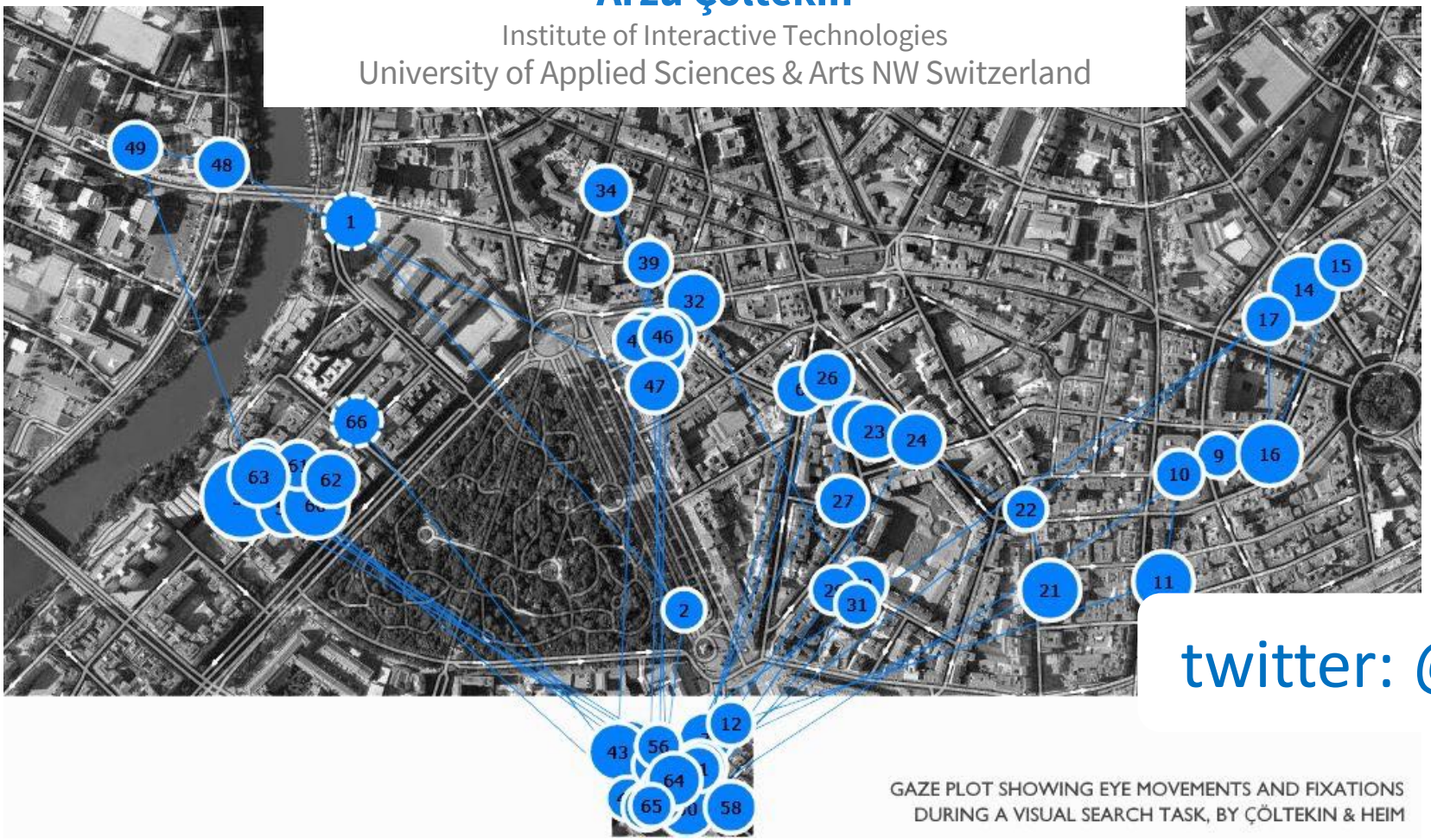
13th of November 2023

Visualization of science and a science of visualization

Arzu Çöltekin
Institute of Interactive Technologies
University of Applied Sciences & Arts NW Switzerland



GAZE PLOT SHOWING EYE MOVEMENTS AND FIXATIONS
DURING A VISUAL SEARCH TASK, BY ÇÖLTEKIN & HEIM

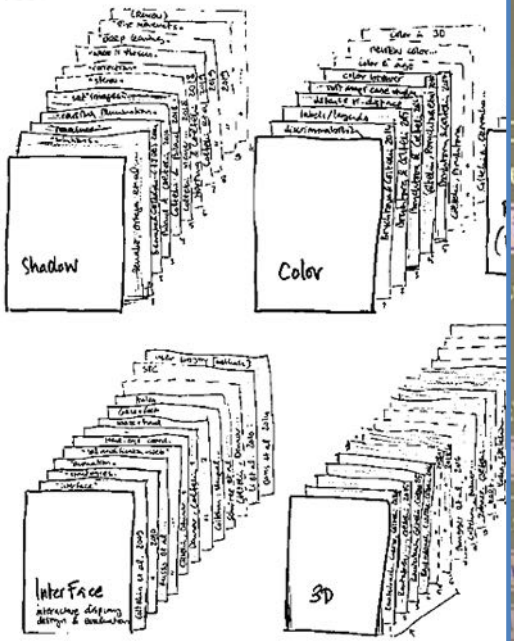
twitter: @acolt

About me

- Director of the Institute of Interactive Technologies (IIT) at the University of Applied Sciences & Arts Northwestern Switzerland ($\mathbf{n}|\boldsymbol{w}$)
- Professor of Computer Science Human-Computer Interaction & Extended reality (since Feb 2019)
- Research affiliate Seamless Astronomy group at Harvard
- Previously: Yıldız Tech Uni Istanbul, Helsinki Uni Tech (now Aalto), Uni Zurich CH
- Research stays in TU Delft NL, U Melbourne AU, NRC CA, U St. Andrews UK, Harvard Uni US

- Leadership / service in a few communities
  - ICA Co-chair Commission on Geovisualization
  - ISPRS Chair XR & Visual Analytics Working Group
  - ISDE Council member Digital Earth
  - Board member data visualization Zurich

HCI, XR, Vision, Visualization



Vis projects

XR & Vis projects

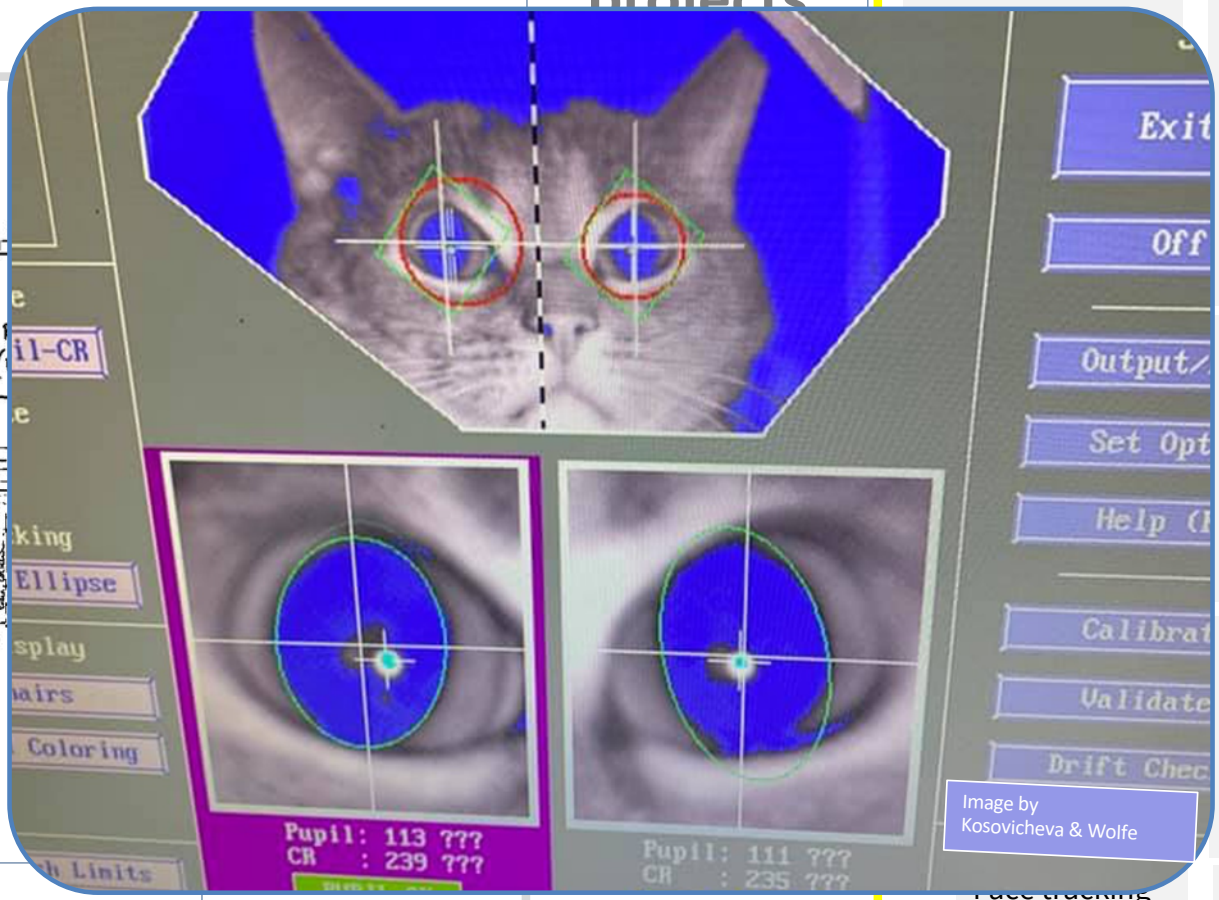


Image by Kosovicheva & Wolfe

Eye tracking

CollabMR Spatial decision

VR as labs in education (2x)

MR / serious games for prediction, prevention & rehabilitation age-related cognitive issues

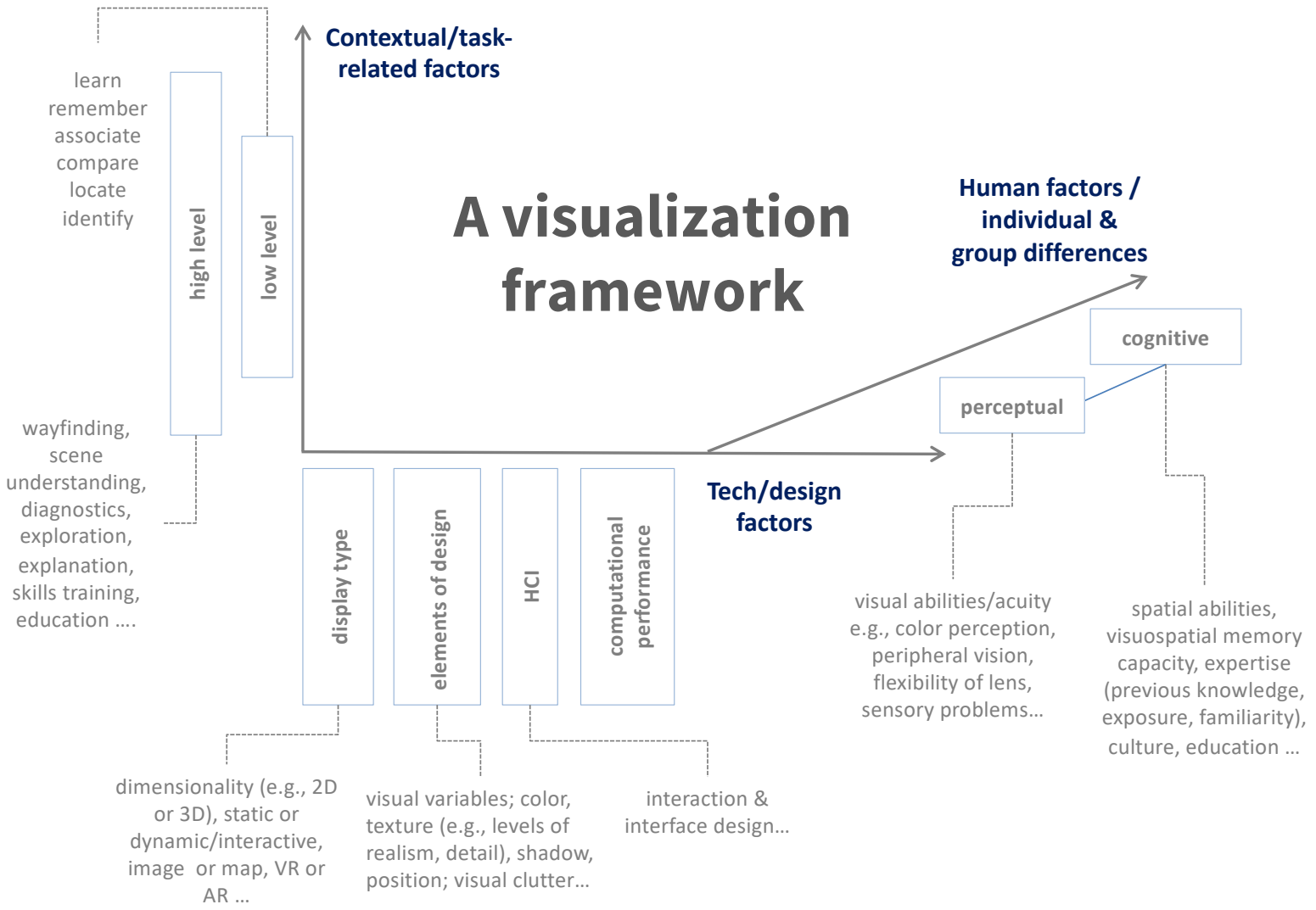
Image2XR Automation of XR content creation & perceptual examination of visual quality

UAV / flow vis Spatiotemporal sense making with flow visualizations

Sensory filtering VR

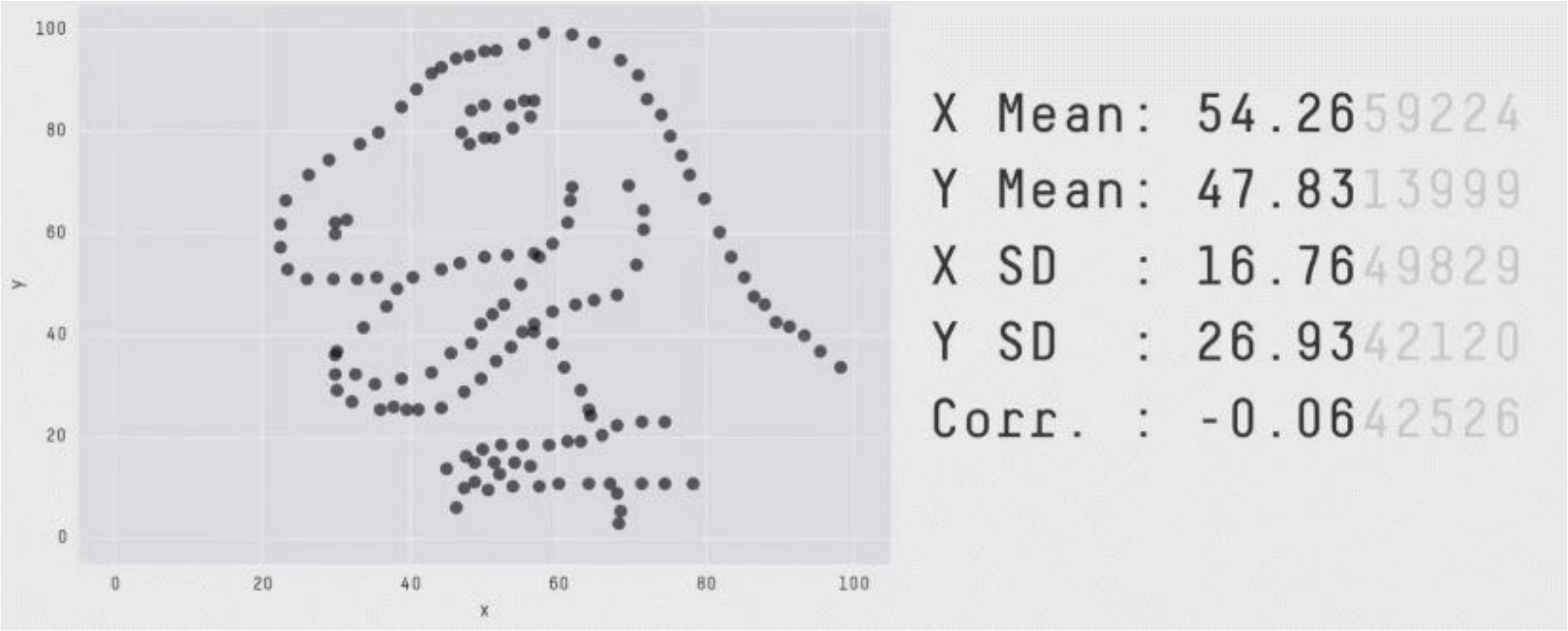
…

LLMs / AI



Çöltekin, A. (2019). What contributes to the complexity of visuospatial displays?
Abstraction, Scale and Perception, International Cartographic Association Joint Commission Workshop, Jul 15, Tokyo, Japan

