Raising task state awareness in teams by means of Augmented Reality

Human Factors and Systems Safety Thinking Conference
Automation and Human factors Integration

2-4 October 2019
Hotel Puerta América, Madrid
What we are interested in

Taskwork

- Skill acquisition and retention
  - The threat of skill decay
  - Effects of refresher trainings

Teamwork

- Cognitive Readiness for **non-routine/abnormal** situations
  - Information overload
  - Task overload

- Team Training for High Responsibility Teams and performance under stress („Team performance breakdowns“)
  - Training for adaptability
  - Task reprioritization
  - Task allocation
  - Mutual support
  - Back up behavior

Organization

- Safety Management in High Reliability Organisationen
- Organizational Learning from Errors
- Organisational Forgetting (adaptation to information overload)
- Stressors as antecedence for safety related rule violations („work safe tension“)

Training for Decision Making under stress
- Stress exposure training
- Training for Surprise
- Task Technology Fit and technical support (App for Fault Diagnosis)
Agenda

• Introduction: **Digital Realities** for task work and team work
• Augmented Reality, Augmented Virtuality & Virtual Reality
• Their potential to support learning, transfer and daily work
• General Challenges in **team work**
• Digital Assistance for team coordination
• Task state awareness as a specific challenge
• Possible solutions and first results from 2 pretest
Digital Realities
Digitization, Digitalization & Digital Transformation

- **Digitization**: Transitioning from analog to digital—e.g. from hard copies to e-checklists

- **Digitalization**: Making digitized information work for the organization—processes reengineering by using **all available data** (Internet of Things/ IoT, Sensors, real time data...)

- **Digital transformation**: Taking advantage of digitalization to create completely new business concepts, e.g. by using AI, AR, etc...

Enablers of Digital transformation

....depends on a number of new and innovative technological developments:

• The application of information and communication technology (ICT) to digitize information and integrate systems at all stages of product creation and use (including logistics and supply), both inside companies and across company boundaries;

• Cyber-physical systems that use ICTs to monitor and control physical processes and systems. These may involve embedded sensors, intelligent robots that can configure themselves to suit the immediate product to be created, or additive manufacturing (3D printing) devices;

• Network communications including wireless and internet technologies that serve to link machines, work products, systems and people, both within the manufacturing plant, and with suppliers and distributors;

• Simulation, modelling and virtualisation in the design of products and the establishment of manufacturing processes;

• Collection of vast quantities of data, and their analysis and exploitation, either immediately on the factory floor, or through big data analysis and cloud computing;

• Greater ICT-based support for human workers, including robots, augmented reality and intelligent tools.

Examples of Augmentation
ThyssenKrupp Elevator
https://www.youtube.com/watch?v=8OWhGiyR4Ns
Characteristics of Task work & Team work
Couplings and interconnections require the operator to simultaneously process the interplay of cross-coupled variables in order to either assess a process state or predict the dynamic evolution of the plant.

Dynamic effects require the operator to mentally process and envisage the change rates of cross-coupled variables and to develop sensitivity for the right timing of decisions in order to be successful.

Non-transparency requires the operator to work with more or less abstract visual cues that need to be composed into a mental representation and need to be compared with the operator’s mental model.
HRO Task Work Characteristics - II

Multiple or conflicting goals require the operators either to balance management intentions or to decide on priorities in case of goal conflicts in the decision making process, e.g. which course of actions to take.

Crew coordination complexity incorporates small crews and supervisors, who are responsible for overall system operations and calls for the operators to concurrently interact with team members in order to orchestrate individual actions into a coordinated flow of actions to either assess the situation or choose a course of actions.

