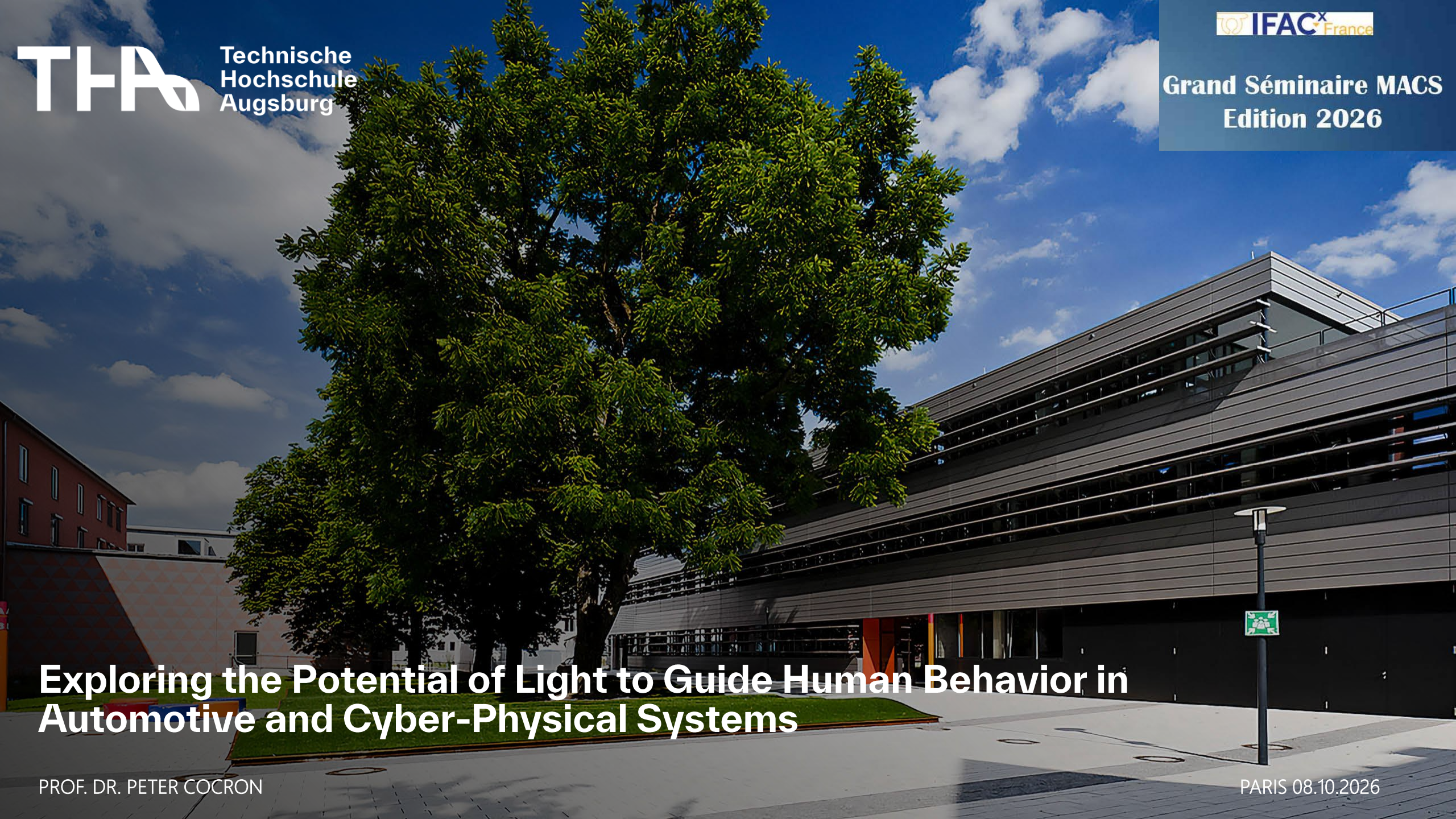


Exploring the Potential of Light to Guide Human Behavior in Automotive and Cyber-Physical Systems

PROF. DR. PETER COCRON

PARIS 08.10.2026

Exploring the Potential of Light to Guide Human Behavior in Automotive and Cyber-Physical Systems

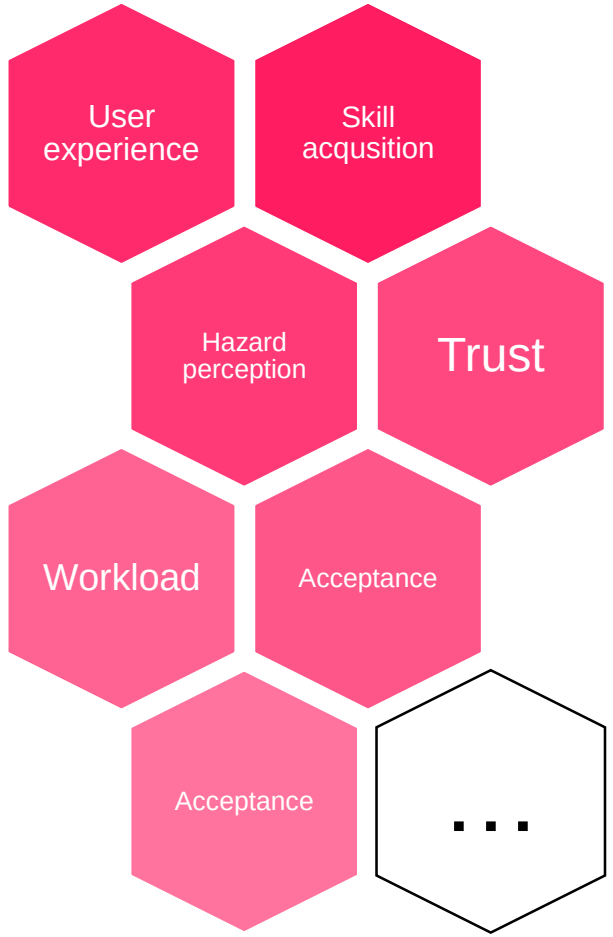
Agenda

- Short introduction
- The lenses of perception
- Why light?
- Open Industrial Training Center (OITC)
- Project BeamAssist
- Summary

