A Framework and Practical Guidelines for Sharing Open Benchmark Datasets in Cartographic User Research Utilizing Neuroscientific Methods

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International Cartographic Association
Association Cartographique Internationale

MapAI workshop, ICC '23

Using Eye Tracking and AI to Personalize Map Reading: The importance of open benchmark datasets

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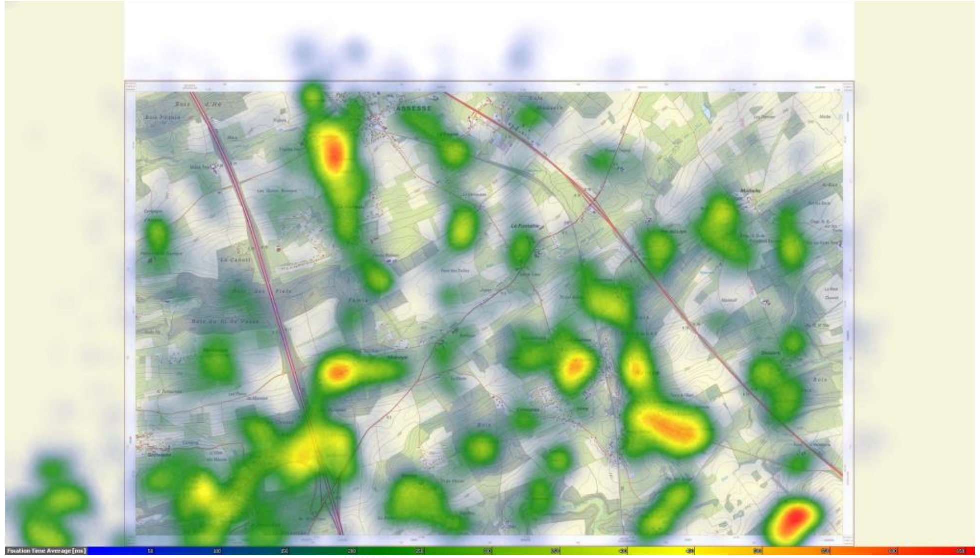
Keywords: eye tracking, geoAI, benchmark datasets, open eye tracking datasets

