GeAR

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A short introduction to

Experimental Study Design & Usability Research

IMI Retreat

02.11.2022

Kristin Altmeyer, Luisa Lauer

GEFÖRDERT VOM

Bundesministerium für Bildung und Forschung

Welcome!

Luisa Lauer

- Department of Physics @UdS

Research focus:

- Learning with digital media, especially AR
- Design and development of digital educational tools

M.Sc. Psych. Kristin Altmeyer

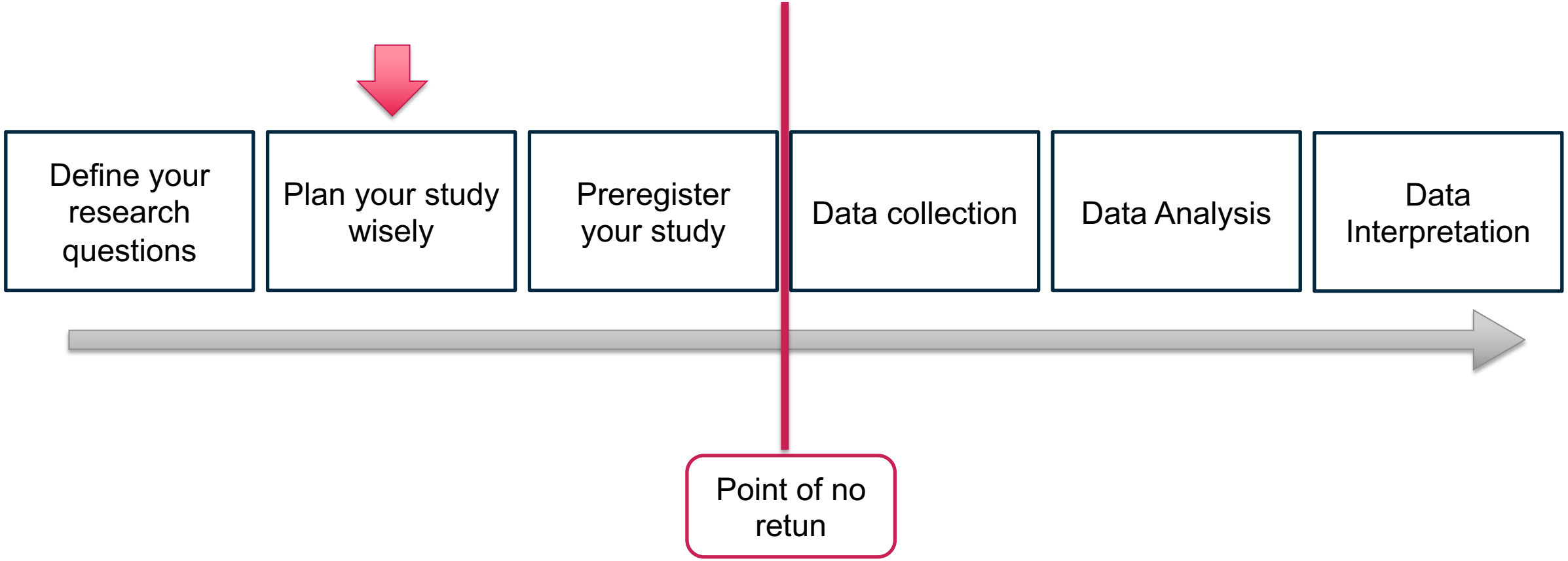
- Department for Education @UdS
- AWS-Institute for Digital Research

Research focus:

- Learning with digital (multi) media, especially AR
- Learning processes and cognitive load

Experiment Design

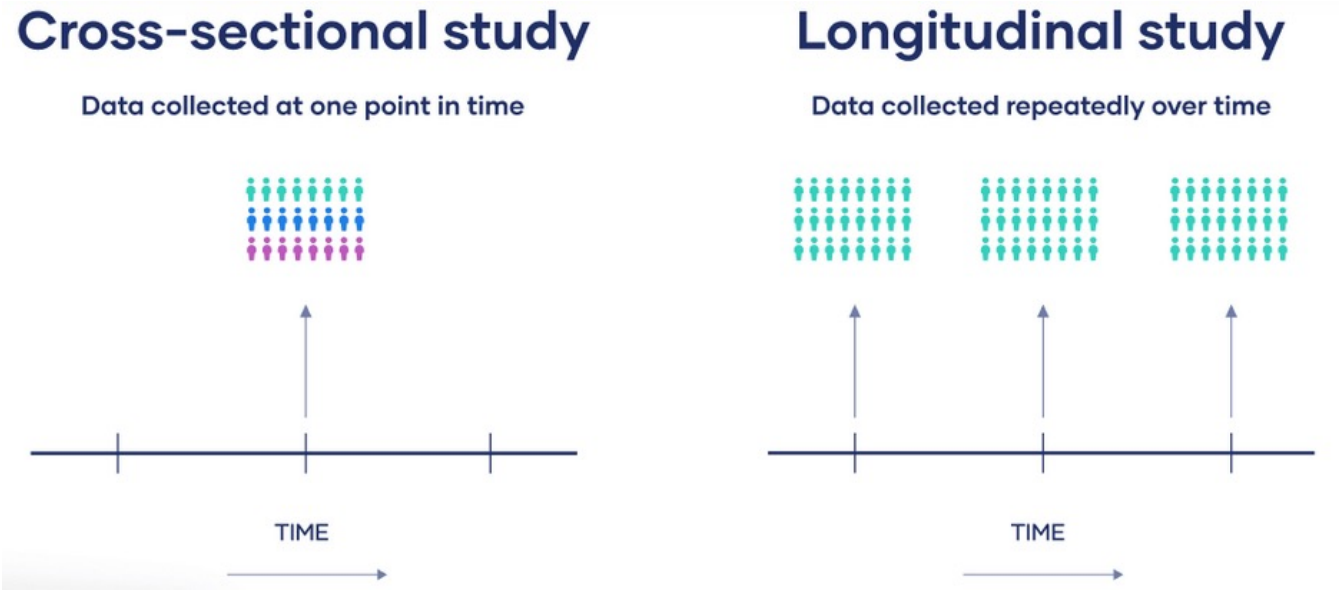
„I would like to conduct a study…."



