

Eye-tracking:

Nástroj pro nahlédnutí do hlavy čtenáře mapy

Doc. RNDr. Stanislav Popelka, Ph.D.

Olomouc, 27. 2. 2026



O mě

- **Doc. RNDr. Stanislav Popelka, Ph.D.**
 - Eye-trackingu se věnuji od roku 2011
 - Vedoucí eye-tracking laboratoře KGI UP
 - Hodnocení a optimalizace map...

...ale i spolupráce s dalšími obory

- Fyzika
- Psychologie
- Filmová věda
- Religionistika
- Didaktika
- Lingvistika
- ...



Kognitivní kartografie

- Úkolem kognitivní kartografie je poznání, jakým způsobem uživatelé jednotlivé prvky mapy čtou a jak se liší význam přiřazený těmto prvkům mezi jednotlivými uživateli.
- Kognice zahrnuje:
 - vnímání, učení, paměť, myšlení, uvažování, řešení problémů, komunikaci
- Dnes jsou tématu jsou v rámci **Mezinárodní kartografické asociace (ICA)** vyčleněny dvě komise:
 - Commission on Cognitive Issues in Geographic Information Visualization
 - Commission on User Experience



Význam kognitivní kartografie

- Virrantaus, Fairbairn, & Kraak (2009)
- **Research agenda pro celou ICA – cílem je dát doporučení pro komise a umožnit lepší spolupráce mezi komisemi a pracovními skupinami**
- **Vybráno 10 prioritních oblastí**
 - Geographic information
 - Metadata and SDIs
 - Geospatial analysis and modelling
 - **Usability**
 - Geovisualization, visual analytics
 - Map production
 - Cartographic theory
 - History of cartography and GI science
 - Education
 - Society
- **Předsedové všech komisí a pracovních skupin odpovídali, nakolik se těmito tématy ve své agendě zabývají.**

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VIEWPOINT PAPER

ICA Research Agenda on Cartography and GI Science

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The paper presents the ICA research agenda on Cartography and GIScience. The first part discusses the research topics and the second part deals with the implementation of the agenda by the ICA's Committees and Working Groups.

Keywords: Research Agenda

BACKGROUND TO THE ICA RESEARCH AGENDA

Maps and geographic information (GI) have spread across the globe through their ability to connect and integrate data over the inherent geographical location, and present the information content in a user-friendly and understandable form and manner (see, for example, the long-term research project as an internet property of the map articles, as well as contemporary publications). The process of map and geographic data handling has been recently recognized as an essential and useful application and strategic decision-making situation related to current topics like crisis management, early warning systems, efforts for supporting sustainability, and disaster relief projects.

The International Cartographic Association (ICA), as a globally well-represented and transnationally visible organization, has a special position and role as a promoter of the development of cartography and GI science. Research and development in ICA aims to generate and create theory and methods for cartography and GI science. By applying theory and methods in various fields, new tools are created for cartographic and GI practice, both as an addition to the state-of-the-art of ICA, to support the development of the scientific community. These organizations are formally established by one of the established ICA General Assemblies, although interim Working Groups can also be established between General Assemblies for the ICA Executive Committee (EC) to address specific short-term issues.

The idea of the ICA Research Agenda on Cartography and GI Science was initially conceived by the ICA Executive Committee meeting during the 1998th, but the specific decision to work on a research agenda was taken at the London EC meeting in 2001, with a plan to organize a workshop on the topic at the International Cartographic Conference in Beijing in 2003. This workshop resulted in several initial recommendations, including those from the ICA Executive Committee, the ICA Working Group, and the ICA Research Agenda on Cartography and GI Science. The workshop also resulted in the ICA Research Agenda on Cartography and GI Science.

Since 2003, the ICA has been working on the development of the ICA Research Agenda on Cartography and GI Science. The agenda is a strategic document that outlines the ICA's research agenda and provides a framework for the development of the ICA's research agenda. The agenda is a strategic document that outlines the ICA's research agenda and provides a framework for the development of the ICA's research agenda. The agenda is a strategic document that outlines the ICA's research agenda and provides a framework for the development of the ICA's research agenda.

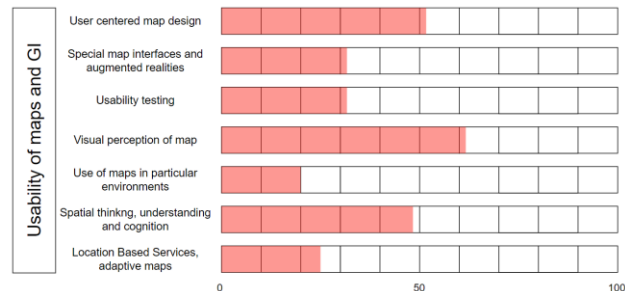
made during the Mexico City EC meeting in 2003. It was realized that several ICA Committees had overlapping research concerns which were one challenging topic were outside of any Committee's field. A further Research Agenda would have a significant role in addressing Committee overlaps, fostering Assembly Debates and ICA members, of the integrated nature of research activity in Cartography and GI Science, the expanding scope of research and the role of ICA in promoting basic research. It should be realized that the content of the agenda represents a snapshot in time. Agenda-like items should continue to be considered on a biennial basis, adapting to new technological and methodological developments over time. This paper consists of two major parts, the content of the research agenda and the current implementation by the ICA's Committees and Working groups.

THE GOAL OF THE RESEARCH AGENDA

The goal of the agenda is primarily to give some guidelines for the Committees' work as well as to be used to support the development of the scientific community. The agenda can also be used to support the development of the scientific community of ICA. From a practical point of view, the agenda may outline the broad contours of the proposed International Handbook for cartography and GI science.

