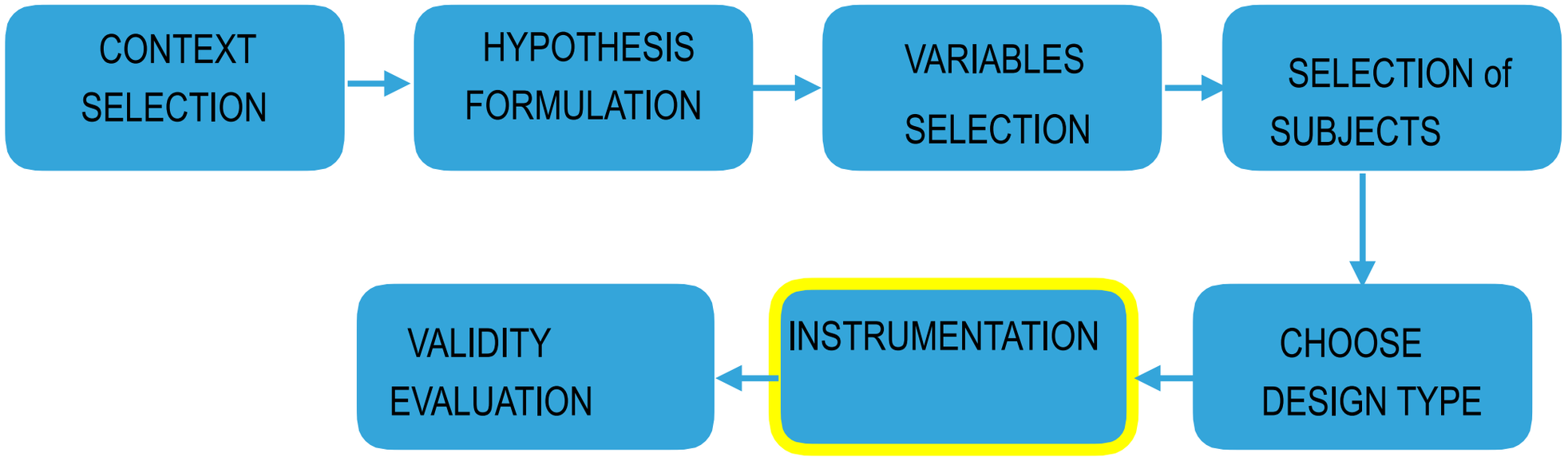
WHY BOTHER ABOUT BETWEEN & WITHIN SUBJECTS???

WHY BOTHER ABOUT BETWEEN & WITHIN SUBJECTS???

- A within-subjects design is **more statistically powerful than a between-subjects design**, because individual variation is removed.

- Between-subjects **minimizes the learning and transfer** across conditions**.**

EXPERIMENT PLANNING



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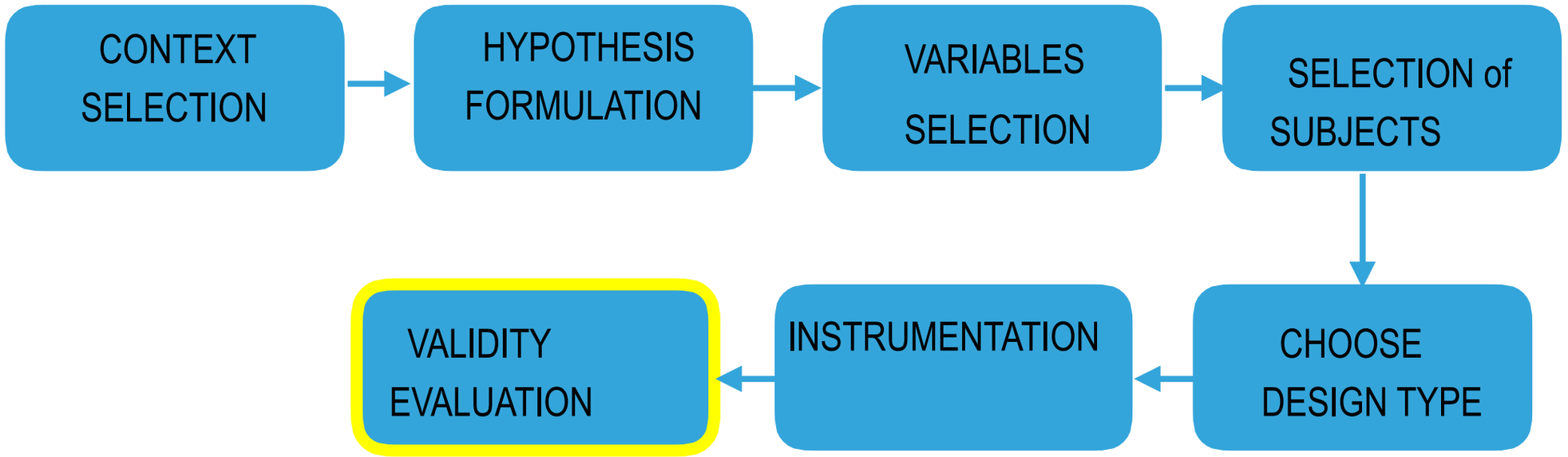
INSTRUMENTATION

- Objects of experiment
  - Two versions of the same e-commerce application.
- Guidelines
  - Information to the participants about the process of experiment, e.g., what they need to do, tools to interact with.
  - Training
- Measurement instrument - how to collect the data
  - Logs
  - Pre-experiment and post-experiment interview
  - Interaction data
  - Direct observation