Why should we visualize data



Human brain is 60% visual

https://www.autodeskresearch.com/publications/samestats

Human visual information processing

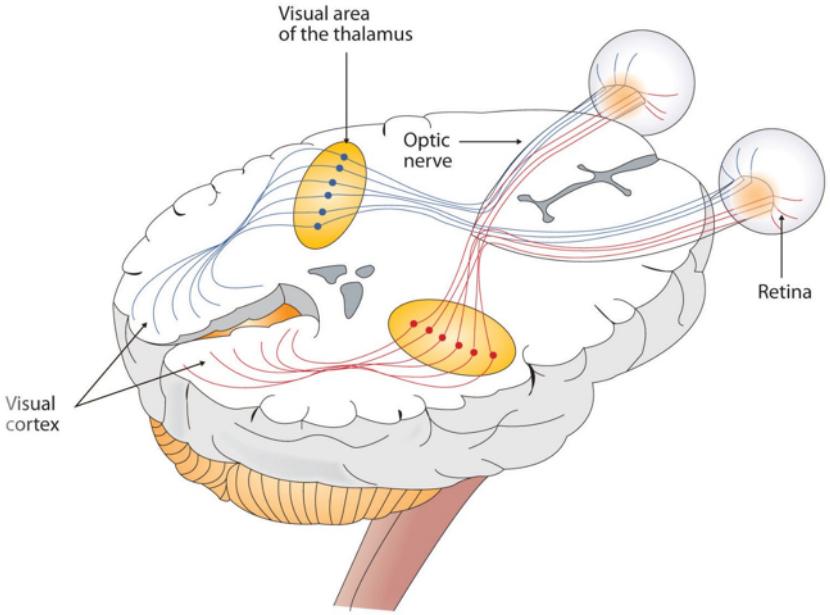
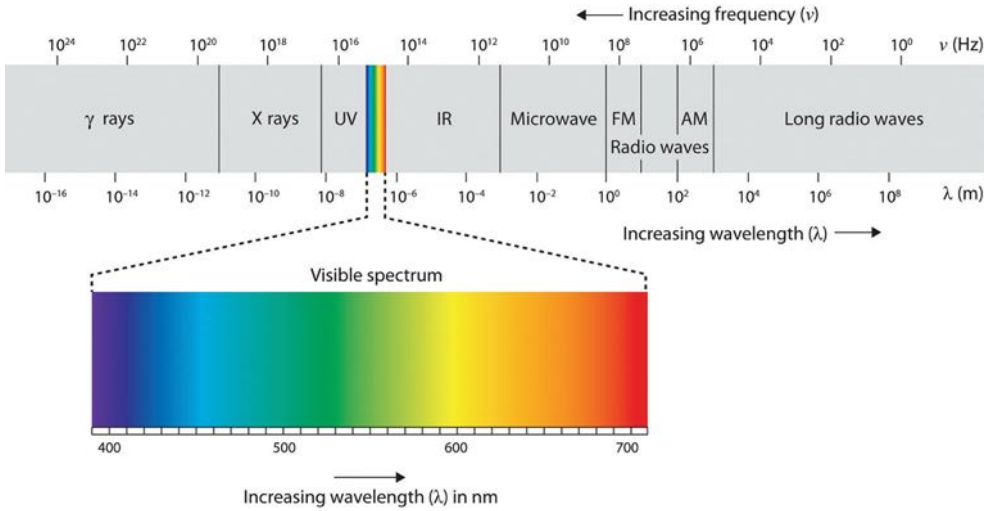


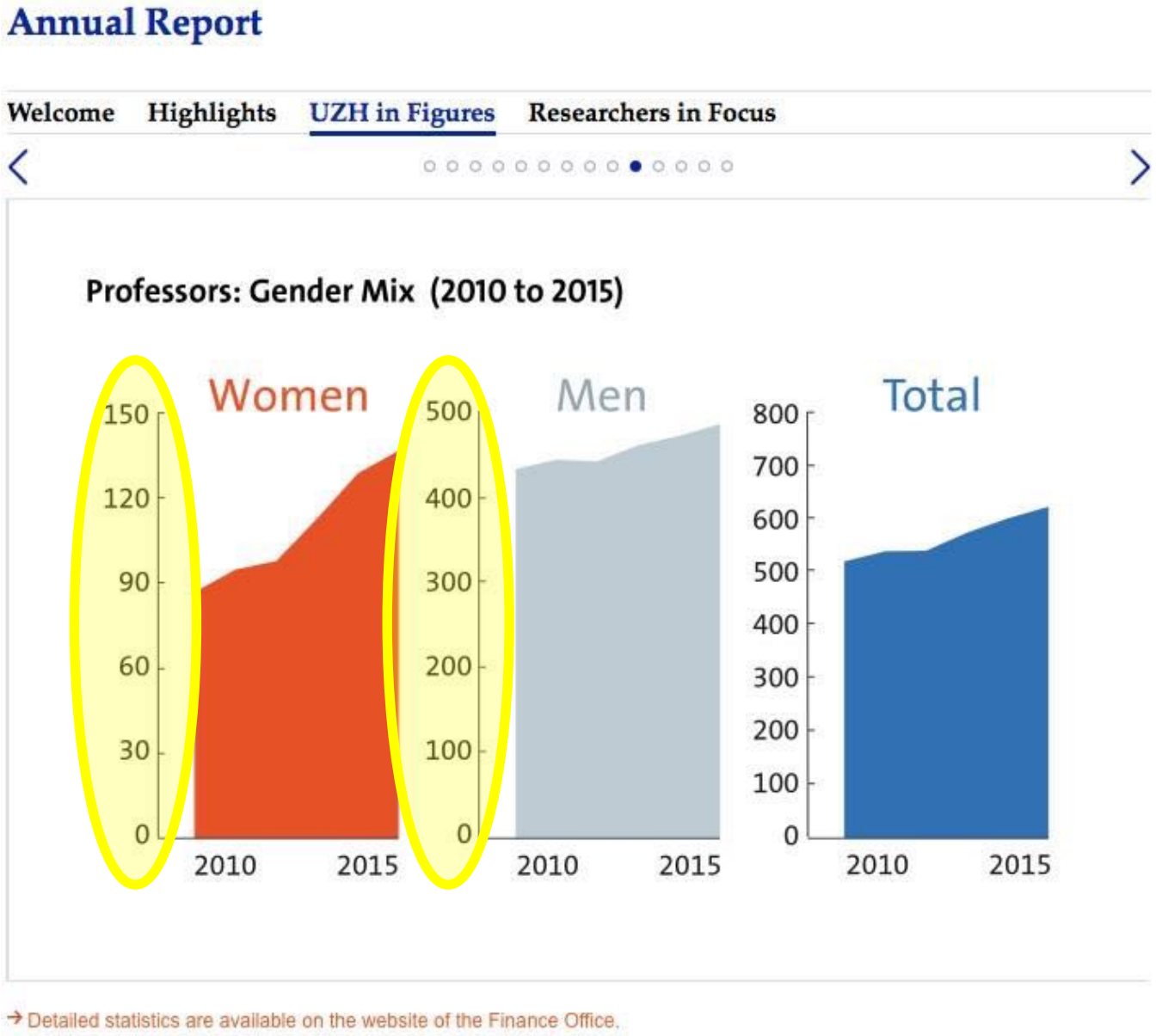
Illustration: C. Stangor

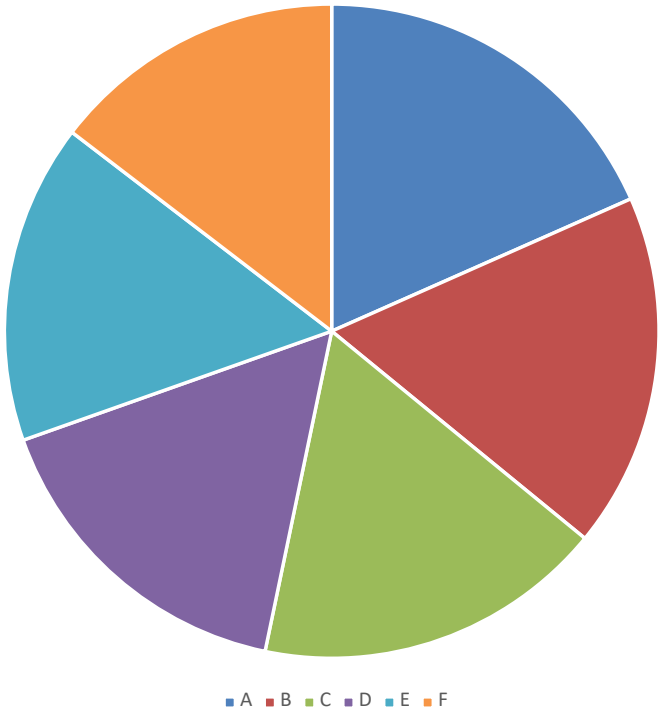


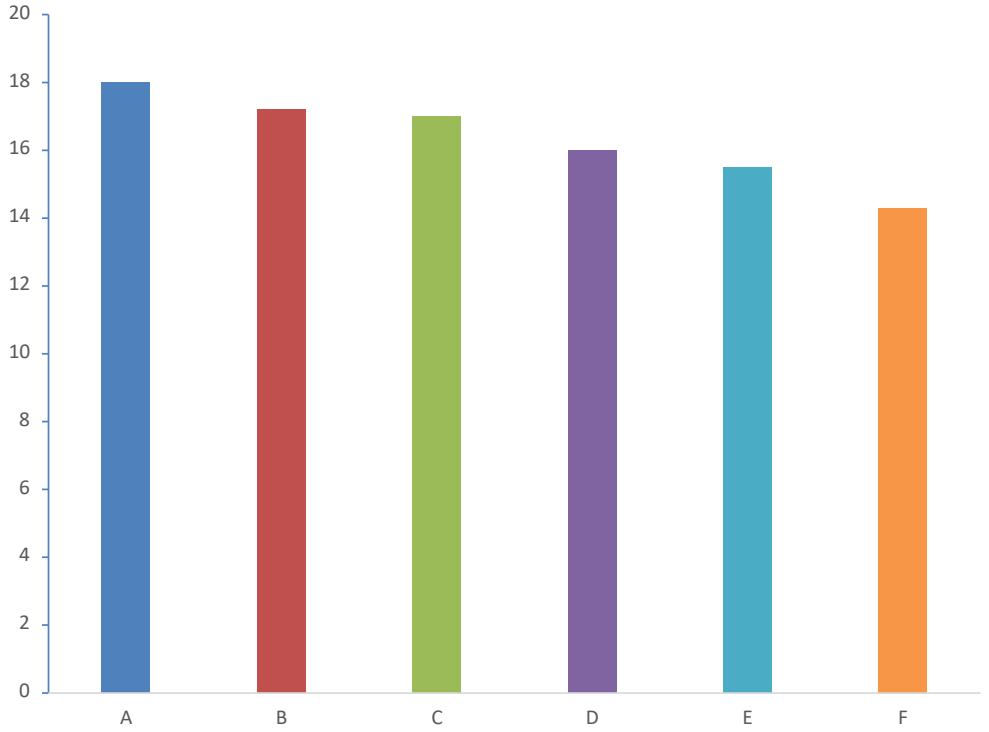
40%

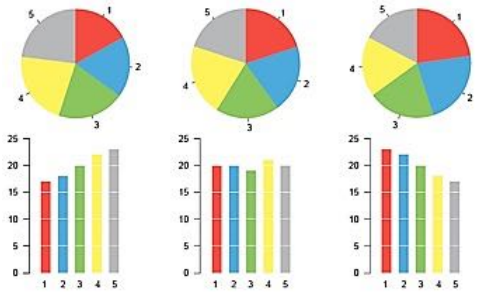
Hofmann 2000, Ware 2008

However …


Annual Report
Welcome
Highlights
UZH in Figures
Researchers in Focus
Professors: Gender Mix (2010 to 2015)
Women
Men
Total
150
120
90
60
30
0
500
400
300
200
100
0
800
700
600
500
400
300
200
100
0
2010
2015
2010
2015
2010
2015
Detailed statistics are available on the website of the Finance Office.







Human perception is fickle

Whoever designed this floor is evil. THATS A FLAT CARPET.

10:33 PM - 20 Sep 2017

https://twitter.com/MrMuselk/status/910738757019566086

Adelson (1995) Checker shadow illusion. Video: Youtube user brusspup. More: https://en.wikipedia.org/wiki/Checker_shadow_illusion

Hollow mask illusion

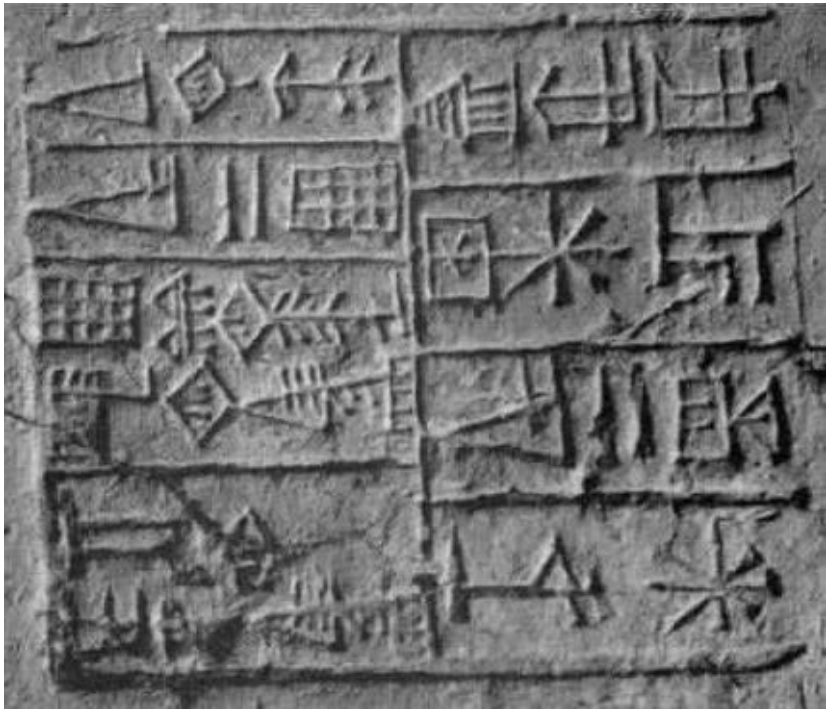
Source: http://www.youtube.com/watch?v=iR9WVhiaIeYm, uploaded by: daarkniight

Light from above prior (or assumption)

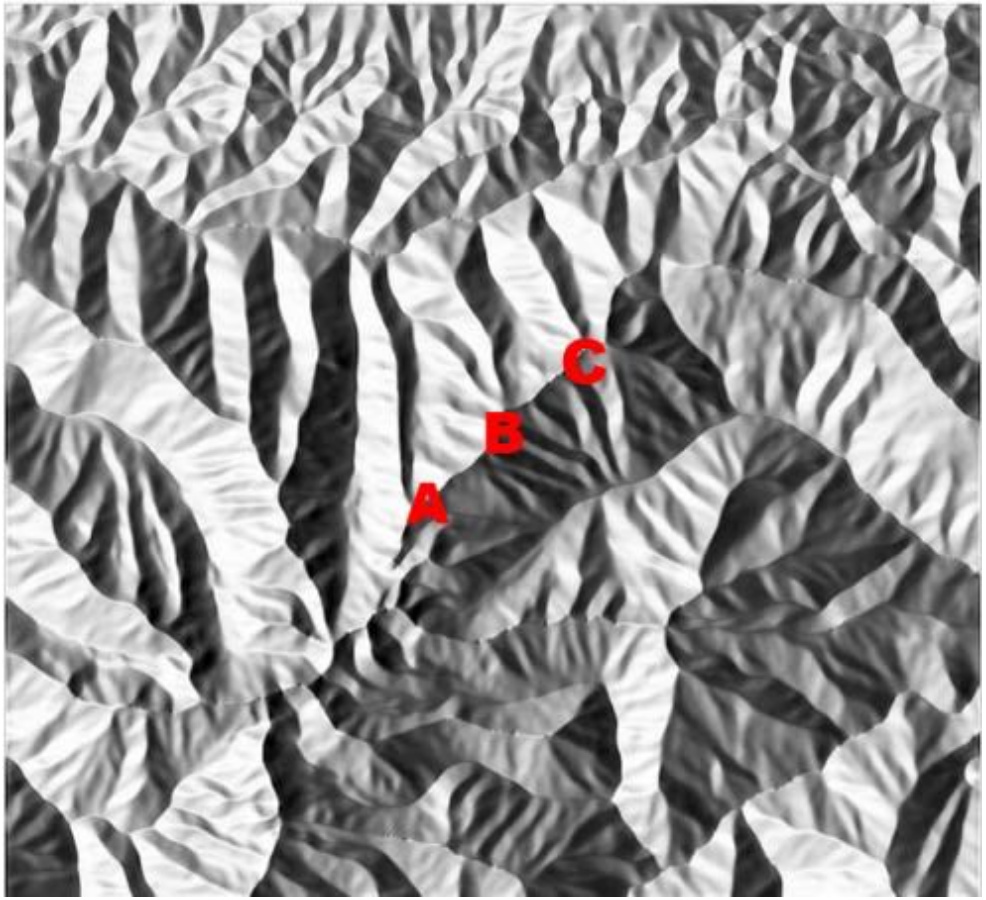
(Kleffner & Ramachandran, 1992; Mamassian and Goutcher 2001)

Original

Rotated 180º



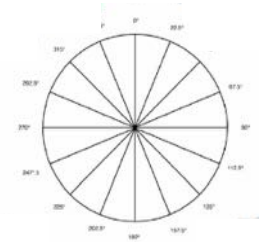
http://www.cartesia.org/geodoc/icc2005/pdf/oral/TEMA6/Session%208/ANGEL%20BERNABE.pdf