Team work requirements

**Team Work Skills**

**Communication**
- Information exchange
- Phraseology
- Closed-loop communication

**Coordination**
- Knowledge requirements
  - Goal related knowledge
  - Task related knowledge
  - Process related knowledge
  - Team related knowledge
  - Shared SA
  - Shared Shared Mental Model

**Cooperation**
- Mutual performance monitoring
- Back up behavior
- Adaptability
- Team orientation
- Collective efficacy
- Mutual Trust
- Team cohesion

The Reality-Virtuality Continuum
Mixed Realities - a continuum

AR supplements reality
Ideally, it would appear to the operator that virtual and real objects coexist in the same space („Who framed Roger Rabbit?“)

AV augments the virtual system through real inputs

VR replaces reality, completely immerses user inside a synthetic environment (Azuma, 1997)


Augmented Reality
AR-Support of cognitive processes in work contexts

Perceive

Recall

Act
Augmented Reality

- AR is a set of innovative and effective Human Computer Interaction (HCI) techniques
- **AR enriches the way that users experience the real world by embedding virtual objects to coexist and interact with real objects in the real world** (Wang et al, 2016)
- E.g. Google Glass, Pokemon go, Museums.... head worn versus hand held tables, smartphones...
- Has been applied successfully in areas such as medicine, maintenance and repair, cultural heritage, and education
- Has been used for planning, design, ergonomics assessment, operation guidance and training, by creating an augmented environment where virtual objects (instructions, visual aids, and industrial components) coexist and interact with real objects and environment.
- AR is one of the nine enabling technologies that power the digital transformation supported by Industry 4.0 (Davies 2015, Uva et al., 2018)
- AR uses **head worn display** for hands free work (but can also be projections)


https://www.youtube.com/watch?v=0m67O1Em7dY
Augmented Reality

AR- aiming to provide digital **intuitive instructions** at the same time as operators are working on the task (Oliviera et al., 2014)

With AR, artificial information about the environment and its objects can be **overlaid on the real world** in order to enhance the operator's perception of reality (Syberfeldt et al., 2015)

An AR system has

- the ability to combine real and virtual objects
- ability to **register (align) real and virtual objects** with each other,
- ability to run interactively, in three dimension, and in real time

(Kreveln and Poelman, 2010, Azuma, 1997)
Augmented Reality

Examples from AZUMA „Real Desk“

- AR **adds** objects to the real world but also can **remove** objects (e.g. to hide irrelevant information or cues)
- AR might apply to all senses not just sight (Azuma, 1997) focus on blending real and virtual images and graphics but AR can be extended to include **sound** (adding synthetic directional 3D sound) or **tactile feedback** (gloves that provide tactile feedback and augment real forces in the environment)

-> in the following I speak mainly about **see through HMD**- lets the user see the real world with virtual objects super imposed by optical technologies (Azuma, 1997)

Examples from Azuma (1997)

- Medicine
- Manufacturing an repair (Thyssen Krupp Film)
- Annotation and Visualization
- Robot Path Planning
- Military - Striker II

**Figure 1:** Real desk with virtual lamp and two virtual chairs. (Courtesy ECRC)

AR Applications

• AR for Hazard Identification and risk recognition, sensing, analysing and extracting potential danger

• AR for safety training and education: visualization-based training to experience-based training in safety (Li et al., 2018)

• AR for safety inspection and instruction: AR for recognizing safety risks, for inspection, supervision and strategizing

• AR for high risk equipment operation

Military

https://www.google.com/search?client=firefox&q=Striker%20II%20Helmet

Striker II

https://www.youtube.com/watch?v=mdPylWKX6uA
AR for training of procedures

Ability to combine abstract concepts and 3D spatial information in the context of real-world objects makes AR an ideal tool for training in situations which requires manipulation of objects, e.g. assembly or maintenance tasks (Westerfield et al., 2015)

- Capacity to **deliver hands-on training where users receive visual instructions** in the context of real-world objects
- Combining **work and maintenance instruction and safety instruction** in AR (Tatić & Tešić, 2017).
- Intelligent tutoring systems (ITS) provides customized instruction to each student
- The integration of ITS and AR creates new possibilities (Westerfield et al., 2015)
- AR can **avoid the burden of fusing information displayed on several screens** (Ruano et al., 2017)

Collaborative AR

Collaborative AR (Billinghurst & Kato, 2002)

AR can be used to **enhance a shared physical work space**, presence of spatial cues for face-to-face and remote collaboration

AR system **promotes information exchange and SA** for teams (Lukosch et al, 2015) eg.