What would you like to investigate?

- Descriptive questions (observations)
- Cause and effect relationships (interventions, experiments)

- Longitudinal questions
- Cross-sectional questions



Experimental Design - Variables

Experimental Design - **Independent** Variables

- Between-subjects design
  - Experiment vs. Quasi-experiment
  - Choosing the right control group

	Treatment A	Treatment B	Posttest
Group A	x		o
Group B		x	o

- Within-subjects design

	Treatment A	Posttest 1	Treatment B	Posttest 2
Group	x	o	x	o

- Mixed Design
  - Time x Treatment

	Pretest	Treatment A	Treatment B	Posttest
Group A	o	x		o
Group B	o		x	o

Mixed Design - Example

Setting

Domain: physics (electricity)
Learning objectives:
Experiment 1: Linking current and brightness of light bulbs;
Experiment 2 + 3: Kirchhoff's laws (serial and parallel circuits)

IV

Presentation format of virtual information (measured values of current)
Tablet AR vs. separate tablet display

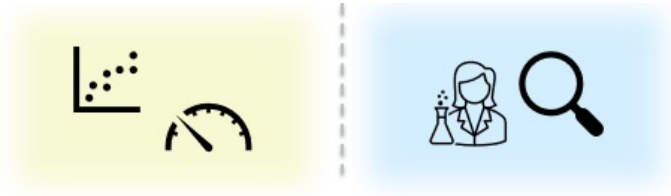
DV

Cognitive load, conceptual knowledge, performance in tasks differing in demands on global coherence, gaze behavior

Sample

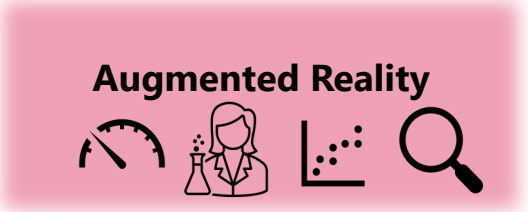
N = 59 children, (Tablet AR = 28, Separate Tablet Display = 31)
Age: *M* = 9.32, *SD* = 0.90
32% female

Split source format: separate tablet displays



vs.

Integrated format: tablet-based AR



Mixed Design - Example

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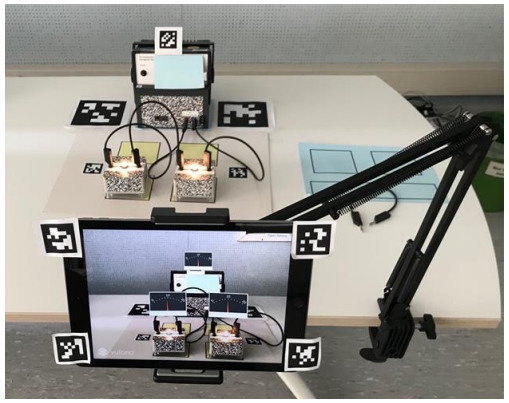
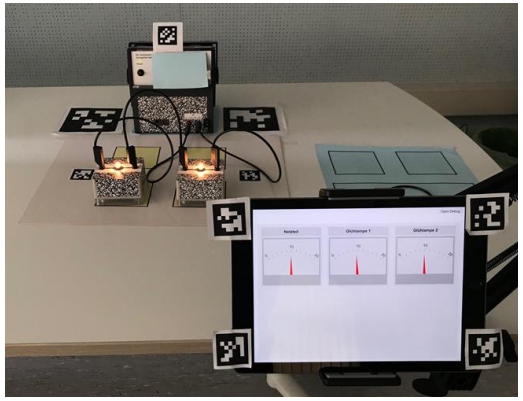
Prior knowledge test	**Standardized Interview:** Conceptual knowledge test on electricity
Lab work phase	**3 science experiments** *building circuits, observing measurements of current, solving tasks*

Tablet-based AR



Eye Tracking



Separate tablet display

Post-test phase	Cognitive load questionnaire (ICL + ECL, adapted from Klepsch et al., 2017), standardized interview on conceptual knowledge, 4 tests varying in demands on global coherence

Experimental Design – **Dependent** Variables

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- Cognitive outcomes
- Emotional outcomes
- Behavioral outcomes

