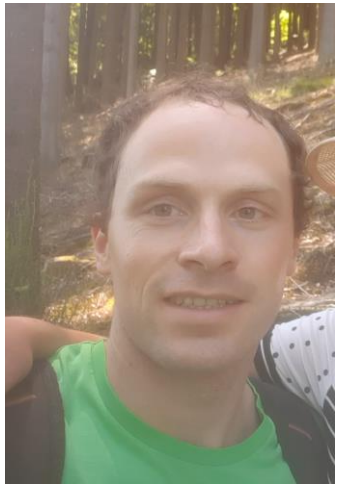
Towards personalised AR/VR instructions to tailor cognitive support during learning



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ITEC, imec research group at KU Leuven

Media & Learning conference

November 19 2020 (online)

Session on Researching the learning possibilities offered by XR

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3. Theoretical underpinning
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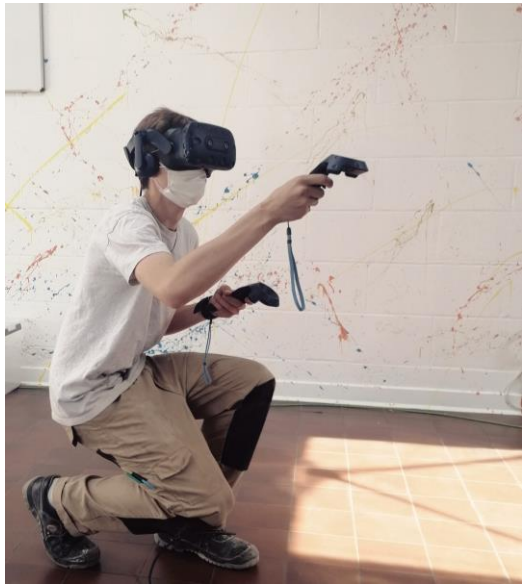
6. Two data collection phases: aims, methodology & results

1. Problem statement

Typical approach: In a first step, a person trains a skill using AR / VR as cognitive support

AR

VR



Second step: the support is removed, assuming the learner masters the skill.

… does it make sense to give the same amount of instructional support to a beginning and to an advanced learner?

… when can we remove the support, while being confident that the (s)he will still master the task in the real world?

→ Personalised AR / VR instructions

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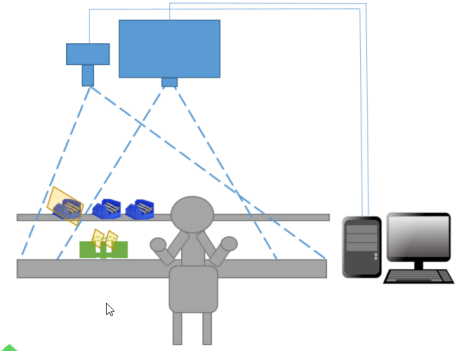
2. Brief zoom on the COSMO-project

- COgnitive Support in Manufacturing Operations (May 2019 – September 2021)
- Display technologies:
  - VR: HTC Vive Pro  & AR (video-projection)
- Secondary education schools:
  - VR: 3rd grade technical oriented schools & AR: special needs schools
    - Train digital skills
    - Get to know tools of their future workplace
    - Make complex work more simple: let people grow in their job & increase employability
- Applications of focus:
  - Assembly, but the idea could equally apply to learning other skills / concepts

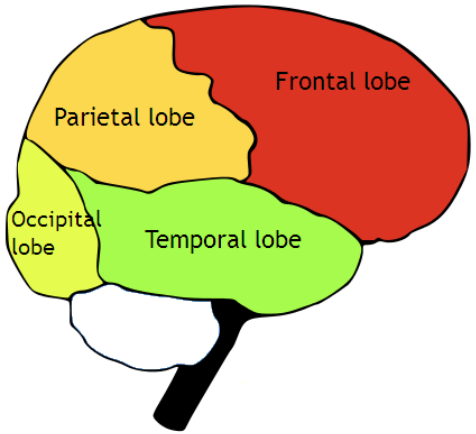
- Innovation goals:
  - Make content creation more automatic
  - Bring AR and VR technologies to schools (next session by Kim Dekeyser)
  - Study how personalising instructions could be beneficial
  - Modelling of learning curves and well-being of operators