EXPERIMENT PLANNING



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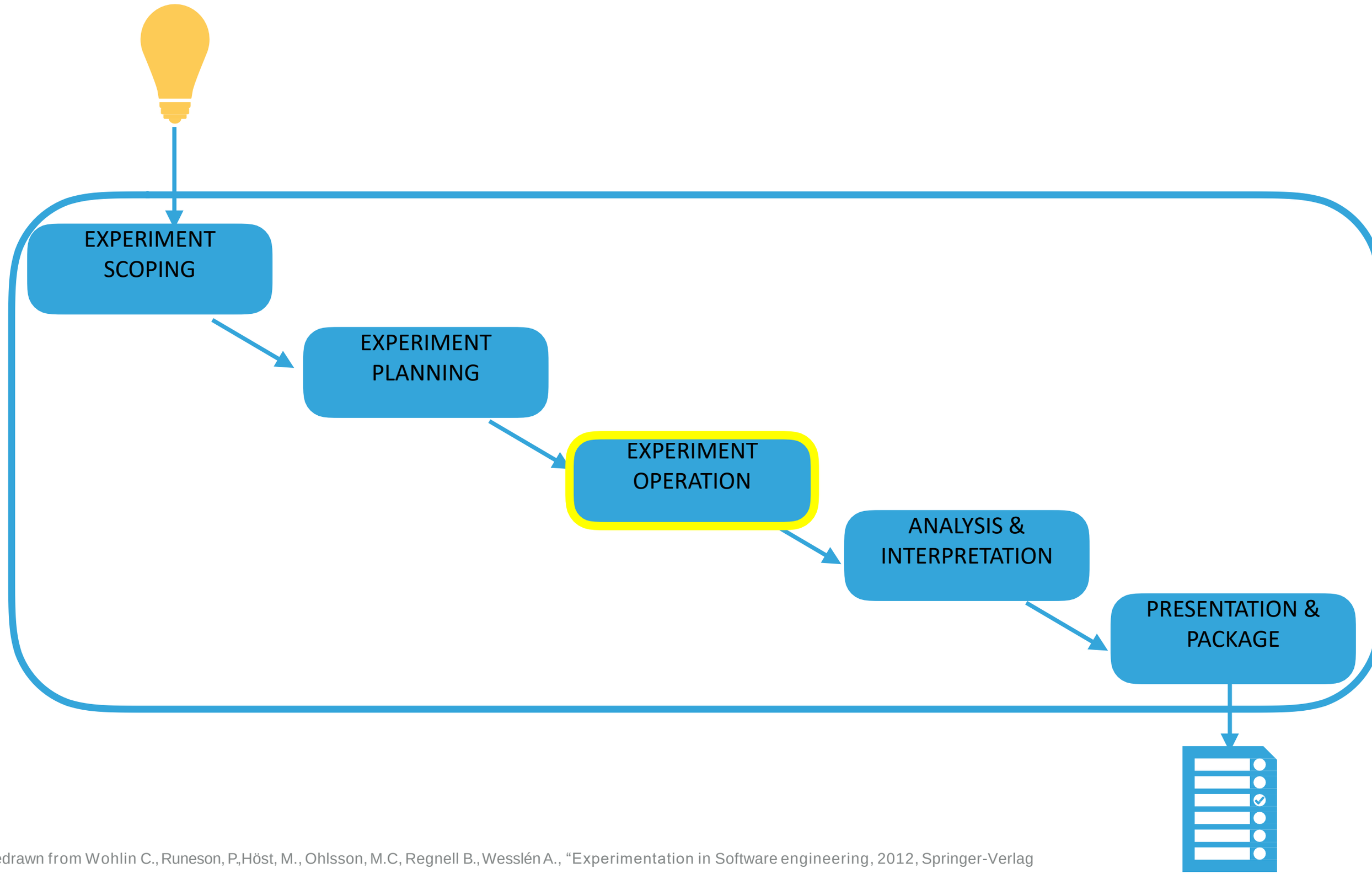
VALIDITY EVALUATION

- How can we trust the result of your experiment?
- You have to ensure that the design and execution of your experiment ensure reliable result.
- You have to ensure that the experiment instruments you use lead to reliable results.

WHAT TO DO????

- You need to **inspect instruments** that you use in the experiment, make sure there is no errors.
  - Make sure the “quick view” feature actually works.
  - Make sure your guideline is understandable.
- Make sure the **variables** you choose represents the concepts from the theory.
  - User navigation -> quick view?
- Carefully select your **subjects**.
  - Visually impaired subjects are not helpful.
- Choose your **analysis methods** carefully.
  - Statistical power and assumptions.
- Acknowledge that the **results** of your experiment may not be applicable in other contexts, e.g., other e-commerce site, or other web applications.
  - If you have a homogeneous subjects (all female between 19-25), it may not be applicable to the wider population.