Short introduction

Peter Cocron

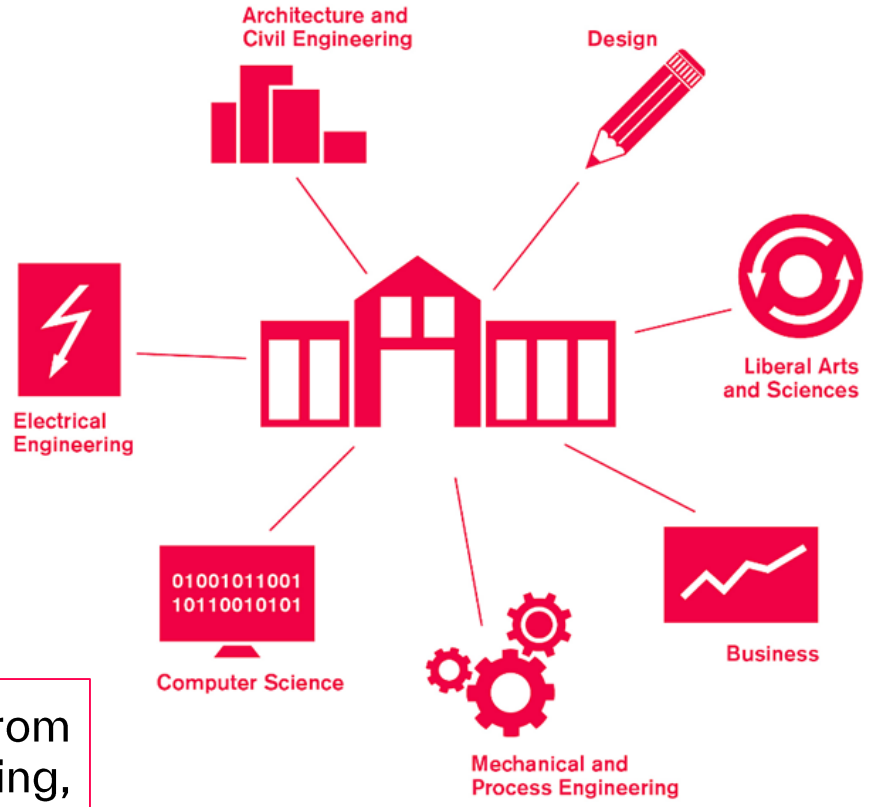
- Professor of Work Psychology at Technical University of Applied Sciences Augsburg, Germany
  - Focus: human machine interaction and human factors
- Team Manager at Bertrandt Group in Ingolstadt, Germany
  - Focus: human machine interfaces (HMI), UX, infotainment systems
- PhD and PostDoc at Chemnitz University of Technology, Germany
  - Focus: traffic and transport psychology, electric vehicles



Technical University of Applied Sciences Augsburg

Key facts

- approx. 8.000 students from 70 countries
- 7 faculties
- 50 different programmes
- 5 Technology Transfer Centers in the region
- Focus on applied research and development



... develop solutions for critical issues of the future - ranging from energy-efficient planning and construction and autonomous driving, through artificial intelligence and social work, to data security, renewable energy, and the **optimization of production processes**.

The lenses of perception

Example#1

"Imagine you own a large insurance company. **You are meeting with a real estate manager**, discussing plans for a new campus of company buildings.

The campus consists of a row of five buildings, the last two with T-shaped courtyards providing light for cafeteria and fitness center.

If the real estate manager showed you the map shown in the [following] figure, you would see five black shapes representing the buildings."

(Johnson, 2010)

The lenses of perception

Example#1

Example from:
Johnson, J. (2010). *Designing with the mind in mind: simple guide to understanding user interface design guidelines*. Morgan Kaufmann.

The lenses of perception

Example#2

"Now imagine that instead of a real estate manager, **you are meeting with an advertising manager**.

You are discussing a new billboard ad to be placed in certain markets around the country. The advertising manager shows you the same image, but in this scenario the image is a sketch of the ad, consisting of a single word.

In this scenario, you see a word, clearly and unambiguously."

(Johnson, 2010)

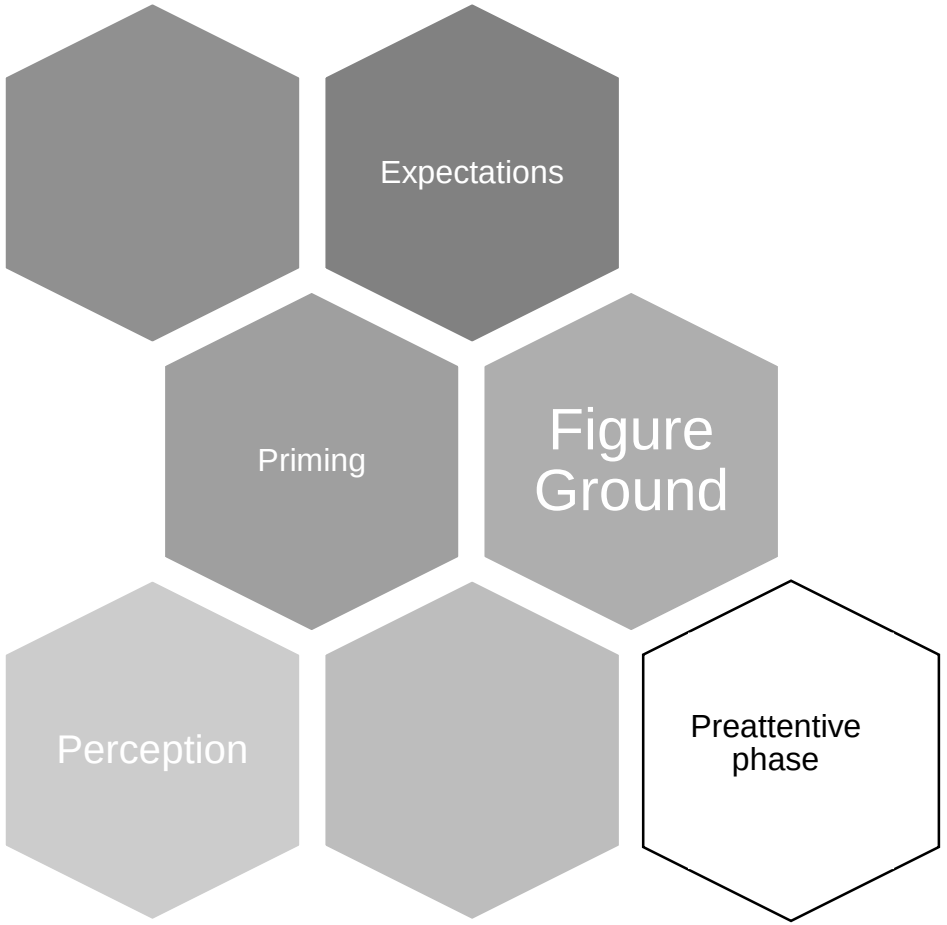
The lenses of perception

Example#2

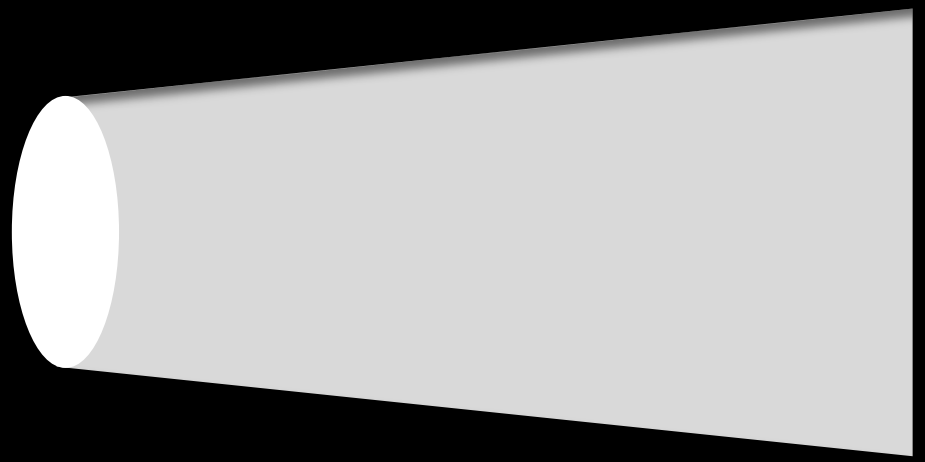
Example from:
Johnson, J. (2010). *Designing with the mind in mind: simple guide to understanding user interface design guidelines*. Morgan Kaufmann.