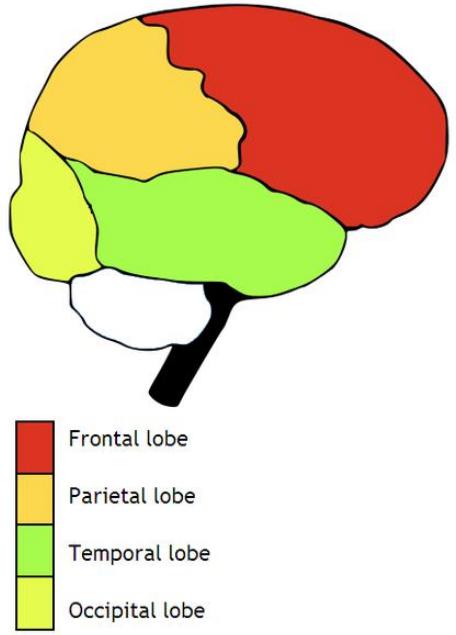


- Proven and relatively simple
- Safe
- Handsfree
- No batteries
- Suitable to use “all day”

3. Theoretical underpinning

- AR instructions:
  - Multimedia principles (Mayer, 2014): e.g. AR spatially merges the instruction onto the task.
    Spatial and temporal contiguity reduce the split-attention effect (instruction <-> task)





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- VR instructions:
  - Learning effects can be explained from a constructivist approach: experience, 3D immersive space, multi-sensory

- Personalised instructions
  - Learning is fostered when learners are given just the right amount of support needed
    - The idea of scaffolding (Reiser, 2009)
    - Vygotsky's (1978) notion of the zone of proximal development

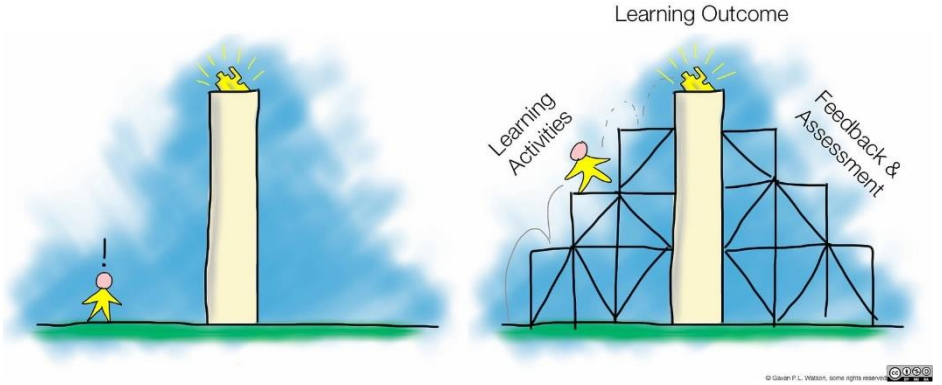
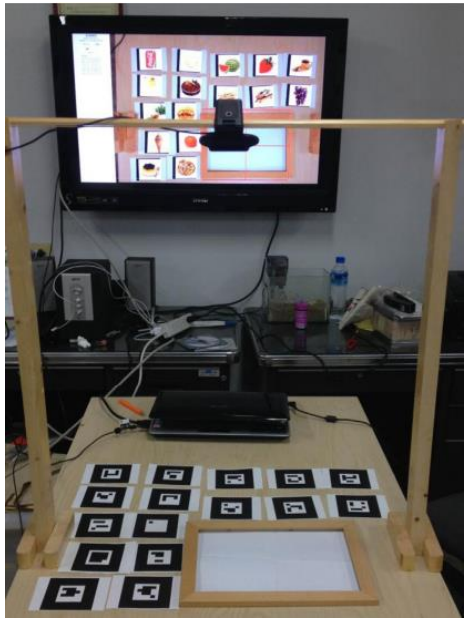


Photo credit: Gavatron on Visual hunt / CC BY-NC-SA

Mayer R. E. (2014). Multimedia Instruction. In J.M. Spector et al. (eds.). *Handbook of Research on Educational Communications and Technology* (pp. 385 – 399). New York: Springer
Reiser, B. J. (2009). A scaffolding design framework for software to support science inquiry. *Journal of the Learning Sciences*, *13*(3), 37–41. https://doi.org/10.1207/s15327809jls1303
Vermunt, J., & Verloop, N. (1999). Congruence and friction between learning and teaching. *Learning and Instruction, 9*(3), 257-280.
Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

4. Previous research – AR & learning

- Meta-analysis (sixteen single-case studies) on AR in special education:
  - AR is most beneficial in promoting a subject's learning skills, followed by social, physical and living skills (Baragash et al., 2019)
- Study on personalised AR (assembly) instructions (Westerfield, Mitrovic and Billinghurst , 2015):
  - Only beneficial for novice learners
- Study on using AR to support subjects with weaker cognitive skills during short-order food preparation (pick-and place routine) (Chang, Kang & Huang (2013):
  - increased accuracy
  - Clear learning effect: four weeks after the intervention, without AR: similar skill level.