Mainly, the agenda is written in order to show ICA's actual and potential contributions to scientific research within the global society, and to serve as a guideline for discussion in that forum. In order to implement the agenda, research groups, to ensure that geographical information is captured in maximum detail for the benefit of science and society (ICA Strategic Plan, 2003), ICA must have a clear agenda for research covering all fields and regions under the title Cartography and GI Science. The agenda, however, does not control research activity in these fields, suggest areas where more

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Historie kognitivní kartografie

- Výzkum zaměřený na design map a kognitivní aspekty v kartografii odstartovalo vydání knihy „**The Look of Maps**“ (Robinson, 1952).
 - Ranný výzkum v kognitivní kartografii se opíral o převzaté a dále rozvíjené psychologické teorie (např. gestaltické principy)
 - Tyto psychologické principy byly dále implementovány do **Bertinových vizuálních proměnných**, **Dentova vizuálního kontrastu**, **Flanneryho percepčních objemových symbolů** a **Robinsonovy vizuální hierarchie**

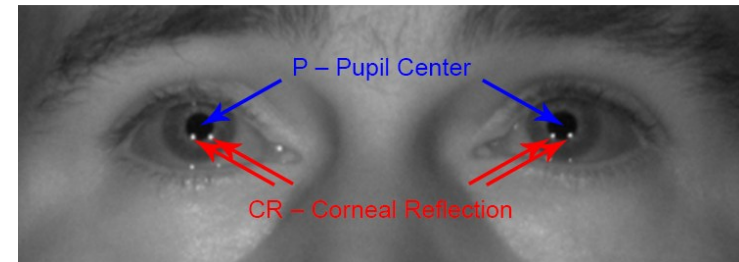
Historie kognitivní kartografie

- Výzkum v kognitivní kartografii dále rozvíjely Robinsonovy doktorandky, Barbara Petchenik a Judy M. Olson
 - Důraz na empirické porozumění kognitivním procesům čtení map
 - Jak lidé – zejména děti – vnímají a mentálně reprezentují geografický prostor (Petchenik, 1977, Robinson & Petchenik, 1975)
 - Hodnocení mapových znaků, používání barev, vizuální hierarchii a design (Olson, 1975, 1976a, 1976b, 1979, 1981)
 - Přínos Judy Olson byl obzvláště významný v nastolení široké agendy „empirického experimentování v kognitivní kartografii“

Historie kognitivní kartografie

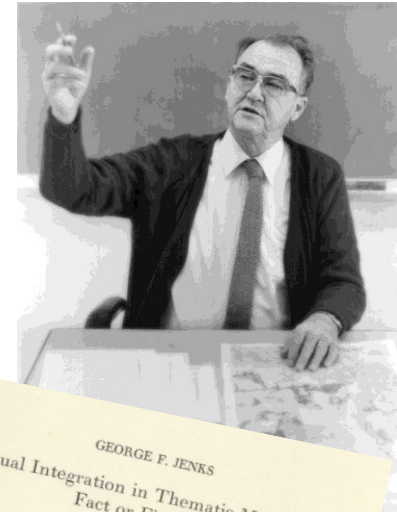
- Vědecká práce Judy Olson a jejích doktorandů, jako byla Cynthia Brewer a později Amy Lobben, sehrály klíčovou roli při formování moderního výzkumu kognitivní kartografie
 - Hlubší porozumění vnímání barev při návrhu kartogramů (Brewer, 1989, 1992, 1996; Harrower & Brewer, 2003; Olson & Brewer, 1997)
 - Nástroj ColorBrewer byl nakonec přijat nejen v kartografii, ale široce napříč oblastmi vizualizace dat v rámci HCI
 - Amy Lobben začala v geografii využívat **funkční magnetickou rezonanci (fMRI)** k testování kartografických a geograficko-informačních paradigmat

Moderní eye-trackery

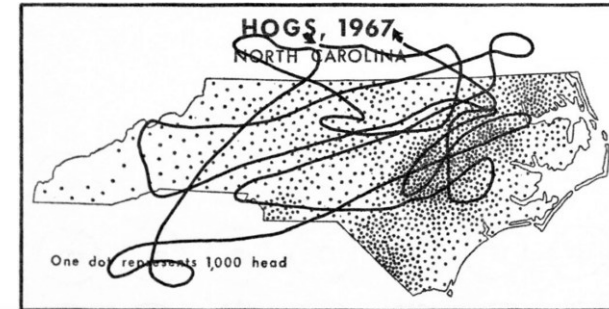
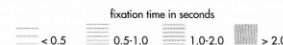
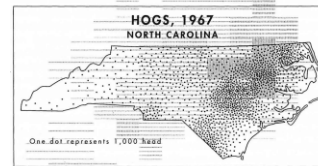


Eye-tracking v kartografii – historie

- Symposium **Influence of the Map User on Map Design** (1970, Ontario, Kanada)
- Jedním z přítomných kartografů byl **George Jenks**, který později prohlásil, že eye-tracking nabízí možnost „**dostat se dovnitř hlavy čtenáře mapy**“
- Využití eye-trackingu v kartografii přirovnal k otevření **Pandořiny skříňky**

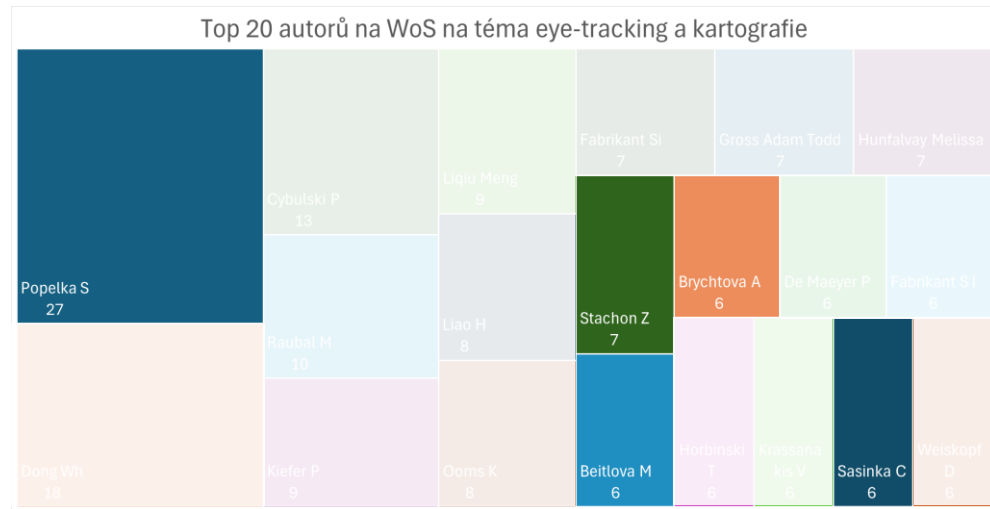
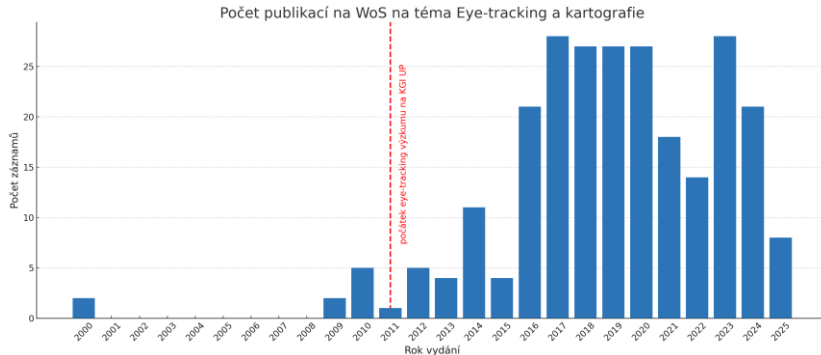