- remote user AR support,
- local user AR support
- localization and mapping
- shared memory space


Augmented Virtuality
Augmented Virtuality

Augments the virtual system through real inputs (AV), (Borsci et al. 2015), if tactile feedback is required

Augmented Virtuality (AV) = integrating real operating elements in a virtual environment for Head-mounted Displays (Neges et al., 2018)—separate visual and haptic perception


Virtual Reality
VR Applications

VR is to generate immersive environments from which users can experience unique insights into the way the real world works (Li et al., 2018)
Their potential to support learning, transfer and daily work
Adaptive Intelligent System
Interactive digital assistance systems for an augmented operator

Examples of the new possibilities for employee support are assistance systems that support employees individually in carrying out work steps based on their qualifications or competences already acquired.

-> enables job rotation through on-the-job training and execution support (Prinz, Kreimeier & Kuhlenkötter, 2017)

-> also known as situational employee qualification (Kreggenfeld & Kuhlenkötter, 2016).

-> supports employees,

• even without many years of experience at a workplace
• special work activities or
• with problems that occur rather rarely, to carry out these activities within a defined standard despite a lack of routine (Kreggenfeld & Kuhlenkötter, 2016).

In the case of situational support, a systematic comparison of requirements and employee-related knowledge and skill requirements takes place in the work process or in the process chain.

-> particularly relevant in the heterogeneous and complex work

-> supports the employees on-the-job, which can be used more flexibly with the assistance system (Kreggenfeld & Kuhlenkötter, 2016).


Challenges in learning and executing complex tasks

- **High interinsic load** – due to learning task complexity (challenging for working memory capacity during learning)

- **High cognitive load while learning**
  - High extraneous load – due to inappropriate training methods
  - e.g. split attention effect

- **High mental work load while working** – individual task
  - High mental workload e.g. due to changing rules that need to be recalled and applied

- **High mental work load while task execution**
  - High additional mental workload due to team work requirements – team task
  - The integration of task work and teamwork skills is a concurrent task demand. It shares elements of a dual task, which requires time-sharing and attention allocation.
Challenges in learning and executing complex tasks

High cognitive load while learning
- High interinsc load – due to learning task complexity (challenging for working memory capacity during learning)
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High mental workload while task execution
- High mental work load while working – individual task
- High mental workload e.g. due to changing rules that need to be recalled and applied
- High additional mental work due to team work requirements – team task

AR can help visualize dynamic effects (e.g. prediction)
- AR can visualize conflicting goals
- AR can superimpose virtual elements that are intransparent
- AR can superimpose checklist items to reduce memory requirements
- AR can be used as a situative assistance for non-routine situations
- AR can superimpose information from different screens
- AR can serve as a coordination assistance system

The integration of task work and teamwork skills is a concurrent task demand. It shares elements of a dual task, which requires time-sharing and attention allocation.
An example for an digital assistance (overlay)

Recall support with Gaze Guiding as cued recall

- **Dynamic computer-based job aids** have been used for the learning of skills and can be applied through various methods, such as the Attention Guidance Technique and Visual Cueing.

- **Combination of Attention Guidance Technique, Visual Cueing and further textual information** (De Koning, Tabbers, Rikers & Paas, 2010; Lin & Atkinson, 2011)
Gaze Guiding- Demonstration
http://www.aow.ruhr-uni-bochum.de/fue/gazeguiding.html.de
Method Exp. 1-3: Participants & Procedure

Participants

<table>
<thead>
<tr>
<th>Experiment 1: Fix</th>
<th>Experiment 2: Parallel</th>
<th>Experiment 3: Contingent</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N = 36 ) (15 female)</td>
<td>( N = 40 ) (13 female)</td>
<td>( N = 35 ) (12 female)</td>
</tr>
<tr>
<td>Age: 21.97 (2.43, 18-28)</td>
<td>Age: 22.65 (3.56, 18-31)</td>
<td>Age: 22.74 (2.81, 19-30)</td>
</tr>
</tbody>
</table>