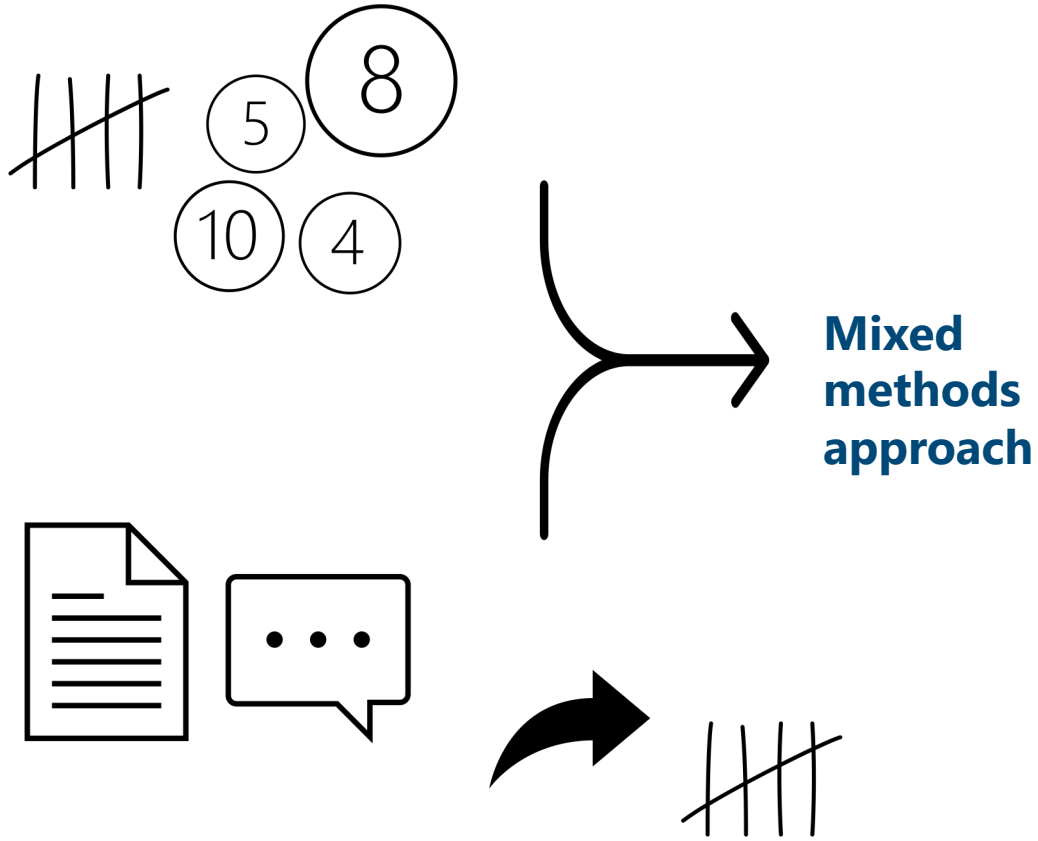
- Physiological data
- Observational data
- Subjective data

What would you like your (raw) **data** look like?

Or rather: how can you best approach your research aim

- Quantitative data
  - Questionnaires (e.g., Likert scales)
  - Performance data (e.g., test results, time on task)
  - Process data (e.g., eyetracking data)

- Qualitative data
  - Interviews
  - Performance data (e.g., open questions)
  - Process data (e.g., thinking aloud protocols)



What **sample** would you like to investigate?

- Representative? →Generalizability

- **Characteristics**
  - •Age
  - •Prior knowledge (experts, novices,…)
  - •Gender
  - •Language
  - •…

- **Size**
  - • **a priori** sample size estimation! (e.g., using G*Power)
  - •Based on prior effect sizes (other studies, pilot studies)
  - •Based on practical usage of effect sizes

Sources of variance in a dependent variable

Total variance (in DV) = Wanted variance + Unwanted variance

Independent variables → Wanted variance

Confounding Variables → Unwanted variance

Maximize

Control

Minimize

Confounding Variables

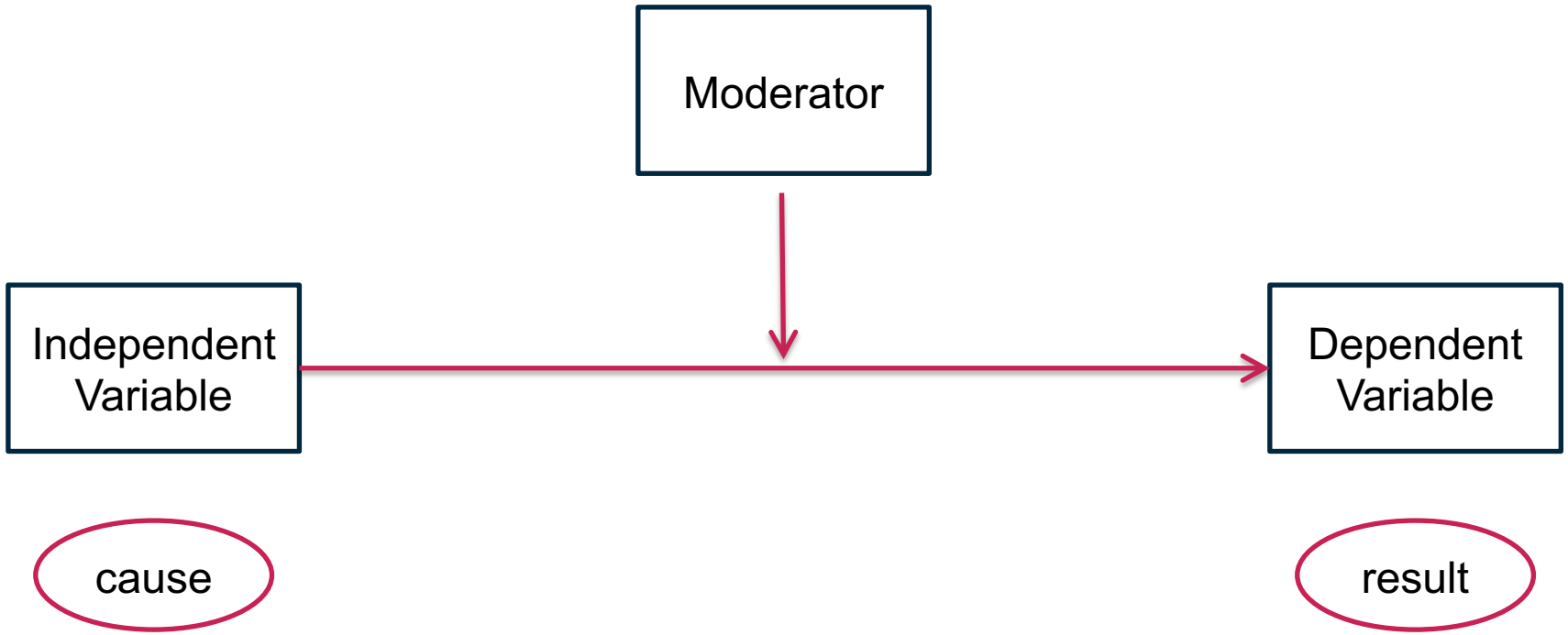
….to (statistically) control for or minimize

- Gender
- Prior knowledge
- Spatial abilities
- Subject of studies

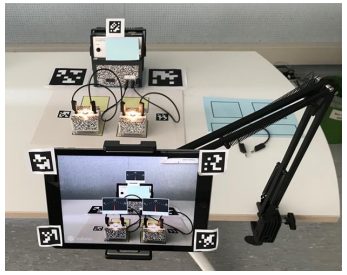
- Sequence effects
- Measurement errors
- Experimenter effects
- Environmental effects (sounds, light,….)