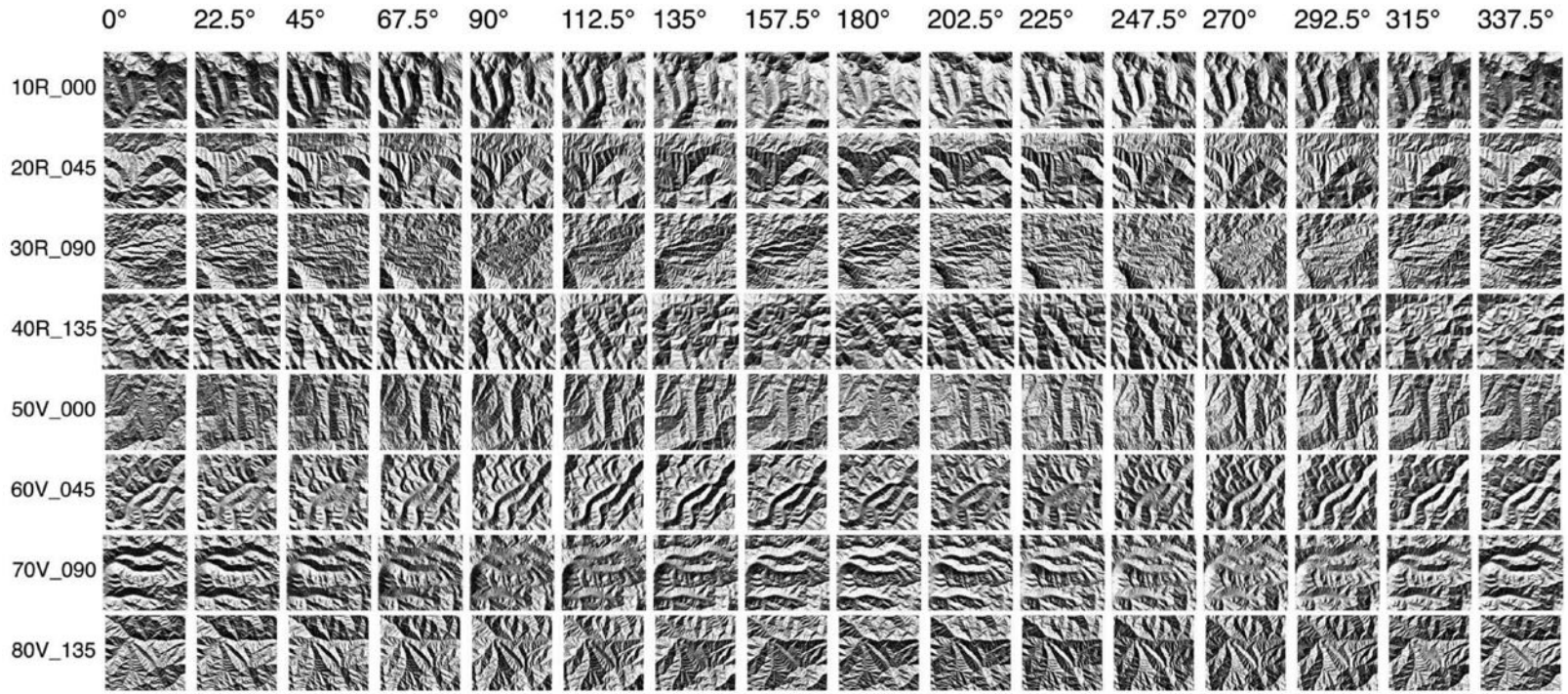


(1) The line „ABC“ appears as:

clearly a valley	a valley	unsure	a ridge	clearly a ridge
○	○	○	○	○

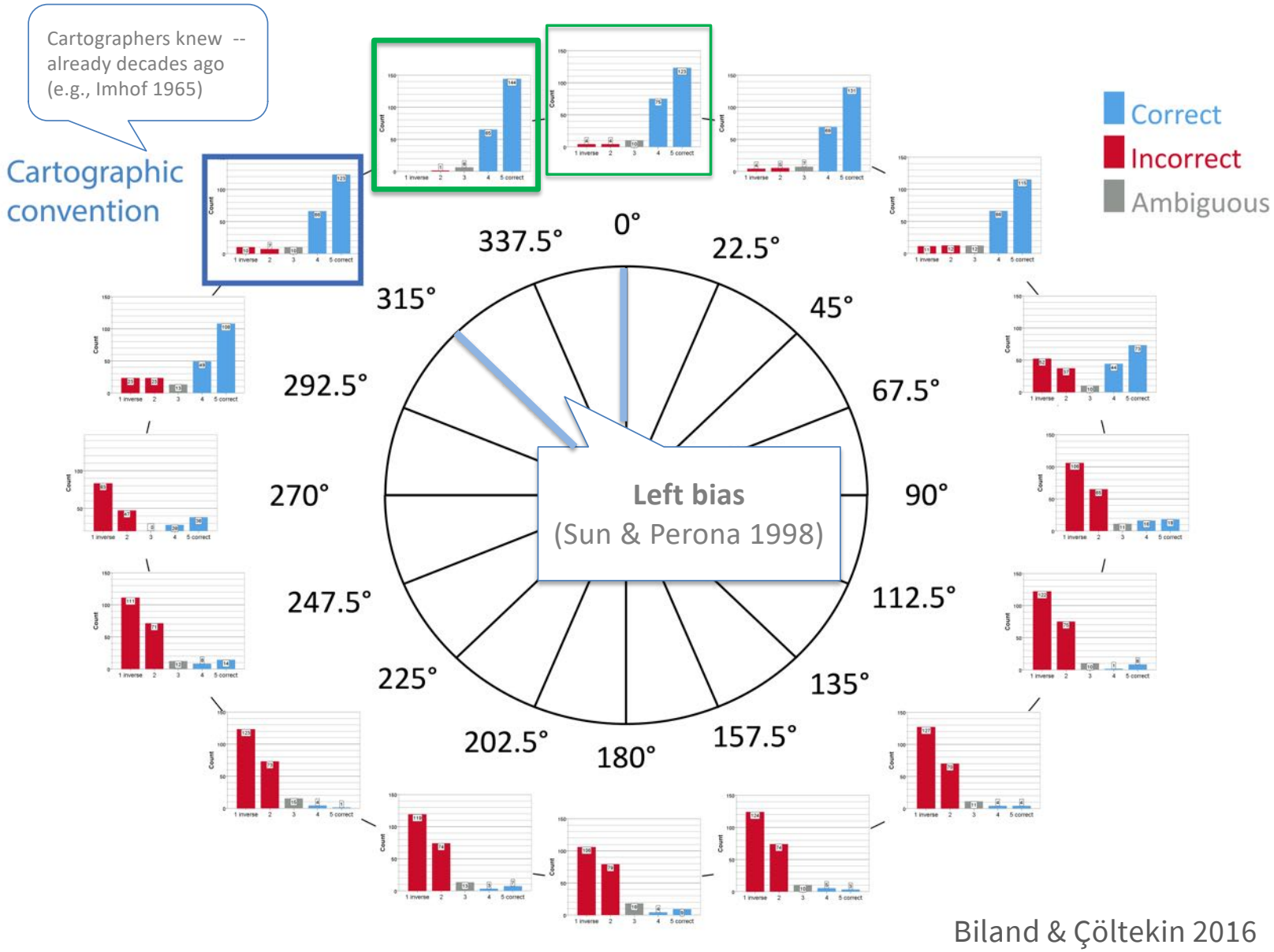
Biland J., & Çöltekin A. (2016): An empirical assessment of the impact of the light direction on the relief inversion effect in shaded relief maps: NNW is better than NW, *Cartography and Geographic Information Science*, DOI: 10.1080/15230406.2016.1185647





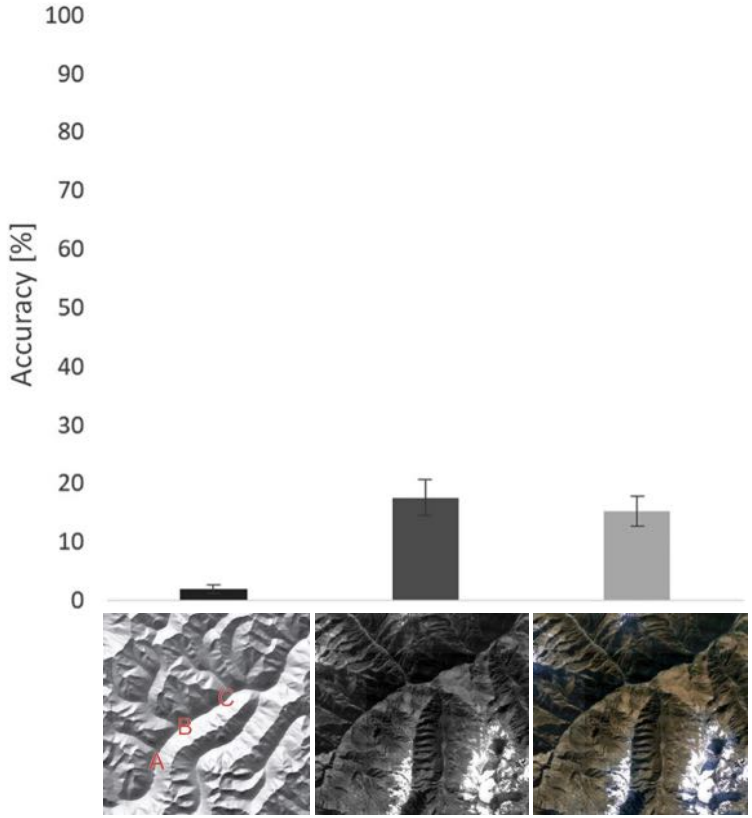
128 terrains (8 landform configurations, 16 illumination directions)
29 participants

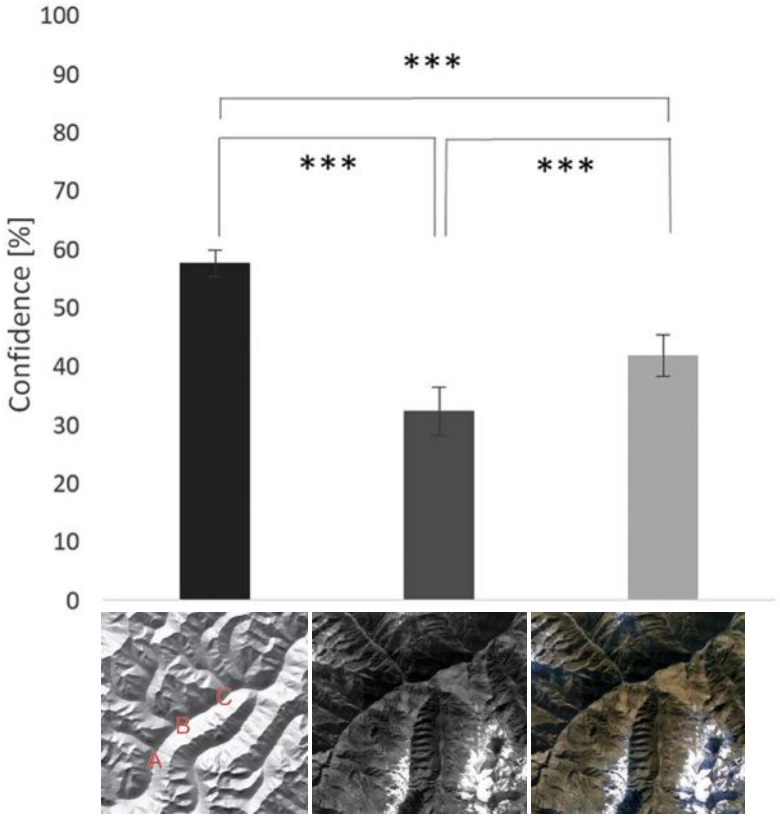
Biland J., & Çöltekin A. (2016): An empirical assessment of the impact of the light direction on the relief inversion effect in shaded relief maps: NNW is better than NW, *Cartography and Geographic Information Science*, DOI: 10.1080/15230406.2016.1185647



Biland J., & Çöltekin A. (2016): An empirical assessment of the impact of the light direction on the relief inversion effect in shaded relief maps: NNW is better than NW, *Cartography and Geographic Information Science*, DOI: 10.1080/15230406.2016.1185647

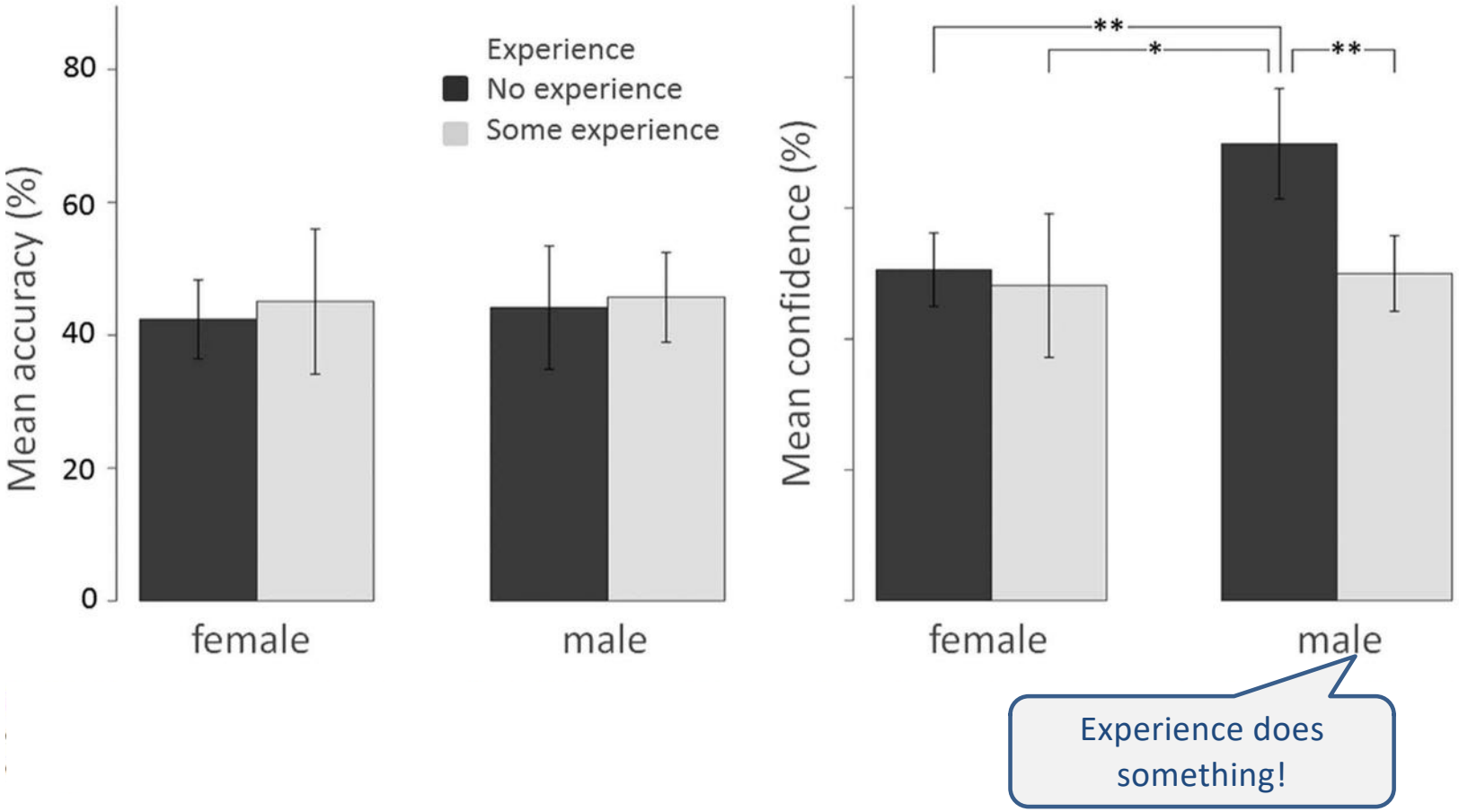
Accuracy vs. confidence





Çöltekin, A., & Biland, J. (2019). Comparing the terrain reversal effect in satellite images and in shaded relief maps: an examination of the effects of color and texture on 3D shape perception from shading. *International Journal of Digital Earth*, *12*(4), 442-459.