EXPERIMENT PROCESS



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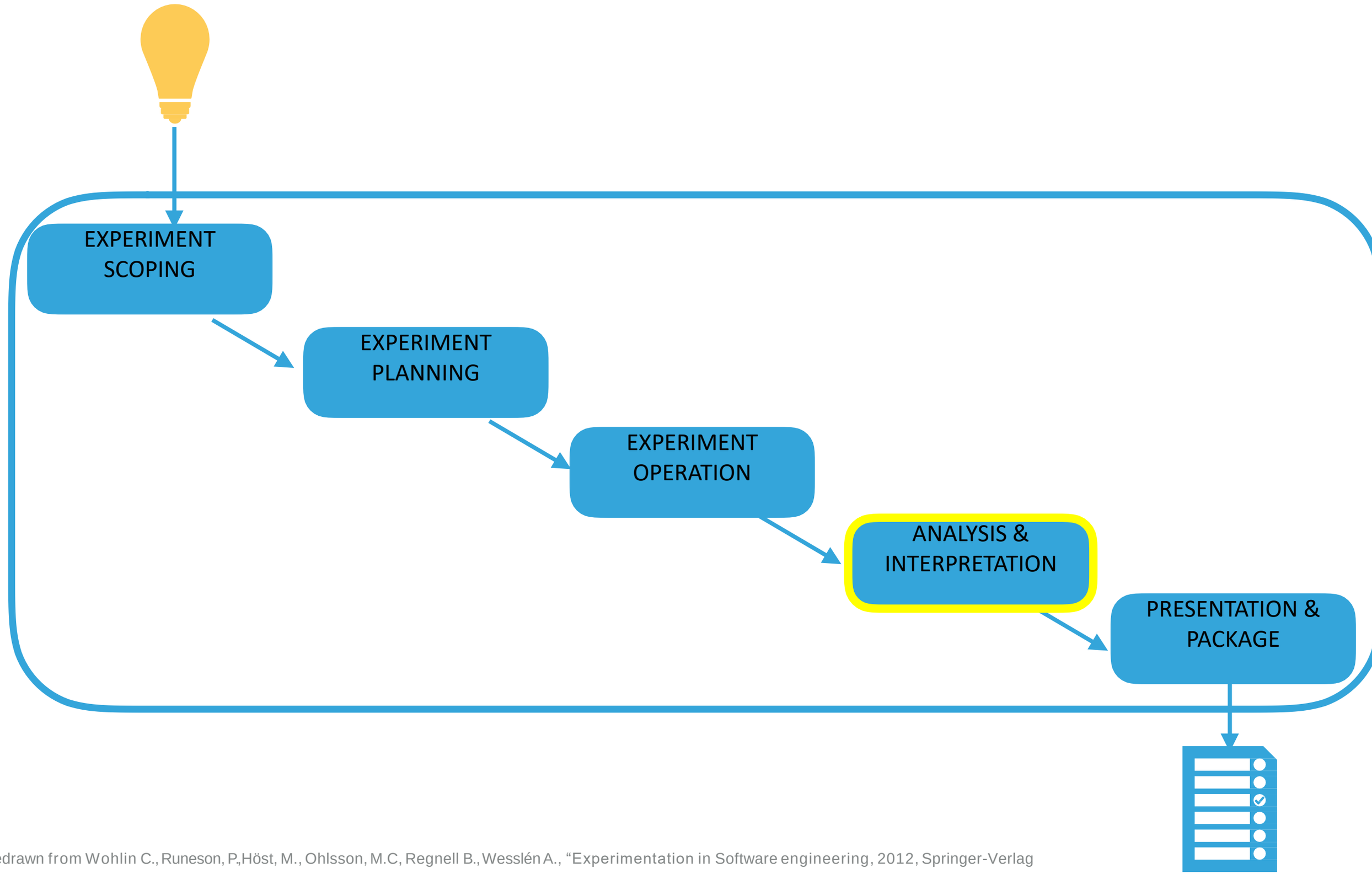
EXPERIMENT OPERATION

- Pilot the experiment first!
- Find the participants, if possible get their demographics first.
  - Get their consent!
- Use a consistent environment.
  - Use the same computer, browser, etc.
- Explain what the participants need to do
- Once data is collected make sure that it is valid or correct.
  - Don’t wait till the end. Do it once an experiment is done with a subject.

EXPERIMENT PROCESS



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QUANTITATIVE DATA ANALYSIS

QUANTITATIVE DATA ANALYSIS

- Descriptive Statistics
- Inferential Statistics

DISCLAIMER

- This is not a stats class
- Details of statistical testing will not be covered

Break (10 min)