GEORGE F. JENKS
*Visual Integration in Thematic Mapping:
Fact or Fiction?*

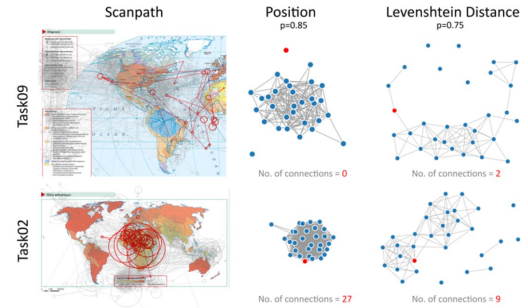
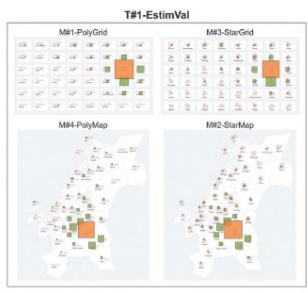
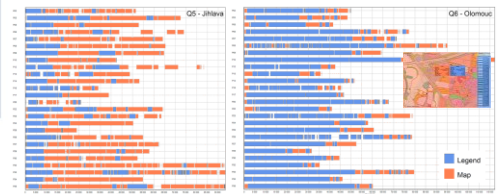
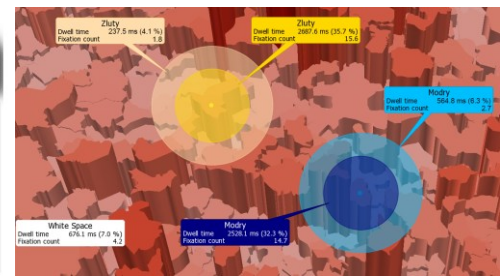
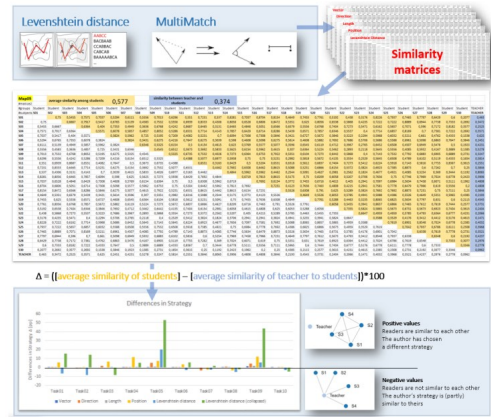
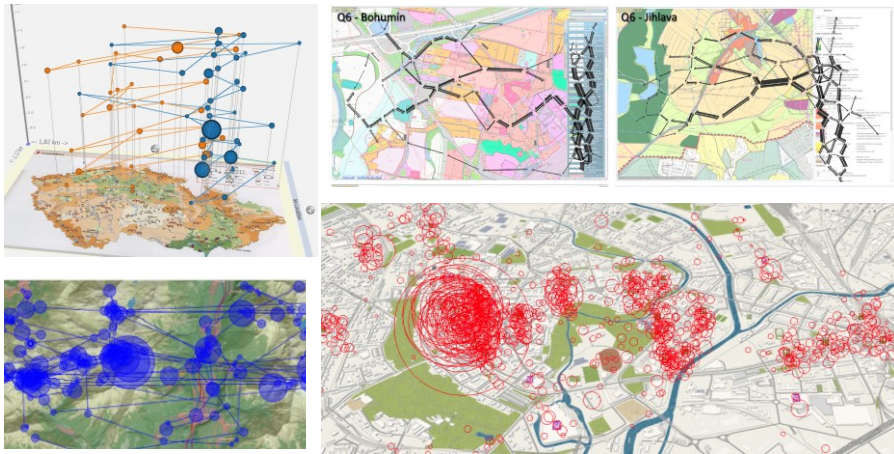


Eye-tracking v kartografii – současnost

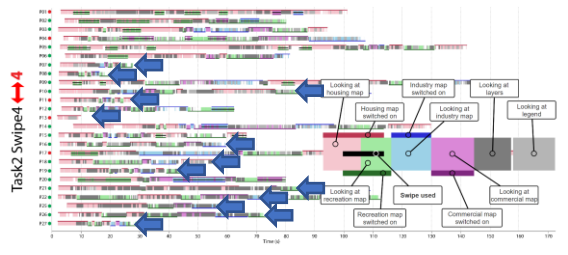
- Eye-tracking výzkum na KGI UP začal ve správný čas (2011)
- Česká stopa je jasně patrná



Využití eye-trackingu v kognitivní kartografii

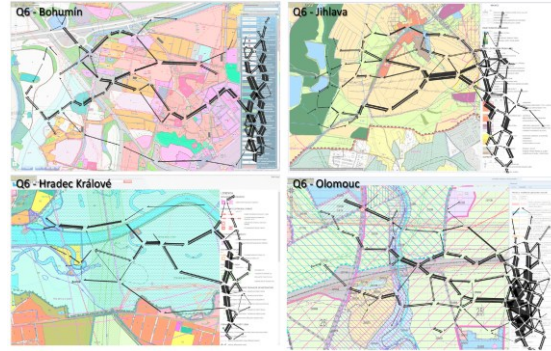
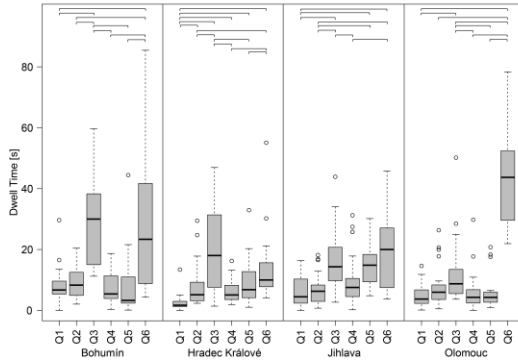


