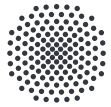

Impact of Gaze Uncertainty on AOIs in Information Visualisations

ETVIS 2022

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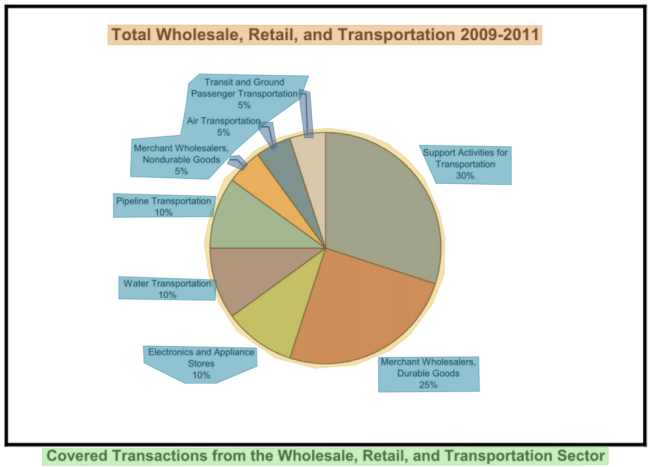
Area-of-Interest (AOI)



information visualisation *Borkin et al. [2015]*

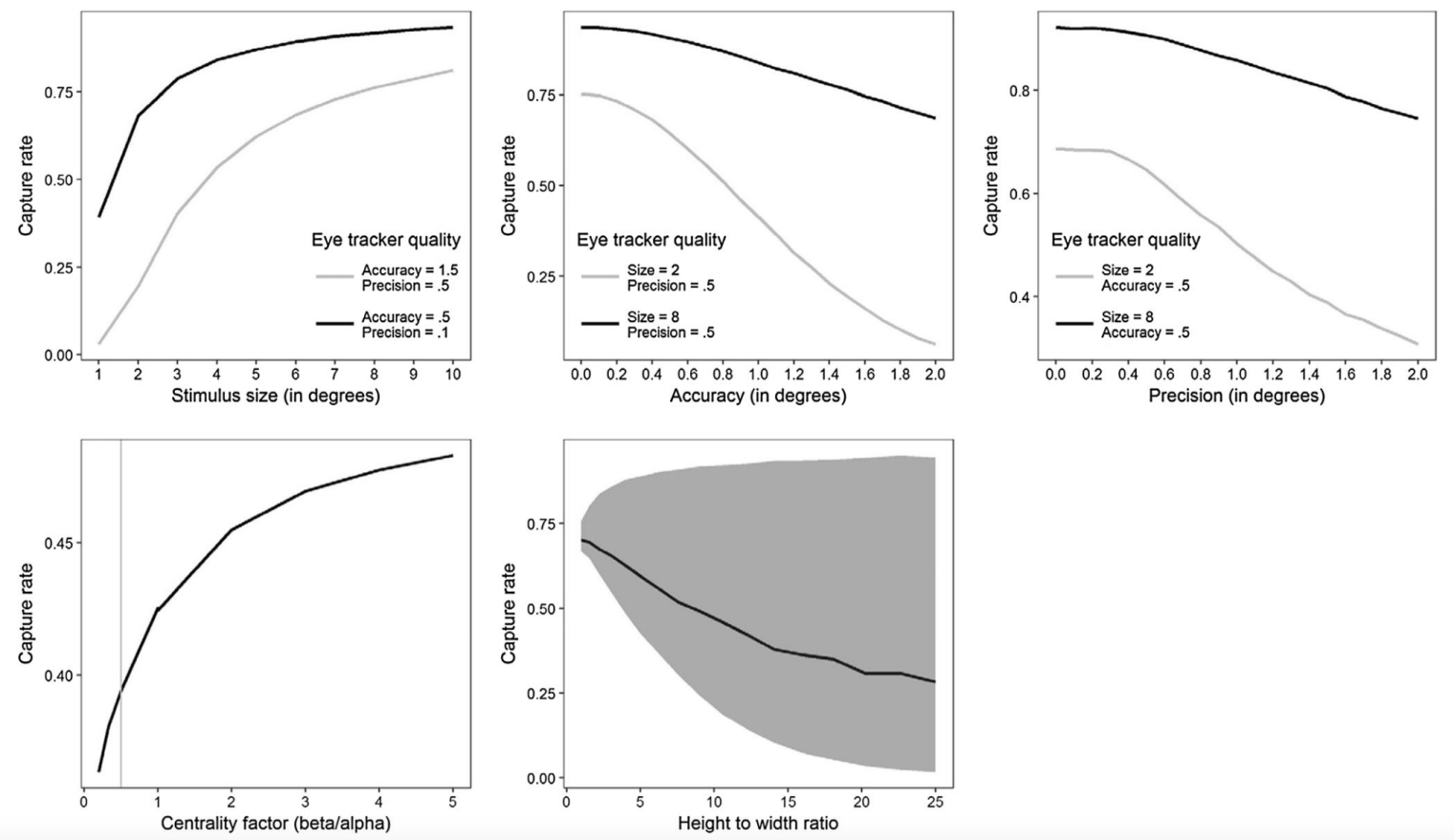
webpage *Drusch et al. [2014]*

Gaze Estimation Error

Source: tobiipro.com