Initial Training

<table>
<thead>
<tr>
<th>30 min</th>
<th>60 min</th>
<th>10 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Training Phase</td>
<td>Training (Manual)</td>
<td>Test 1</td>
</tr>
</tbody>
</table>

Retention Assessment

<table>
<thead>
<tr>
<th>30 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 2 with GG</td>
</tr>
</tbody>
</table>

Experiment 1: Fix
- Gaze Guiding
- Control Group

Experiment 2: Parallel
- Gaze Guiding
- Control Group

Experiment 3: Contingent
- Gaze Guiding
- Control Group

Start-up mistakes

Results: Hypothesis

Start-up mistakes

Interaction of time and group:
\[ F(1,34) = 27.28, p < .001, n^2_p = 0.05 \]

Interaction of time and group:
\[ F(1,38) = 4.96, p = .032, n^2_p = 0.12 \]

Interaction of time and group:
\[ F(1,32) = 17.60, p < .001, n^2_p = 0.04 \]

Interaction of time and group:
\[ F(1,108) = 29.77, p < .001, n^2_p = 0.22 \]

**All participants of the Gaze Guiding-group used the gaze guiding-tool at least 1x**

Digital assistance for team work
The impact of ambient awareness on temporal coordination of dispersed teams
Objective of the study

-> to build and empirically investigate the effects of **temporal coordination artifacts**

-> that support the **temporal coordination** of teamwork of

-> **spatially dispersed teams** in production settings

-> by means of enhanced **task state awareness**.
Spatially dispersed teams
Spatially dispersed teams
Temporal Coordination

Temporal coordination (Badram, 2000)
1) the correct sequencing of joint action (knowing and executing what comes first, second, third, etc.),
2) the correct timing (knowing the best moment to execute the task, not too early and not too late, e.g. Hollnagel, 1998), and
3) the adaptation of dynamic effects as variables in the team’s context (Kluge et al., 2018)

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3) the adaptation of dynamic effects as variables in the team’s context (Kluge et al., 2018)

- timing errors, such as problems of synchronization,
- errors in judging durations, dealing with low levels of shared temporal cognition,
- errors in matching periods of time with bundles of activities (McGrath, 1991)

Temporal Coordination

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2) the correct timing (knowing the best moment to execute too early and not too late, e.g. Hollnagel, 1998), and
3) the adaptation of dynamic effects as variables in the team’s context (Kluge et al., 2018)

“not being on the same page” (Mohammed & Nadkarni, 2014)
→ leads to disagreement about when to start and finish sub-tasks and to team members subscribing to different schedules and pacing (Gevers & Peeters, 2009)

Task State Awareness

- **Awareness of the task state** (Kraut et al., 2002; Wallace, Scott, Stutz, Enns & Inkpen, 2009),

- ....which is the awareness of the current state of the collaborative task in relation to an end goal (Kraut et al., 2002).

**Supported by**

- **Scripted coordination** (Bardram, 2000),

- **shared visual space** (Fussell, Kraut & Siegel, 2000; Kraut, Gergle & Fussell, 2002; Sebanz et al., 2006; Vesper, Schmitz, Safra, Sebanz & Knoblich, 2016)

**Coordination Artifacts**
Central Proposition

AR technology allows superimposition of critical process states, which leads to ambient awareness, leading to task state awareness, leading to optimal temporal team coordination.
Why AR?

Peripheral & Ambient Awareness (Cadiz et al., 2002)

• “peripheral awareness interfaces: a class of awareness interfaces that seeks to provide awareness via software that resides in the user’s peripheral attention”.

• Awareness on Primary Displays: One area of peripheral awareness research examines methods for embedding peripheral information within a user’s primary screen”

• “Team coordination and productivity can be enhanced if people can maintain better awareness of the activities of the team and the events in the world that may affect their team -especially with teams that have to work at different times and in different locations” (Streitz et al. 2003).

• „Ambient devices present dynamic information in an at-a-glance manner and have low attentional requirements.” (Downs, Plimmer & Hosking 2012)
The realised use case
Individual and Team Task
The general Set-up
Pretest- I
Design

Learning to use the HoloLens (15 min.)