(over)confidence



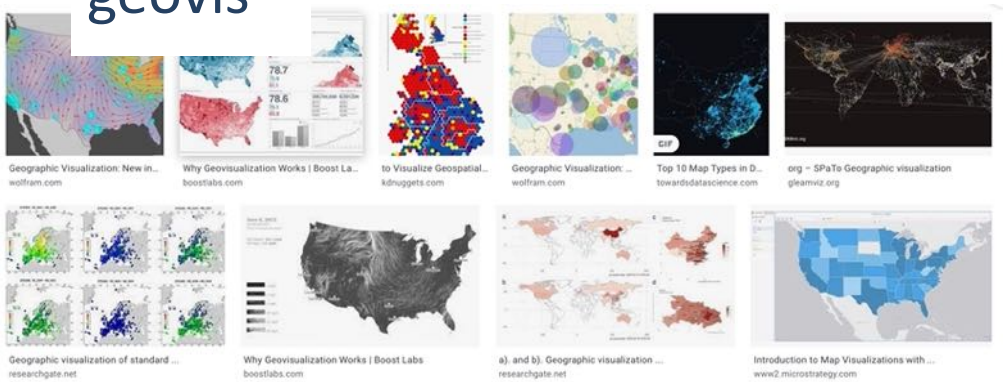
Biland J., & Çöltekin A. (2016): An empirical assessment of the impact of the light direction on the relief inversion effect in shaded relief maps: NNW is better than NW, *Cartography and Geographic Information Science*, DOI: 10.1080/15230406.2016.1185647

What we know

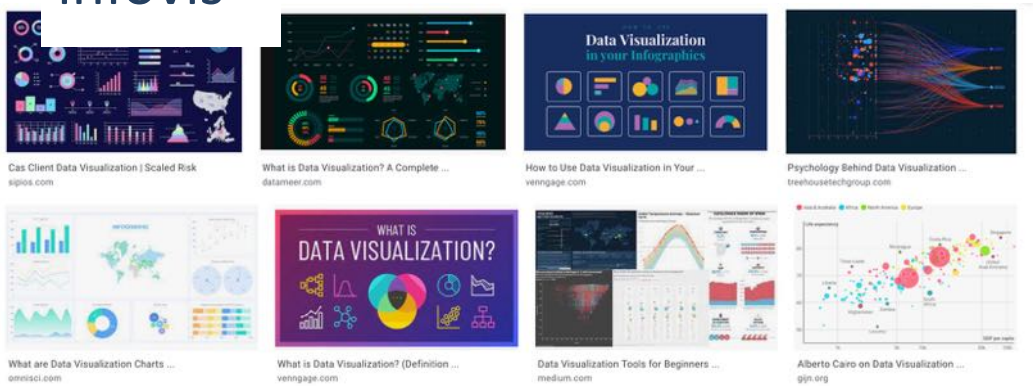
- Occurs in shaded relief maps (Imhof, 1960s) and in satellite images (Saraf et al. 1996, Bernabé-Poveda et al. 2005)
- Prevalent
  - up to 98% in SRMs (Bernabé-Poveda & Çöltekin, 2014; Biland & Çöltekin, 2016)
  - ~40-60% in satellite images (Çöltekin and Biland, 2018)
- Texture reduces, color strengthens the illusion (Çöltekin and Biland, 2018)
- There is a *left bias* (Çöltekin and Biland, 2018; Çöltekin et al., 2018)
- *Handedness* matters in left bias
  (Sun and Perona, 1998; Mamassian and Goutcher 2001; Gerardin, Kourtzi, and Mamassian 2010)
- Non-expert men more *confident*, but not more accurate
  (Biland & Çöltekin, 2016)
- Reproducible (e.g., Çöltekin et al., 2018, more on the way)
- Fixable (Saraf et al., 2005; Bernabé-Poveda, Sanchez-Ortega, Çöltekin, 2011; Gil 2010; 2014, Hartung & Çöltekin 2020)

SciViz seems to contain a lot of **3D**

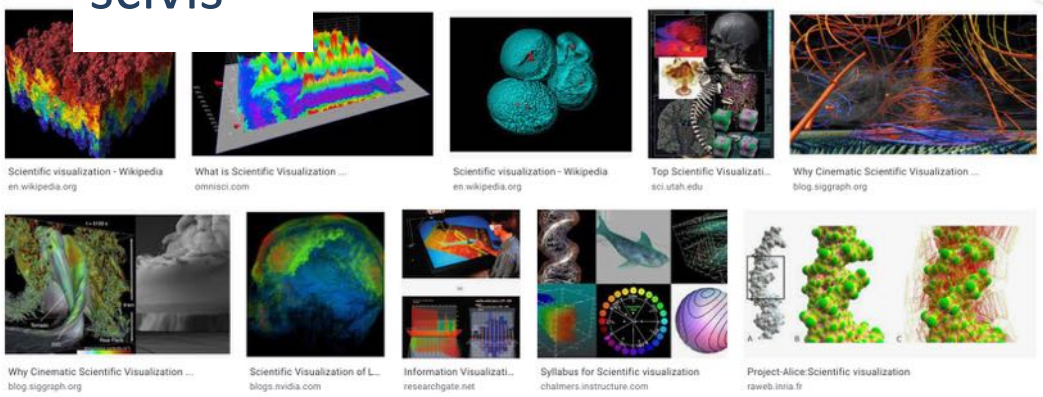
geovis



infovis



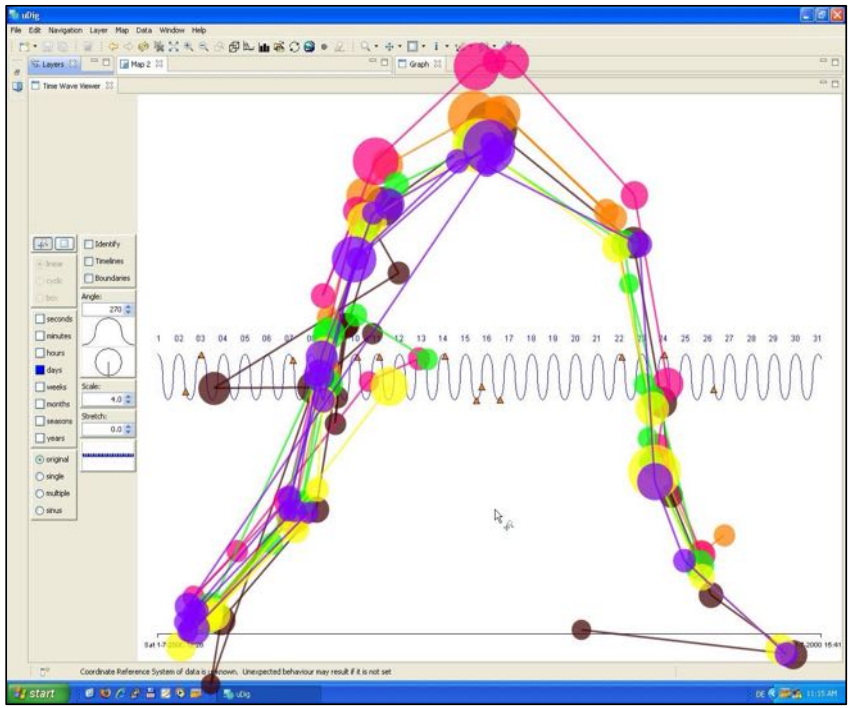
scivis

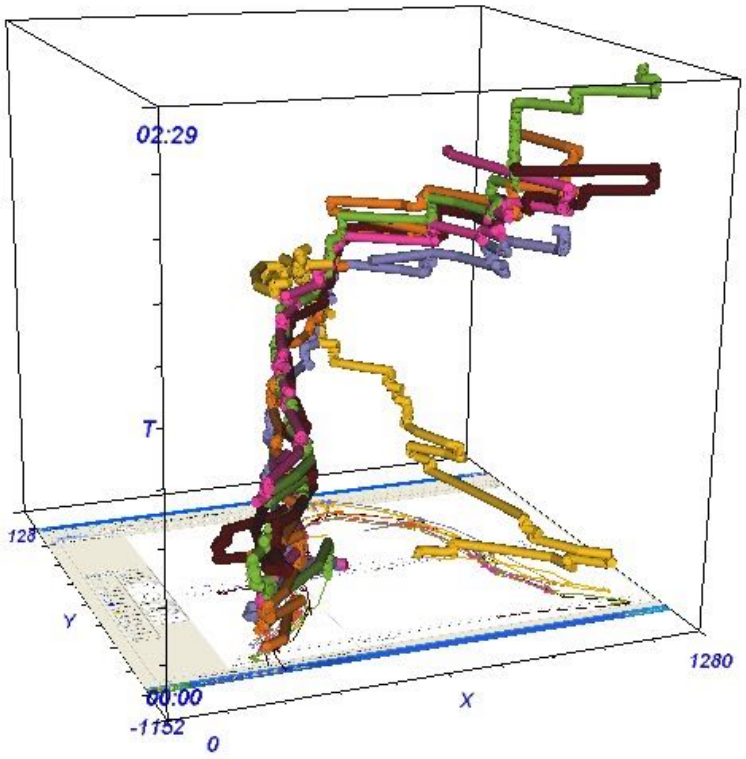


datavis

Is 3D better than 2D?

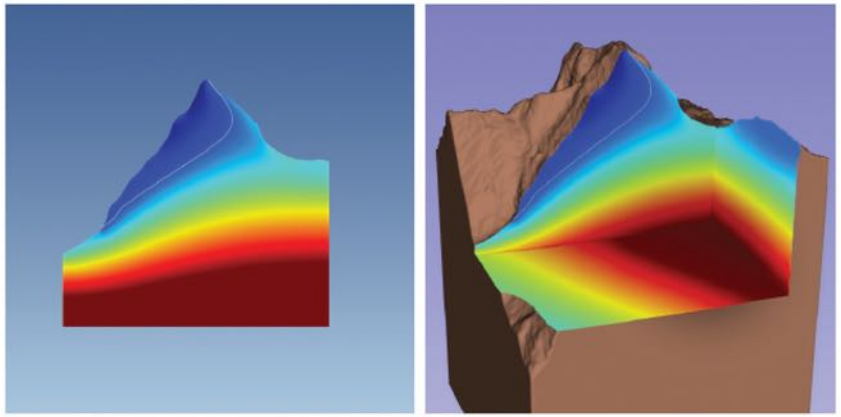
2D vs 3D Patterns and anomalies in eye movement data



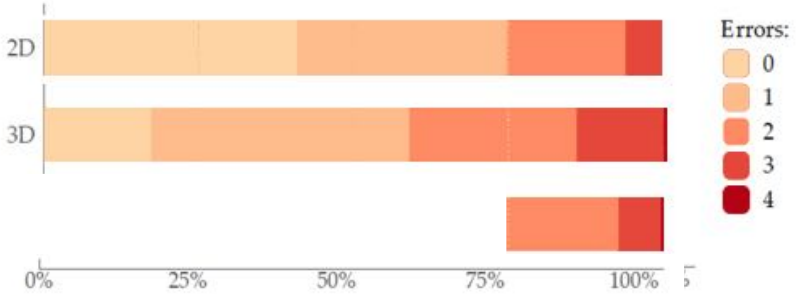


Li, X., Çöltekin, A., Kraak MJ., 2010. Visual exploration of eye movement data using the Space-Time-Cube . Lecture Notes in Computer Science, 2010, Volume 6292/2010, 295-309.

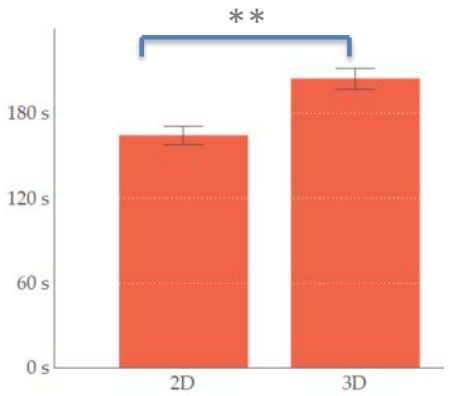
2D vs 3D Reading temperature from permafrost visualizations



Number of errors **2D/3D**



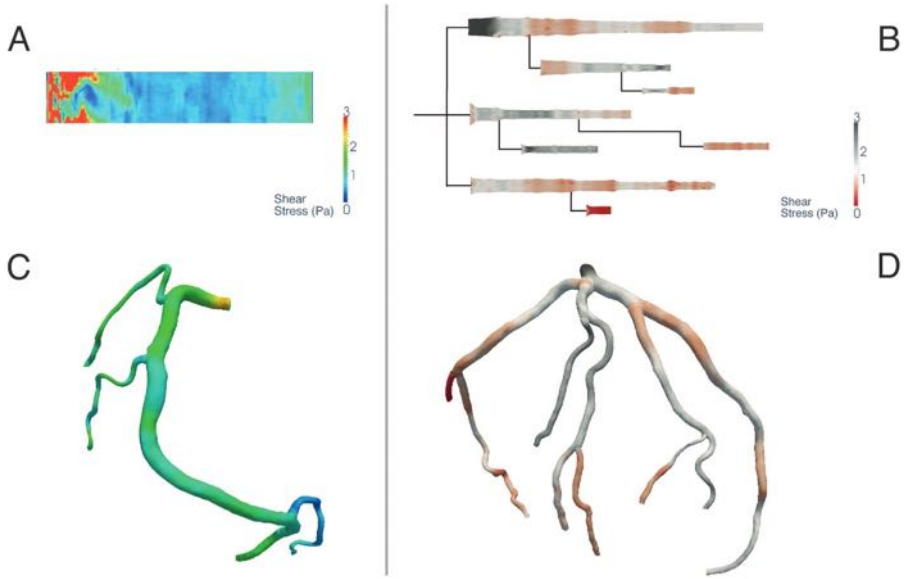
Response time 2D/3D

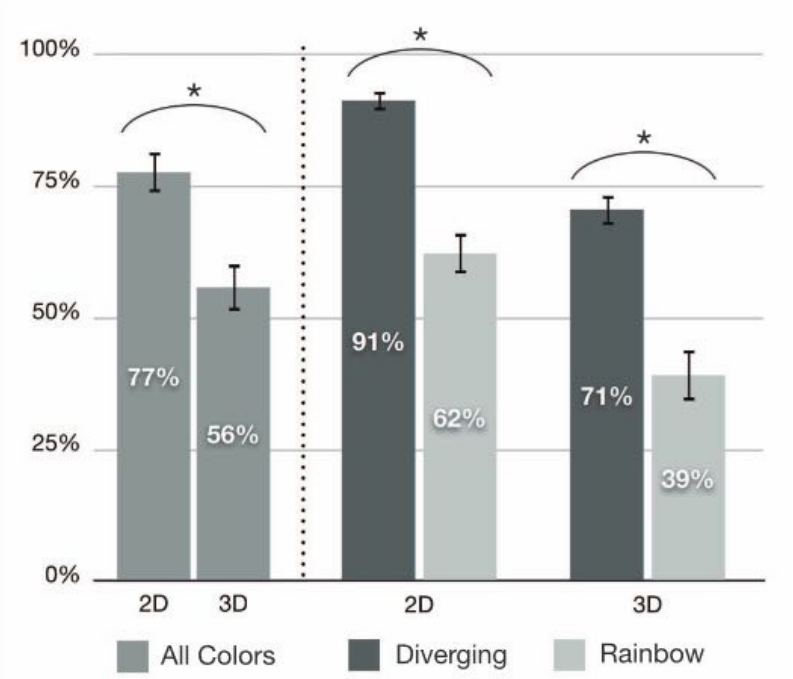


** p < .01

Dall'Acqua, L., Çöltekin, A., & Noetzli, J. (2013). A Comparative User Evaluation of Six Alternative Permafrost Visualizations for Reading and Interpreting Temperature Information. In GeoViz Hamburg 2013 Interactive Maps that Help Poeple Think.

2D vs 3D Artery visualizations for heart disease diagnosis





Changing to 2D helps but color is even more important!

Borkin, M. A., Gajos, K. Z., Peters, A., Mitsouras, D., Melchionna, S., Rybicki, F. J., ... Pfister, H. (2011). Evaluation of Artery Visualizations for Heart Disease Diagnosis. IEEE Transactions on Visualization and Computer Graphics, 17(12), 2479–88.

A detour about color

Gołbiowska, I. M., & Çöltekin, A. (2020). Rainbow Dash: Intuitiveness, interpretability and memorability of the rainbow color scheme in visualization. *IEEE transactions on visualization and computer graphics*, *28*(7), 2722-2733.

Gołębiowska, I., & Çöltekin, A. (2022). What's wrong with the rainbow? an interdisciplinary review of empirical evidence for and against the rainbow color scheme in visualizations. *ISPRS Journal of Photogrammetry and Remote Sensing*, *194*, 195-208.

McIntire et al.'s (2014) review on **stereo 3D**

- based on 160 papers (51 years of research), stereo 3D
  - improved performance in 60% of the experiments
  - made no difference in 25%
  - harmed performance in 'rare' cases
- studied contexts
  - judgments of positions and/or distances
  - finding, identifying, or classifying objects
  - spatial manipulations of real or virtual objects
  - navigation
  - spatial understanding, memory, or recall
  - learning, training, or planning

https://65.media.tumblr.com/0c0f998dca1d85f9a21f1ee489e9e21e/tumblr_ndrxkeyThR1r238sko1_500.jpg

https://twitter.com/vladobotsvadze/status/1023911128911552512


OMG!

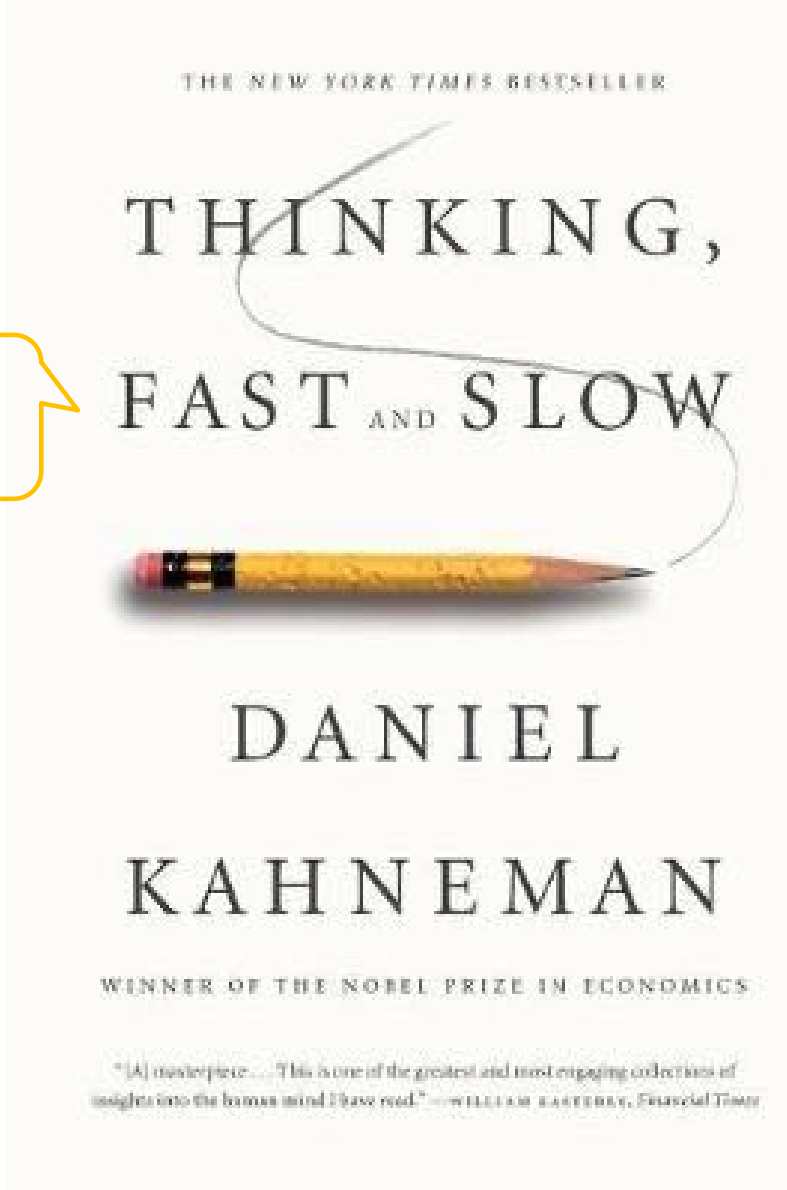
University of Applied Sciences and Arts
Northwestern Switzerland

Another way to think about visualization+:

system 1 & system 2

Extended reality (XR)

Complementing rational thinking (classical vis) with experience based, memorable moments



X is variable – virtual, augmented, mixed

- You have a virtual cat in a digital room, entirely simulated (VR)
- Show a virtual cat at a *random* place in the real world (AR)
- The virtual cat can hide in the physical box, system interprets the box, *spatially referenced* (MR)

Oliver the Virtual Cat
https://appadvice.com/app/oliver-the-virtual-cat/1378235214


MR example
by Alexandre Devaux
Çöltekin, A., Lochhead, I., Madden, M., Christophe, S., **Devaux**, A., Pettit, C., ... & Hedley, N. (2020). Extended reality in spatial sciences: A review of research challenges and future directions. *ISPRS International Journal of Geo-Information*, *9*(7), 439.