The lenses of perception

Why?



Why light?

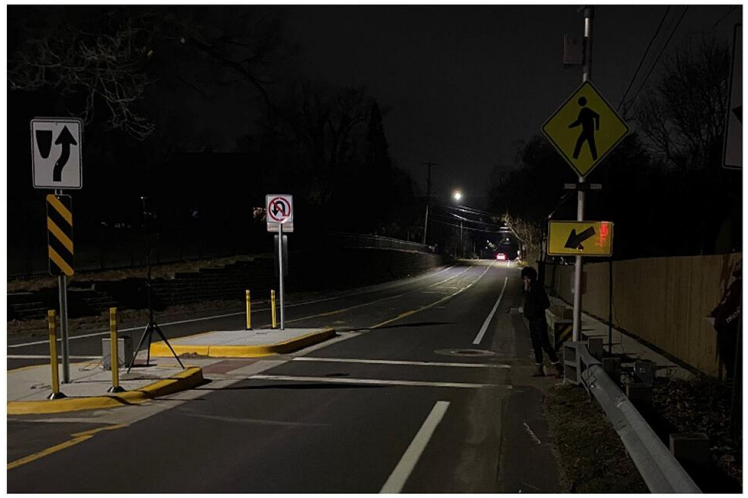


- can guide our attention
- can be rapidly perceived
- can be quicky processed
- can easily be understood
- ...

Using light ...

... to enhance the communication of infrastructure

- Lighting interventions have a positive effects on human behavior such as
  - **motorists yielding compliance** and **pedestrian detection distances** (Hu et al., 2025).
  - **pedestrians crossing** a road.
  - **children** reacting to **in-pavement traffic lights** in school zones (Lee, 2026).





(Hu et al., 2025)

Using light ...

...to enhance the communication with other road users

- **Dynamic external HMIs (eHMIs)** tend to improve crossing efficiency by reducing decision time and increasing certainty or willingness to cross (De Clercq et al., 2019; Holländer et al., 2019; Alhawiti et al., 2024)

- **Static automation-status displays** do not meaningfully change pedestrian decisions or behavior compared with no eHMI, dynamic eHMI led to earlier and more certain decisions (Wilbrink et al., 2021)

(concept by Nissan)

- **BUT: interpretation of motion is decisive:** pedestrians primarily use speed, distance, gap size, and deceleration to decide whether to cross

(concept by Mercedes Benz)

Using light ...

...to enhance the communication with the driver

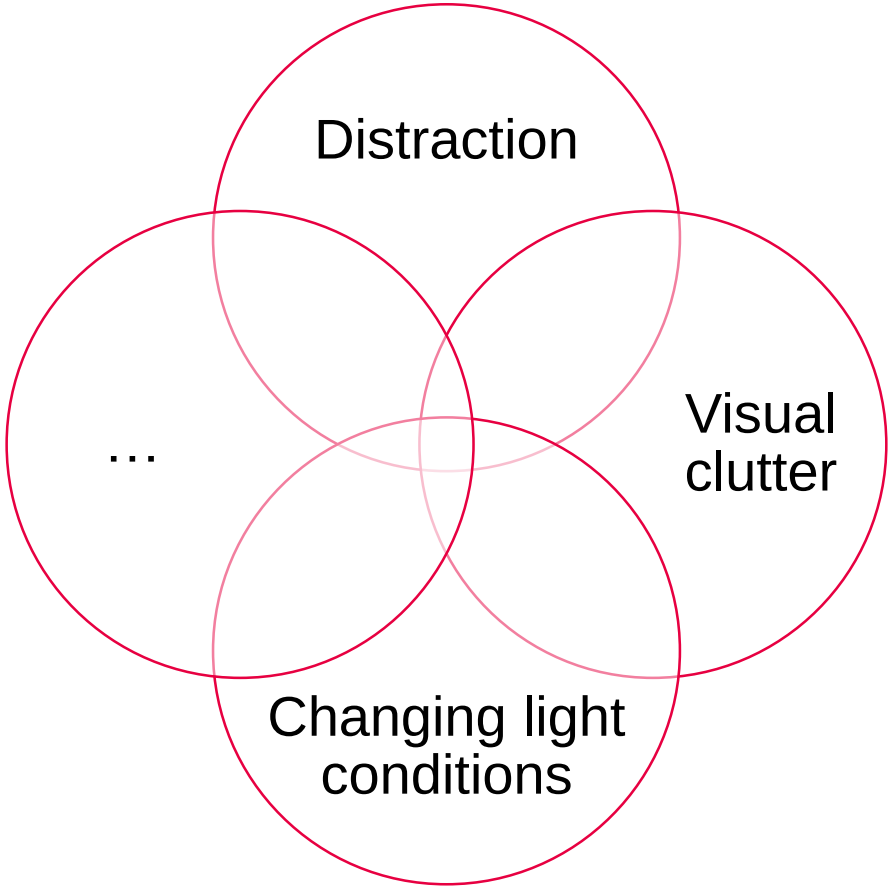
- Drivers tend to **check their mirror more often** when driving a vehicle with a blind spot monitoring system (Kiefer & Hankey, 2008)
- Blind spot monitoring systems, often integrated in mirrors, can reduce **lane-change crashes** by 15% (Keall & Newstead, 2026)
- 6-week evaluation of lane departure warning systems revealed a significant drop in lane departures → successful **visuo-attential guidance** (Navarro et al., 2023)

(concept by Volkswagen)

(concept by Renault)