- Intrinsic error of all eye trackers *Barz et al. [2016]*

Capture Rate

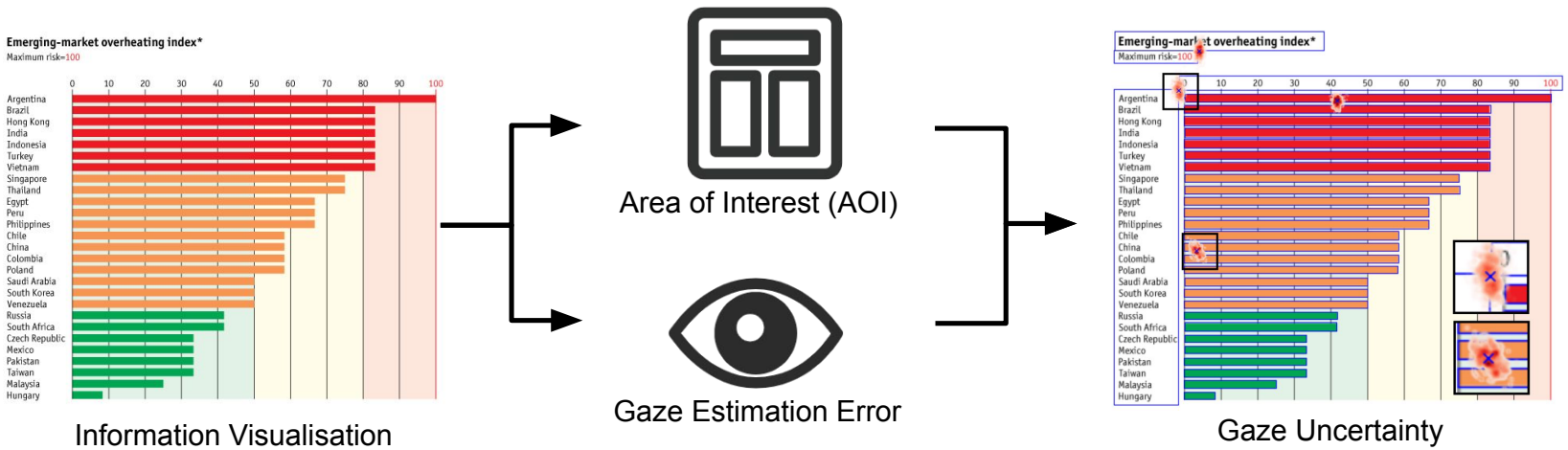


Source: Orquin and Holmqvist [2018]

- The increase in the size of AOIs and distances between AOIs can benefit the Capture Rate

PUI Perceptual User Interfaces

Impact of Gaze Uncertainty on AOIs in Information



- eye-tracking study on 40 visualisations in MASSVIS Borkin et al. [2015]