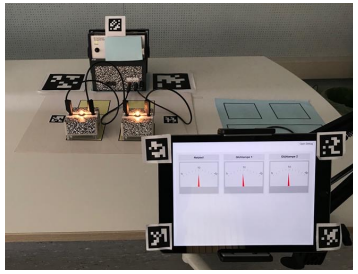
And so on and so on and so on…

Moderating Variable (Interaction)

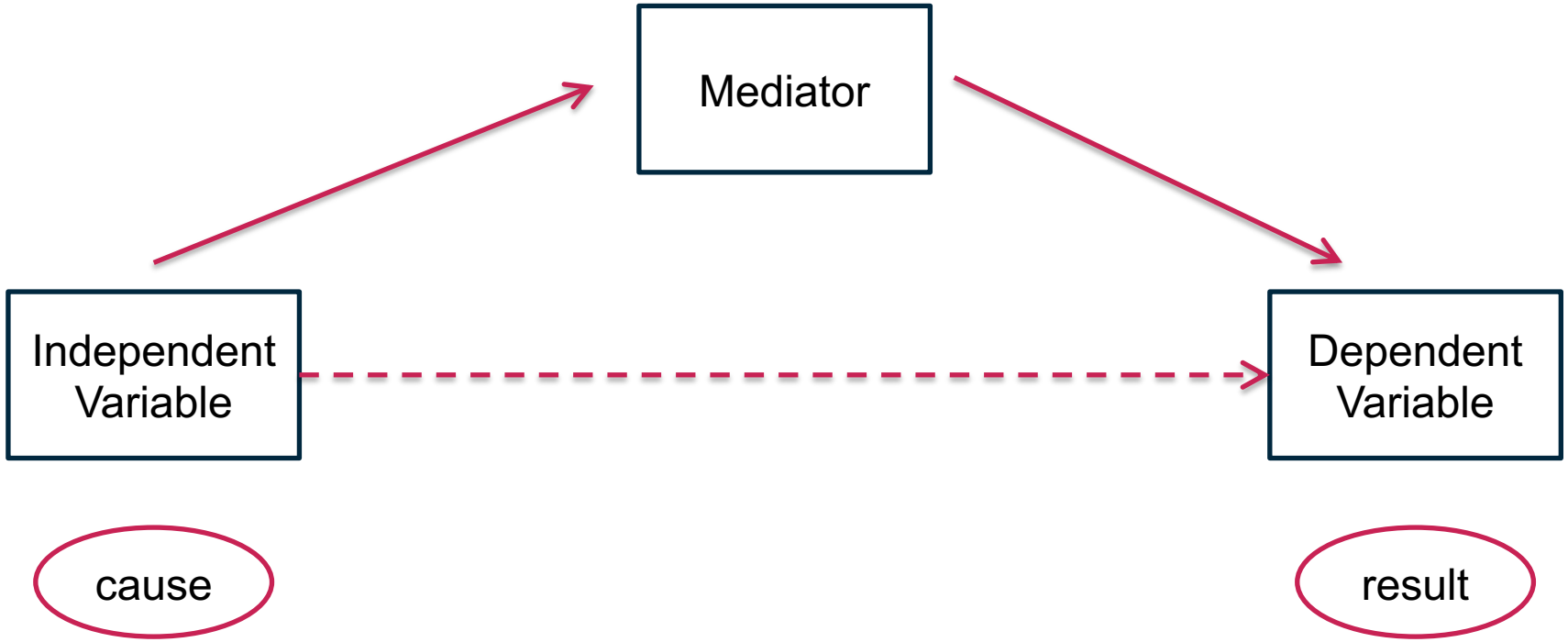


Moderation - Example

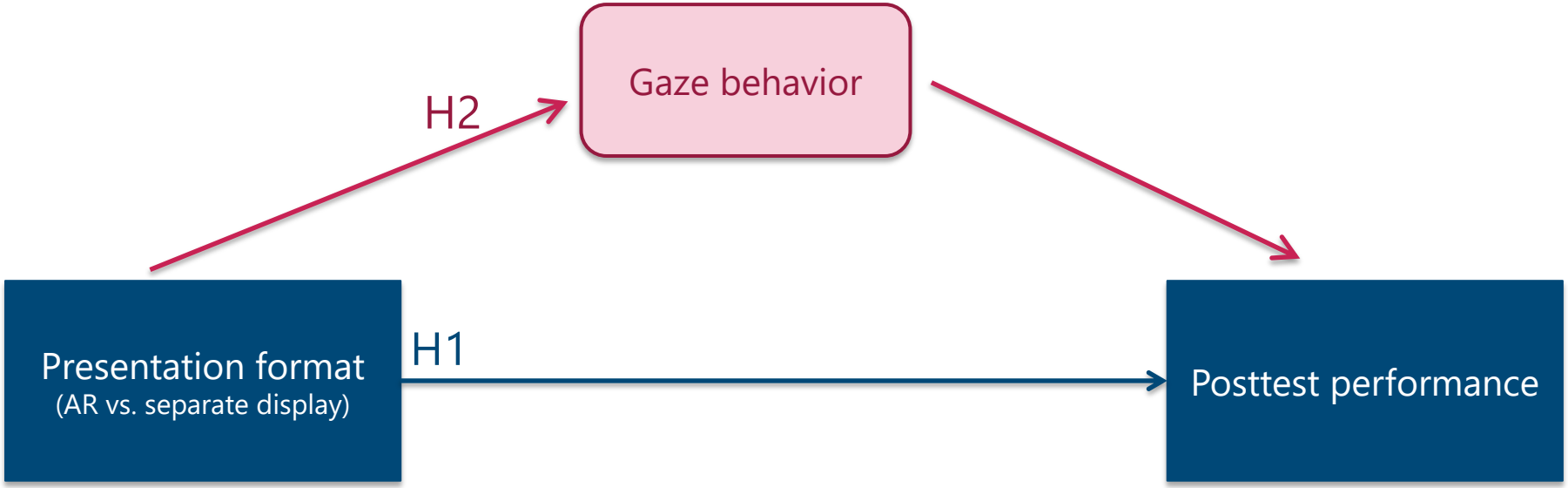




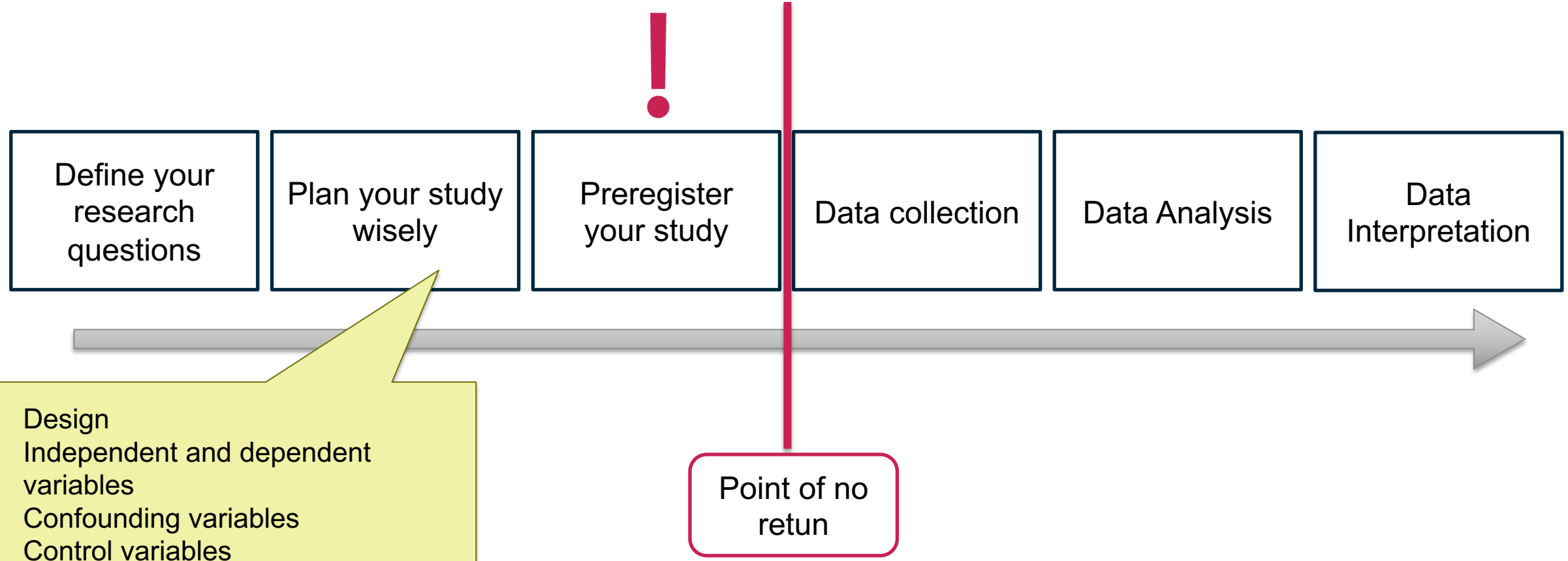
Mediating Variable



Mediation - Example



I would like to conduct a study....



