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Extended (virtual, augmented, mixed) reality in spatial sciences

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Review

Extended Reality in Spatial Sciences: A Review of Research Challenges and Future Directions

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XR is inherently spatial

- Tries to replicate real world feeling of space and place (VR)
- Computes space, i.e., does real time ‘surveying’ (MR)
- Relies on spatial registration, essentially the same concept as georeferencing (to a lesser degree on VR, critical for MR)
- Overlays attribute data on real or virtual spaces (AR, MR, VR), thus it has parallels to GIS
- Combines analytical and experiential approaches in one (AR, MR, VR – immersive analytics)

... non-geographic XR possible but hard to argue for a non-spatial XR
XR is often information rich

• Back in 1999, MacEachren listed four “I”s to characterize virtual environments. One of them is information intensity.
... as we age, this happens

Ok, at least wisdom is real 😊
Virtual environments as memory training devices in navigational tasks for older adults

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Tech/design: Manipulate levels of realism & landmark position
Context: Route learning, navigation
Human factors (individual & group differences): Aging & spatial abilities

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context: navigation
goal: route learning (recall)

Dependent variables:
Recall accuracy, confidence
(task time & eye movements also measured but analysis on-going)

counterbalanced for gender and expertise & repeated one week later!
randomized order of tasks & vis types
Fictitious city, created using procedural modeling, presented in a virtual environment. (scenes created by Ismini-Eleni Lokka, see Lokka & Çöltekin 2017 and 2018 papers) (Lokka & Çöltekin, 2017, 2018, 2019)

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Recall accuracy: The MixedVE “wins”

(visit for tasks)


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... and it helps with calibrating confidence

O: overconfident
U: underconfident

(visuospatial tasks)
... helps a little against naïve realism too
(Smallman & John 2005, 2011)

People prefer realism as a display principle even if it might not be their best option. Especially people with weaker spatial abilities.
Spatial abilities among our participants? (median split)

Visuospatial memory capacity

Mental rotation task

(Lokka & Çöltekin, unpublished work)
More from / related to this project

• Task types matter: Visuospatial pronounced, visual somewhat better spared by age, spatial ~chance level in some cases (Lokka & Çöltekin 2017, 2020)
• Perspective switch especially difficult for older participants (Lokka & Çöltekin 2017, 2020)
• Spatial abilities interact with recall performance and preferences (Lokka & Çöltekin 2017, 2019, 2020)
• Eye movement analysis is on-going

Several spin-off projects on spatial memory, brain health & aging and cognitive interventions

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Predicting dementia and XR?

A science spinoff, Altoida Inc, developed a smartphone app

• Select neurophysiological measures
• An AR / MR app that measures spatial memory
  predict dementia risk ahead of time (~10 years)
  predict conversion from mild cognitive impairment to Alzheimer’s disease

We’re working with them to improve diagnostics & assess prevention and rehabilitation options
Some research challenges as identified in the collaborative paper (Çöltekin et al., 2020)

- **Theoretical frameworks** for technology, design, human factors
- Improved **visual quality**, more efficient rendering
- Improved interaction and maximized **immersion**
- **Automated content creation** with machine learning and AI
- Meaningful **content** creation: story telling vs. analytics
- Meaningful, functional, desirable **design**: Aesthetics, interaction and visualization
- Customization and **personalization**
- Solutions for **marginalized** users
- Establishing a culture for **proper user testing and reporting, reproducibility**
- Better interaction paradigms for **collaborative XR**
- Better support for science experiments & human factors research: **XR as virtual laboratories**
- Clear **rules of thumb** for practitioners
- More awareness for **sociopolitical and ethical issues**

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Thank you

"Somebody must be watching us."

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