Common strategy
Unique strategy

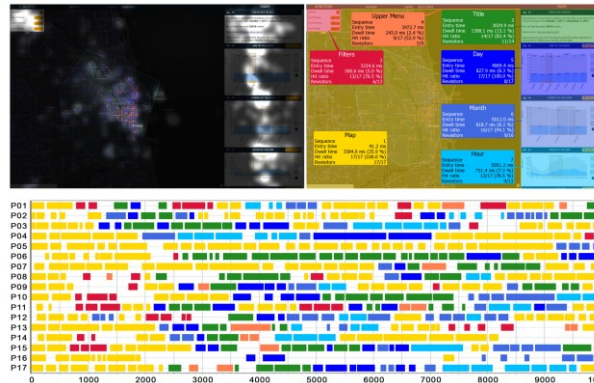
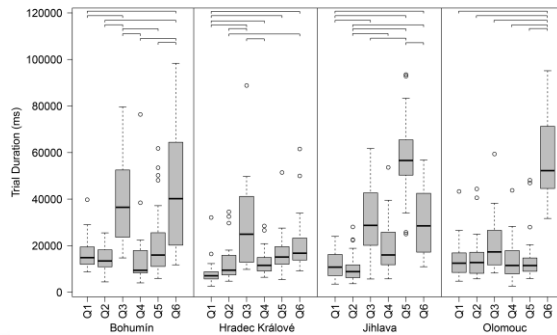


Jak se dostat „Dovnitř hlavy čtenáře mapy“?

Dwell Time for AOI "Legend"

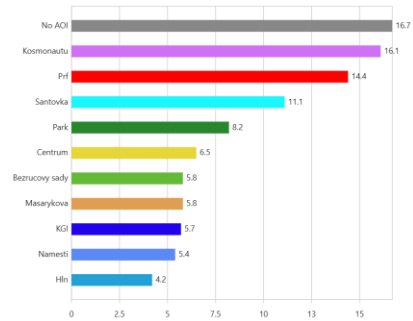


Trial Duration

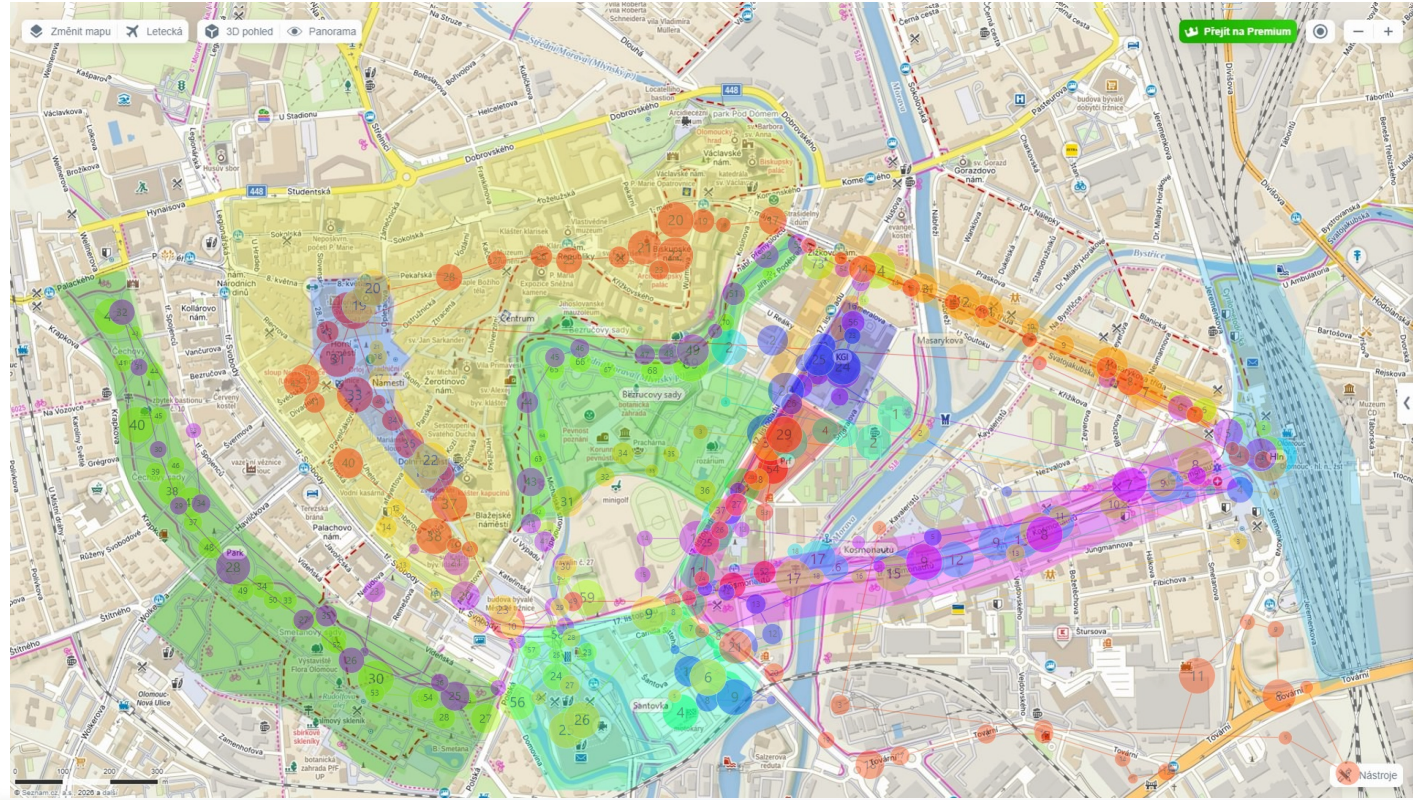
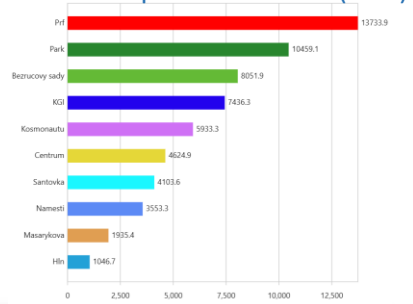


Jak se dostat „Dovnitř hlavy čtenáře mapy“?