Usability Research

Agenda

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- **What is usability, usability evaluation**
- **Deep dive: Usability of HMD-AR in primary school children**
- **Lessons learned, take-home**

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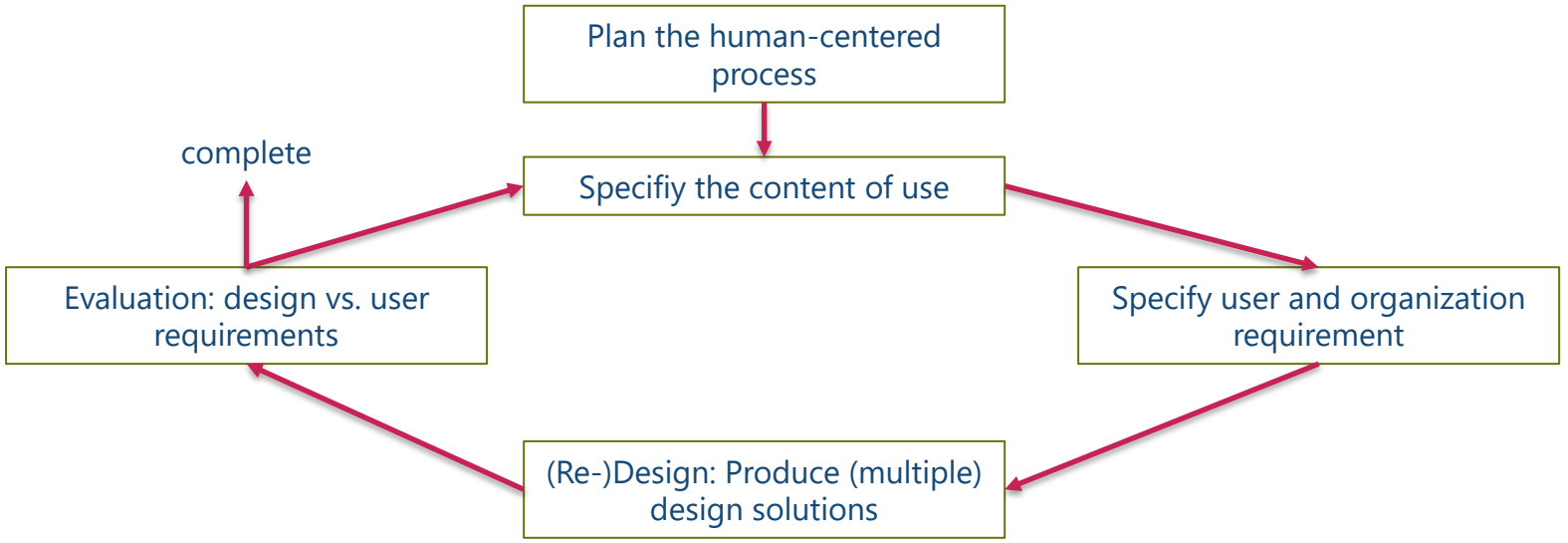
What is Usability?