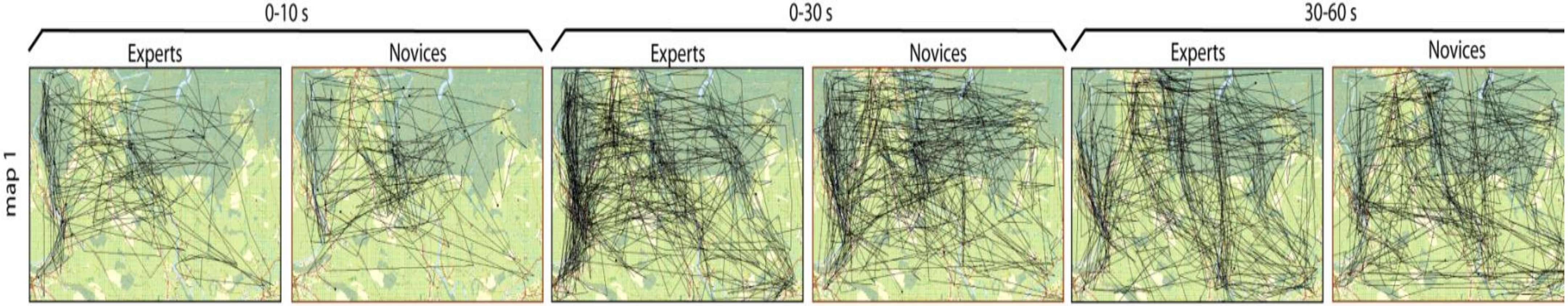
EYE TRACKING

a non-invasive method of measuring the gaze location, where one is looking

x,y,t → fixations, saccades, blinks & pupil metrics

good for visual attention, perception, learning, HCI interaction





Ooms, 2012

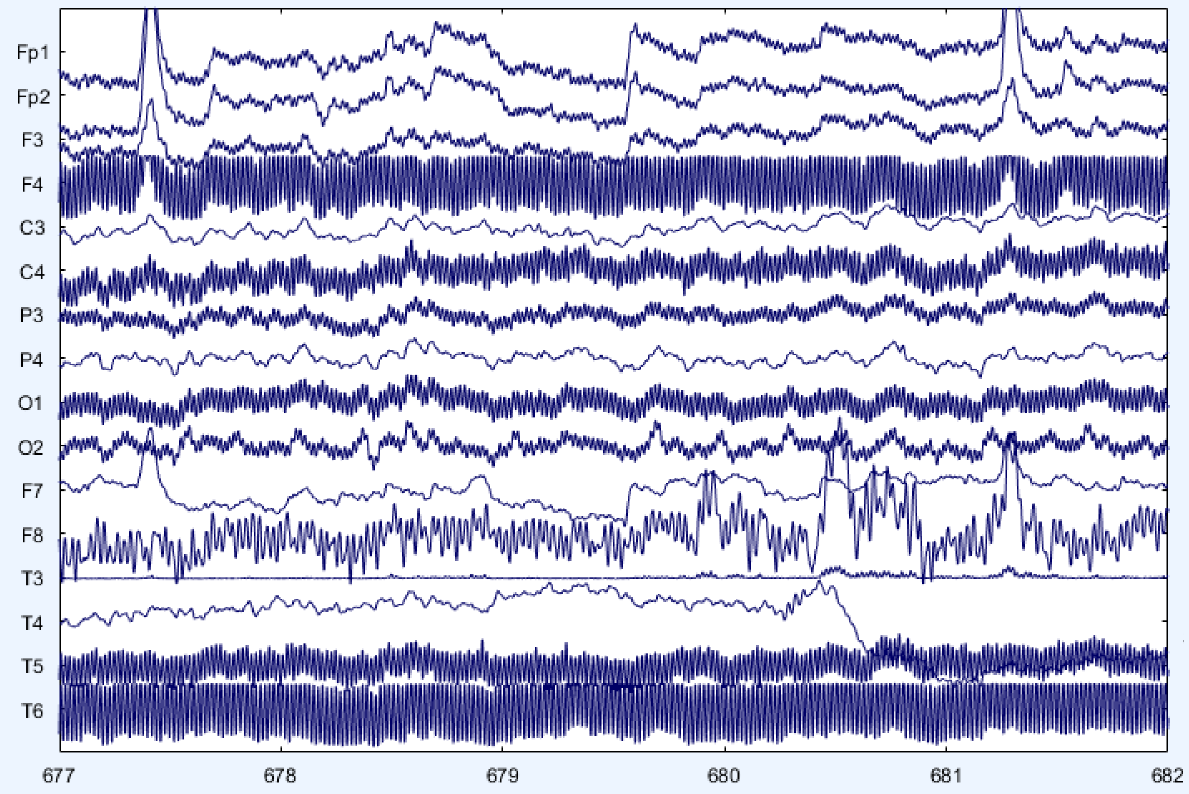
EEG

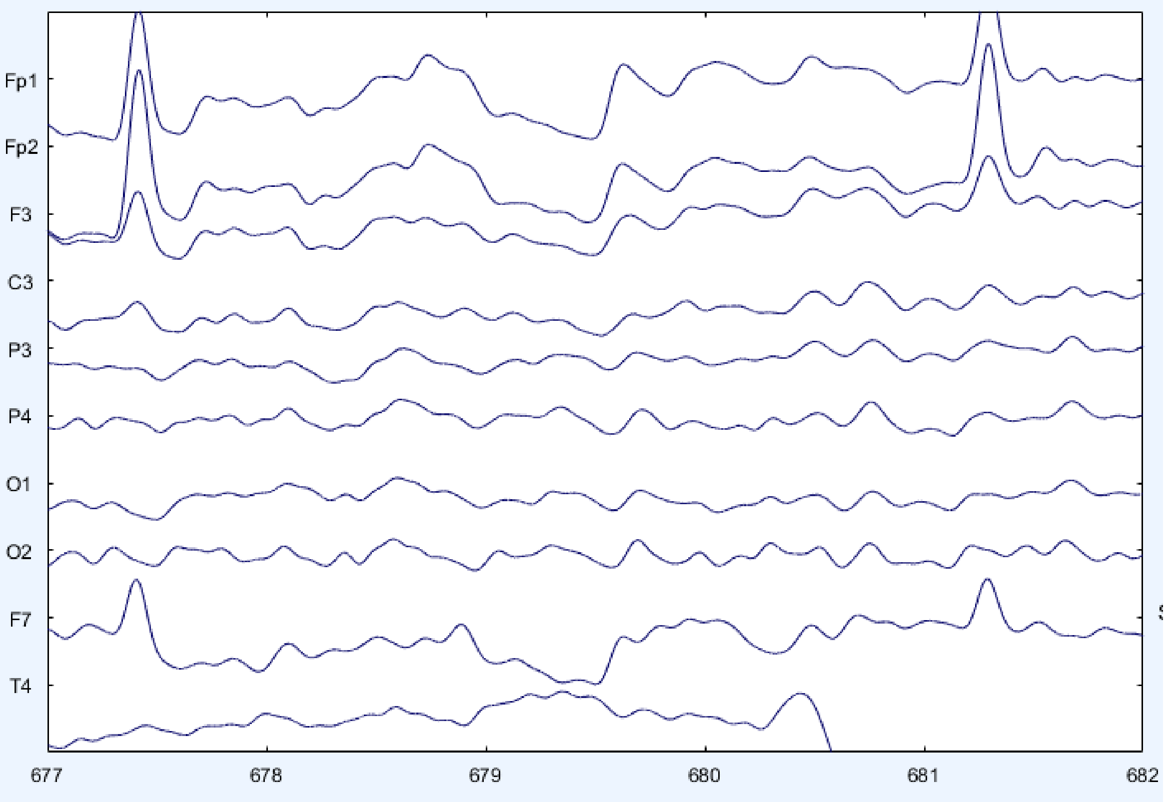
electroencephalogram

a non-invasive method of recording electrical activity of the brain

measures the voltage fluctuations occurring between different regions of the scalp

a valuable tool to extract cognitive load





Keskin, 2020

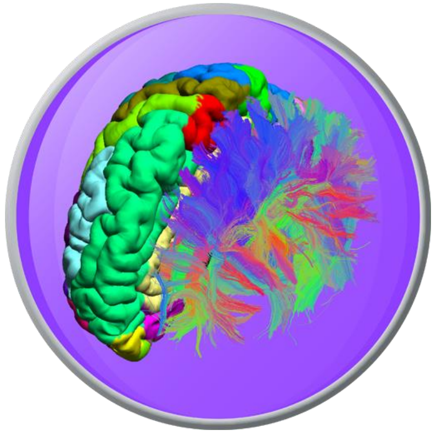
fMRI

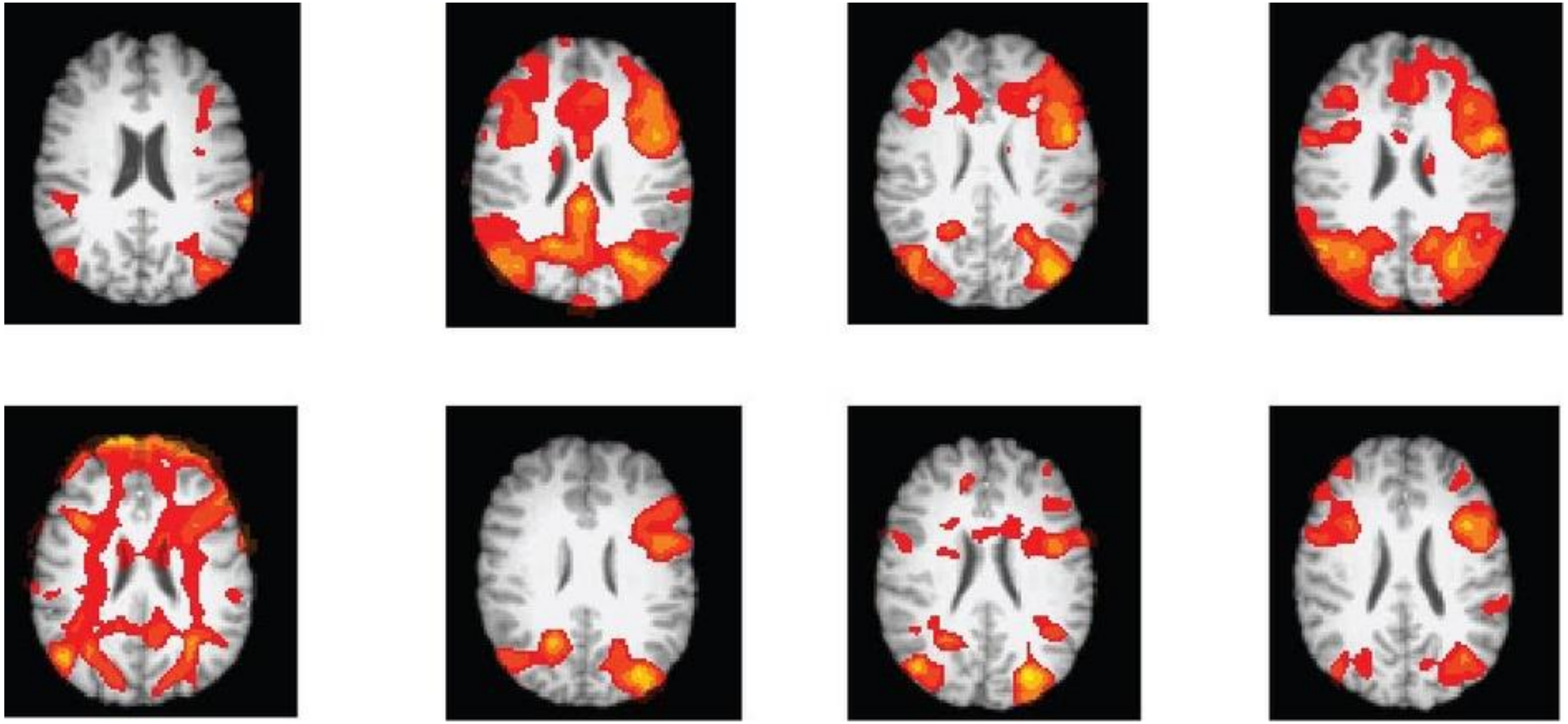
functional magnetic resonance imaging

measures brain activity by detecting changes in blood flow.

measures magnetic differences between oxygen-rich hemoglobin and deeoxygenated hemoglobin: active brain region = more blood flow

a valuable tool to extract sensory response





Lobben et al., 2005

Relevant case study examples

Computers, Environment and Urban Systems
Volume 99, January 2023, 101919

Perceptions of space and time of public transport travel associated with human brain activities: A case study of bus travel in Beijing

Tong Qin [a b], Weihua Dong [a], Haosheng Huang [b]

travel recall

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Using fMRI to Explore the Influence of Road Network Patterns on Geospatial Cognition

Bing Liu [a, b], Weihua Dong [b, *], Lin Zhu [b], Huiping Liu [b], Liqiu Meng [a]

orientation
shortest-route-selection

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Visual attention and neuro-cognitive processes in map use

Tong Qin [a, *], Haosheng Huang [a, *]

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global search
distance comparison
route following
route planning

Differences in the Gaze Behaviours of Pedestrians Navigating between Regular and Irregular Road Patterns

by Bing Liu [1,2], Weihua Dong [1,*], Zhicheng Zhan [1], Shengkai Wang [1] and Liqiu Meng [2]

road pattern
orientation
shortest route selection

Exploring the Cognitive Load of Expert and Novice Map Users Using EEG and Eye Tracking

by Merve Keskin [1,2,*], Kristien Ooms [1], Ahmet Ozgur Dogru [2] and Philippe De Maeyer [1]

memorability - recognition landmarks

With the increasing amount of neuroscientific/physiological data collected, there is a growing need for further analytical and methodological research in map reading.