Čas v AOI (%)



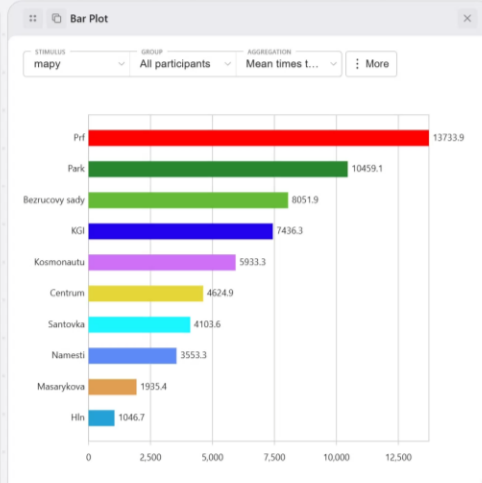
Čas do první fixace(ms)



GazePlotter

GazePlotter Free eye-tracking data visualisation

Transform eye gaze data from eye trackers to interactive scarf plots.
No registration, no ads and no data stored on a server. We love open science.

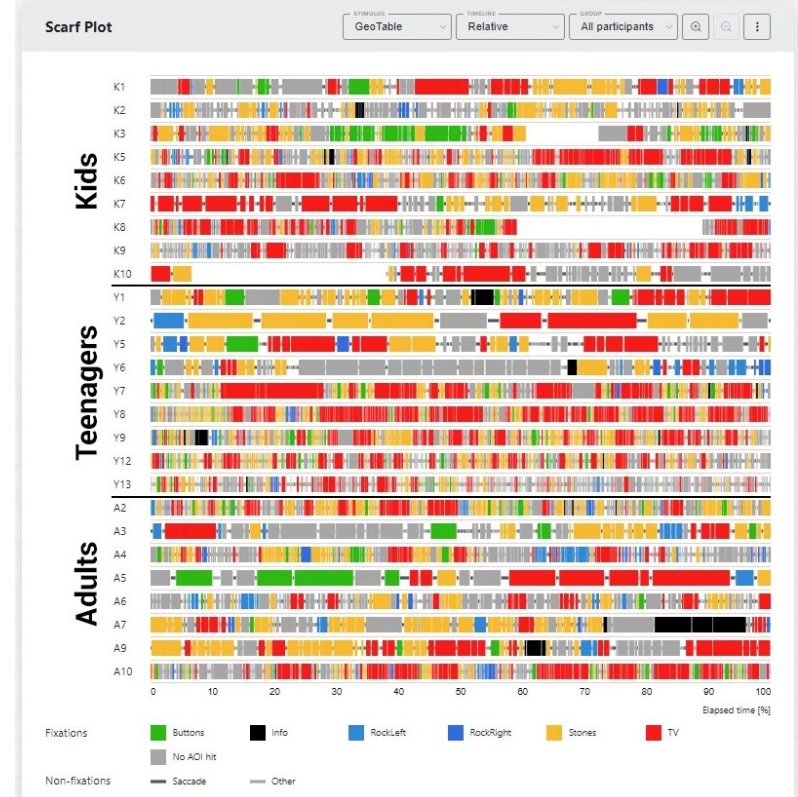
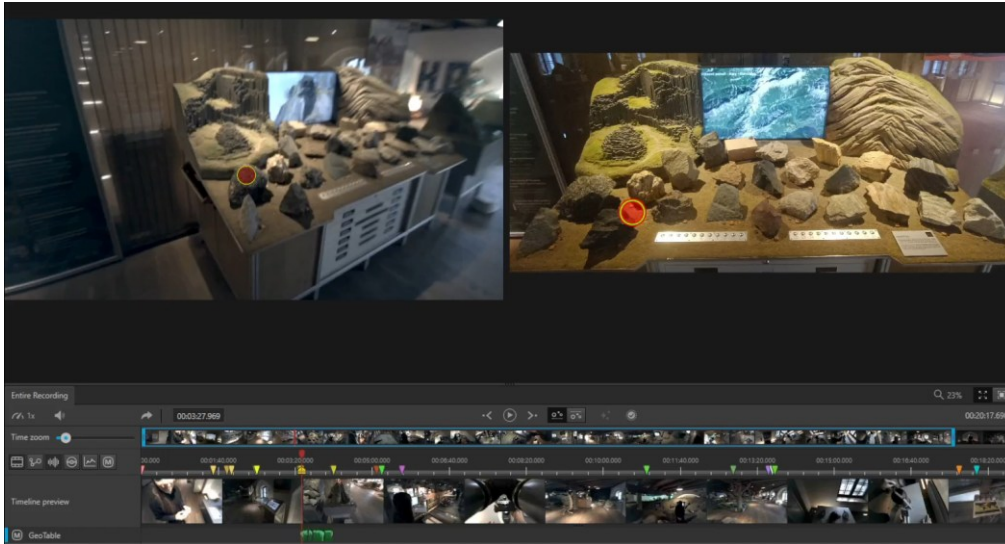
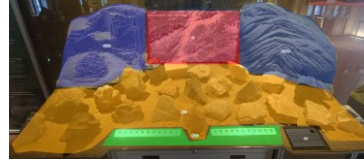
[Import workspace or data](#)
[Reload Demo](#)
[Export workspace or data](#)