Human-centered design process for interactive systems

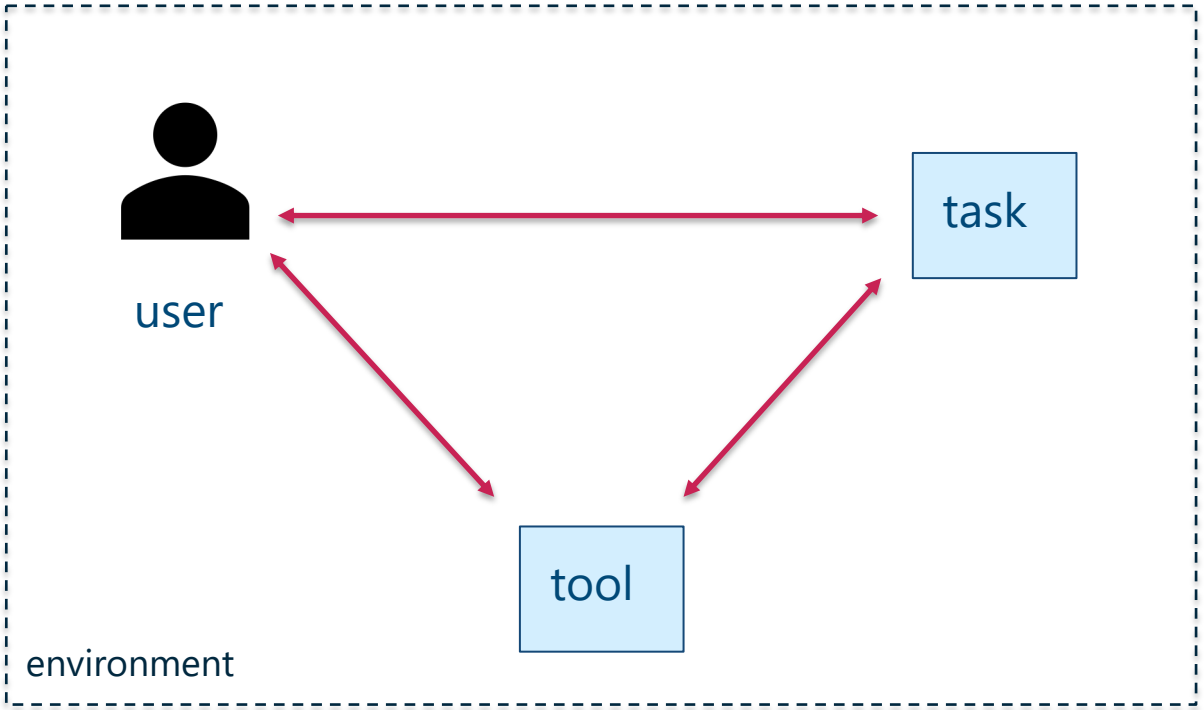


The ISO 13407 principle for a "Human-centred design process for interactive systems (graphic by Sohaib & Khan, 2010, 34)

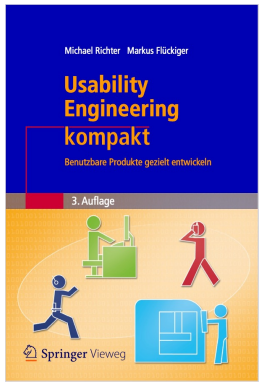
What is Usability?

Usability (german: „Benutzbarkeit“, „Gebrauchstauglichkeit“) describes how well users can use a tool in their environment to accomplish their tasks (Richter & Flückinger, 2013).

Usability Engineering: Understanding and systematically adressing the usability demand of a customer (Lee & McCrickhard, 2007).



Richter & Flückinger, 2013, 5



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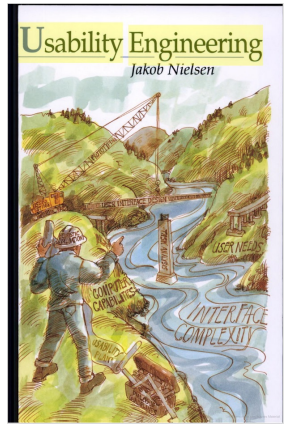
What is Usability?

- **Learnability**: How easy to learn is a system? How rapifly can the users get started?
- **Efficiency**: How high is the possible level of productivity once the user has learned how to use the system?
- **Memorability**: How easy to remember is the use of the system?
- **Errors**: How often do errors occur (error rate)? How easy is it to recover from errors?
- **Subjective satiscation**: How pleasant is the use of the system?