Future efforts should focus on developing models

to automatize the analyses of existing and large volumes of user data,

to predict user behavior and personalize maps (*in terms of design, content, context*)

anticipating users' intention

providing the most suitable map design

adapting to the context of use

GeoAI

To develop predictive models,
we need data generated during the observation of maps.

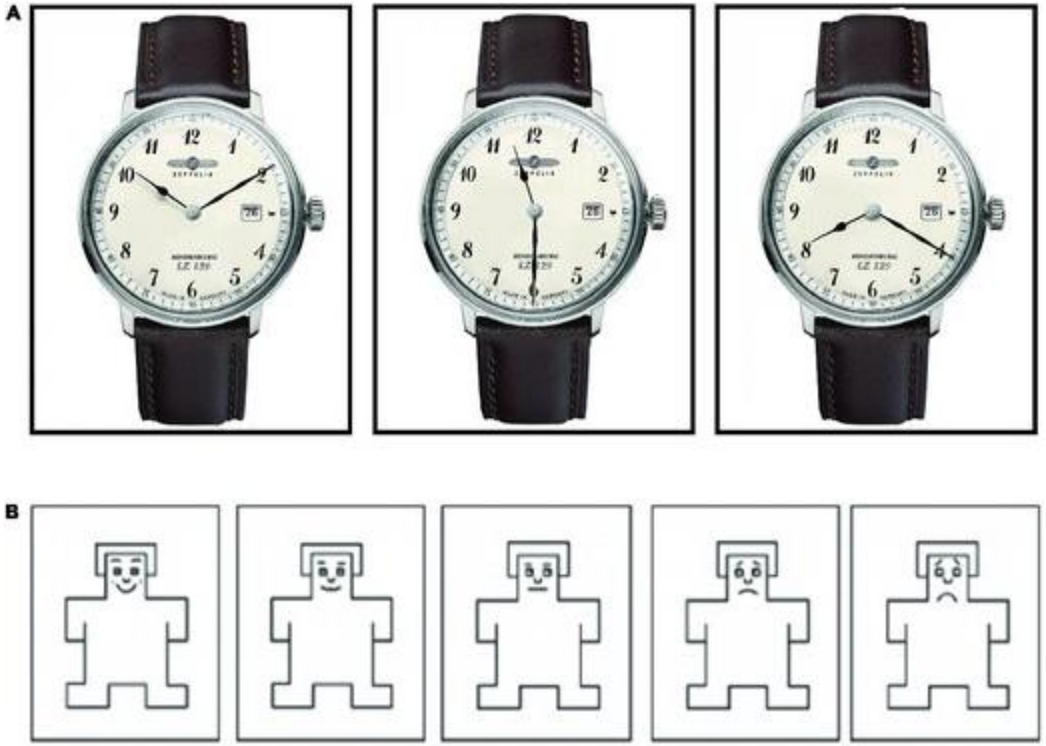
A comprehensive structure for
benchmark datasets
&
guidelines for open-data sharing

in neuroscientific/physiological user research*
for geospatial data and maps

*focusing on eye tracking, EEG, and fMRI

Why?

Geospatial data and maps present unique complexities that differentiate them from traditional stimuli subjected to experimental psychology. Therefore, it becomes imperative adapt existing practices to suit the specific requirements of geospatial tasks.



Karim et al., 2017

He et al., 2023, GeoEye dataset

Research Gap 1.1: There are not many open (eye-tracking) datasets available **for map-reading tasks.**

Traditional saliency models are designed to predict visual attention during the observation of natural images, free viewing and cannot perform as well when it comes to maps.

MIT/Tuebingen Saliency Benchmark

Dataset	Citation	Images	Observers	Tasks	Durations	Extra Notes
MIT300	Tilke Judd, Fredo Durand, Antonio Torralba. A Benchmark of Computational Models of Saliency to Predict Human Fixations [MIT tech report 2012]	**300** natural indoor and outdoor scenes *size:* max dim: 1024px, other dim: 457-1024px 1 dva* ~ 35px	**39** *ages:* 18-50	free viewing	3 sec	This was the first data set with held-out human eye movements, and is used as benchmark test set in the MIT/Tübingen Saliency Benchmark. *eyetracker:* ETL 400 ISCAN (240Hz) Download 300 test images.
CAT2000	Ali Borji, Laurent Itti. CAT2000: A Large Scale Fixation Dataset for Boosting Saliency Research [CVPR 2015 workshop on "Future of Datasets"]	**4000** images from 20 different categories *size:* 1920x1080px 1 dva* ~ 38px	**24** per image (120 in total) *ages:* 18-27	free viewing	5 sec	This dataset contains two sets of images: train and test. Train images (100 from each category) and fixations of 18 observers are shared but 6 observers are held-out. Test images are available but fixations of all 24 observers are held out. *eyetracker:* EyeLink1000 (1000Hz) Download 2000 test images. Download 2000 train images (with fixations of 18 observers).

Research Gap 1.2: There are not many open (physiological) datasets available for **map-reading tasks.**

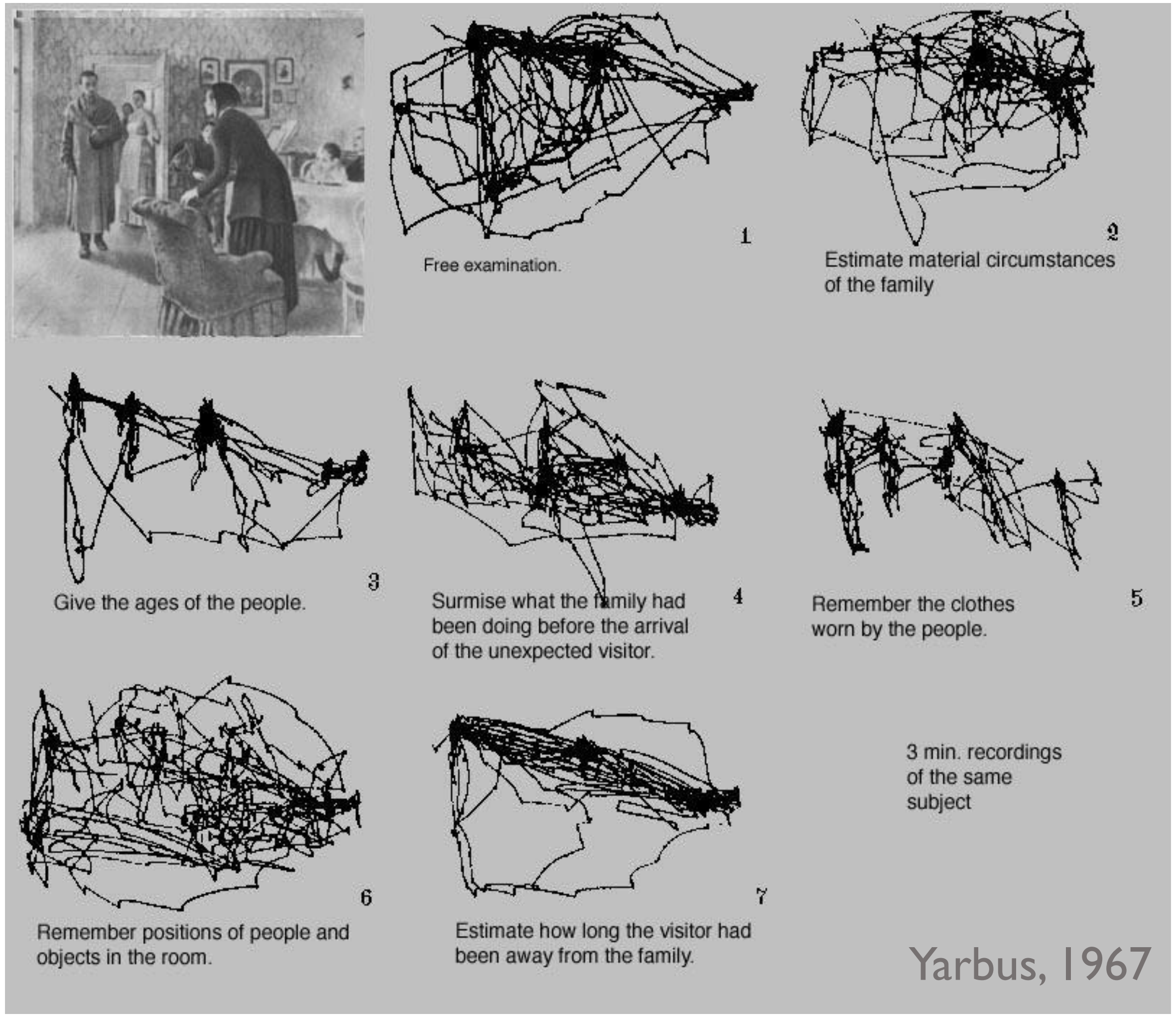
EEG datasets (github): *https://github.com/meagmohit/EEG-Datasets*
visual perception, memory, and motor control (Agarwal, 2023)