Using light

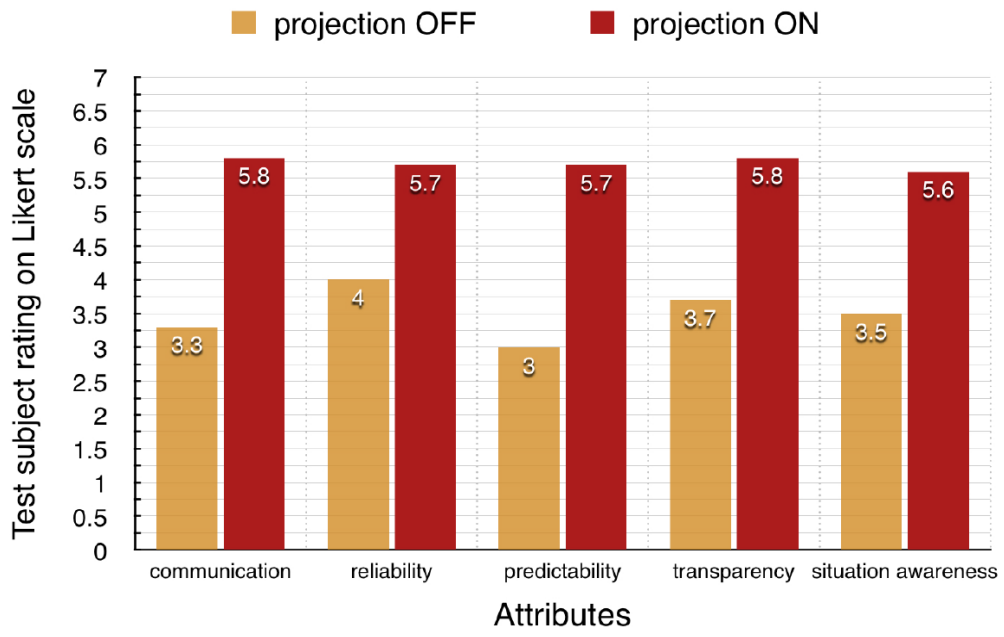
… also faces several drawbacks



Using light

...to communicate intentions and planned actions

- Display of simple information, such as the **trajectory** and the **space to be occupied** by a robot improves human responses and is **evaluated** positively (Chadalavada et al., 2015)



- **Intention visualization via projection** in human robot communication (Wengefeld et al., 2020)



Using light

...to initiate tasks and human behavior

- “Projector-based AR technology in manufacturing marks a significant evolution from traditional methods. By using projectors, detailed instructions and visual cues can be displayed directly on the surfaces where assembly tasks are performed” (medium.com, 2024).
- Laser-based projection system LARS developed by Fraunhofer IML as a mean to address challenges due to lack of skills and high turnover
- Pick-by-light systems led to **better performance** and **human well being** compared to pick-by-scan system (Lucchese et al., 2025)
- Compared to tablet system an in-situ projection system led to **reduced task completion time** but revealed **similar well-being scores** in an assembly task (Lucchese et al., 2025)

https://renderscripter.medium.com/revolutionising-assembly-lines-projectar-illumination-unveils-the-future-of-manufacturing-f60af75eef73

https://techxplore.com/news/2026-07-laser-based-workers-warehouses.html

Open Industrial Training Center (OITC) as a Living Learning Company



The overarching goal of OITC…

> …is to evolve traditional learning factories (LF) into comprehensive, user-centric ecosystems that tackle the complexities of modern, highly connected, flexible, and secure production.

(Öfele et al., 2025)

Connected, digital and secure production across locations

The structure of the Open Industrial Training Center in Augsburg



PLANT 3

Flexible Automation

Faculty of Electrical Engineering, Center for Production Technology

- ✓ **Industrial Robotics**
- ✓ **Digital Twins**
- ✓ **Manufacturing Assistance Systems**
- ✓ **AI in Manufacturing**



PLANT 1

Assembly

Faculty of Mechanical and Process Engineering, Center for Production Technology

- ✓ **Worker Assistance Systems**
- ✓ **Production Organisation**
- ✓ **Digitalisation of Assembly**

OITC



ERP and Sustainable Logistics

School of Business, Reserach Group for Optimized Value Creation

- ✓ **Information Systems (ERP, MES)**
- ✓ **Smart Circular Economy**
- ✓ **Integration of Business Information Systems**
- ✓ **Enterprise Service Bus**

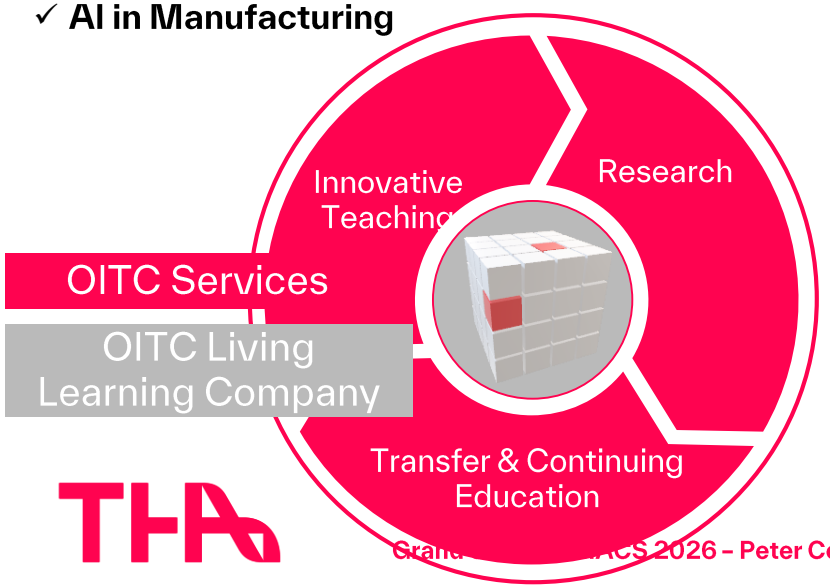


PLANT 2

Innovative Security

Faculty of Computer Science, Institute for Innovative Safety and Security

- ✓ **Machine Safety**
- ✓ **IT Security**
- ✓ **Secure Site Connectivity**



OITC - PLANT 1 MANUFACTURING AND ASSEMBLY

OITC Plant 1 demonstrates what manufacturing of the future might look like.

New worker assistance systems enable efficient and resource-efficient production, even for batch sizes as small as 1.

- Manual assembly of drones
- Training and continuing education for talented employees “on the shop floor”
- Further development of methods and technologies for the industrial production of the future