GazePlotter

Free eye-tracking data visualisation

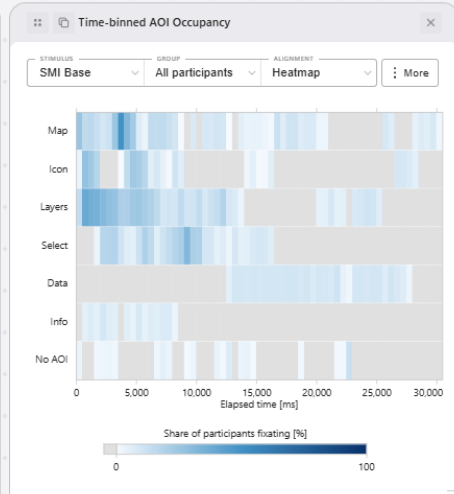
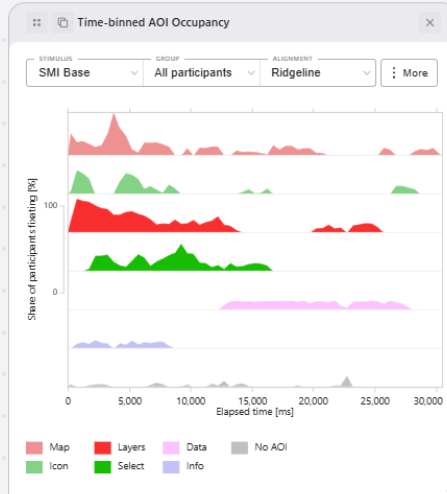
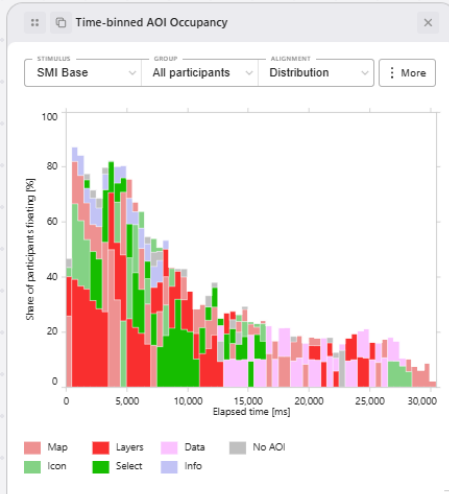
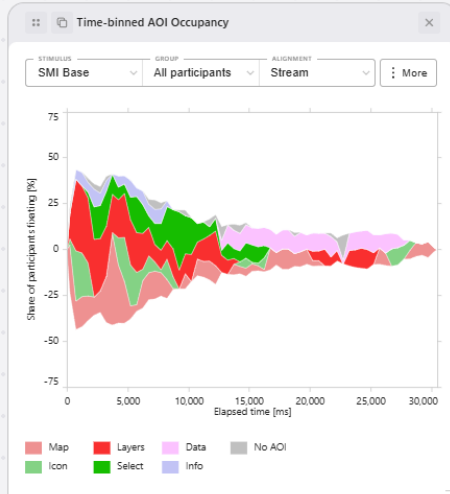
Video: <https://youtu.be/vtl1QiKGtYA>

Hodnocení expozice v Pevnosti Poznání

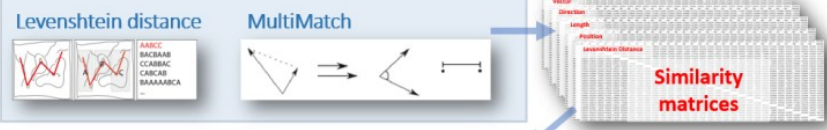


(Popelka & Vysloužil, 2025)

GazePlotter – nové možnosti vizualizace



ScanGraph



30 students

their geography teacher

Maple		average similarity among students										similarity between teacher and students											
Maple	Student	Student	Student	Student	Student	Student	Student	Student	Student	Student	Student	Student	Student	Student	Student	Student	Student	Student	Student	Student	Student	Teacher	Teacher
0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577
0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374

$$\Delta = ([\text{average similarity of students}] - [\text{average similarity of teacher to students}]) * 100$$



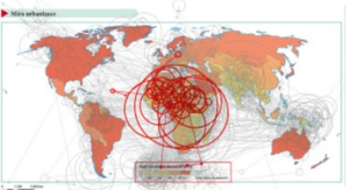
Scanpath

Position
p=0.85

Levenshtein Distance
p=0.75



Task09



Task02



No. of connections = 0

No. of connections = 2

No. of connections = 27

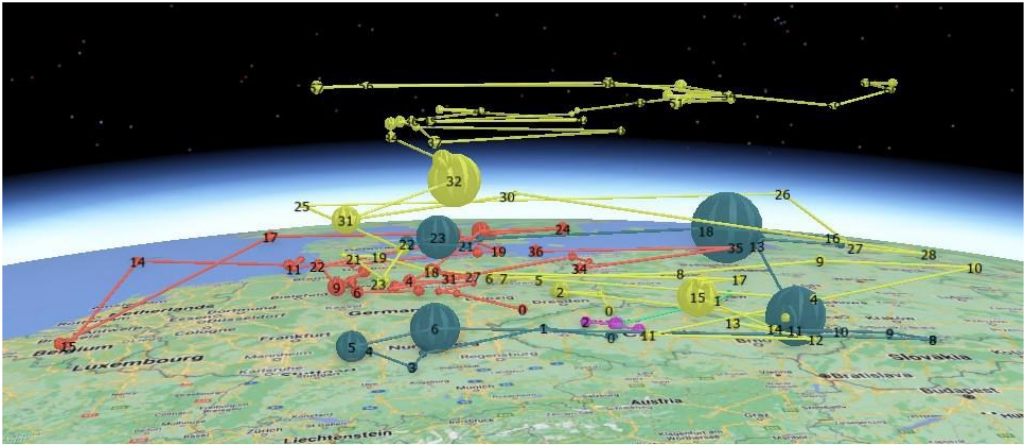
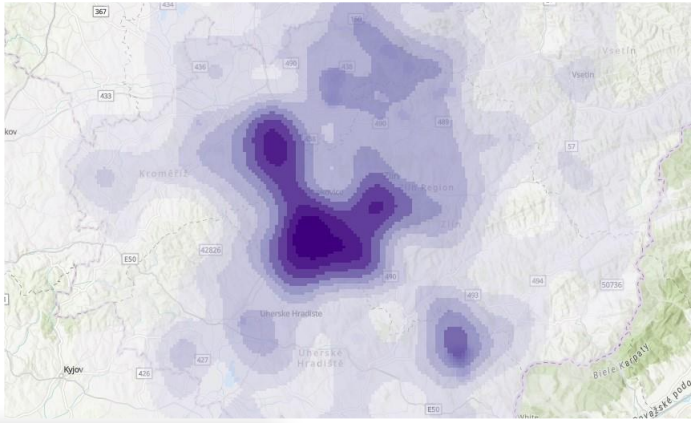
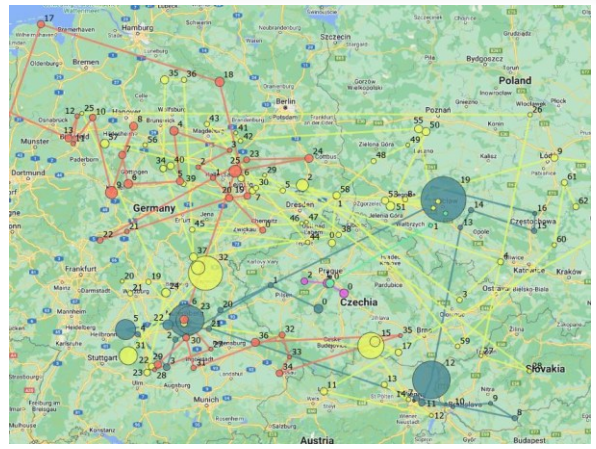
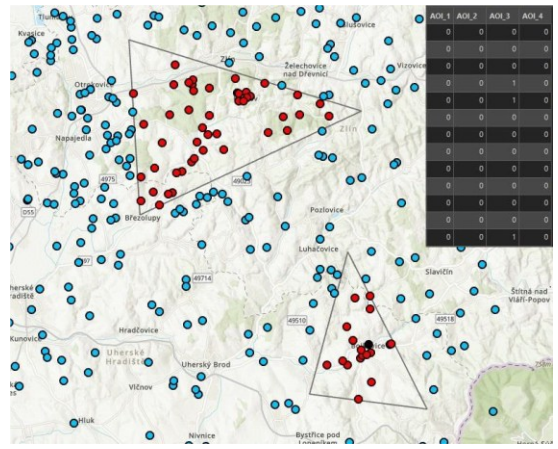
No. of connections = 9