Baragash, R. S., Al-Samarraie, H. I., Alzahrani, A., & Alfarraj, O. (2019). Augmented reality in special education: A meta-analysis of single-subject design studies. *European Journal of Special Needs Education, 1-16.*
Chang, Y., Kang, Y., & Huang, P. (2013). An augmented reality (AR)-based vocational task prompting system for people with cognitive impairments. *Research in Developmental Disabilities, 34*(10), 3049-3056.
Westerfield, G., Mitrovic, A., & Billinghurst, M. (2015). Intelligent augmented reality training for motherboard assembly. *International Journal of Artificial Intelligence in Education, 25*(1), 157–172. https://doi.org/10.1007/s40593-014-0032-x

4. Previous research – VR & learning

Two meta-analyses on the effectiveness of VR on students' learning:

- Meta-analysis by Merchant et al. (69 studies, > 8000 learners)
  - Games show higher learning gains than simulations and virtual worlds
  - Better performance when playing individually than in group
- Meta analysis by Wu et al., 2020 (35 studies, > 1800 learners):
  - VR is in general more effective than non-immersive learning approaches, with a small effect size (*ES* = 0.24)

> - " (…) don't exaggerate the advantages of VR (34% of the studies: no effect or a negative effect)"
> - " (…) VR is no magic solution, but a promising complement that can diversify learning experiences."

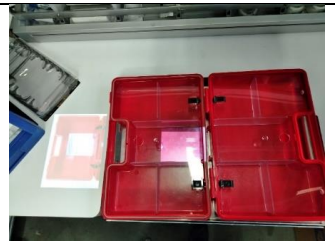
  - VR improves both knowledge and skill development, especially good for science education
  - VR has a greater impact on K-12 students than on post-secondary students' learning

> " (…) more customized HMD learning applications with the sound instructional design are needed to improve its usefulness."

Merchant, Zahira, Goetz, Ernest T, Cifuentes, Lauren, Keeney-Kennicutt, Wendy, & Davis, Trina J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers and Education, 70*, 29-40
Wu, Bian, Yu, Xiaoxue, & Gu, Xiaoqing. (2020). Effectiveness of immersive virtual reality using head-mounted displays on learning performance: A meta-analysis. *British Journal of Educational Technology, 51*(6), 1991-2005.

5. AR and VR instructions with different levels of detail

AR

LEVEL OF INSTRUCTIONAL DETAIL	PICKING	POSITIONING / ASSEMBLY
"**Low detail**" instruction: Does not show pictures nor text nor arrows; highlights which and how many parts should be picked (but does not indicate from which shelf); highlights where the part is to be put/assembled		
"**Medium detail**" instruction: Shows picture(s) and arrows; Does not show detailed text; highlights important details; highlights which and how many parts should be picked (but does not indicate from which shelf); highlights where the part is to be put/assembled		
"**High detail**" instruction: Shows picture(s), text and arrows; highlights important details; highlights which and how many parts should be picked from which shelf; highlights where the part is to be put/assembled		

VR

- Low detail:
  - Compass
  - Haptic feedback
- Medium detail
  - + Light up the part to be picked
  - + Assembly ghosting
- High detail:
  - + audio instructions
  - + trajectory towards assembly location

6. Two data collection phases

- Collecting empirical data in schools and companies

- Before operationalising adaptivity, first …

Phase 1: Gather scientific evidence on the effect of AR & VR instructions with different levels of detail on different outcome variables (error-making, perceived complexity, stress, etc.)