Donders Data Repository: *https://github.com/Donders-Institute/meg-hackathon*
Brain imaging (fMRI, MEG, EEG) datasets:
language, attention, and emotion
FAIR (Findable, Accessible, Interoperable, and Reusable) principles

The SJTU Emotion EEG Dataset (SEED): *https://bcmi.sjtu.edu.cn/home/seed/*
BCMI laboratory datasets for emotion recognition

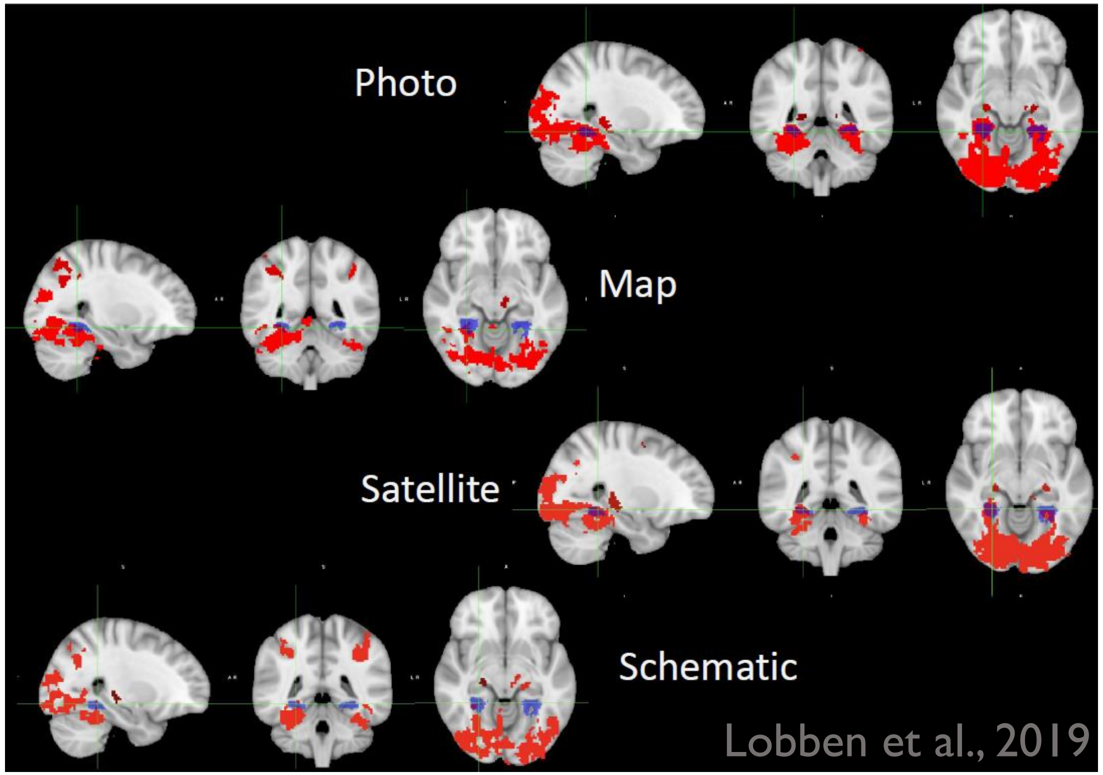
Radboud Coregistration Corpus of Narrative Sentences (RaCCooNS): *https://repository.ubn.ru.nl/handle/2066/296635*
eye-tracking-with-EEG data during reading:
human sentence comprehension and for evaluating the cognitive validity of computational language models

Research Gap 2: Benchmarks should be aimed at **specific scientific issues** rather than just data standards.



Not free viewing, task-specific

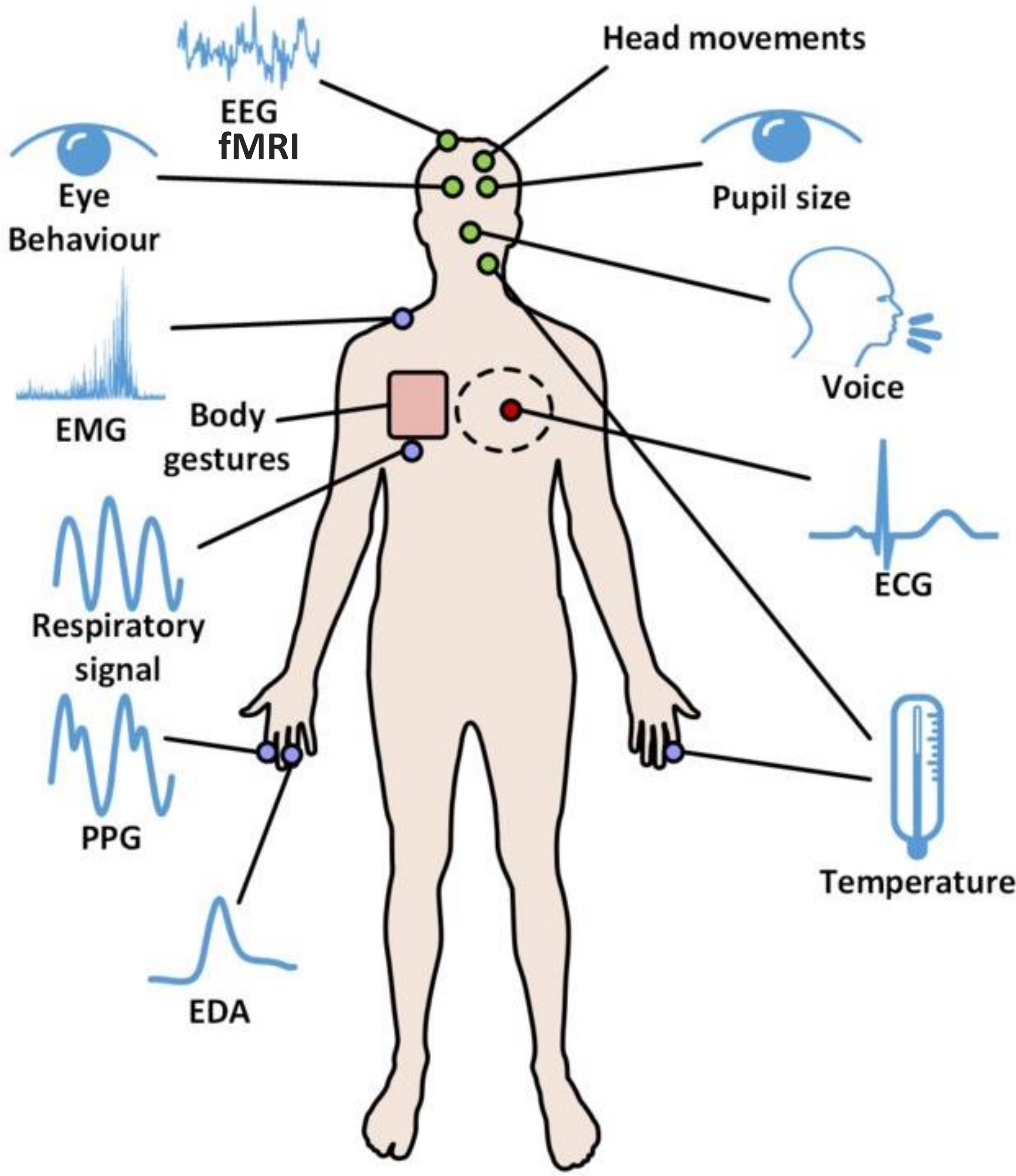
We know that eye movements and brain activities show different patterns for different tasks



Research Gap 3: There exists no standards for reporting **multi-modal physiological user data**

The multi-modal information fusion and analyses methods are well-developed.