Learning to operate AWA-Sim (TI only; 15 min.)

Operating AWA-Sim TT & TI parallel (5 times; 30 min.)

Measuring:
- general self-efficacy (Schwarzer & Jerusalem, 1999)
- Technology Usage Inventory (Kothgasser, et al. 2013)
- Process / technical knowledge (Kluge & Frank, 2014)
- Collective orientation (Hagemann & Kluge 2017)

Measuring:
- Specific self-efficacy (Kluge, 2004)

additional questionnaires

Participants:
Students ($n = 11$, female: 9, male: 2)
Including two female experts for the waste-water simulation

Schüffler, Rosenski & Liedtke, 2018
Gaze Guiding (GG) and Ambient Awareness enable non-experts to work as **correctly** as experts.

Gaze guiding and ambient awareness do not enable non-experts to work as fast as experts.
Subjective Measures

- Cognitive load (Klepsch, Schmitz and Seufert, 2017)
- Ambient superimposition evaluation (Weyers, Frank & Kluge, 2017)
- Gaze-Guiding usage questionnaire (Weyers, Frank & Kluge, 2017)
- Ambient information questionnaire (Haniff & Baber, 2003)
- Technology acceptance in AR settings (Wojciechowski, & Cellary, 2013)
- Technology acceptance model 3 (Venkatesh & Bala, 2008)
- Possession of technical objects (Schüffler, 2018)
- Technology experience (Mollenkopf et al, 2000)
- Technology attitude (Mollenkopf et al, 2000)
- Sociodemographic data
## Extracts of Pre-Post Test Ratings on Impressions, Technology Acceptance etc.

Scale Range from 1 = totally disagree, 7 = totally agree

<table>
<thead>
<tr>
<th>Item</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Before) „I am curious to use the technology“</td>
<td>6.0</td>
<td>0.9</td>
</tr>
<tr>
<td>„The superimposition at the side are designed attractive“</td>
<td>4.14</td>
<td>1.1</td>
</tr>
<tr>
<td>„The superimpositions were helpful to operate the plant“</td>
<td>4.43</td>
<td>1.4</td>
</tr>
<tr>
<td>„The superimpositions at the side were disturbing“</td>
<td>1.86</td>
<td>0.9</td>
</tr>
<tr>
<td>„It was easy for me to operate the plant by using the Hololens“</td>
<td>4.4</td>
<td>1.01</td>
</tr>
<tr>
<td>„Working with the Hololens was boring“</td>
<td>1.78</td>
<td>1.3</td>
</tr>
<tr>
<td>„The Hololens helped me to execute the task more efficiently“</td>
<td>5.4</td>
<td>1.6</td>
</tr>
<tr>
<td>„I think the Hololens was useful for supporting task execution“</td>
<td>6.0</td>
<td>1.0</td>
</tr>
<tr>
<td>„It takes not much mental effort to interact with the Hololens“</td>
<td>5.4</td>
<td>1.8</td>
</tr>
</tbody>
</table>

I love it!
Extracts of Pre-Post Test Ratings on Impressions, Technology Acceptance etc.

Scale Range from 1 = totally disagree, 7 = totally agree

<table>
<thead>
<tr>
<th>N = 10</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>„I could perform my task with the Hololens well ... ....if no one would be there to explain the task“</td>
<td>4.78</td>
<td>2.1</td>
</tr>
<tr>
<td>... if some one explained to me the task first“</td>
<td>6.44</td>
<td>.72</td>
</tr>
<tr>
<td>... if I had experienced a similar task before“</td>
<td>6.44</td>
<td>.72</td>
</tr>
<tr>
<td>„I had fun using the Hololens“</td>
<td>5.4</td>
<td>1.2</td>
</tr>
<tr>
<td>„Results of using the Hololens are obvious“</td>
<td>5.8</td>
<td>.02</td>
</tr>
</tbody>
</table>

Great idea 😊
Pretest - II

How to augment?
Holodeck I and II
How to augment in an ambient way?