Inside OITC

Plant 1

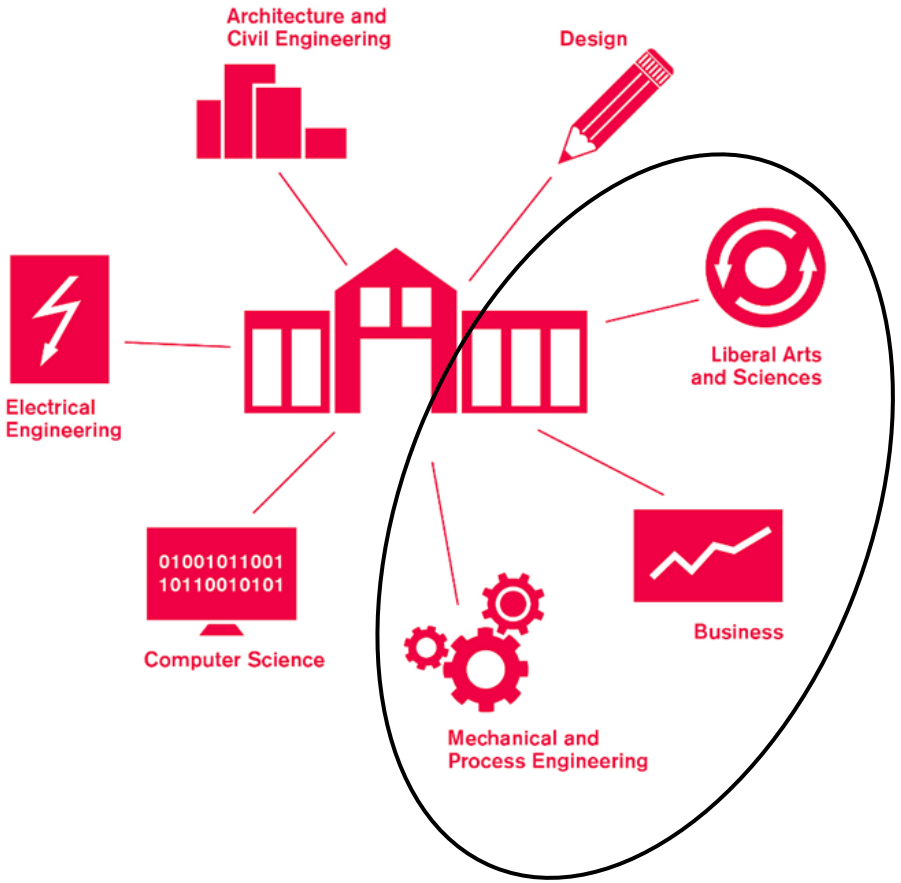




(OITC, 2025; Rieger et al., 2026)

OITC meets Business Psychology

Human Machine Interaction and User Experience @OITC

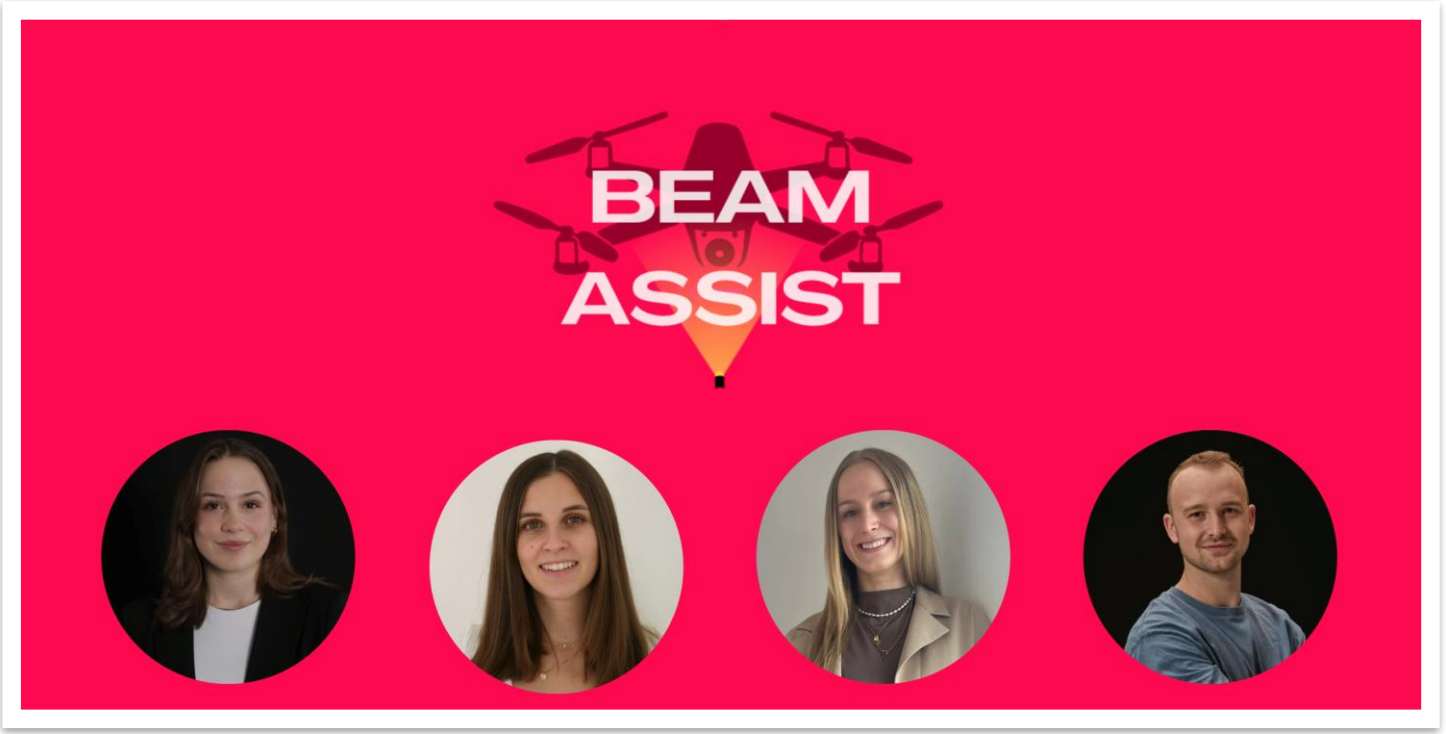


Project BeamAssist

The goal of the student project was …

… to create a work environment at OITC in which a **projector** serves **as a digital assistance system**, guiding people through their tasks in an intuitive, motivating, and more efficient way - for higher quality and greater job satisfaction.