Reporting results and sharing datasets and methods?



Existing standardization work

for reporting eye tracking

Table 1 Checklist of information to include when reporting an eye tracking study

Category	Item no.	Checklist item	Reported on page no.
Items to be reported by all eye tracking studies	A1	Manufacturer and model	
	A2	Software and firmware versions	
	A3	Eye tracking technology	
	A4	Sampling frequency	
	A5	Head movement restrictions	
	A6	Eye(s) recorded	
	A7	Parameters recorded	
	A8	Environment lighting	
	A9	Calibration	
	A10	Measurement uncertainty	
	A11	Data processing steps	
	A12	Data loss	
Additional item to be reported by studies of eye movement dynamics	B1	Signal latencies	
Additional item to be reported by studies reporting screen-based gaze coordinates	C1	Participant to display monitor distance	

Behavior Research Methods
https://doi.org/10.3758/s13428-023-02187-1

Check for updates

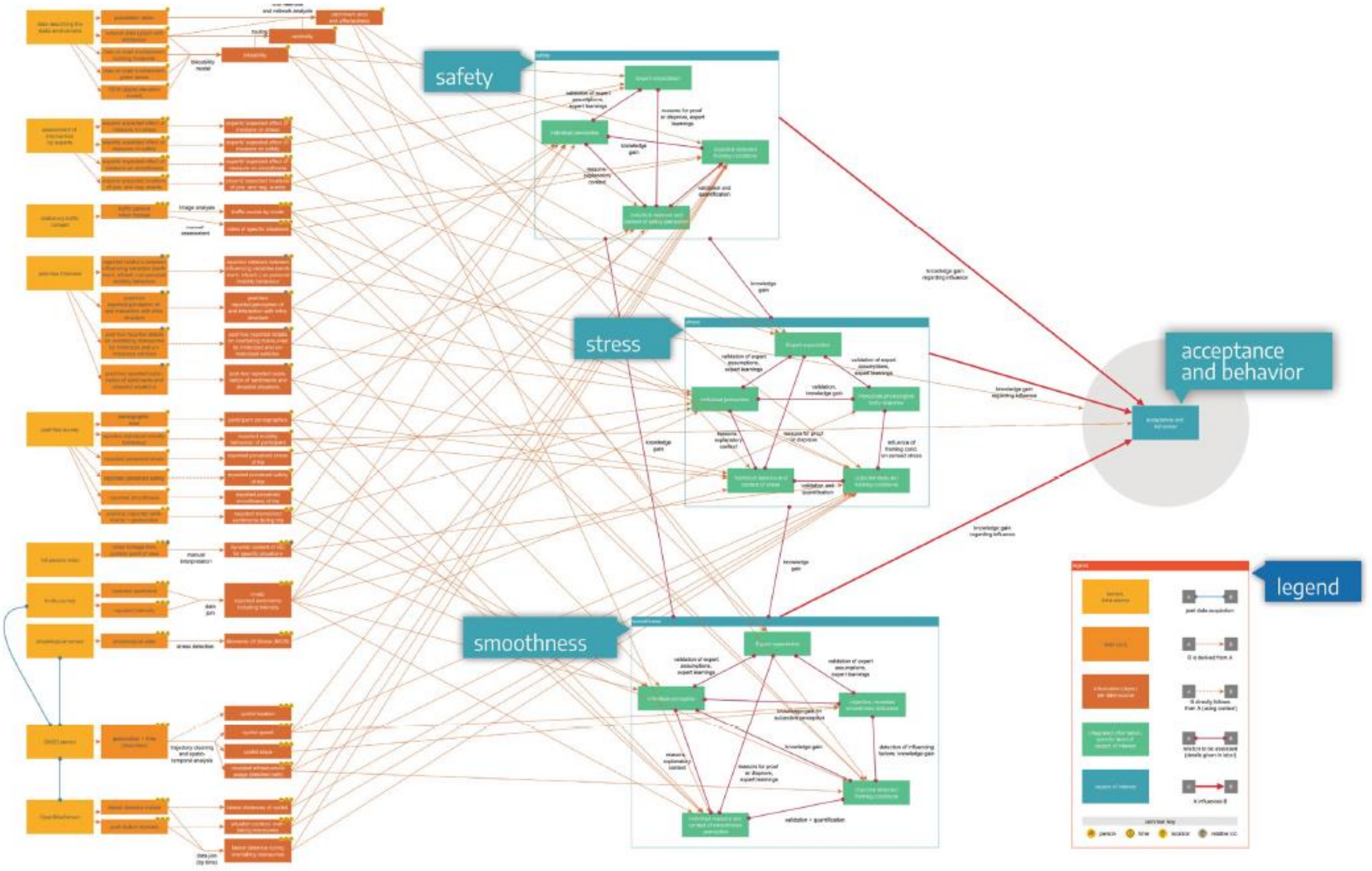
Minimal reporting guideline for research involving eye tracking (2023 edition)

Matt J. Dunn[1] · Robert G. Alexander[2] · Onyekachukwu M. Amiebenomo[1] · Gemma Arblaster[3,4] · Denize Atan[5] · Jonathan T. Erichsen[1] · Ulrich Ettinger[6] · Mario E. Giardini[7] · Iain D. Gilchrist[8] · Ruth Hamilton[9,10] · Roy S. Hessels[11] · Scott Hodgins[12] · Ignace T. C. Hooge[11] · Brooke S. Jackson[13] · Helena Lee[14] · Stephen L. Macknik[2] · Susana Martinez-Conde[2] · Lee Mcilreavy[1] · Lisa M. Muratori[15] · Diederick C. Niehorster[16,17] · Marcus Nyström[16] · Jorge Otero-Millan[18,19] · Michael M. Schlüssel[20] · Jay E. Self[14] · Tarkeshwar Singh[21] · Nikolaos Smyrnis[22] · Andreas Sprenger[23]

Accepted: 28 June 2023

A framework to facilitate advanced mixed methods studies for investigating interventions in road space for cycling *(Werner et al., 2022)*

The Knowledge Graph *available on Zotero: GraphML editor to adapt and extend the graph for specific use cases*



WHAT WE HAVE DONE

guidelines for open-data sharing

CONTROLLED CONDITIONS

WELL-DEFINED TASKS & RESEARCH QUESTIONS

WELL-DEFINED DATA

WELL-DEFINED METRICS

WELL-DEFINED PARTICIPANT CHARACTERISTICS

WELL-DEFINED STIMULUS PROPERTIES

ETHICS

CONTROLLED CONDITIONS

- Medium/display
- Performance for data collection and system specification
- Input modality
- Recording devices
- Extraneous variables

WELL-DEFINED TASKS & RESEARCH QUESTIONS

- Purpose with keywords defining the study
- Full procedural details (e.g., standard flowchart)
- Free viewing *vs.* task-specific
- In labs or in real-world environments
- Visuospatial or perceptual tasks
- Trial tasks, orientation and instructions
- Task design (e.g., randomized block design, event-related design)
- Task duration and total recording length