DESCRIPTIVE STATISTICS

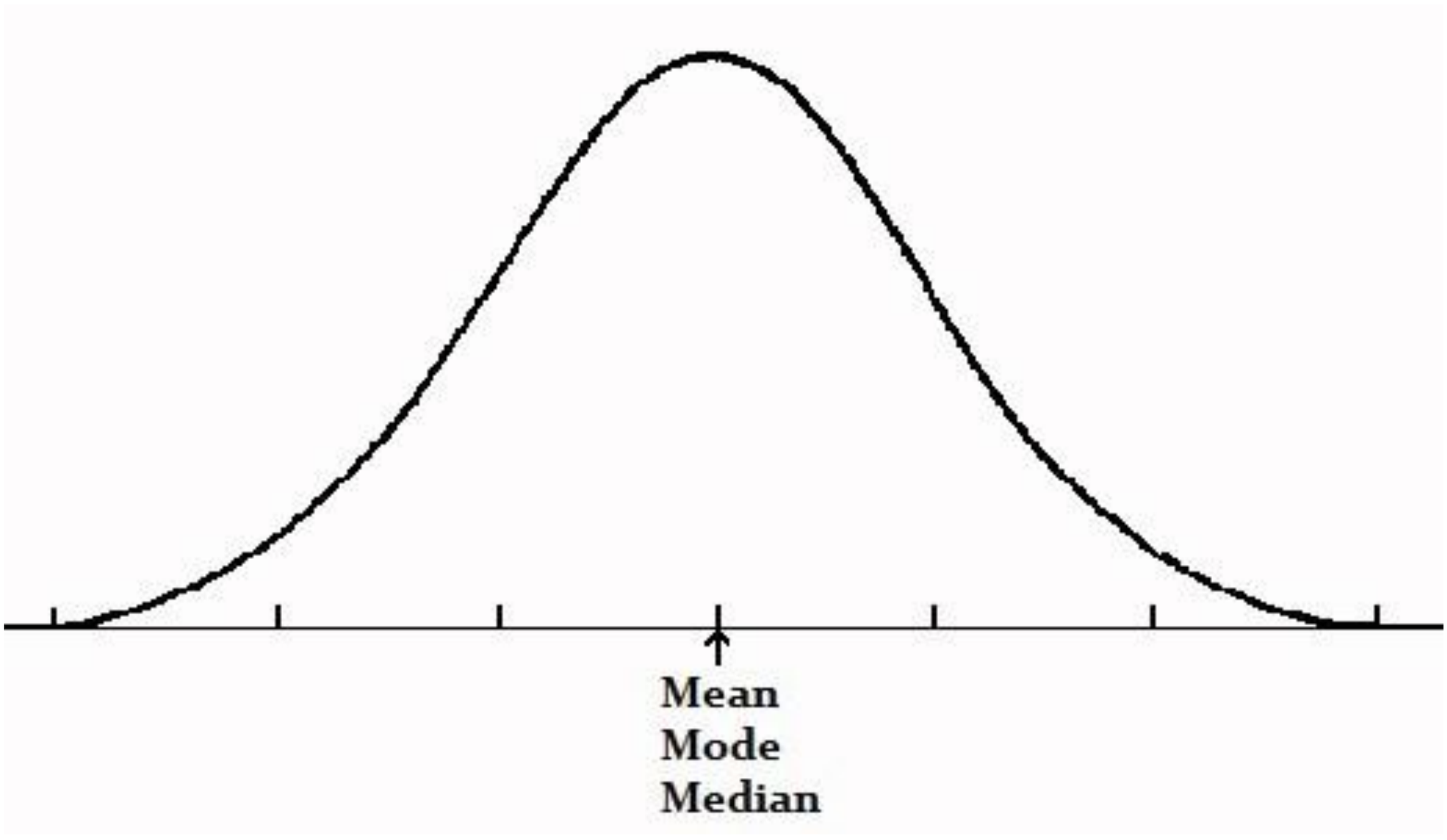
- Summary of the data
- Measure of central tendency, i.e., mean, median, mode
- Measure of variability, i.e., standard deviation, variance

- Outliers
- Skewness (symmetric and asymmetric distribution)

STATISTICS & SCALE TYPE

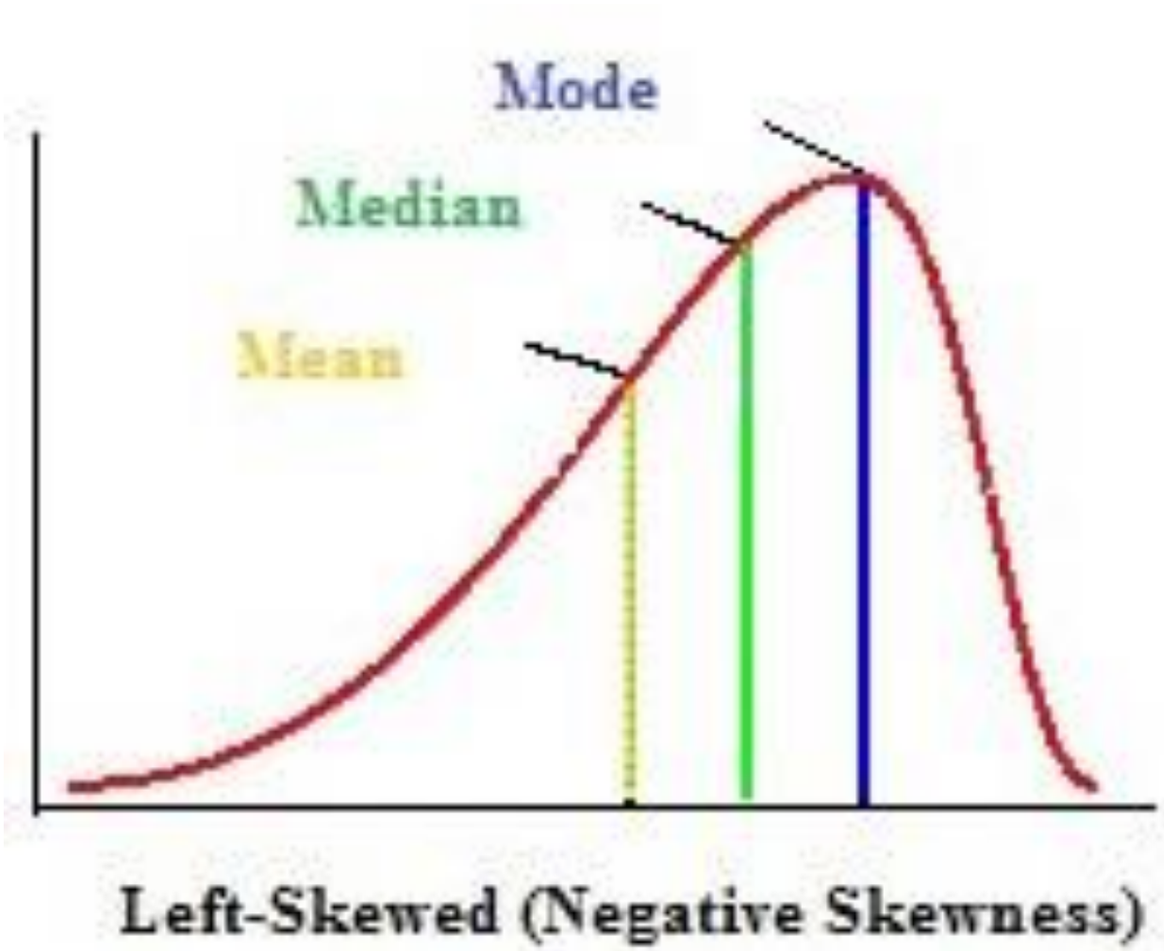
Scale Type	Measure of central tendency
Nominal	Mode
Ordinal	Median, mode
Interval	Mode, median, arithmetic mean
Ratio	Geometric mean $\sqrt[n]{x_1..x_n}$