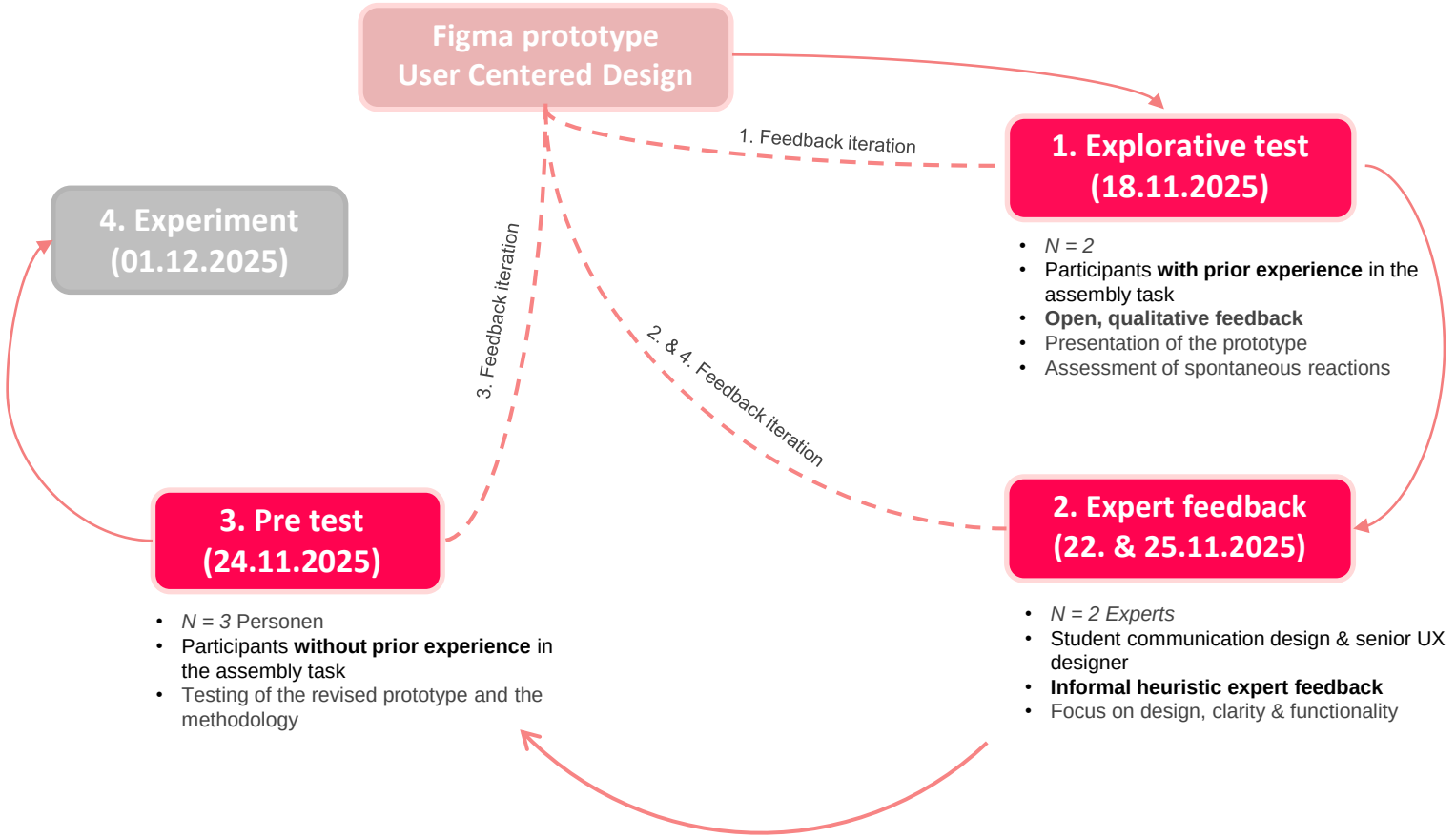
(Rieger et al., 2026)



Anna Rieger | Marie-Amelie Heffinger | Maria Jackl | Robin Niederhuber

Project BeamAssist

Methodology



(Rieger et al., 2026)

Project BeamAssist

Comparision of two concepts

Instruction via tablet



The task of participants in both groups at station 6:

Assemble the third rotor arm to the drone‘s body according to the instructions

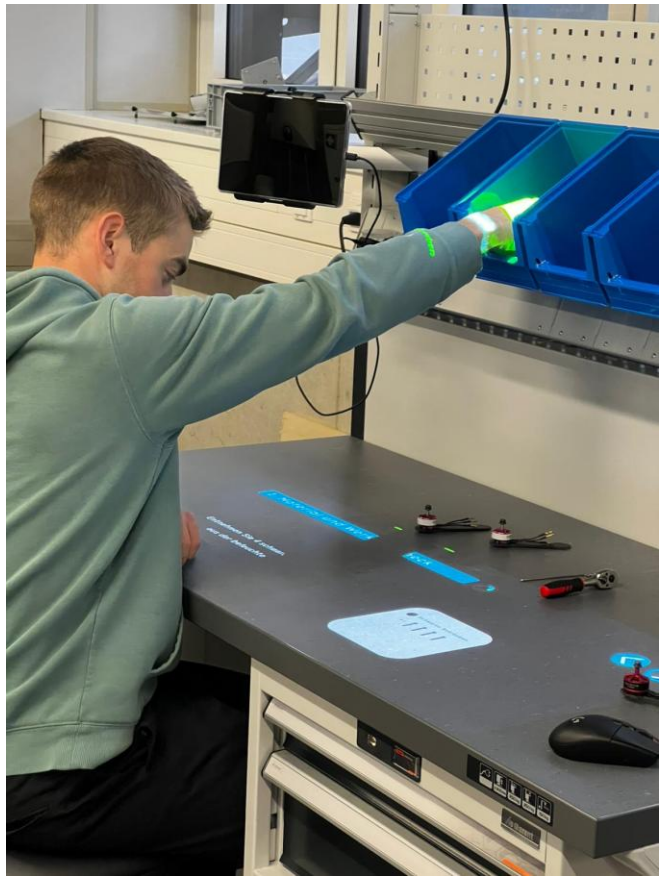
Instruction via projector

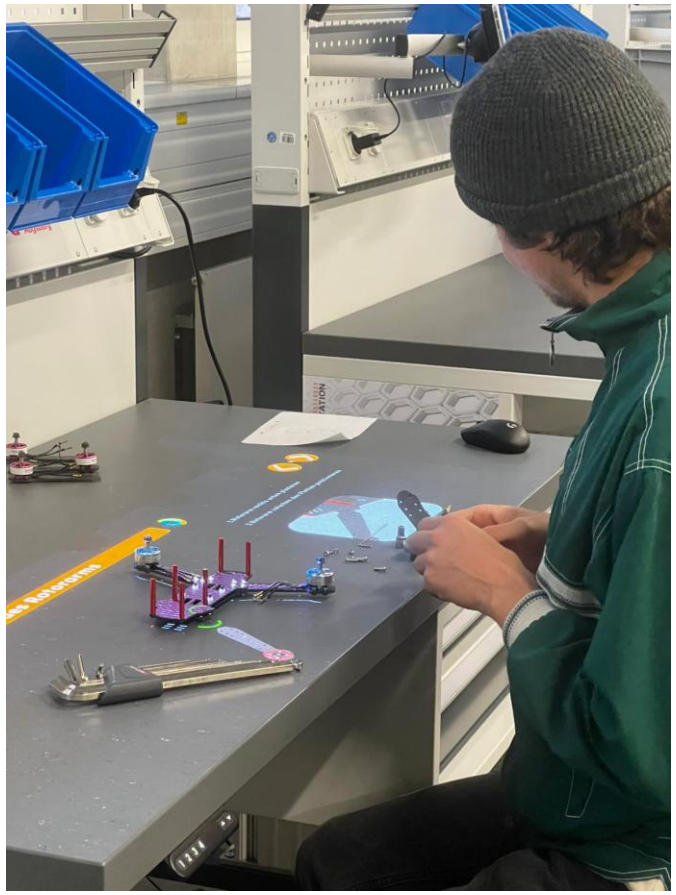


(Rieger et al., 2026)

Project Beam Assist

The setup





(Rieger et al., 2026)

Project BeamAssist

Functions of the prototype

	Function	Description	Benefits
1	Colored lights 	Relevant **material bins are illuminated** in color	- Quick identification - Error reduction
2	Illustrated Step-by-Step Guide 	Images show the **exact sequence** of the process steps	- Easy to understand - Error reduction
3	Video overlay 	Video demonstrates how to **properly install a component**	- Simplification of complex steps
4	Visual Positioning Aids 	Illustration and overlays show the **exact assembly or positioning location** on the product	- Increase of precision and safety during installation - Error reduction