WELL-DEFINED DATA

Artifact-free or raw data

Data quality

Sufficiently large data samples to ensure the generalizability of the results

Data format and compatibility

Detailed documentation
data collection, pre-processing and analysis protocols, and open codes for such analysis

Relevant scientific research and/or other relevant references

Data specific descriptions:

- *Eye tracking*: dominant eye, resolution, fixation recognition algorithm/parameters
- *EEG*: resolution, the number, type, and spatial distribution of electrodes
- *fMRI*: the number of channel head coils, repetition and echo time (for functional/structural images), layer scan

WELL-DEFINED METRICS

Behavioral metrics: response time, response accuracy

Eye tracking:
fixation- or saccade-related, AOI- (area of interest) specific metrics, scanpaths, heatmaps

EEG:
time-domain: *Event-Related Potentials (ERP)*
frequency-domain: *Power Spectral Density (PSD)*
time frequency-domain: *Event-Related Synchronization&Desynchronization (ERS/ERD)*

fMRI:
Blood Oxygen Level Dependent (BOLD) Signal
Functional Connectivity

WELL-DEFINED PARTICIPANT CHARACTERISTICS

- Sample size: often large for EEG and fMRI
- Individual participant characteristics (age, gender, education)
- Additional tests to classify participants based on spatial abilities
- Color blindness, users with other disabilities
- Self-reports, pre- or post-test questionnaires, and structured verbal interviews

WELL-DEFINED STIMULUS PROPERTIES

- Screen map, animation, web-service
- 2D, 3D or XR
- Static, dynamic, interactive
- Size, position, and format of the media
- Visual or task-related manipulation
- Experimental stimuli preparation details

ETHICS

- Asking local ethics committees for permission if needed
- Adhering to ethical standards, *i.e.*, consent from participants
- Anonymization of participants' data

CartoGAZE

an open eye tracking dataset from a map memorability experiment

HARVARD
Dataverse

Harvard Dataverse >

CartoGAZE

Version 1.0

40+ downloads
since Jan 2023

- AOIs
- AOIs_all_results
- Calculate_AOI_areas
- Final_Fixations
- Map_stimuli
- Raw_ET_data
- Data_description.pdf

Open Access | Article

isprs International Journal of Geo-Information

Visual Attention and Recognition Differences Based on Expertise in a Map Reading and Memorability Study

by Merve Keskin [1,*], Vassilios Krassanakis [2] and Arzu Çöltekin [3]

[1] Finnish Geospatial Research Institute, National Land Survey of Finland (FGI/NLS), Vuorimiehentie 5, 02150 Espoo, Finland

[2] Department of Surveying and Geoinformatics Engineering, Egaleo Park Campus, University of West Attica, Ag. Spyridonos Str., 12243 Egaleo, Greece

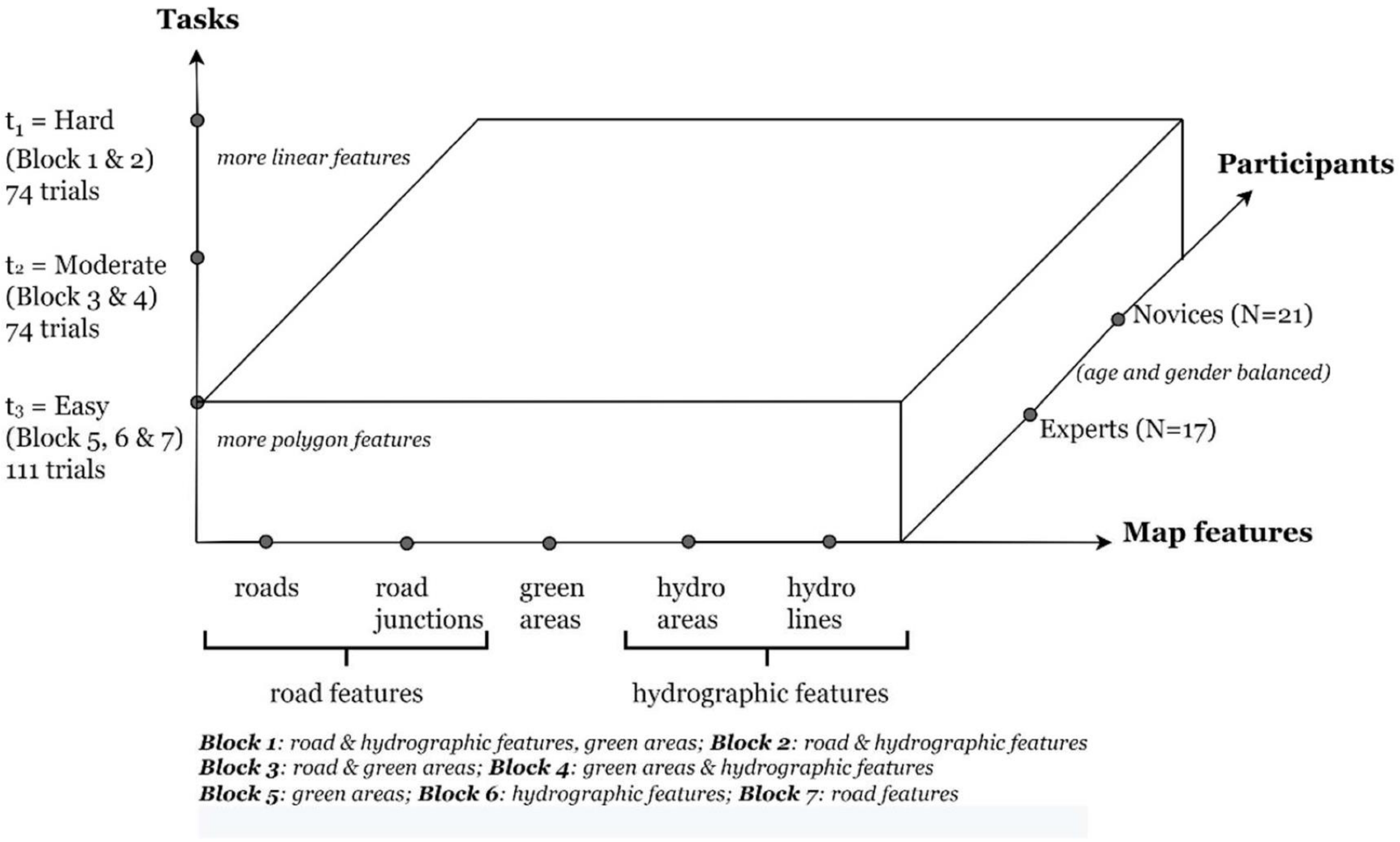
[3] Institute of Interactive Technologies, School of Engineering, University of Applied Sciences and Arts Northwestern Switzerland, Bahnhofstrasse 6, 5210 Windisch, Switzerland