SYMMETRIC (NORMAL) DISTRIBUTION

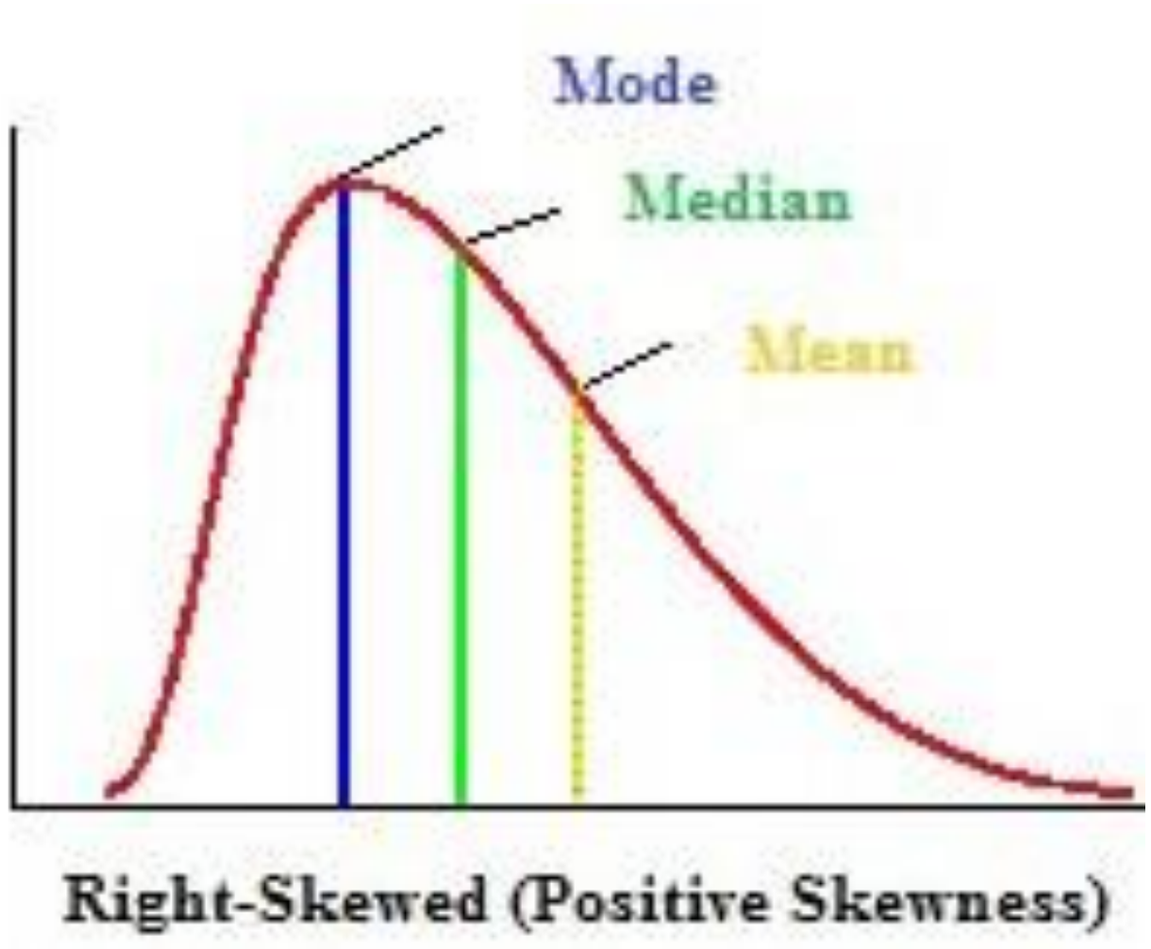


Source: Statistics How To https://www.statisticshowto.datasciencecentral.com/symmetric-distribution-2/

ASYMMETRIC DISTRIBUTION



Left-Skewed (Negative Skewness)



Right-Skewed (Positive Skewness)