(Rieger et al., 2026)

Project BeamAssist

Sample

N = 6

Age: 20 – 27 years

♂ N = 3

♀ N = 3





Tablet group			
ID	Age	Gender	Assembly experience
VP1	20	female	✗
VP3	23	male	✗
VP5	21	female	✗

→ ⌀-Age = 21 years



Projector group			
ID	Age	Gender	Assembly experience
VP1	27	male	✓
VP3	27	male	✓
VP5	26	female	✗

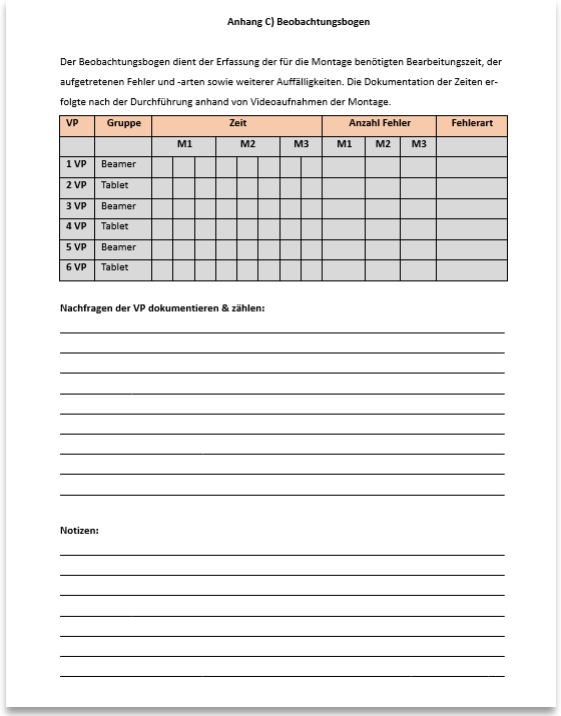
→ Ø-Age = 27 years

(Rieger et al., 2026)

Project Beam Assist

Oberservation during the experiment

Observation form:



Anhang C) Beobachtungsbogen

Der Beobachtungsbogen dient der Erfassung der für die Montage benötigten Bearbeitungszeit, der aufgetretenen Fehler und -arten sowie weiterer Auffälligkeiten. Die Dokumentation der Zeiten erfolgte nach der Durchführung anhand von Videoaufnahmen der Montage.

VP	Gruppe	Zeit						Anzahl Fehler			Fehlerart
		M1		M2		M3		M1	M2	M3	
1 VP	Beamer										
2 VP	Tablet										
3 VP	Beamer										
4 VP	Tablet										
5 VP	Beamer										
6 VP	Tablet										

Nachfragen der VP dokumentieren & zählen:

Notizen:

2 Observers:

→ count errors

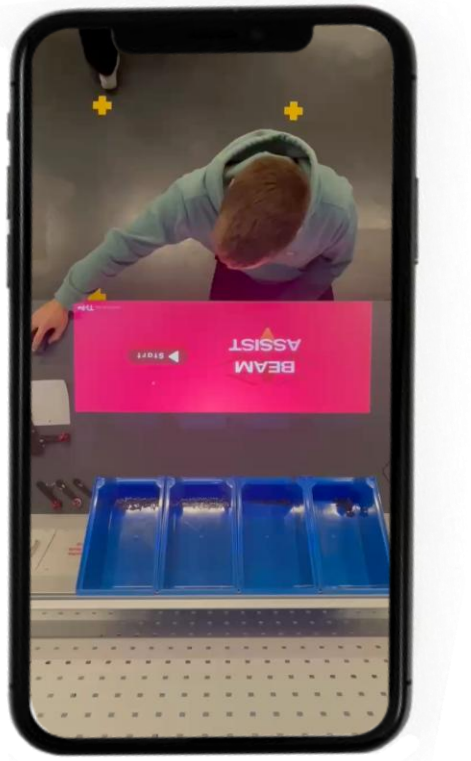
→ describe errors

→ record total task time

→ document inquiries by partivcipants

→ take additional notes

Video recording:



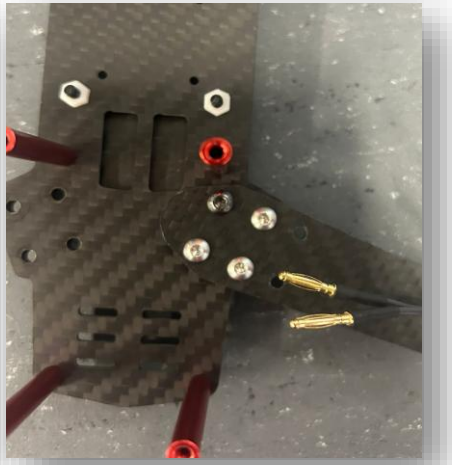
Measure efficiency

(Rieger et al., 2026)