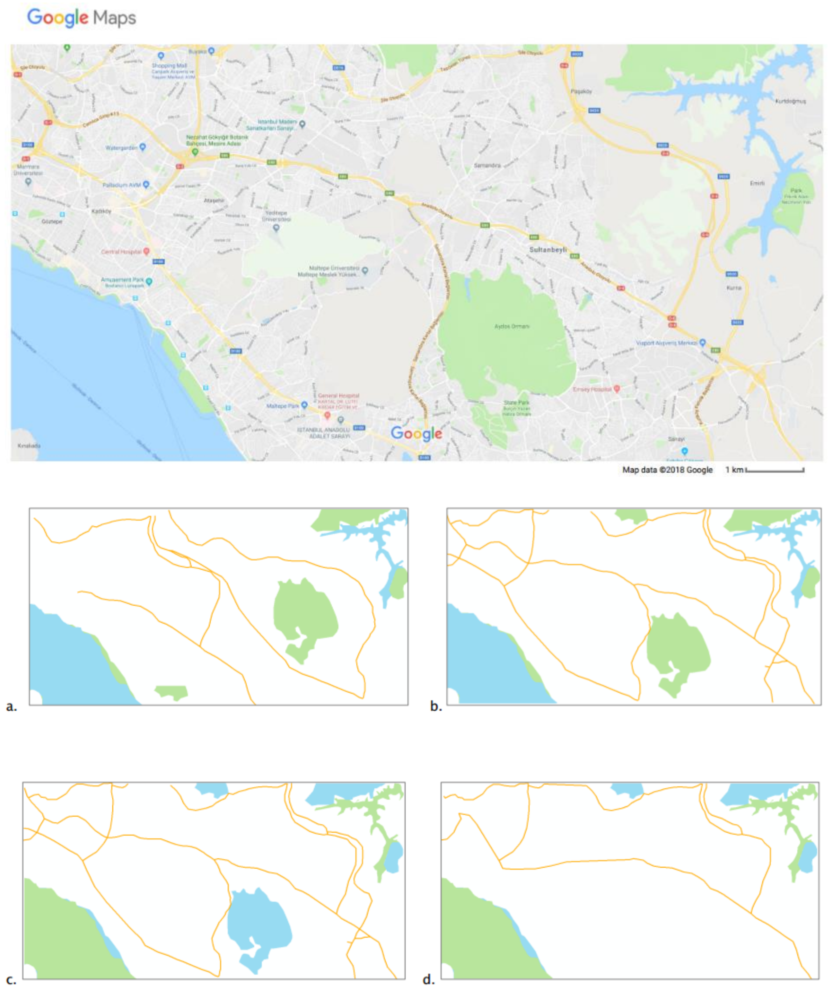
[*] Author to whom correspondence should be addressed.

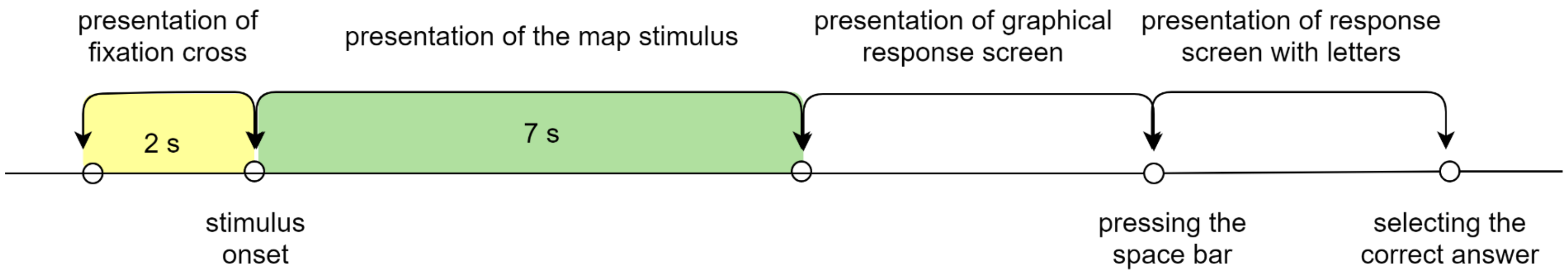
ISPRS Int. J. Geo-Inf. **2023**, *12*(1), 21; https://doi.org/10.3390/ijgi12010021

Received: 30 October 2022 / Revised: 26 December 2022 / Accepted: 6 January 2023 / Published: 12 January 2023

Automated AOI-based fixation analysis of large eye tracking data







HARVARD
Dataverse
Harvard Dataverse >

CartoGAZE

Version 1.0

REPURPOSING CartoGAZE

SFB-TRR 161
Quantitative Methods for Visual Computing

The transregional Collaborative Research Center 161 (SFB-TRR 161) is an interdisciplinary research center of the University of Stuttgart, University of Konstanz, Ulm University, and the LMU Munich.

the **Dimensionality Reduction** Special Interest Group (DR SIG) Hackathon (in 2024):

DR for Eye-tracking (DR4ET)

User Performance and Reading Strategies for Map Users: An Evaluation of Eye Tracking Study

Merve Keskin[1,†] **and Kun-Ting Chen**[2,†]

[1]Department of Geoinformatics - Z-GIS, University of Salzburg (PLUS), Salzburg, Austria.
[2]Centre for Research on Engineering Software Technologies (CREST), University of Adelaide

From Hackathon, we expect

- automatic or semi-automatic user grouping based on AOI-gaze features
- guiding statistics framework for analyzing gaze data and visualizing outcomes (e.g., *statistical grayscale heatmaps*)
- automatic classification of participants and recommending suitable visualization of map designs.

Relation to Dimension Reduction: find the most critical spatiotemporal eye tracking data characteristics and visual variables of the map features, relating to task difficulty, expertise group, and spatial memory strategies of human operators

What can our geo-community do?

Creating a platform disseminating open datasets and repositories

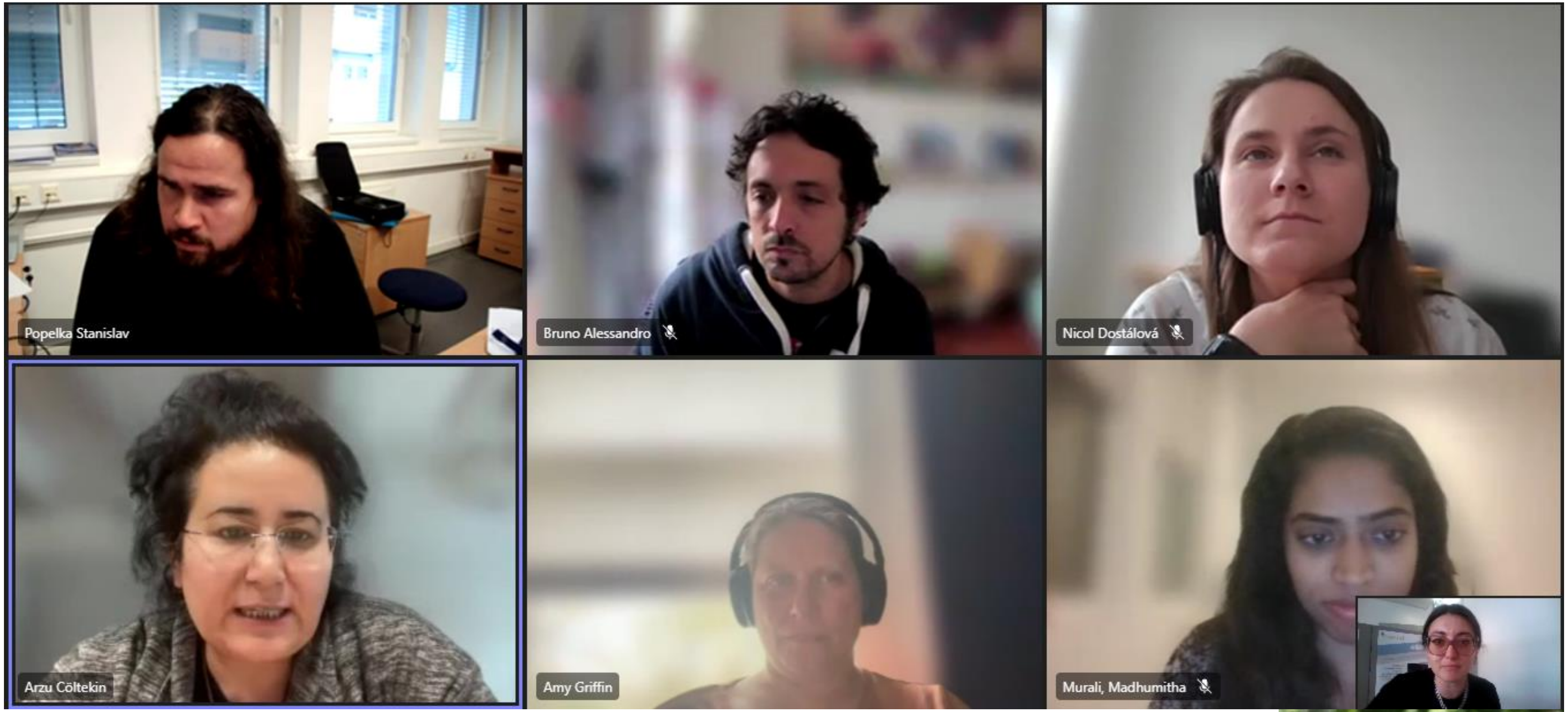
– similar to MIT/Tuebingen Saliency Benchmark but with a "geo" focus and compatible with FAIR data sharing standards