- In a second step:

Phase 2: Investigate different methods to implement personalised instructions (adaptivity)

6.1. Data collection phase 1

Aims: 1) Investigate the effects of AR/VR instructions with three different levels of detail on


Productivity


Quality


Perceived complexity


Physical effort


Competence frustration


Stress


Cognitive load

Methodology: 90 participants (AR) ; 96 paraticipants (VR) ; across 5 tasks ; repeated up to 3 times

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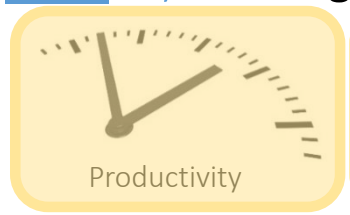

Productivity


Quality


Perceived complexity


Physical effort


Competence frustration


Stress


Cognitive load

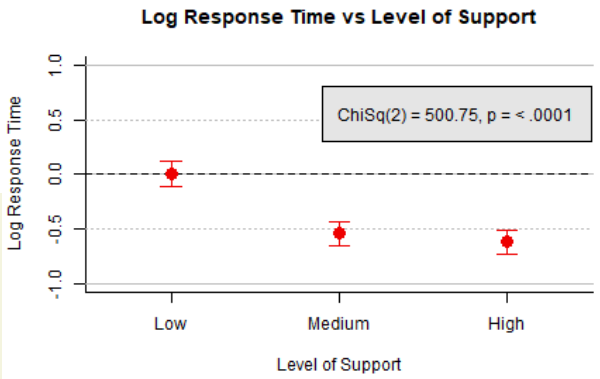
2) Compare this novel (AR) approach with the traditional (paper) approach.

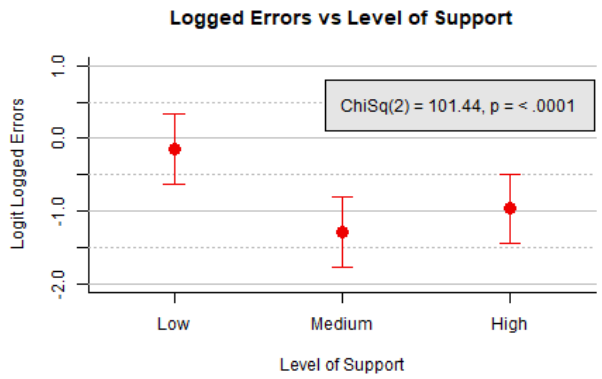
Methodology: 90 participants (AR) ; 96 paraticipants (VR) ; across 5 tasks ; repeated up to 3 times

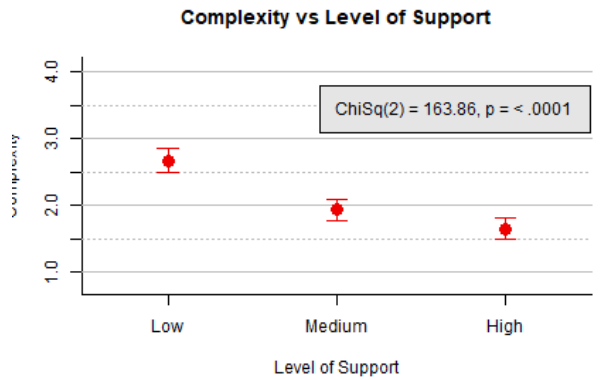


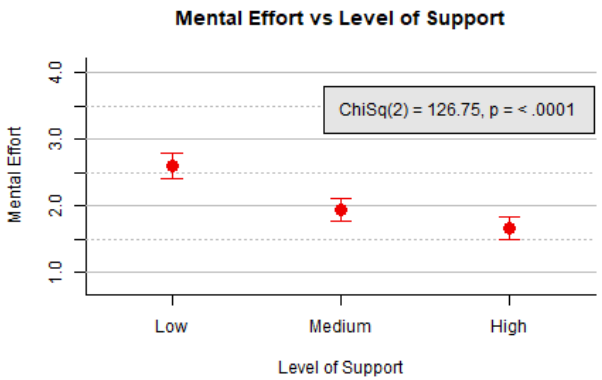



Results (VR): More instructional details positively impact all outcomes (+ make M level of detail a bit harder)
Highest effects for productivity, quality, perceived complexity and cognitive load.
(We expect similar results for AR)









6.2. Data collection phase 2

Aim: Investigate the effect of different types of personalised instructions (adaptivity) on …

Productivity

Quality

Perceived complexity

Physical effort

Competence frustration

Stress

Help-seeking behaviour

Cognitive load

Methodology: test 3 adaptivity methods across 3 tasks (each repeated up to 7 times):

- No adaptivity (High level of support)
- Adaptivity on task level
- Adaptivity on step level

Planned between February ~ May 2021.

In this way, we aim to implement the best possible way to personalise instructions.

Thank you for your attention & follow cosmo!

Project website (Dutch): https://cosmo.kuleuven-kulak.be/

Website research group Itec: https://itec.kuleuven-kulak.be/

Contact e-mail: pieter.vanneste@kuleuven.be

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Happy to answer any questions!