Team task
Individual task

Ambient Awareness Teamtask

Gaze Guiding Tool

Ambient Awareness Tool

Individual Task
UX Ambient Awareness

1. Evaluation of the most beneficial:
   - Position (e.g. sideways or below the simulation)
   - Distance (between objects and objects for simulation)
   - Size of objects
   - Object states (static or dynamic)
UX Ambient Awareness

2. Evaluation of the design of the objects
   - 2D/ 2.5D/ 3D
   - Degree of abstraction (to the object design of the simulation surface)
   - colour
   - transparency
   - Surface
Project Phase I

Phase I:
- Measurement of visual acuity
  - Stereoscopic vision (Lang, 1983)
  - Color blindness (Hrsg, Kuchenbecker & Broeschmann, 2016)
- General health questionnaire (Clausen, 2012)
- Sociodemographic questionnaire
- AWASim preknowledge

Project Phase II

Phase II:
- Standardized audio recorded explanation of the experimental background and procedure
- Introduction of the Microsoft HoloLens

Phase III:
- Usability evaluation
- Simulator Sickness questionnaire (Kennedy, 1993)

4–6 weeks

Project Phase II

Online

Phase IV:
- User experience evaluation
  - AttrakDiff (Hessenzahl, Burmester & Koller, 2003)
  - User Experience Questionnaire (Laugwitz et al., 2008)

25 min

15 min

60 min

20–30 min
How should the tanks be displayed?
In which size should the objects be displayed?

Teilen Sie hierzu bitte dem Versuchsleiter die Zahl unter der entsprechenden Darstellung mit.
In which distance to each other should the objects be displayed?

Teilen Sie hierzu bitte dem Versuchsleiter die Zahl unter der entsprechenden Darstellung mit.

[Diagram with options 3, 2, 1]
Where should the objects be displayed?

Teilen Sie hierzu bitte dem Versuchsleiter die Zahl der entsprechenden Darstellung mit.
In which distance to the screen should the objects be displayed?

Teilen Sie hierzu bitte dem Versuchsleiter die Zahl der entsprechenden Darstellung mit.
Where should the progress bars be displayed?

Teilen Sie hierzu bitte dem Versuchsleiter die Zahl der entsprechenden Darstellung mit.
Sample Statistics

N = 22, Age 24.32 (min 19, max 51)
Male: 15
Female: 3
Not specified: 4

Measurement Visual Acuity

Sight correction required (n = 22)

<table>
<thead>
<tr>
<th>Sight correction required</th>
<th>Number of Test Persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>7</td>
</tr>
<tr>
<td>Yes</td>
<td>15</td>
</tr>
</tbody>
</table>

Sight correction used during the experiment (n = 15)

<table>
<thead>
<tr>
<th>Glasses Used</th>
<th>Number of Test Persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glasses</td>
<td>15</td>
</tr>
<tr>
<td>Not Used</td>
<td>0</td>
</tr>
</tbody>
</table>
Pretest: Measurement General Health
(General Health Questionnaire; Claßen, 2012 based on Bullinger & Kirchberger, 1998)

Measurement Visual Acquity
(Lang Stereotest; Lang, 1983)

General Health

- General health condition
- Moving capability
- Visual capability
- Hearing capability
- Current life satisfaction

Stereoscopic vision (n = 22)

- Subject recognizes 3 Objects: 18
- Subject recognizes 2 Objects: 2
- Subject recognizes 1 Object: 2
- Subject recognizes 0 Objects: 0

Achievement of test persons: 18.
Measurement Visual Acuity
(color blindness test; color charts by Kuchenbecker & Broschmann, 2006)

Colour vision (n = 22)

- Ordinary colour vision: 20
- Colour vision salient: 2

Suspect impairment (n = 2)

- Protanomaly (red): 0
- Deuteranomaly (green): 1
- Tritanomaly (blue): 1
Usability Cluster Questionnaire (UCQ; Thomaschewski, 2019)