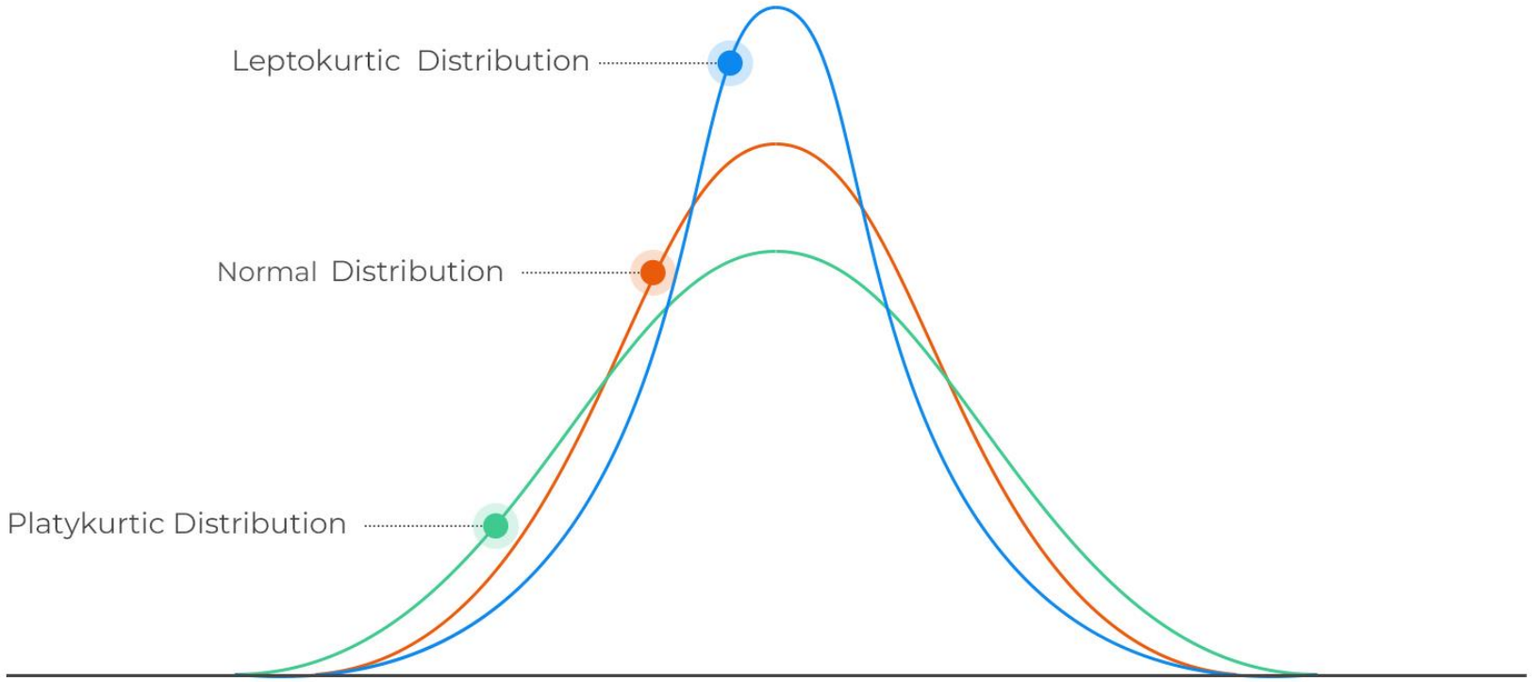
Source: Statistics How To https://www.statisticshowto.datasciencecentral.com/probability-and-statistics/ skewed-distribution/

KURTOSIS

- NORMAL DISTRIBUTION KURTOSIS=3
- PLATYKURTIC (FEW EXTREME OUTLIER), KURTOSIS<3
- LEPTOKURTIC (MANY OUTLIERS), KURTOSIS>3