VR example

TECH INSIDER

XR is powerful

Experiences are **virtual**

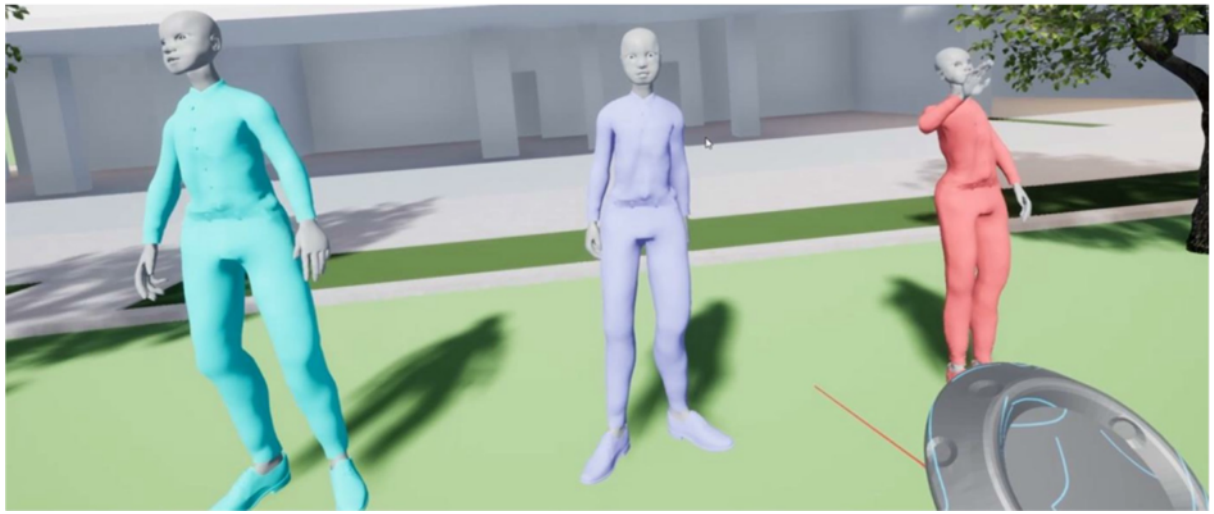
but the emotional and physiological consequences are **real**

In Koçak's view, these glasses (VR headsets) are also emotionally beneficial for animals. He noted that they were less stressed when wearing them, and this is reflected in the milk yield, which is increasing in both quality and quantity. Photograph:(Twitter)

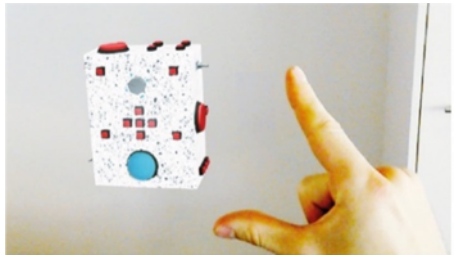
FOLLOW US

https://www.wionews.com/world/cows-in-turkey-enjoy-vr-headsets-owner-reports-they-are-more-relaxed-milk-yield-increased-444060

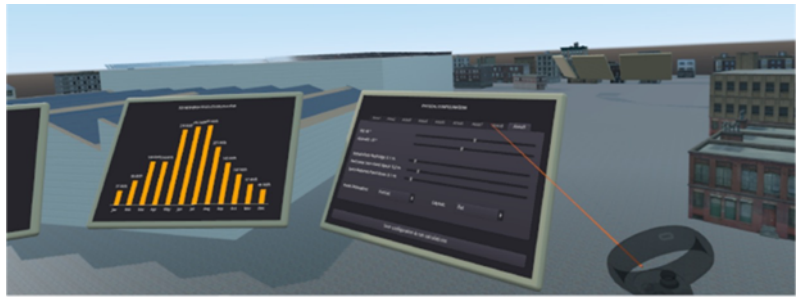
Gaze visualization Bragger et al. (2022)



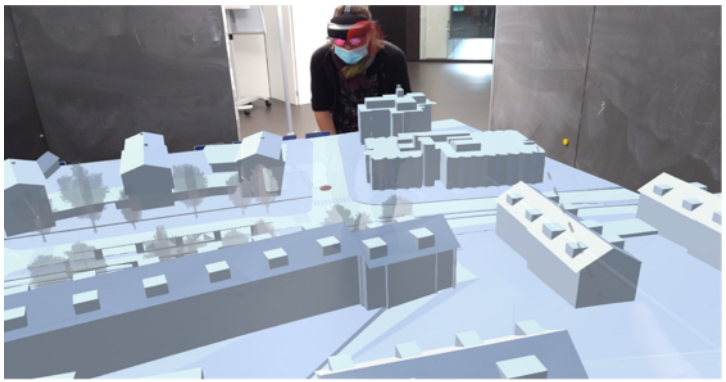
Avatars unpublished work Marti, Schällmann, Fluri, Çöltekin



Digital twins Baumgartner et al. (2022)

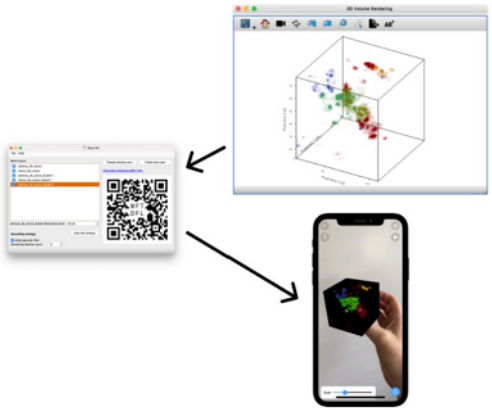


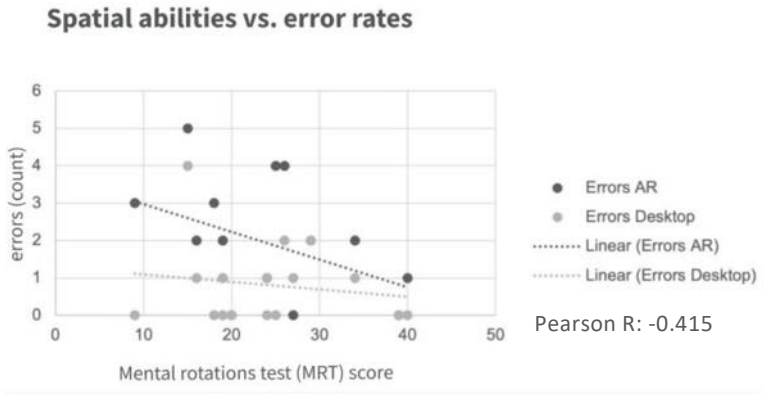
VR Labs unpublished work
Kaufman, Burri, Huesser, Leu, Odermatt, Minamisawa, Çöltekin



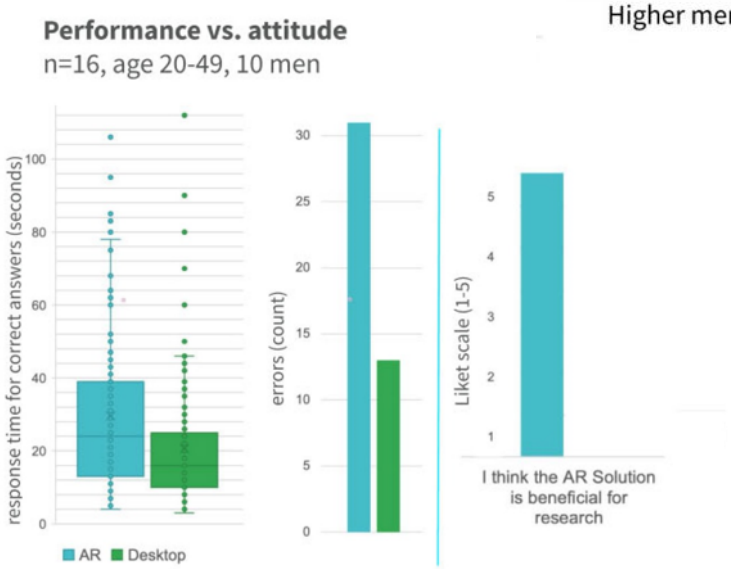
CollabMR unpublished work
Baumgartner, Koebel, Çöltekin

Tangible AR (Study 1)





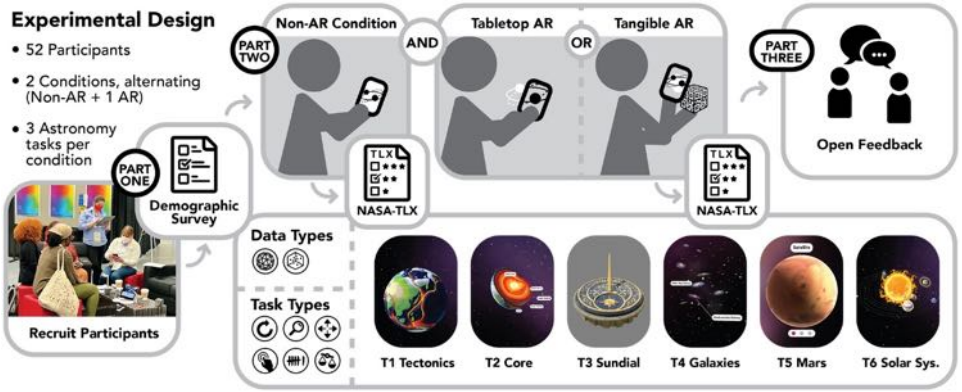
Higher mental rotation abilities correlate with higher performance in AR



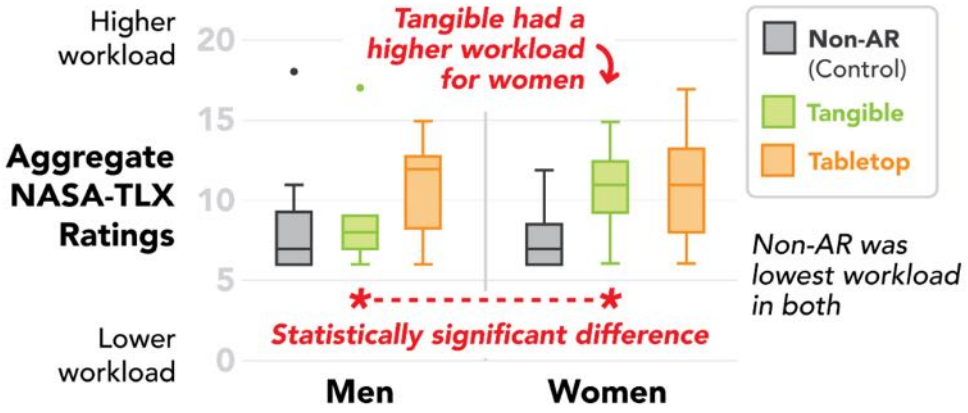
Performance worse in AR (left), unanimous intuition: AR benefits scientific exploration (right)

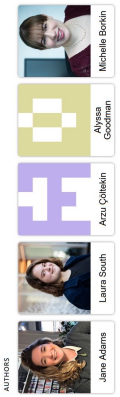
Ambuehl, A., Fluri, L., Zucker, C., Goodman, A., Çöltekin, A. (2022). Effectiveness and perceived usefulness of a handheld AR cube for examining 3D spatial structures. Presented at SpaceCHI Workshop at the CHI2022.

Tangible AR (Study 2)



"For whom"
is the visualization?

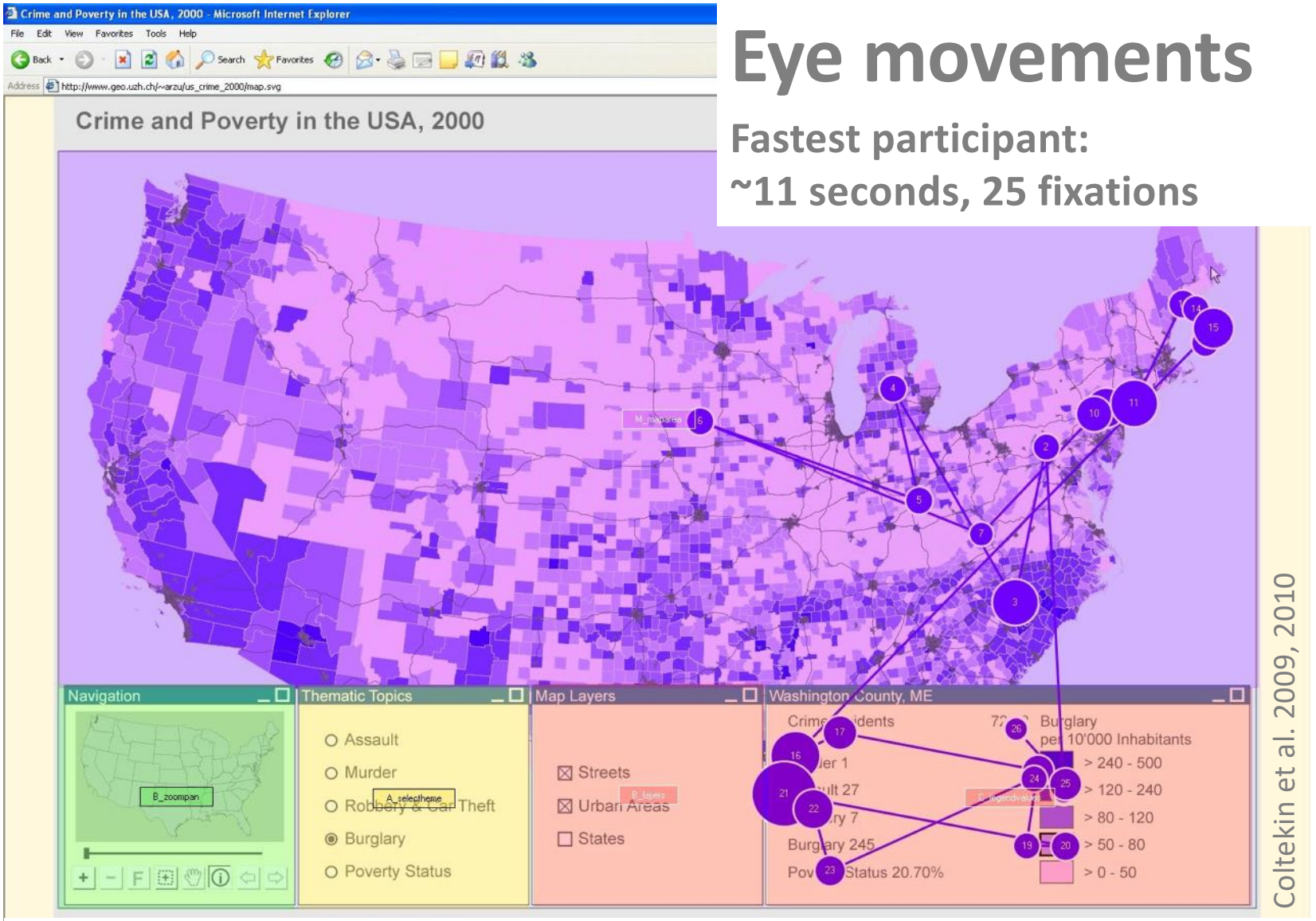




Adams, J., South L., Çöltekin, A., Goodman, A., Borkin, M. (2023) Augmented reality as a visualization technique for scholarly publications in astronomy: An empirical evaluation, IEEE Transactions on Visualization and Computer Graphics—VIS/TVCG. 2023. DOI: 10.31219/osf.io/93brd