<table>
<thead>
<tr>
<th>Scale</th>
<th>Example question</th>
<th>Cluster selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstraction degree</td>
<td>&quot;What is the best representation of a tank?&quot;</td>
<td>Most chosen level (1 of 3), If chosen equally; choice by random number generator (RNG)</td>
</tr>
<tr>
<td>Object size</td>
<td>&quot;The objects are very intrusive.&quot;</td>
<td>forced choice / 3 options</td>
</tr>
<tr>
<td>Object distance</td>
<td>&quot;The distance between the objects is just right.&quot;</td>
<td>forced choice /3 options</td>
</tr>
<tr>
<td>Object position (individual task/ IT)</td>
<td>&quot;I would position the objects at this point.&quot;</td>
<td>forced choice / 5 options</td>
</tr>
<tr>
<td>Object position (team task/ TT)</td>
<td>&quot;The position of the objects is helpful in operating the system.&quot;</td>
<td>forced choice / 5 options</td>
</tr>
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</table>
### Usability Cluster Questionnaire (UCQ; Thomaschewski, 2019)

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<tr>
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<th>Example question</th>
<th>Cluster selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object-simulation distance (individual task/ IT)</td>
<td>&quot;The objects are too far away from the AWASim surface.&quot;</td>
<td>forced choice between three options</td>
</tr>
<tr>
<td>Object-simulation distance (team task/ TT)</td>
<td>&quot;I would position the objects at that distance.&quot;</td>
<td>forced choice between three options</td>
</tr>
<tr>
<td>Progress bar (individual task/ IT)</td>
<td>&quot;The Progress Bar is disturbing at this point.&quot;</td>
<td>forced choice between four options</td>
</tr>
<tr>
<td>Progress bar (team task/ TT)</td>
<td>&quot;I would position the Progress Bar at this point.&quot;</td>
<td>forced choice between four options</td>
</tr>
<tr>
<td>Dynamic indication</td>
<td>&quot;The presentation conveys very well that I can now intervene in the Team Task.&quot;</td>
<td>forced choice between three options</td>
</tr>
<tr>
<td>Background</td>
<td>&quot;The objects stand out strongly enough from their surroundings.&quot;</td>
<td>forced choice between three options</td>
</tr>
</tbody>
</table>
Simulator Sickness
(SSQ; Kennedy et al. 1993)

14 of 22 participants reported no change in physical condition (pre-post)

Combined & weighted score for each participant
(nausea + oculomotor + disorientation)
**Project Phase I: laboratory**

**Phase I:**
- Measurement of visual acuity
  - Stereoscopic vision
    (Lang, 1983)
  - Color blindness
    (Hrsg. Kuchenbecker & Broschmann, 2016)
- General health questionnaire
  (Cladjen, 2012)
- Sociodemographic questionnaire
- AWASim preknowledge

**Phase II:**
- Standardized audio recorded explanation of the experimental background and procedure
- Introduction of the Microsoft HoloLens

**Phase III:**
- Usability evaluation
- Simulator Sickness questionnaire
  (Kennedy, 1993)

**Phase IV:**
- User experience evaluation
  - AttrakDiff
    (Hessenzahl, Burmester & Koller, 2003)
  - User Experience Questionnaire
    (Laugwitz et al., 2006)

**Duration:**
- Phase I: 25 min
- Phase II: 15 min
- Phase III: 60 min
- Phase IV: 20-30 min
Usability – Pretest / online questionnaire
(AttrakDiff; Hassenzahl, Burmester & Koller 2003)

Pragmatic Quality

AttrakDiff – Response Profile – all PPn

Attractiveness

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Usability
(AttrakDiff; Hassenzahl, Burmester & Koller, 2003)
User Experience
(User Experience Questionnaire; Laugwitz et al., 2006)
User Experience
(UEQ; Laugwitz et al., 2006)
Final Interface IT/TT
Final Interface IT/TT (+ dynamic indication)
• AR can help visualize dynamic effects (e.g. progress bars)
• AR can superimpose checklist items to reduce memory requirements
• AR can be used as a situative assistance for non-routine situations
• AR can superimpose information from different screens
• AR can serve as a coordination assistance system for „being on the same page“
• …if we aim for joint optimization of the social and the technical system
Thank your for your attention

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