- Measures of outliers

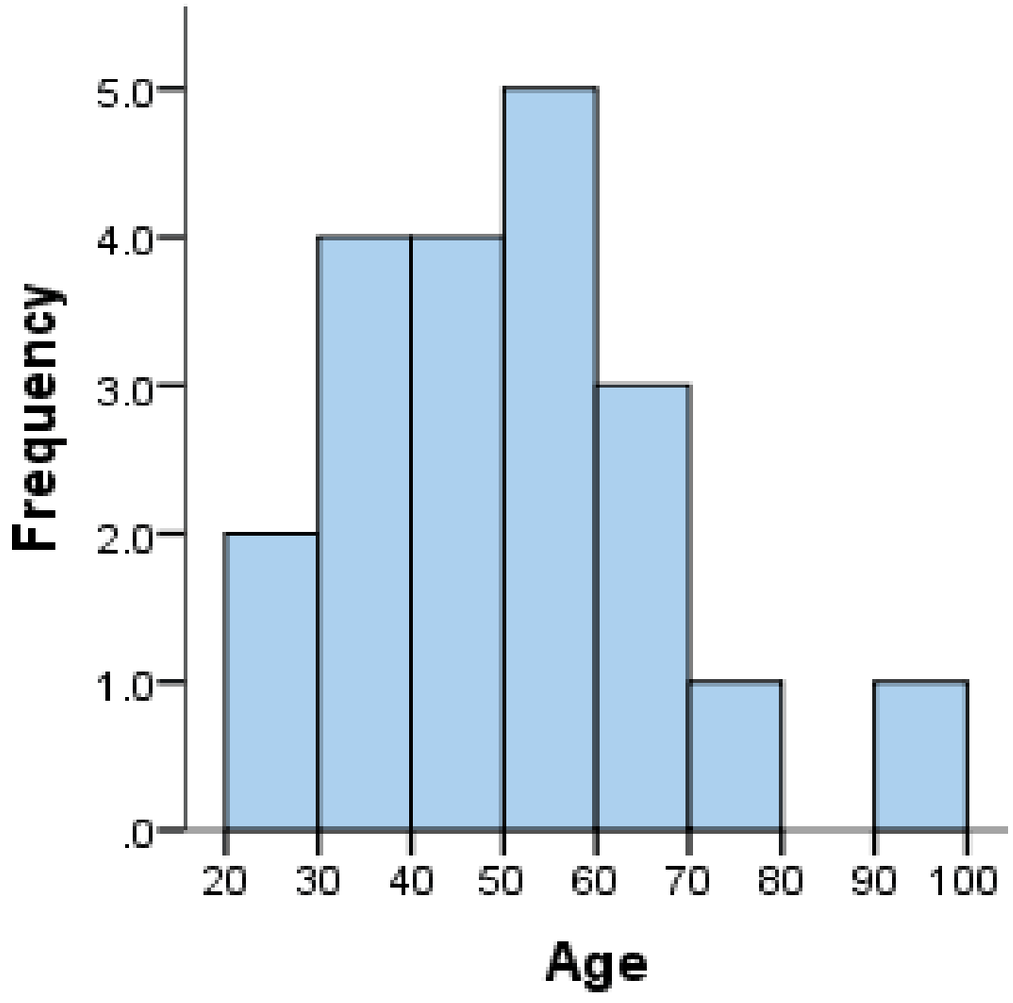
Kurtosis



https://analystprep.com/cfa-level-1-exam/quantitative-methods/kurtosis/

DESCRIPTIVE STATISTICS

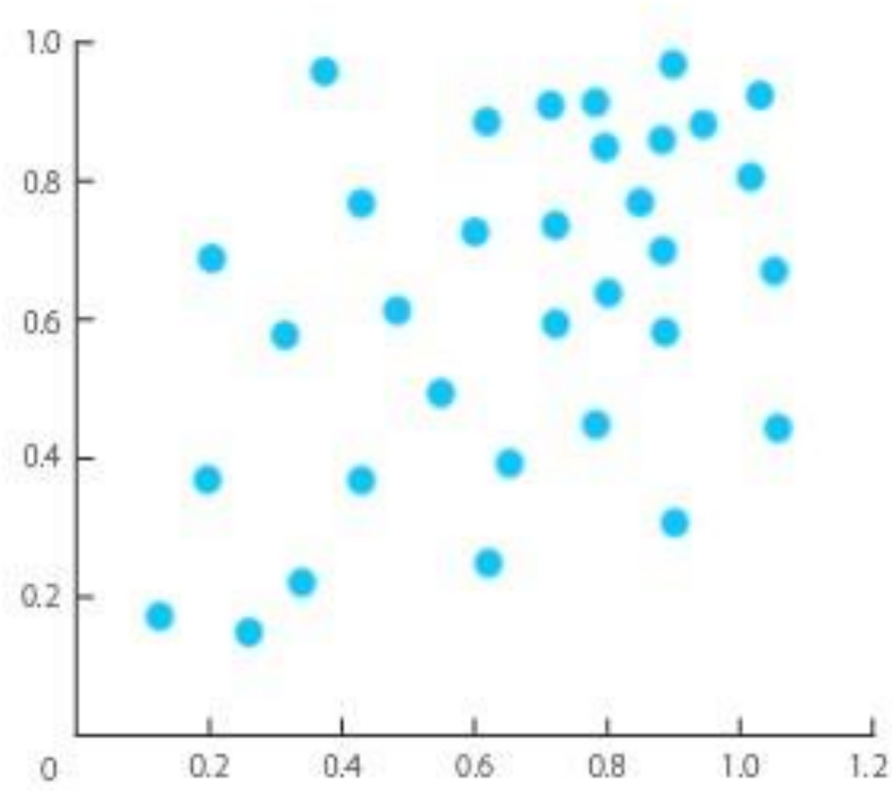
- Graphical representation
  - Histogram
  - Scatterplot
  - Boxplot



Source: Laerd Statistics

DESCRIPTIVE STATISTICS

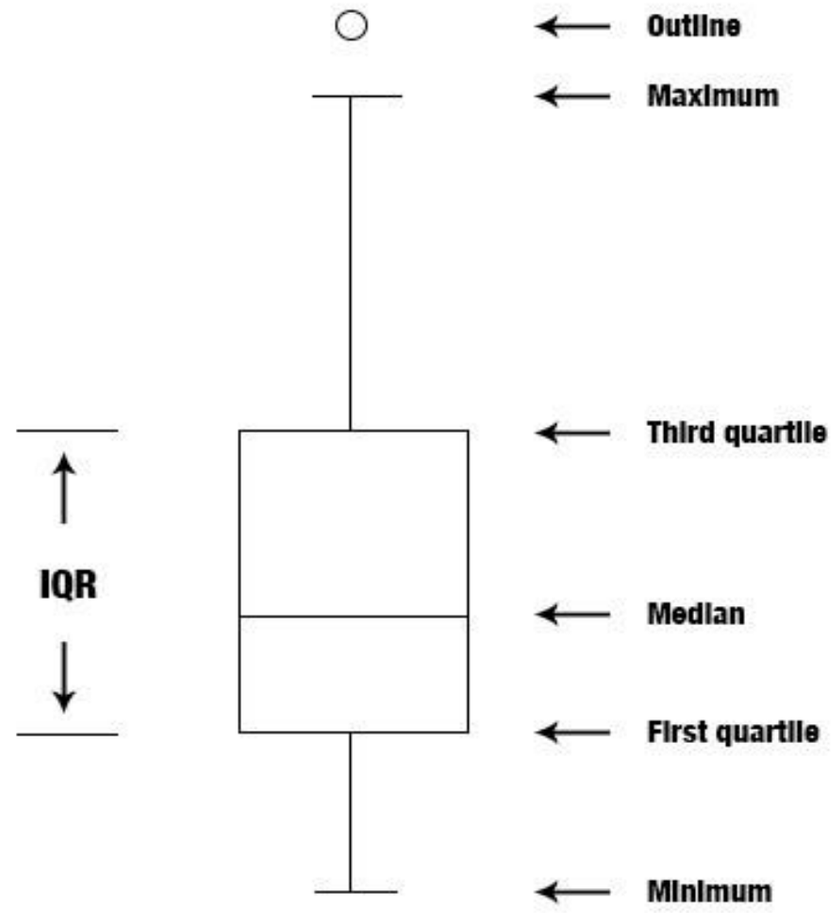
- Graphical representation
  - Histogram
  - Scatterplot
  - Boxplot



Source: Wikimedia Commons

DESCRIPTIVE STATISTICS

- Graphical representation
  - Histogram
  - Scatterplot
  - Boxplot
    - minimum score,
    - first (lower) quartile,
    - median,
    - third (upper) quartile, and
    - maximum score.