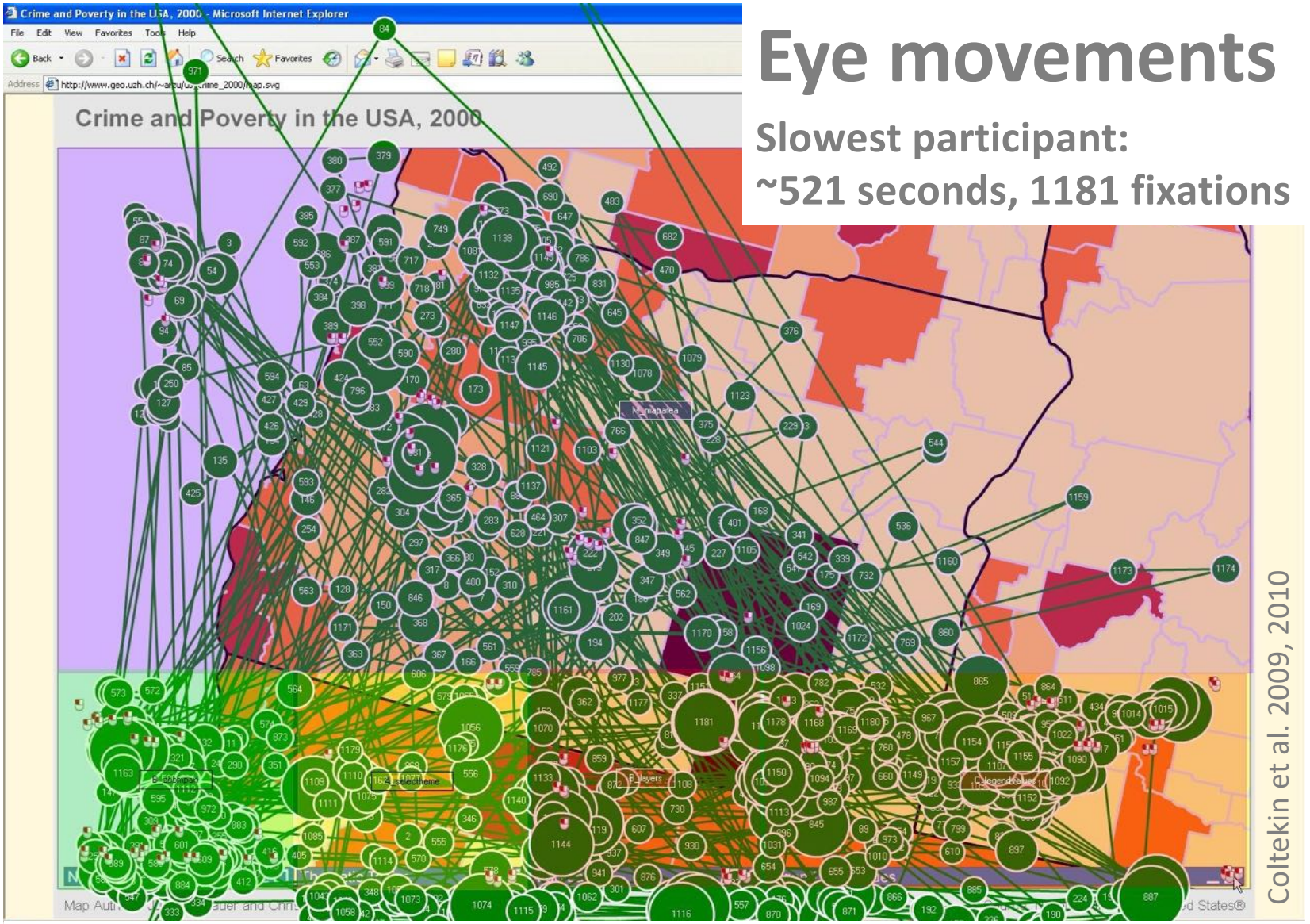
Eye movements

Fastest participant:
~11 seconds, 25 fixations



Coltekin et al. 2009, 2010

Coltekin, A. (2015). Mix well before use: Understanding the key ingredients of user studies . Workshop (position) paper -- at the pre-conference workshop "Envisioning the Future of Cartographic Research" at the *International Cartographic Conference* , ICC 2015, Curitiba, Brazil.



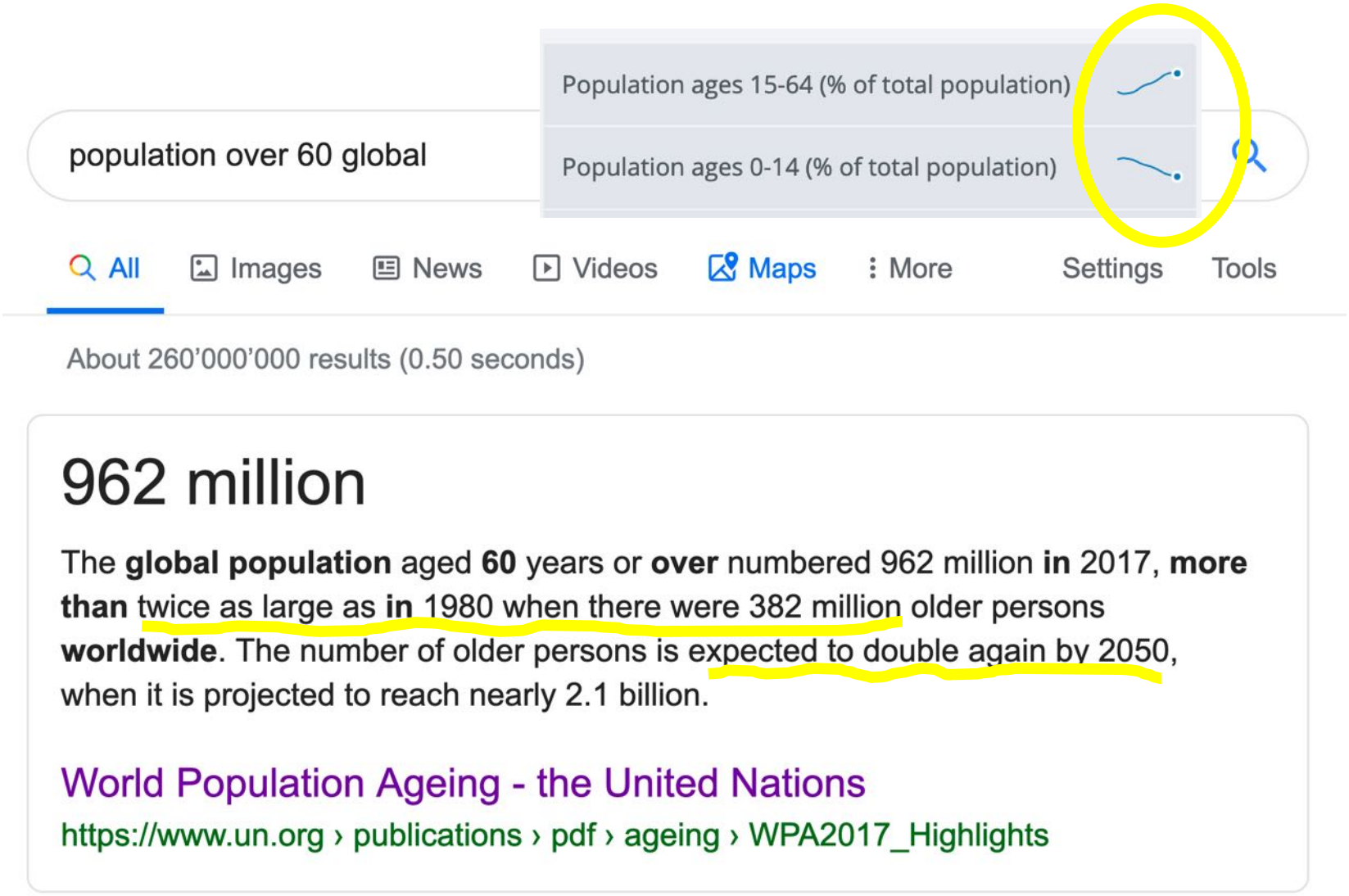
Eye movements

Slowest participant:
~521 seconds, 1181 fixations

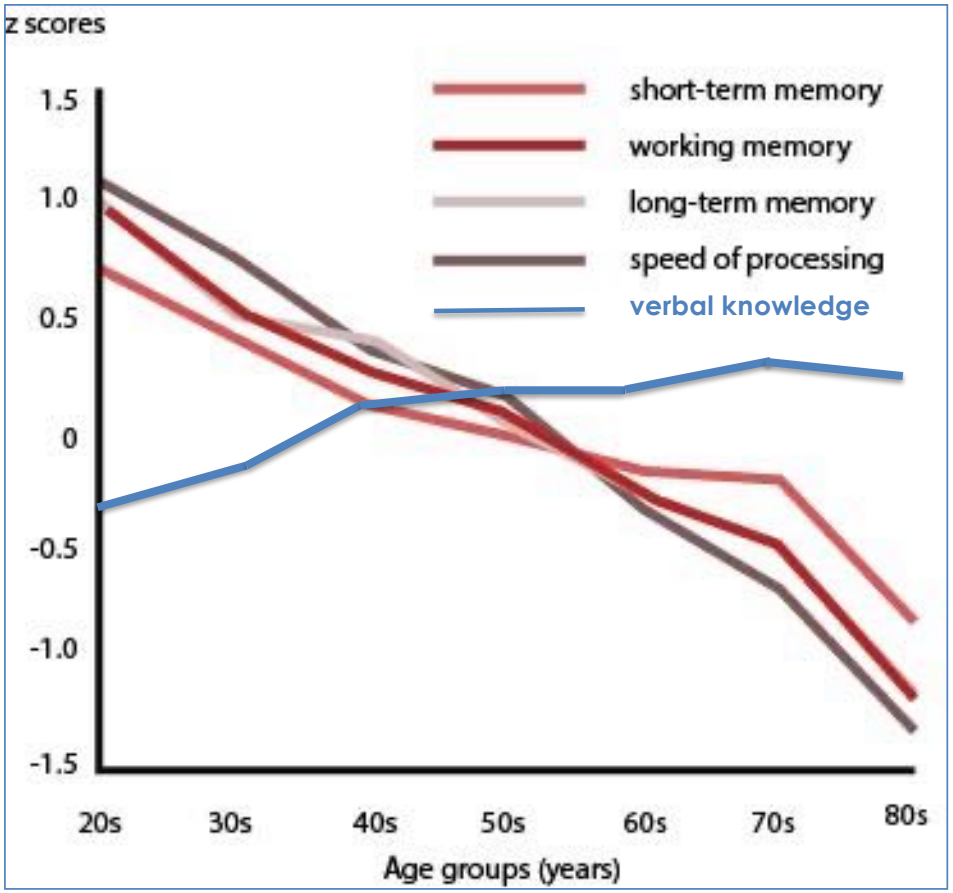
Coltekin et al. 2009, 2010

Coltekin, A. (2015). Mix well before use: Understanding the key ingredients of user studies . Workshop (position) paper -- at the pre-conference workshop "Envisioning the Future of Cartographic Research" at the *International Cartographic Conference* , ICC 2015, Curitiba, Brazil.

Aging


Population ages 15-64 (% of total population)
Population ages 0-14 (% of total population)
population over 60 global
All
Images
News
Videos
Maps
More
Settings
Tools
About 260'000'000 results (0.50 seconds)
962 million
The global population aged 60 years or over numbered 962 million in 2017, more than twice as large as in 1980 when there were 382 million older persons worldwide. The number of older persons is expected to double again by 2050, when it is projected to reach nearly 2.1 billion.
World Population Ageing - the United Nations
https://www.un.org › publications › pdf › ageing › WPA2017_Highlights

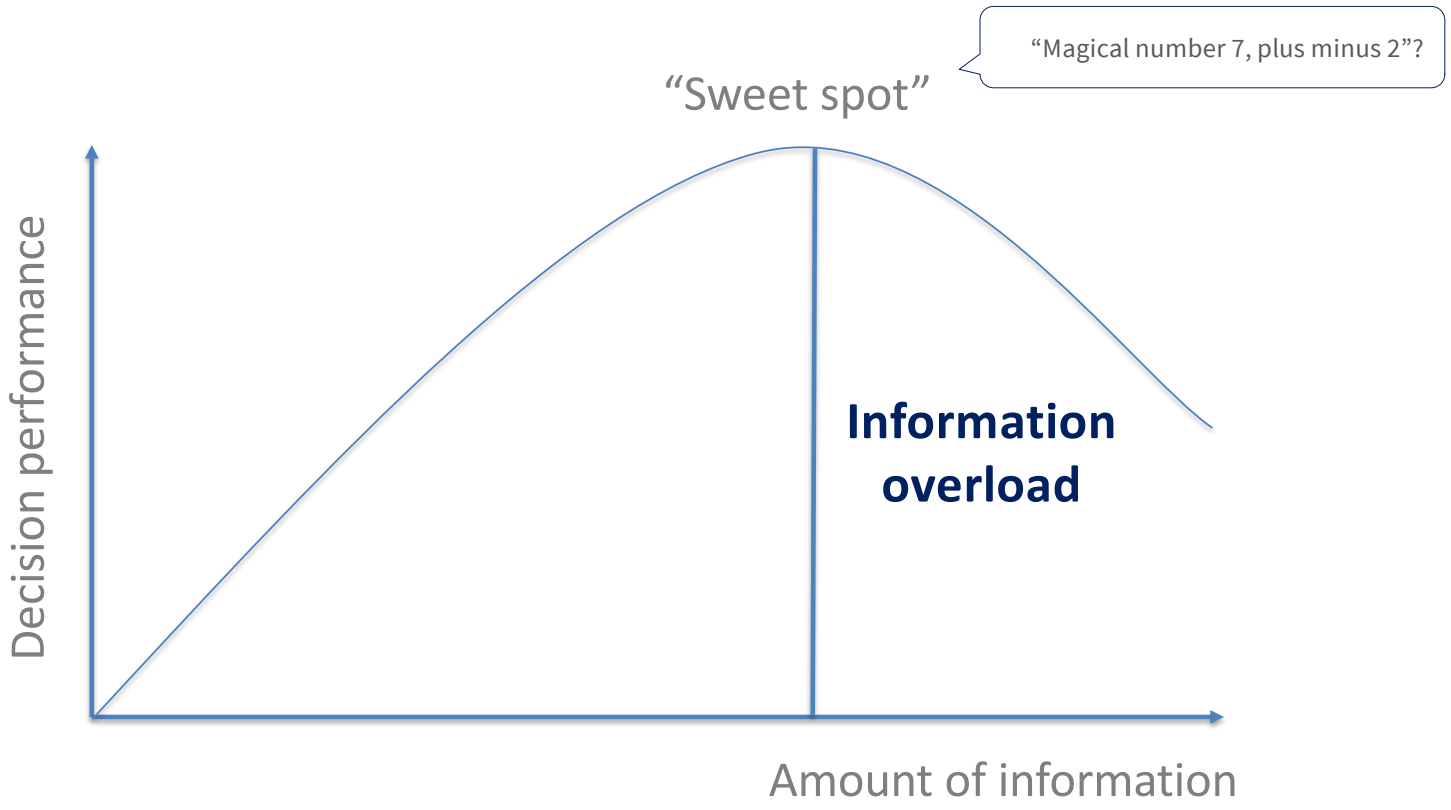
… as we age, this happens



Redrawn from Park, Lautenschlager, Hedden, Davidson, Smith, & Smith (2002)

Ok, at least
wisdom is real ☺

The (infamous) inverted u-curve



Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological Review, 63, 81-97

Eppler, M. J., & Mengis, J. (2008). The Concept of Information Overload-A Review of Literature from Organization Science, Accounting, Marketing, MIS, and Related Disciplines (2004) The Information Society: An International Journal, 20 (5), 2004, pp. 1–20. *Kommunikationsmanagement im Wandel: Beiträge aus 10 Jahren= mcminstitute*, 271-305.