Nielsen (1993).

Usability Evaluation

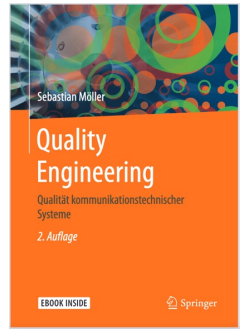
Most used instrument: SUS: A „Quick and Dirty“ Usability Scale (Brooke, 1996).

System Usability Scale

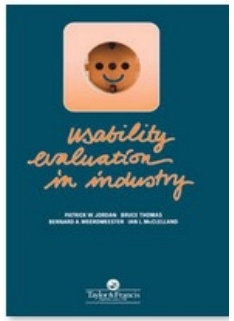
© Digital Equipment Corporation, 1986.

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

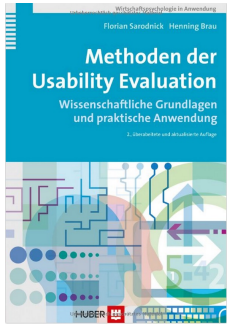
Brooke (1996). https://www.researchgate.net/publication/228593520_SUS_A_quick_and_dirty_usability_scale



Möller (2017).



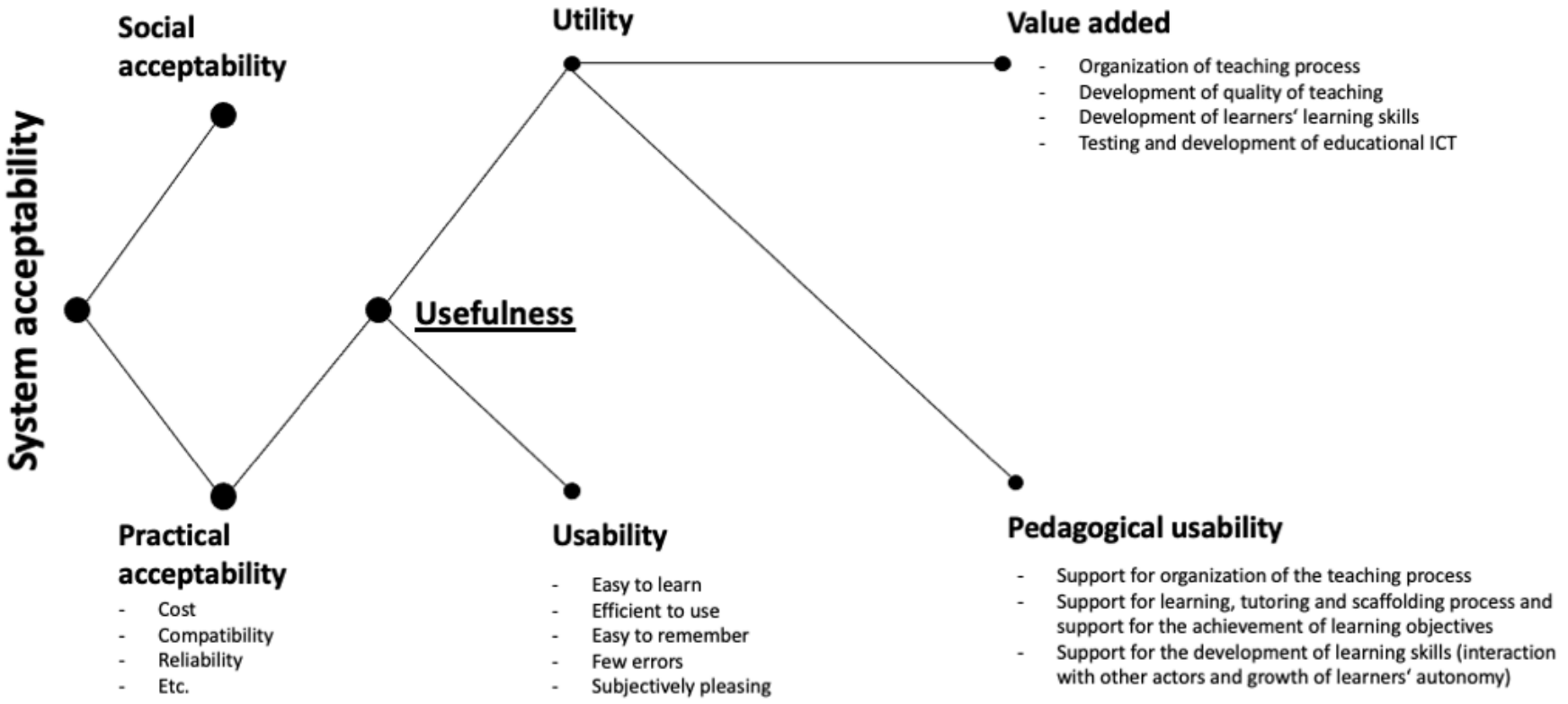
Jordan et al. (2014).

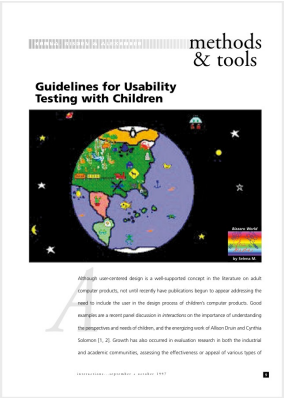


Sarodnick & Brau (2011).

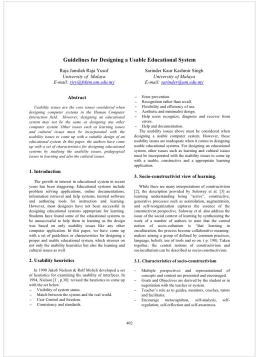
Usability in educational situations

„Model of Usefulness of Web-Based Learning Environments“(Nielsen, 1993; modified by Tervakari & Silius, 2002/2003)





Hanna et al. (1997).