Project Beam Assist

Errors during assembly



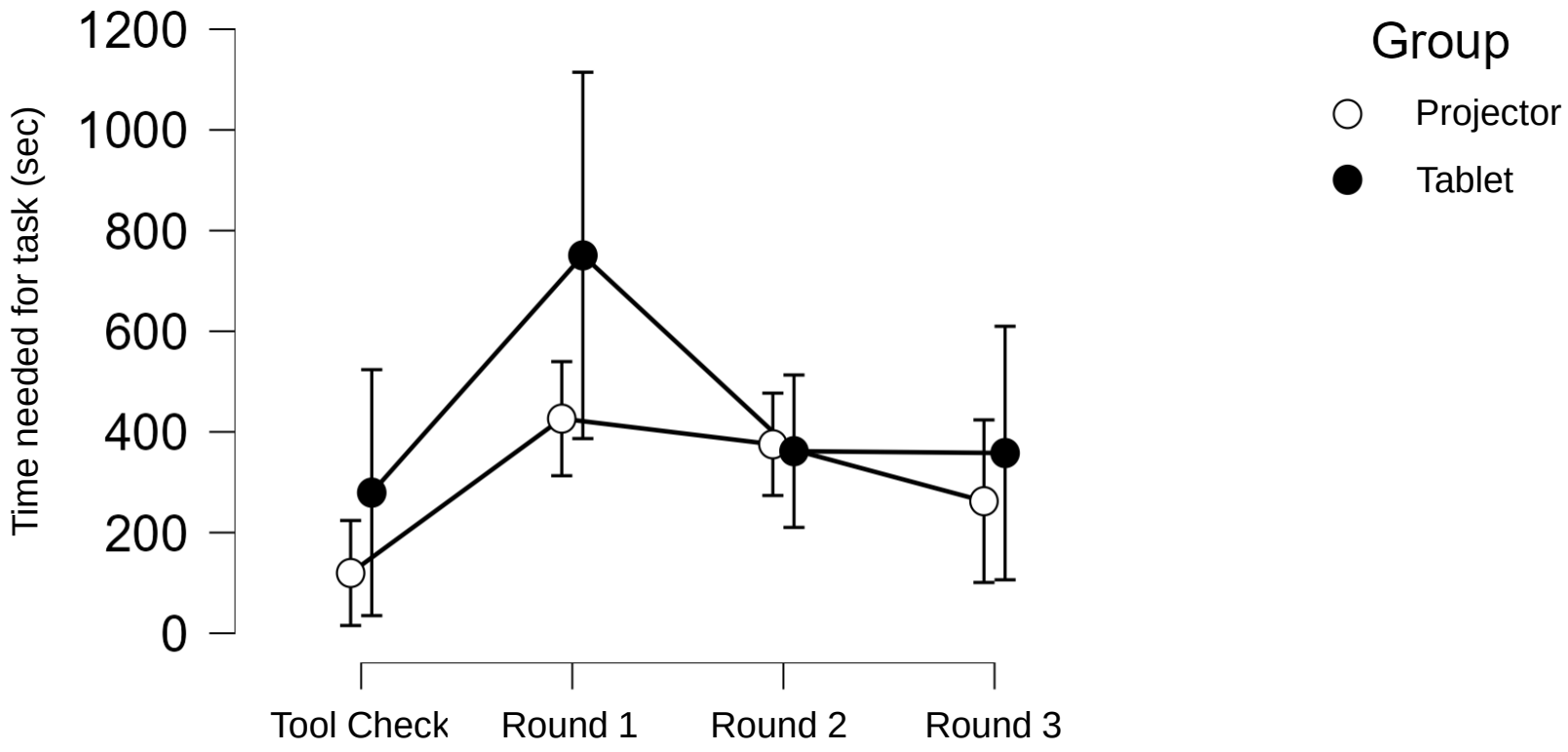


Participant	Group	Round 1	Round 2	Round 3	Total
ID1	Projector	0	0	0	0
ID3	Projector	0	0	0	0
ID5	Projector	0	0	0	0
ID2	Tablet	1 x wrong screws 1 x Rotor arm in wrong position	1 x wrong screws	0	3
ID4	Tablet	1 x Rotor arm in wrong position	1 x Rotor arm in wrong position	1 x wrong screws 1 x Rotor arm in wrong position	4
ID6	Tablet	1 x Rotor arm in wrong position	1 x Rotor arm in wrong position	1 x Rotor arm in wrong position	3

(Rieger et al., 2026)

Project Beam Assist

Time needed for assembly



(Rieger et al., 2026)

Project Beam Assist

Summary findings

“Everything was very clear and helpful.“(ID1)

Positive aspects

Instruction via projector is rated more positively in terms of understandability, design & level of assistance.

“…the third time was the best. I was able to get the hang of it pretty quickly.”(ID5)

Learning curve

Initial problems occured using the tablet instructions, resulting in longer task times and higher number of errors.

Negative aspects

Instruction via tablet receives more negative feedback, particularly regarding understandability and support.

“The first time, I felt a little lost.“(ID4)

Subjektive experience

Mostly a positive experience being instructed by the projector, significantly higher levels of dissatisfaction within the tablet group

”It felt a bit like an IKEA instruction manual. Only more interactive.”(ID3)

(Rieger et al., 2026)

Project Beam Assist

Discussion

- Limitations: sample size, task choice and level of experience
- Instruction via projection has a positive impact on the user evaluation, the error rate and (initial) task completion time
  - Comparable to recent findings on visual guidance in AR settings (Pietschmann et al., 2025) or when comparing tablet and projection systems (Rupprecht et al., 2020)
  - Shape and visualisation plays a role, not just light
- Long term effects on recall of learned tasks need to be considered (Büttner et al., 2020)

Project Beam Assist - Acknowledgements







Thanks to...

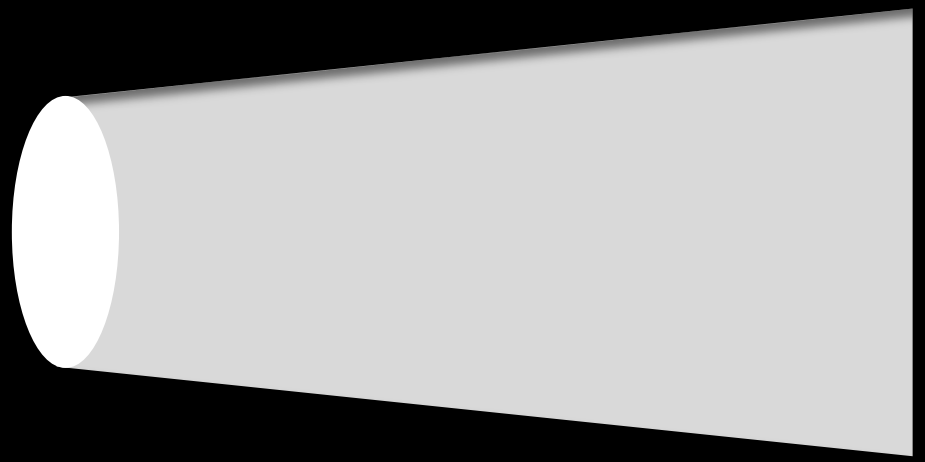
Project Team: Marie-Amelie Heffinger, Maria Jackl, Anna Rieger, Robin Niederhuber

OITC Team: David Rottenegger, Marcel Öfele, Anton Seemüller, Prof. Dr.-Ing. Stefan Braunreuther

Further info:

https://www.tha.de/en/research/research-profile/research-projects/tha-ai-production-network/

So … why light?



- …can be processed preattentively
- …can reduce errors and cognitive load
- …can compensate limited skills (e.g. language, task)
- …can be set up in a rather simple experimental environment
- BUT:
  - More signals and information – more overload?
  - Tasks become too simple – monotony and fatigue?

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Hochschule
Augsburg

Thanks for your attention

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Image directory

- Slide 6 & 8:
  - Johnson, J. (2010). *Designing with the mind in mind: simple guide to understanding user interface design guidelines*. Morgan Kaufmann.
- Slide 11:
  - Hu, W., Van Houten, R., Cicchino, J. B., Engle, J., & Shomaly, L. A. (2025). Effects of crosswalk illuminators and rectangular rapid flashing beacons on speed reductions and yielding to pedestrians at night. *Transportation Research Record*, *2679*(5), 402-413.
- Slide 15:
  - Chadalavada, R. T., Andreasson, H., Krug, R., & Lilienthal, A. J. (2015, September). That's on my mind! robot to human intention communication through on-board projection on shared floor space. In *2015 European Conference on Mobile Robots (ECMR)* (pp. 1-6). IEEE.
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- Slides 19 & 20:
  - Open Industrial Training Center @ Technical University of Applied Sciences Augsburg, Germany
- Slides 22, 24, 25, 28, 30, 34:
  - Rieger, A., Heffinger, M.-A., Jackl, M., & Niederhuber, R. (2026). Beam Assist – projektionsbasierte Assistenz in der Montage. [Unpublished project report] School of Business - Technical University of Applied Sciences, Augsburg