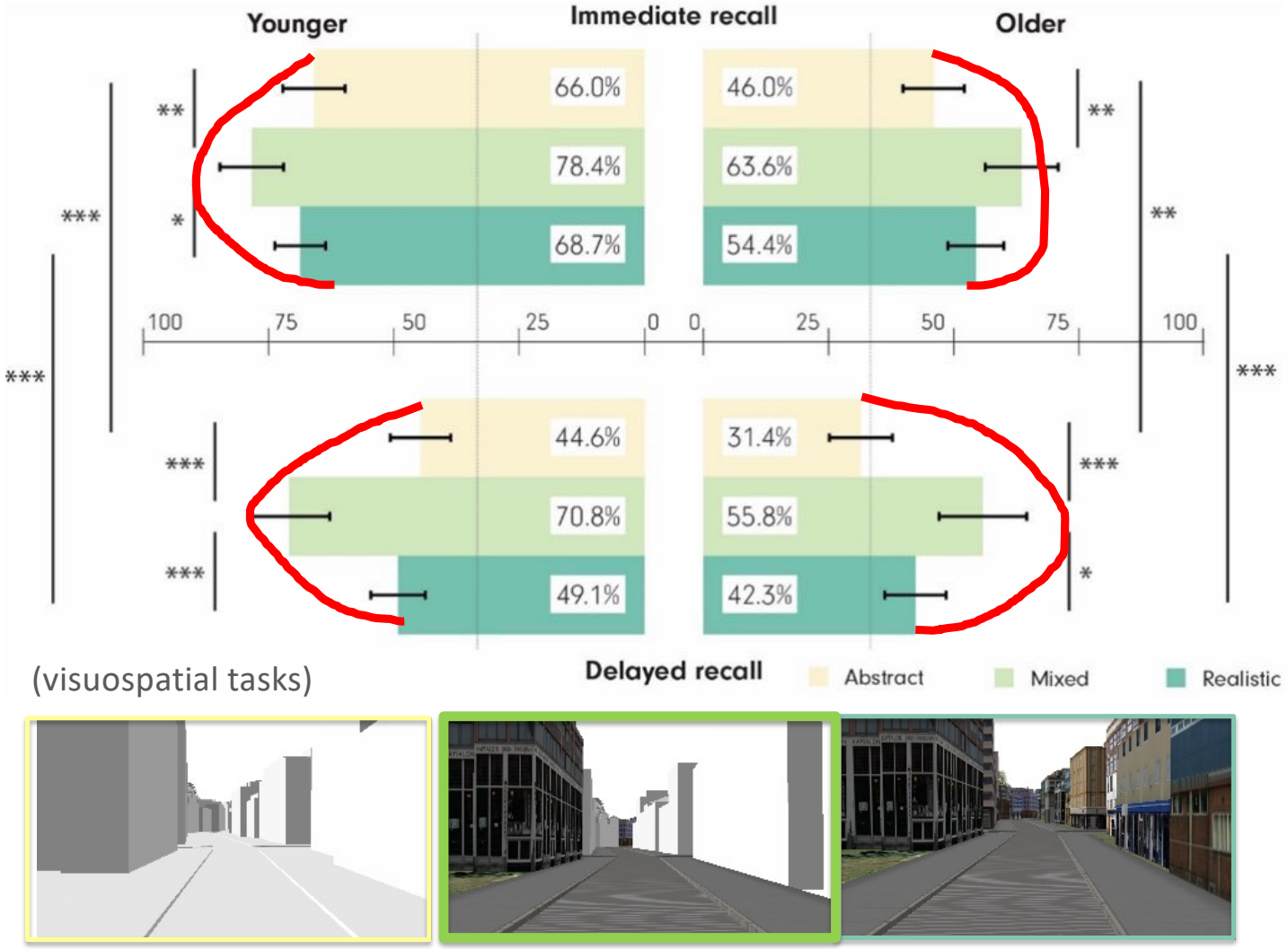
too much information

too little information

a design intervention “mixed realism”

1. Lokka, I-E., Çöltekin, A. (2017). Towards optimizing the design of virtual environments for route learning: An empirical study of memorability with changing levels of realism. *International Journal of Digital Earth.*
2. Lokka, I-E., Çöltekin, A. Wiener, J., Fabrikant, S.I., Roecke, C. (2018). Virtual environments as memory training devices in navigational tasks for older adults. *Scientific Reports.* https://www.nature.com/articles/s41598-018-29029-x
3. Lokka, I-E., Çöltekin, A. (2019). Perspective switch and spatial knowledge acquisition: Effects of age, mental rotation ability and visuospatial memory capacity on route learning in virtual environments with different levels of realism . *Cartography and Geographic Information Science*

Recall accuracy: The MixedVE “wins”

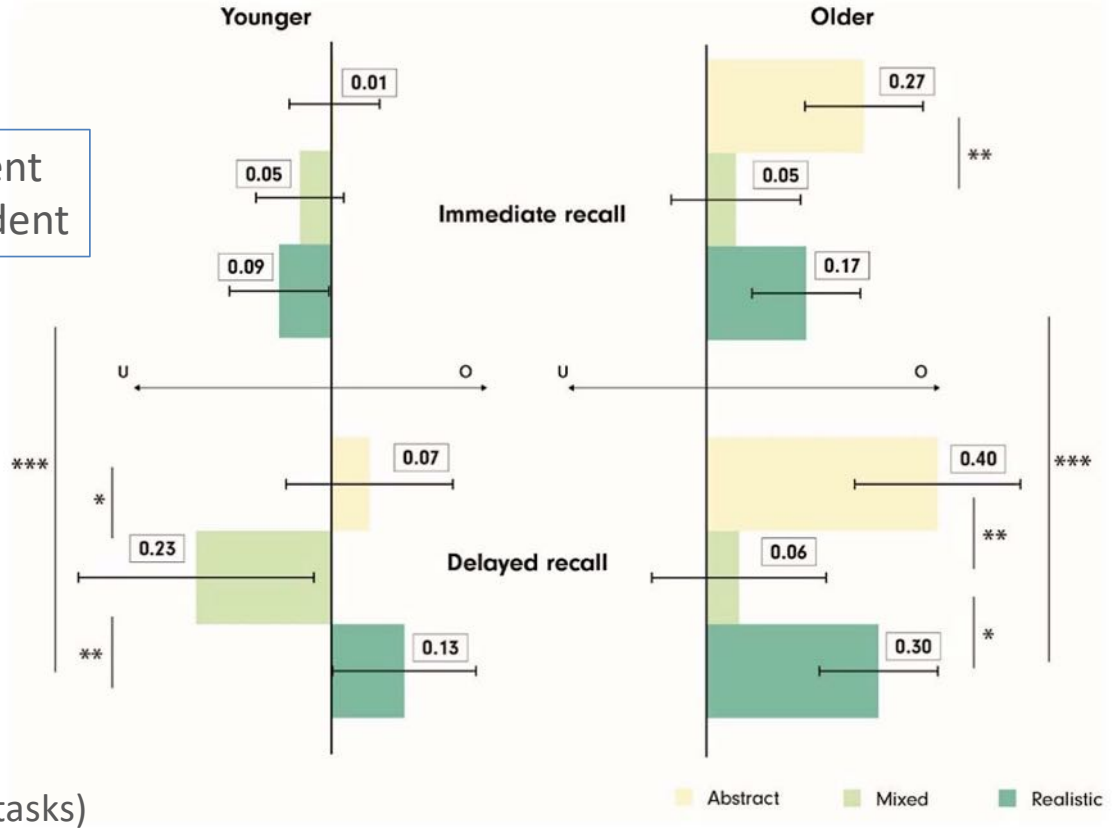


(visuospatial tasks)

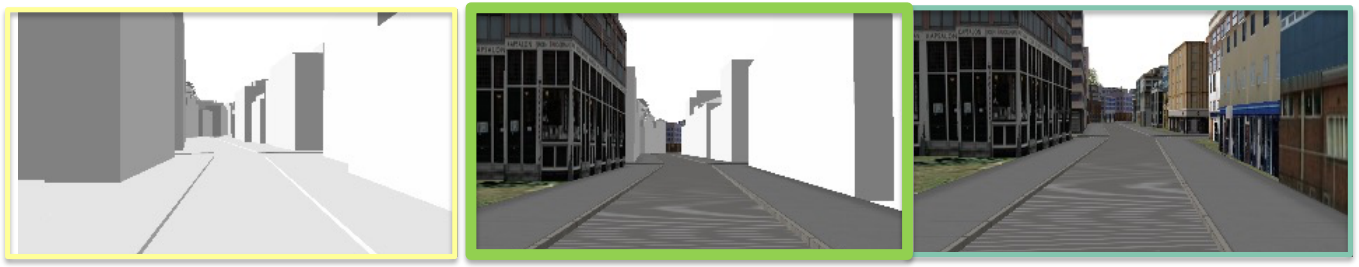
1. Lokka, I-E., Çöltekin, A. (2017). Towards optimizing the design of virtual environments for route learning: An empirical study of memorability with changing levels of realism. *International Journal of Digital Earth*.
2. Lokka, I-E., Çöltekin, A. Wiener, J., Fabrikant, S.I., Roecke, C. (2018). Virtual environments as memory training devices in navigational tasks for older adults. *Scientific Reports*. https://www.nature.com/articles/s41598-018-29029-x
3. Lokka, I-E., Çöltekin, A. (2019). Perspective switch and spatial knowledge acquisition: Effects of age, mental rotation ability and visuospatial memory capacity on route learning in virtual environments with different levels of realism . *Cartography and Geographic Information Science*

… helps calibrating **confidence**

O: overconfident
U: underconfident

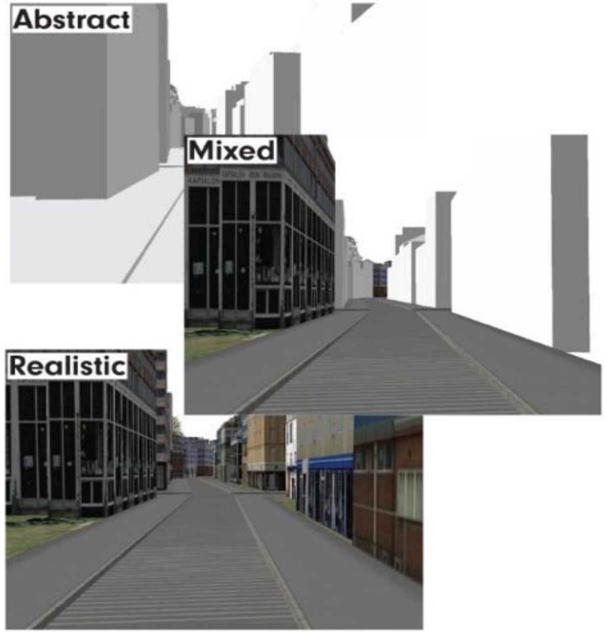


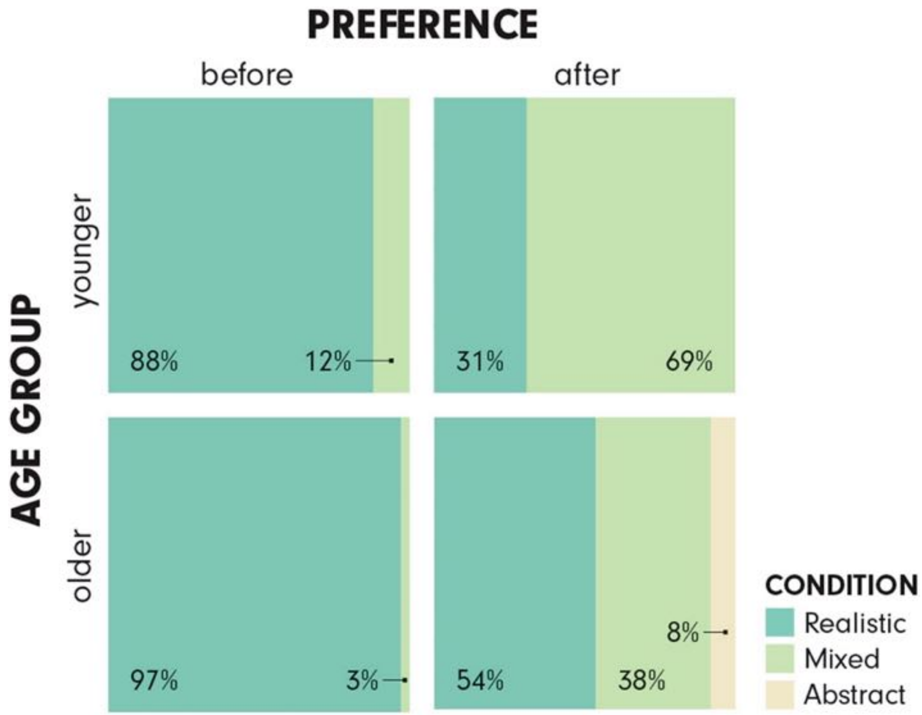
(visuospatial tasks)



1. Lokka, I-E., Çöltekin, A. (2017). Towards optimizing the design of virtual environments for route learning: An empirical study of memorability with changing levels of realism. *International Journal of Digital Earth*.
2. Lokka, I-E., Çöltekin, A. Wiener, J., Fabrikant, S.I., Roecke, C. (2018). Virtual environments as memory training devices in navigational tasks for older adults. *Scientific Reports*. https://www.nature.com/articles/s41598-018-29029-x
3. Lokka, I-E., Çöltekin, A. (2019). Perspective switch and spatial knowledge acquisition: Effects of age, mental rotation ability and visuospatial memory capacity on route learning in virtual environments with different levels of realism . *Cartography and Geographic Information Science*

…help against **naïve realism** (Smallman & John 2005, 2011)





1. Lokka, I-E., Çöltekin, A. (2017). Towards optimizing the design of virtual environments for route learning: An empirical study of memorability with changing levels of realism. *International Journal of Digital Earth.*
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3. Lokka, I-E., Çöltekin, A. (2019). Perspective switch and spatial knowledge acquisition: Effects of age, mental rotation ability and visuospatial memory capacity on route learning in virtual environments with different levels of realism . *Cartography and Geographic Information Science*

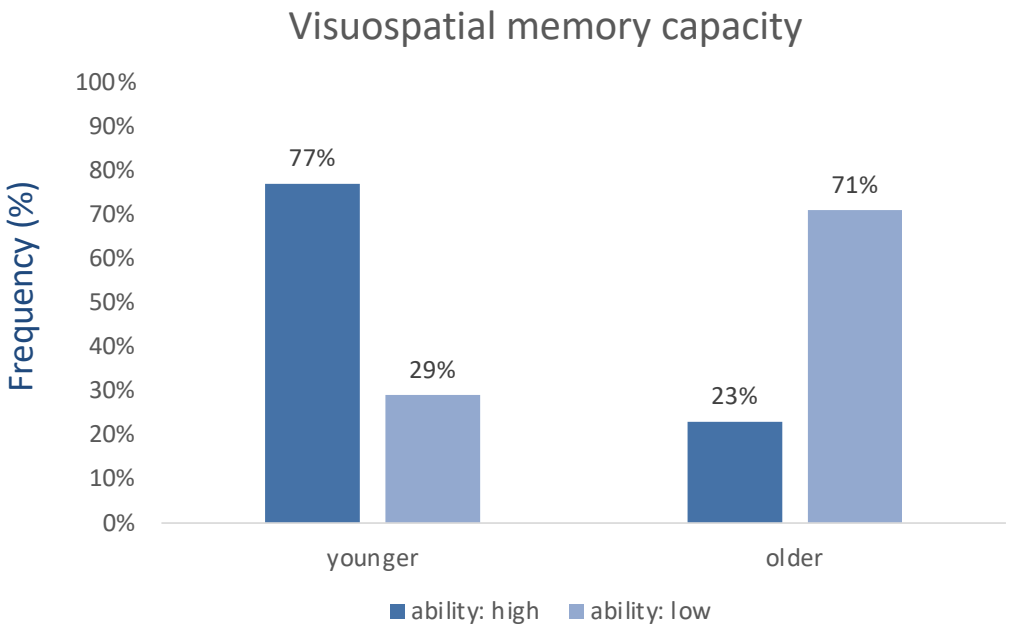
Spatial abilities among our participants?
(median split)

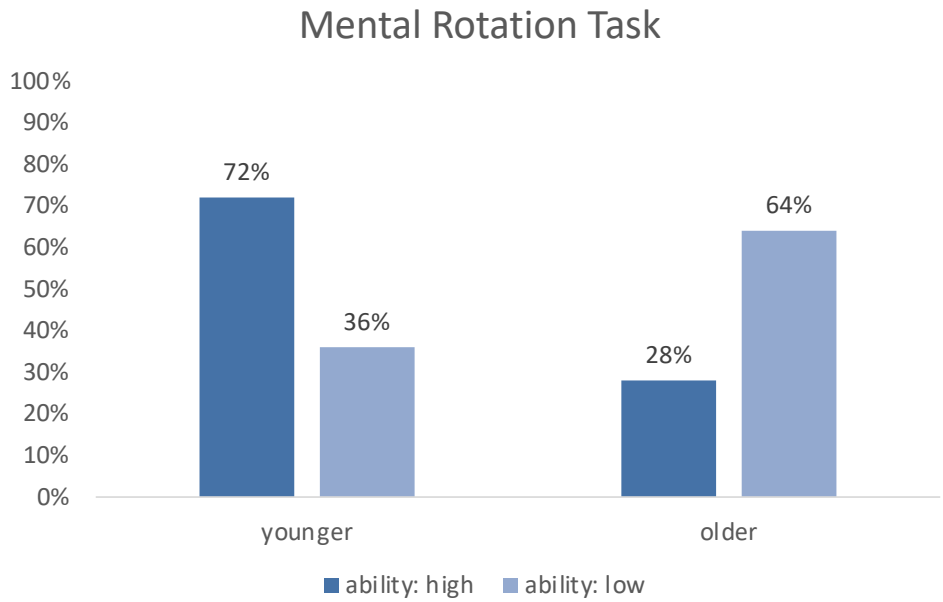
MINI REVIEW ARTICLE
Front. Aging Neurosci., 21 June 2012 | https://doi.org/10.3389/fnagi.2012.00016

Spatial navigation—a unique window into physiological and pathological aging

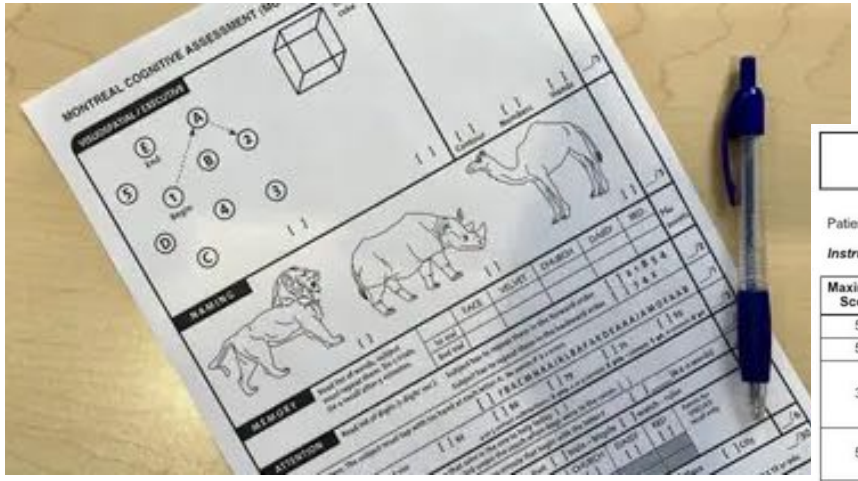
Ivana Gazova[1,2]*, Kamil Vlcek[2,3], Jan Laczó[1,2], Zuzana Nedelska[1,2], Eva Hyncicova[1], Ivana Mokrisova[1], Katerina Sheardova[2] and Jakub Hort[1,2]

[1]Department of Neurology, Memory Disorders Clinic, 2nd Faculty of Medicine, Charles University in Prague and University Hospital Motol, Prague 5, Czech Republic
[2]International Clinical Research Center and St. Anne's University Hospital Brno, Brno, Czech Republic
[3]Department of Neurophysiology of Memory, Institute of Physiology Academy of Sciences of the Czech Republic v.v.i., Prague, Czech Republic

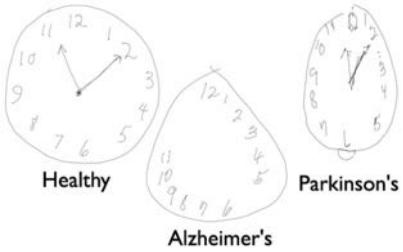




How do we measure cognition?