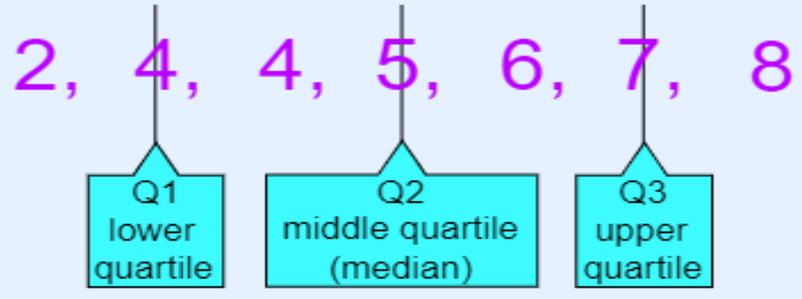


Source: Wikimedia Commons

Example: 5, 7, 4, 4, 6, 2, 8

Put them in order: 2, 4, 4, 5, 6, 7, 8

Cut the list into quarters:



And the result is:

- Quartile 1 (Q1) = **4**
- Quartile 2 (Q2), which is also the Median, = **5**
- Quartile 3 (Q3) = **7**

https://www.mathsisfun.com/data/quartiles.html

SO WHAT????

- If you have a small dataset, you can present your analysis based on the descriptive statistics.

- **BUT,** If you want to do hypothesis testing, why bother whether the data is normally distributed or not?

  - Knowing whether your data is normally distributed or not, will impact which statistical test you can use.

INFERENTIAL STATISTICS

- You want to generalise from a sample to a population with a certain degree of certainty.
  - Quick view -> increase sales with 95% confidence level.
- You do this through hypothesis testing.

HYPOTHESIS TESTING

- Parametric test
- Non-parametric test

HYPOTHESIS TESTING

- Parametric test
  - Assume the data is normally distributed
  - Data is interval or ratio
- Non-parametric test
  - Does not assume that the data is normally distributed
  - Data is ordinal

CORRELATION

- To see dependency between two variables.
  - E.g., Experience in development (in years) and productivity (number of task completed/time).
- Tests:
  - Pearson correlation coefficient (parametric)
  - Spearman rank-order correlation coefficient (non-parametric)

OTHER STATISTICAL TESTS

Design	Parametric	Non-parametric
One factor, two treatment, randomised (between subject)	T-test, F-test	Mann-Whitney, Chi-2
One factor, two treatment, paired (within subjects)	Paired t-test	Wilcoxon, Sign test
One factor, more than two treatments	ANOVA	Kruskall-Wallis, Chi-2

Source: Wohlin C., Runeson, P., Höst, M., Ohlsson, M.C, Regnell B., Wesslén A., "Experimentation in Software engineering, 2012, Springer-Verlag, page 139

P-VALUE & CONFIDENCE INTERVAL

- P-value is the probability value of being able to reject your null hypothesis.

  Common choice of confidence level is 90%, 95%, 99%

  - CI of 90% means that there is a 10% (0.1) chance that the dependency between variable occurs by chance.
  - And so on..

- Confidence intervals gives us a range of possible values we are sure our true values lies in.

Useful Link: https://online.stat.psu.edu/stat200/lesson/6/6.6
https://towardsdatascience.com/the-relationship-between-hypothesis-testing-and-confidence-intervals-43196f1b44bf

EXAMPLE

- H0 - Num. purchased$_{(\text{quick view})}$ = Num. purchased $_{(\text{no quick view})}$
- P= 0.03
- If you choose CI of 95%, p<0.05, you reject null hypothesis
- Choice of CI may lead to, Type I or Type II error.

https://www.abtasty.com/blog/type-1-and-type-2-errors/

WORDING

- You can reject a hypothesis.
  - E.g., p=0.03 (CI=95%), p<0.05, you reject null hypothesis
- **You never accept a hypothesis. You fail to reject a hypothesis.**
  - E.g., p=0.03 (CI=99%), p>0.01, you fail to reject your null hypothesis

WORDING

- You can reject a hypothesis.
  - E.g., p=0.03 (CI=95%), p<0.05, you reject null hypothesis
- **You never accept a hypothesis. You fail to reject a hypothesis.**
  - E.g., p=0.03 (CI=99%), p>0.01, you fail to reject your null hypothesis

STEMS FROM POSITIVIST VIEW "THERE IS NO ABSOLUTE TRUTH"

REMEMBER

- Before choosing a statistical test:
  - Check your data, check which scale type.
  - Check if the data is normally distributed.
  - Read carefully the assumptions associated with each statistical test.

Mini Quiz ☺

1. Experimental research is often used to determine _____.

- ❑ the effects of a treatment
- ❑ trends in the population
- ❑ relationships between factors
- ❑ a complex understanding about a phenomenon

2. Which sampling technique is most desirable in quantitative research?

- ❑ random sampling
- ❑ convenience sampling
- ❑ purposeful sampling
- ❑ criterion-based sampling

3. Which philosophical assumptions are reflected in quantitative research designs?

- ❑ transformative
- ❑ constructivist
- ❑ postpositivist
- ❑ pragmatist