Unique strategy

Common strategy

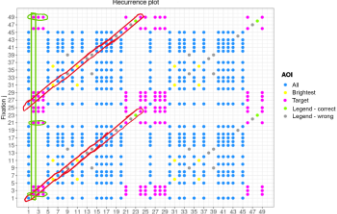
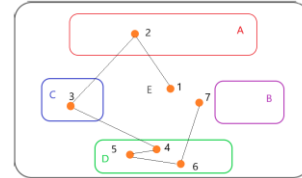
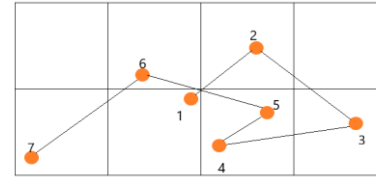
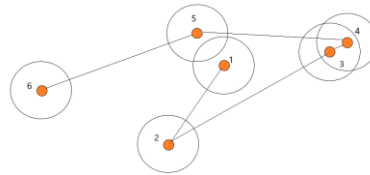
GIS

- ET2GIS.tbx
 - _Import Data
 - AOI Intersect
 - Attribute Visualization Duration
 - Buffer Zone
 - Heatmap
 - Hexagons
 - Kernel Density
 - Nearest Neighbours
 - Scanpaths
 - Space Time Cube
 - Space Time Cube Lines
 - Time Visualization
 - Zoom Level Clustering



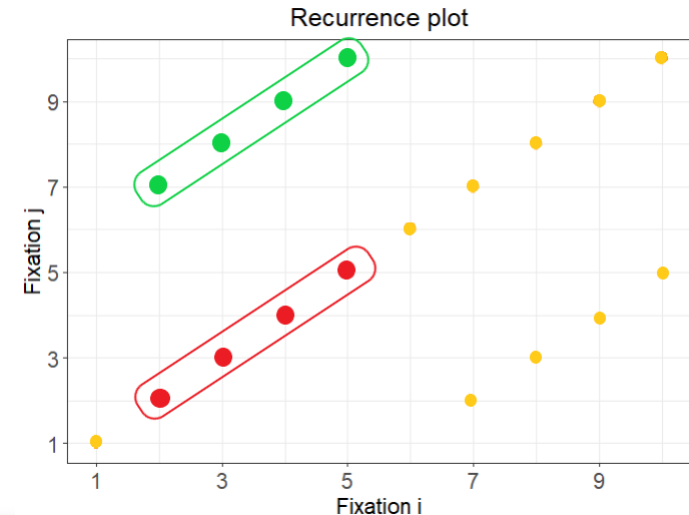
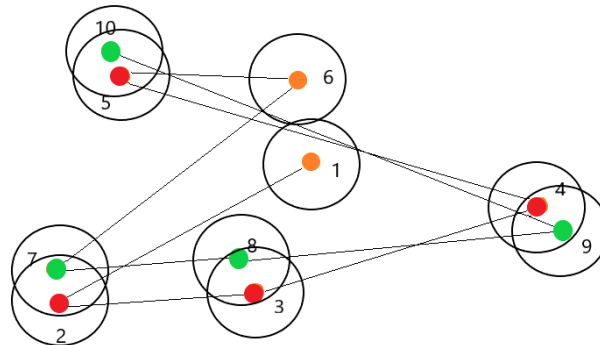
Rekurenční kvantifikační analýza (RQA)

- R – Number of Recurrent points
- REC – Recurrence
- **DET – Determinism**
- LAM – Laminarity
- CORM – Center of Recurrence Mass
- Ambient / Focal Attention



(Kalabusová, 2020)

(Popelka & Vítková, 2024)



Running RQA

(Vojtěchovská a kol., 2025)

RRQA visualizations for eye-tracking

Recurrence—the reappearance of similar states—offers deep insights into complex system dynamics.

Recurrence Quantification Analysis (RQA) extracts quantitative metrics from recurrence plots, revealing hidden patterns in eye-tracking data.

Our innovation, **Running RQA (RRQA)**, displays these metrics as continuous, evolving plots, enabling intuitive, direct comparisons of gaze behavior over time.

Recurrence Matrix Type

AOI-based

Choose the method for calculating recurrence between fixations

Minimum Structure Length

2

Adjust the minimum length required for diagonal and vertical line structures in recurrence plots



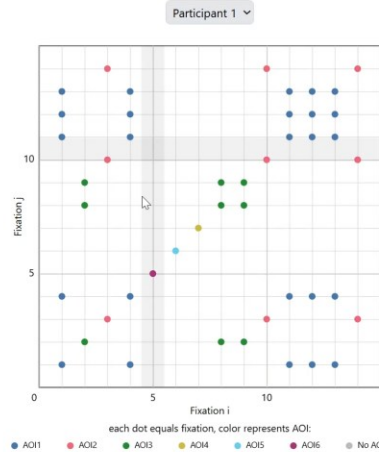
Upload CSV files or drag and drop

Multiple CSV files supported, one per participant

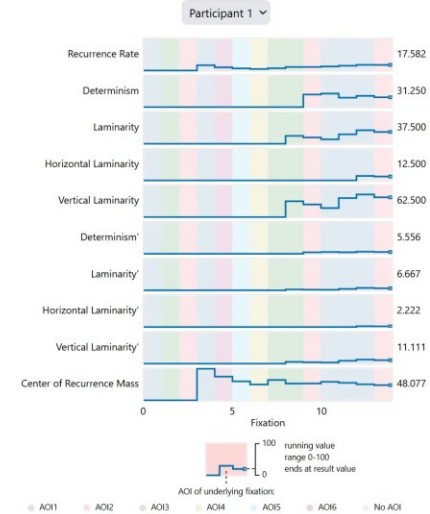
Required CSV format:

- Columns for `timestamp` and `aoi`
- Multiple AOIs can be separated by semicolons
- Optional columns for `x` and `y` coordinates

Recurrence Plot

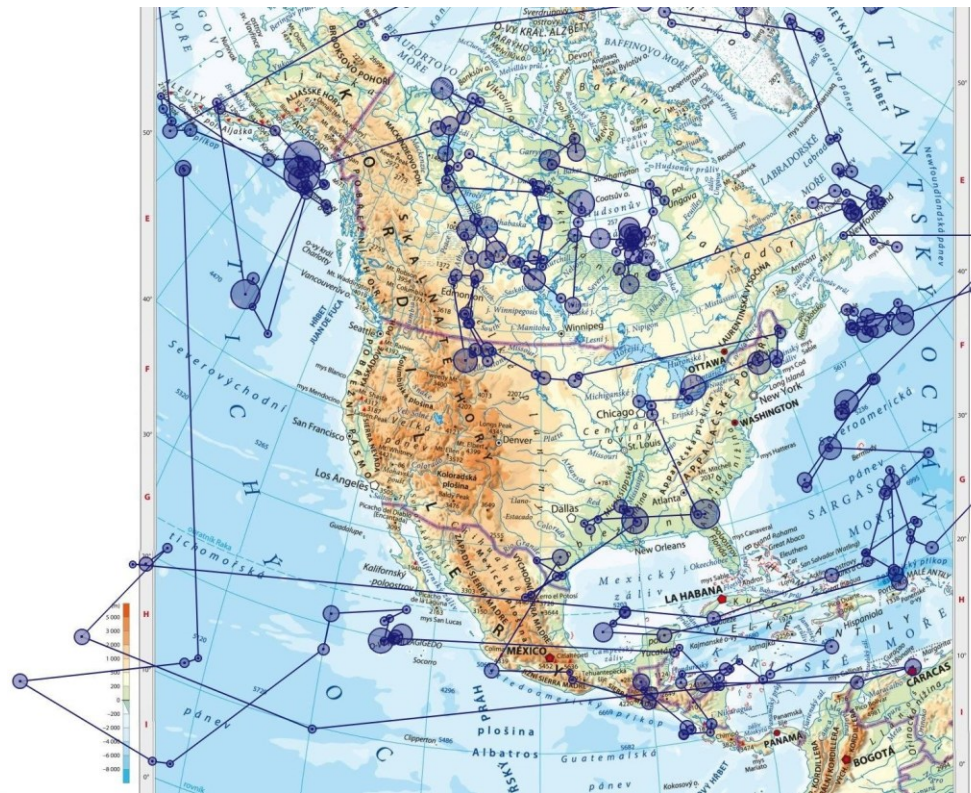


RRQA Worm Plot (Single)



Detailní analýza strategií

- Prozatím manuálně
- Možnost využití strojového učení a umělé inteligence
- Na toto bychom se chtěli zaměřit v budoucnu



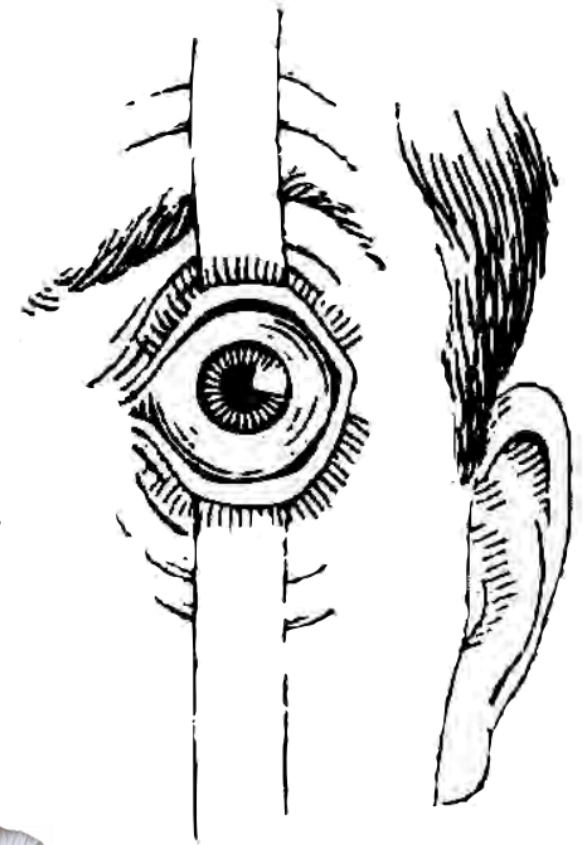
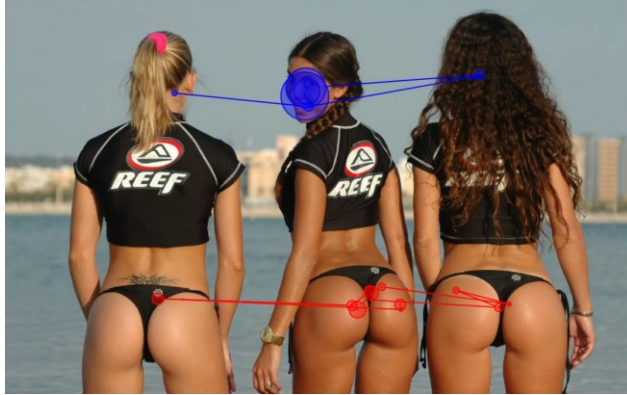
(Beitlová a Popelka, inprint)

Eye-tracking evaluation of USE-IT maps

Video: <https://youtu.be/sJEB1hLJQ0o>

USE-IT Maps | Free maps, made by locals





Eye-tracking:

Nástroj pro nahlédnutí do hlavy čtenáře mapy

stanislav.popelka@upol.cz

www.eyetracking.upol.cz