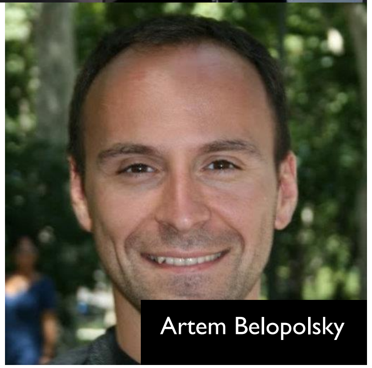
Encouraging ourselves and everyone else to share experimental data within and outside our communities (*datavis, infovis, UX/UI, ET, AI, etc.*)

– benefits: interdisciplinary collaborations, *esp.* with researchers with similar problems

WEBCAM-BASED EYE TRACKING: current capabilities and future opportunities

reviving *Remote Eye Tracking Benchmarking* exercise – initiated by Amy Griffin, 2021





Eye tracking experts from
Geoscience, Computer Science, Psychology, Optometry

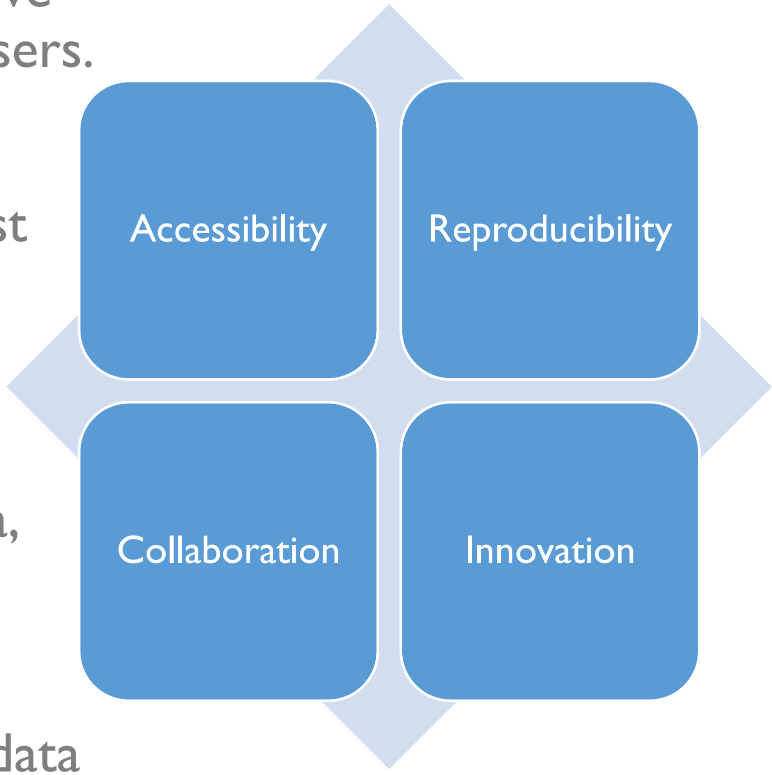
Wrap up

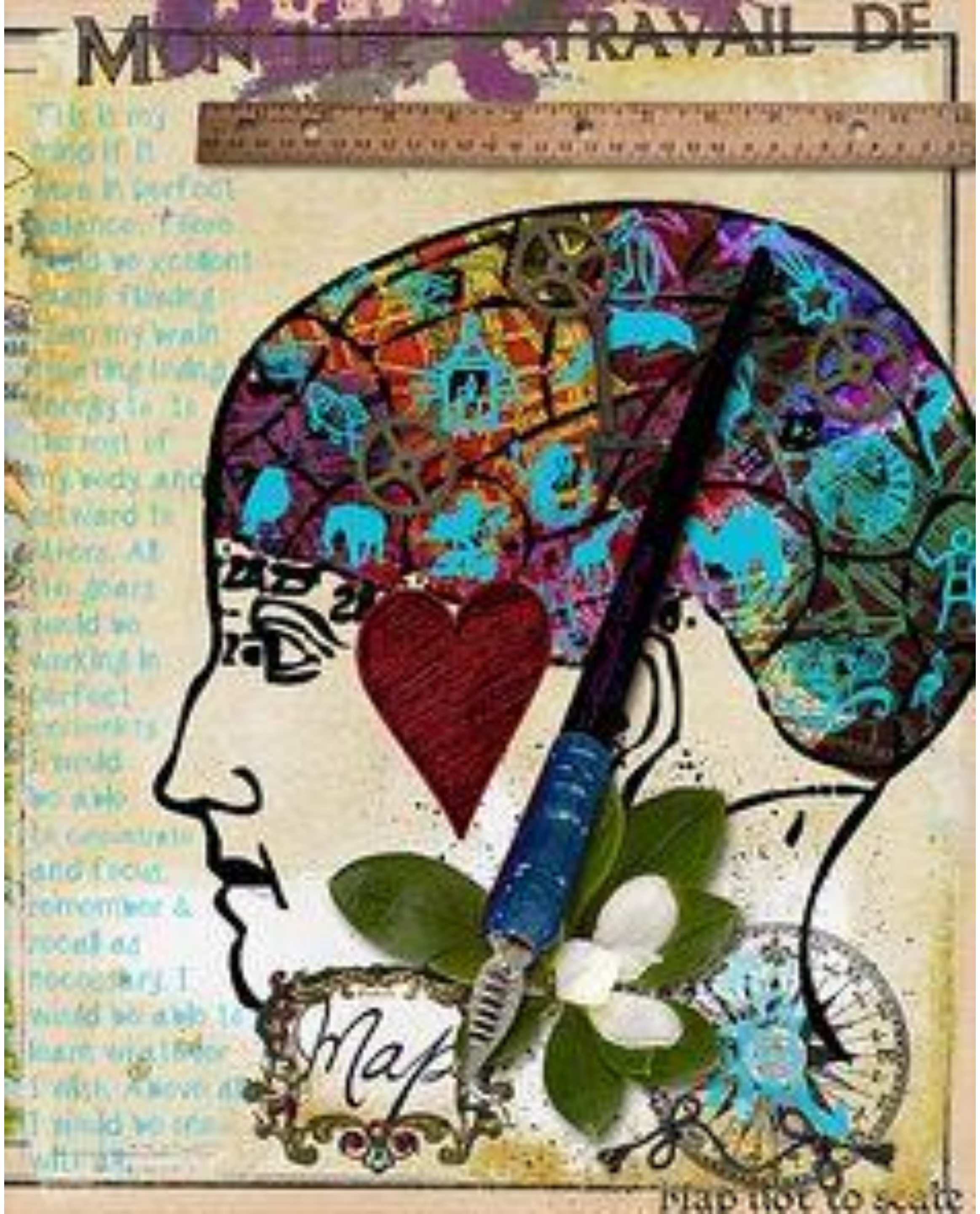
Datasets capable of addressing specific spatial problems hold the potential to become benchmarks in developing complexity algorithms & predictive models that consider the visual attention and map use capabilities of users.

Benchmarks should be aimed at specific scientific issues rather than just data standards.

Researchers across domains bear the responsibility of actively seeking concrete methods to encourage the open sharing of experimental data, complemented by high-quality metadata.

By fostering the creation of benchmark datasets and promoting open-data sharing, collaboration is enhanced, geospatial research advances, and the scientific community is empowered to effectively address cartographic challenges.





Your ideas?

«IT'S OK TO BE
A CARTOGRAPHER»

Georg Gartner, *resident of*
International Cartographic Association (ICA)

drmervekeskin.com