Yusof & Singh(2002).

Agenda

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- What is usability, usability evaluation
- **Deep dive: Usability of HMD-AR in primary school children**
- Lessons learned, take-home

AR-Technologies

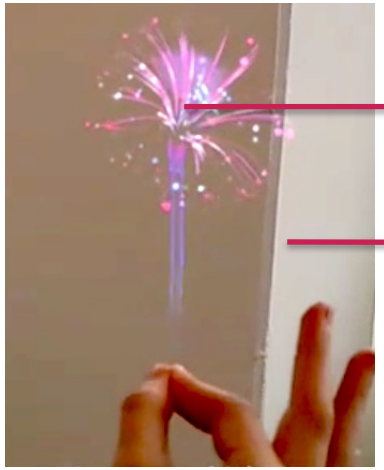
Handheld display devices

Digital image of (**real**) environment

Digital AR-object (**virtual**)

- Everyday devices (smartphones, tablets)
- Most used AR-technology in education (Akçayır & Akçayır, 2017)

Head-mounted Displays (HMD)



Digital AR-object (**virtual**)

Environment (**real**)

- Mostly unknown (especially to young children)
- Little used AR-technology in education (Akçayır & Akçayır, 2017)

Usability of AR-Smartglasses for Elementary School Children

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Challenges for children when using AR-smartglasses:

- Differences in physical characteristics (e. g., arm length or hand size) and in the state of cognitive development in terms of motoric skills or spatial cognition between children and adults (acutal target group of HMD-AR-devices) (Radu & MacIntyre, 2012)
- Individual preferences and skills in using different AR-interaction modes offered by the device (Oviatt et al., 2018)

Challenges caused by the technology when using AR-smartglasses:

- Complex device operation, frequent technical issues (Munoz-Christobal et al., 2015)
- Detection of AR-interaction for device operation can sometimes be unreliable, especially the detection of children‘s voices (Chang et al., 2014; Kennedy et al., 2017; Munsinger et al., 2019)

Usability of the HoloLens 2 for Elementary School Children

Technical innovations and improvements (improved gesture and speech recognition, intuitive opertion) could particularly improve usability for elementary school children

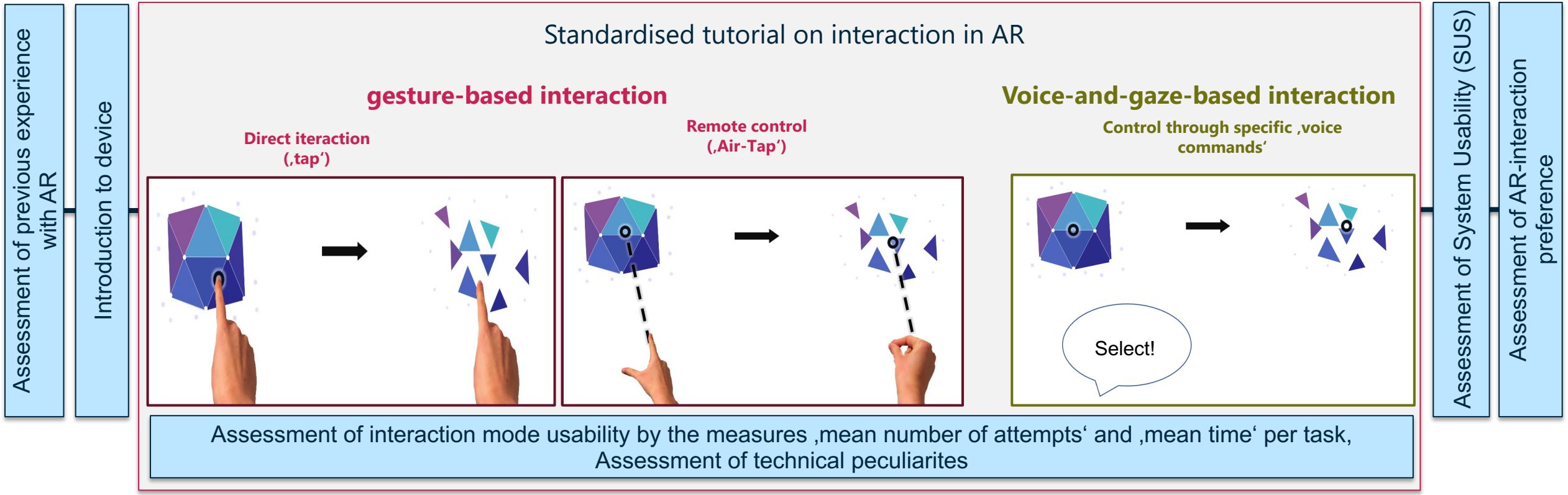
Study: Usability Assessment of Microsoft's HoloLens 2

1. Usability evaluation of the device, efficiency comparison among different AR-inter-action modes offered by the device
2. Assessment of personal interaction preferences in AR and exploration of technical peculiarites of the use of the device with young children

→ **Aim of the study:** acquisition of basic findings concerning general affordances and limitations of the use of AR-smartglasses with elementary school children

Study Design

- Sample: n=43 (27 m, 19 f.; age: 9,3 +/- 0,9 years)
- Within-subjects design, laboratory study with individual appoinments



Results and Discussion

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Personal preferences and technical peculiarites (explorative)

Children's hands are rather small: correctly performed gestures are not alsways registered

Children's arms are rather short: Children neet to step towards AR-objects, causing them to relocate as the device aims to maintain a relative spatial distance

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- **Lessons learned, take-home**

Lessons learned, take-home

- If it works, it works? Engineer/developer perspective vs. user perspective
- Small changes from a technical perspective may induce drastical changes for the user (e.g., from a pedagogical-didactical perspective)
- Participatory development and testing before the start of the actual study!

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