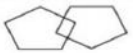
MoCA



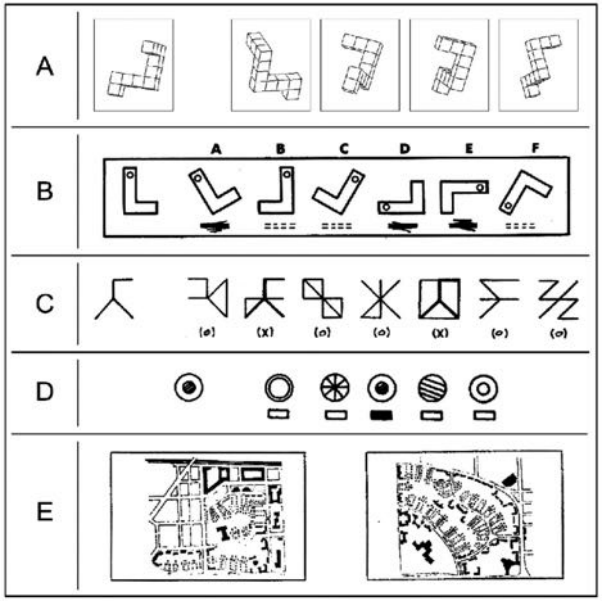
Mini-Mental State Examination (MMSE)

Patient's Name: _____ Date: _____

Instructions: Score one point for each correct response within each question or activity.

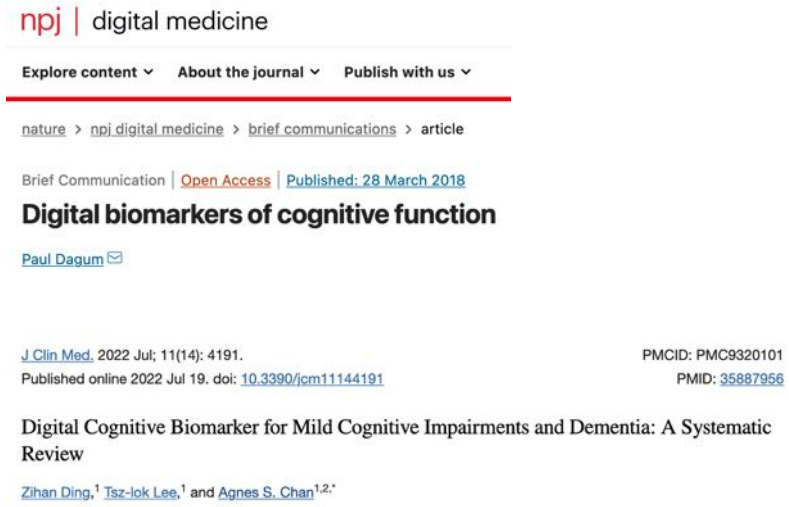
Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day? Month?"
5		"Where are we now? State? County? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then the instructor asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible.
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, ...) Alternative: "Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.) 
30		TOTAL

If we do these digitally, do they measure the same thing? Are they worse, or better perhaps?



Digital biomarkers

- Unobstrutive
- Ecological
- Continuous
- Scalable
- ...
- “digital cognitive biomarkers can be a sensitive and promising clinical tool for detecting MCI and dementia.”



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nature > npj digital medicine > brief communications > article

Brief Communication | Open Access | Published: 28 March 2018

Digital biomarkers of cognitive function

Paul Dagum

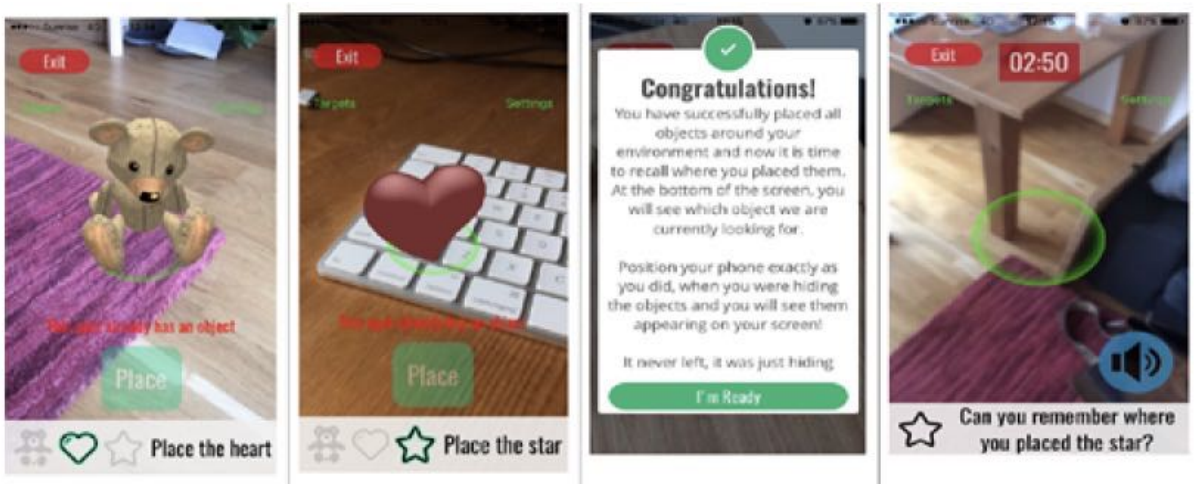
J Clin Med. 2022 Jul; 11(14): 4191. PMCID: PMC9320101
Published online 2022 Jul 19. doi: 10.3390/jcm11144191 PMID: 35887956

Digital Cognitive Biomarker for Mild Cognitive Impairments and Dementia: A Systematic Review

Zihan Ding,[1] Tsz-lok Lee,[1] and Agnes S. Chan[1,2,*]

Augmented reality +

- Various pre-selected visuospatial ability tests
- Motor coordination
- An AR/MR memory “game”



Bill Gates is Optimistic About This Dementia Research

Michael Hunter MD Follow

Sep 21 · 3 min read ★

“He also points to Altoida’s efforts to develop an app that uses **augmented reality** games to assess cognition.”

Detects early & subtle micro-errors (accuracy) and micro-movements (latency)

MCI to AD conversion

npj | Digital Medicine

www.nature.com/npjdigitalmed

ARTICLE OPEN

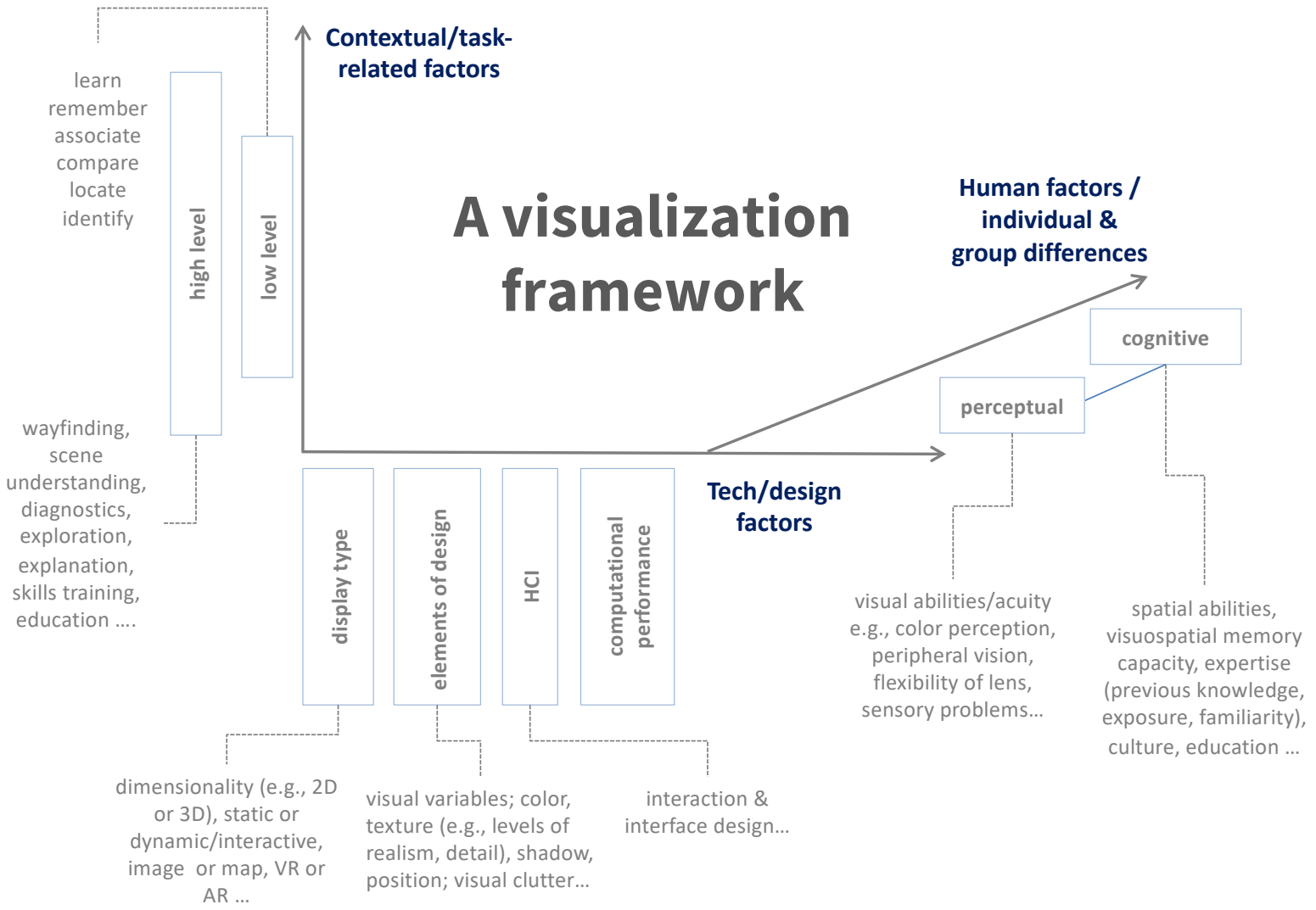
Check for updates

Using a Digital Neuro Signature to measure longitudinal individual-level change in Alzheimer's disease: the Altoida large cohort study

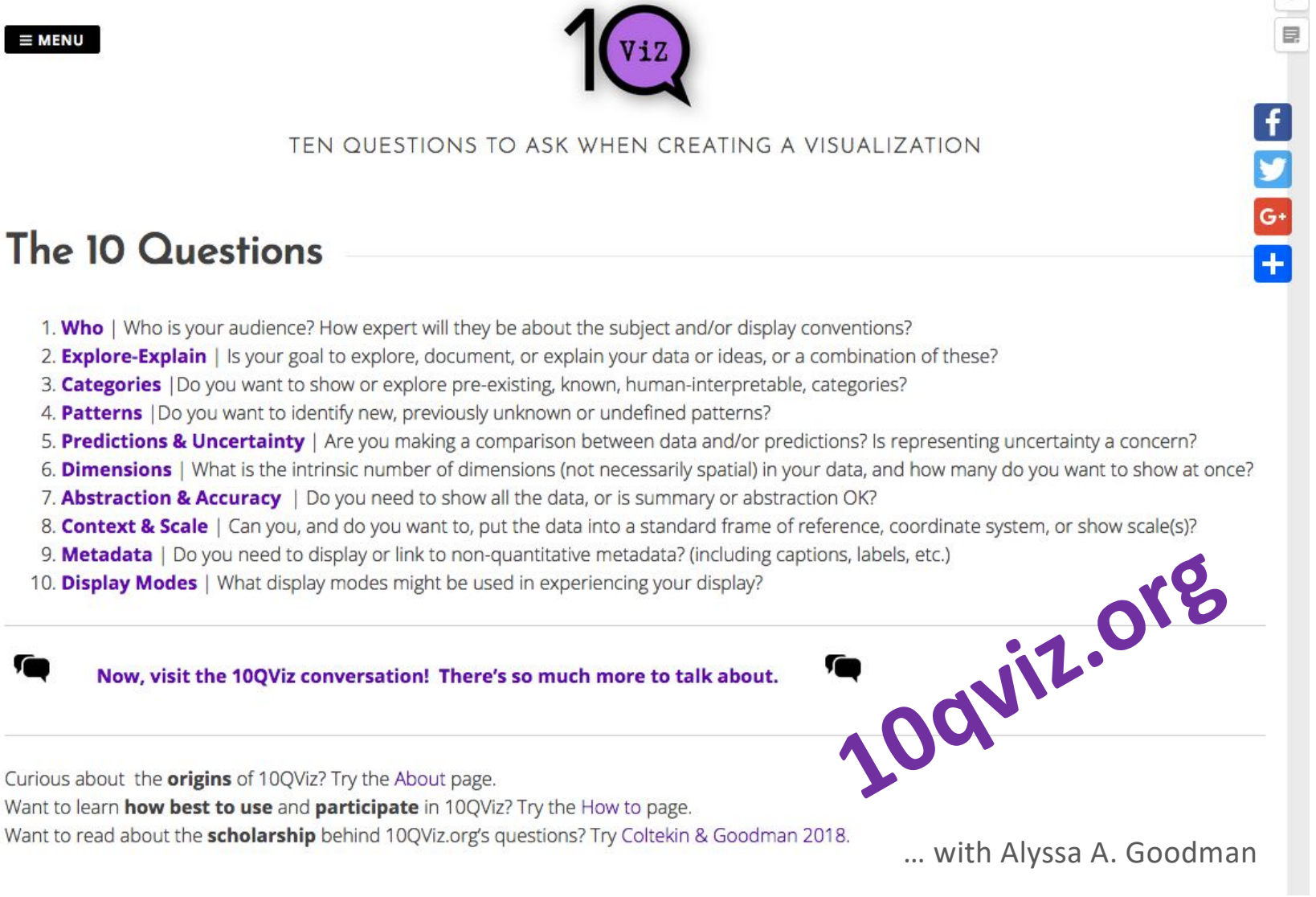
Irene B. Meier[1], Max Buegler[2], Robbert Harms[2], Azizi Seixas[3], Arzu Çöltekin[4] and Ioannis Tarnanas[2,5,6,7]✉

Conventional neuropsychological assessments for Alzheimer's disease are burdensome and inaccurate at detecting mild cognitive impairment and predicting Alzheimer's disease risk. Altoida's Digital Neuro Signature (DNS), a longitudinal cognitive test consisting of two active digital biomarker metrics, alleviates these limitations. By comparison to conventional neuropsychological assessments, DNS results in faster evaluations (10 min vs 45–120 min), and generates higher test-retest in intraindividual assessment, as well as higher accuracy at detecting abnormal cognition. This study comparatively evaluates the performance of Altoida's DNS and conventional neuropsychological assessments in intraindividual assessments of cognition and function by means of two semi-naturalistic observational experiments with 525 participants in laboratory and clinical settings. The results show that DNS is consistently more sensitive than conventional neuropsychological assessments at capturing longitudinal individual-level change, both with respect to intraindividual variability and dispersion (intraindividual variability across multiple tests), across three participant groups: healthy controls, mild cognitive impairment, and Alzheimer's disease. Dispersion differences between DNS and conventional neuropsychological assessments were more pronounced with more advanced disease stages, and DNS-intraindividual variability was able to predict conversion from mild cognitive impairment to Alzheimer's disease. These findings are instrumental for patient monitoring and management, remote clinical trial assessment, and timely interventions, and will hopefully contribute to a better understanding of Alzheimer's disease.

npj Digital Medicine (2021)4:101 ; https://doi.org/10.1038/s41746-021-00470-z



Çöltekin, A. (2019). What contributes to the complexity of visuospatial displays?
Abstraction, Scale and Perception, International Cartographic Association Joint Commission Workshop, Jul 15, Tokyo, Japan



… with Alyssa A. Goodman

Credits (team)

Alumni

Dr. Alzbeta Brychtová

Dr. Victoria Rautenbach

Dr. Tommy Burke

Dr. Kenan Bektaş

Dr. Ismini Lokka

Dr. Giuseppe Marbach

Dr. Marin Tomasic

Dr. Agnieszka Wilk

Dr. Ugo Molteni

Alex Schneiter

Fernando Millan

Madhumitha Murali

Thierry Figini

Daniel Vegh

Louis Baumgartner

Marco Burri

40+ MSc projects, mentees

Kathrin Koebel

Current / recent

Dr. Edel O'sullivan

Dr. Alexandra Diehl

Dr. Alireza Amiraghdam

Raimund Schnurer

Dr. Ian Lochhead

Dr. Remika Gupana

External advisees / mentees

Dr. Leticia Moguel

Dr. Martin Lacayo

Dr. Marianne Santaholma

Dr. Elif Gürçınar

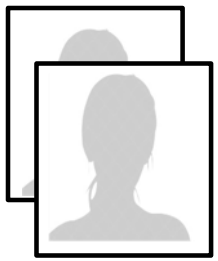
Cèdric Merz

Luca Fluri

Joelle Keller

Andreas Leu

Cloe Huesser



Core team

"Somebody must be watching us."

Thank you

Contact: arzu.coltekin@fhnw.ch