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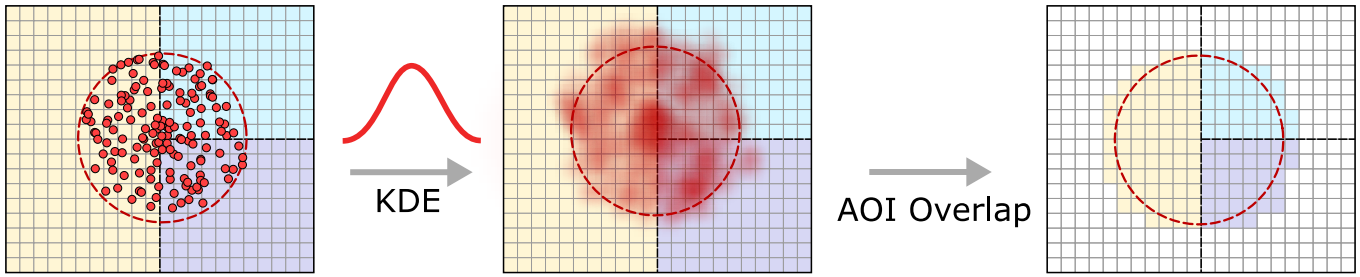
Impact of Gaze Uncertainty on AOIs in Information Visualisations

Flipping Candidate

AOI Probability



the probability of assigning a fixation to the ith AOI:

$$p_i = \int_{x \in \Omega} \mathbb{1}_A(x) \left(\frac{1}{n} \sum_{j=1}^{n} K_h(x - x_j) \right) \, d^2x$$

$\mathbb{1}_A(x)$: pixels that are covered by the ith AOI

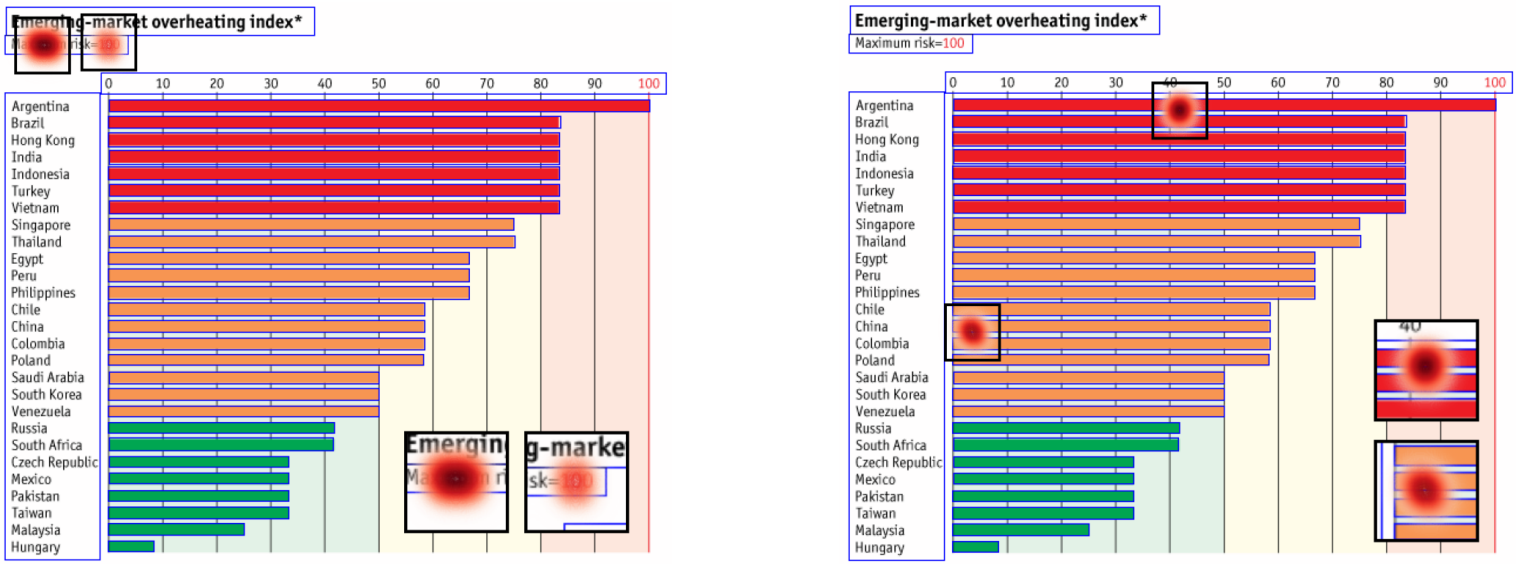
h: the bandwidth of Gaussian Kernel

Flipping Candidate

The flipping candidate score s_k of rank k:

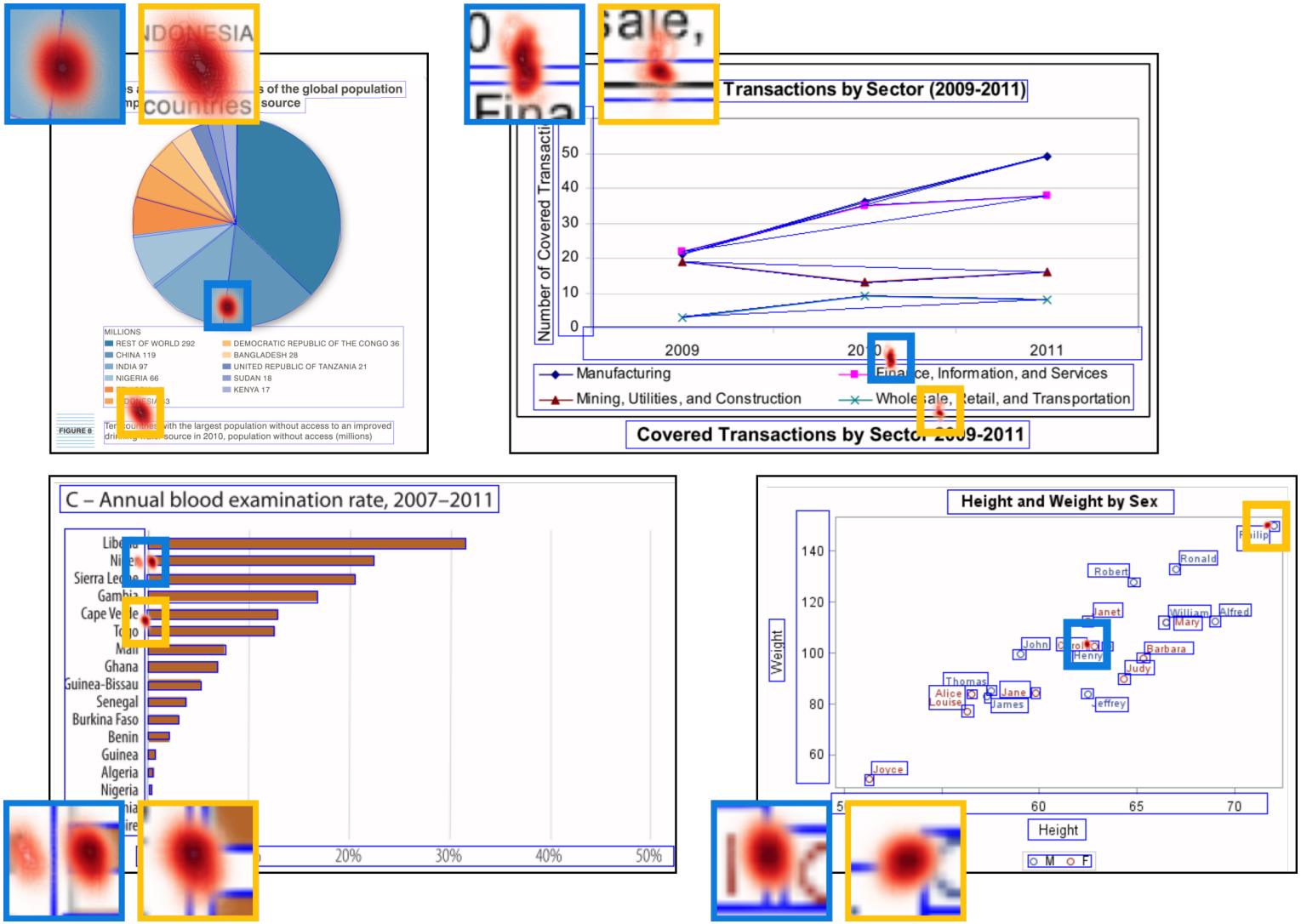
$$s_k = \sum_{i=1}^{N} p_i - \left(\sum_{i=1}^{k} \left| p_i - \frac{1}{k} \right| \right), p_i \geq p_{i+1}$$

$$k = argmax_j(s_j), j \in \{2, 3, 4\}$$



Examples of flipping candidates of rank 2 (left) and rank 3 (right).

Flipping Candidate



Orange: $0.1 < s_2 < 0.5$, Blue: $s_2 > 0.5$.

Metric I — Flipping Candidate Rate (FCR)

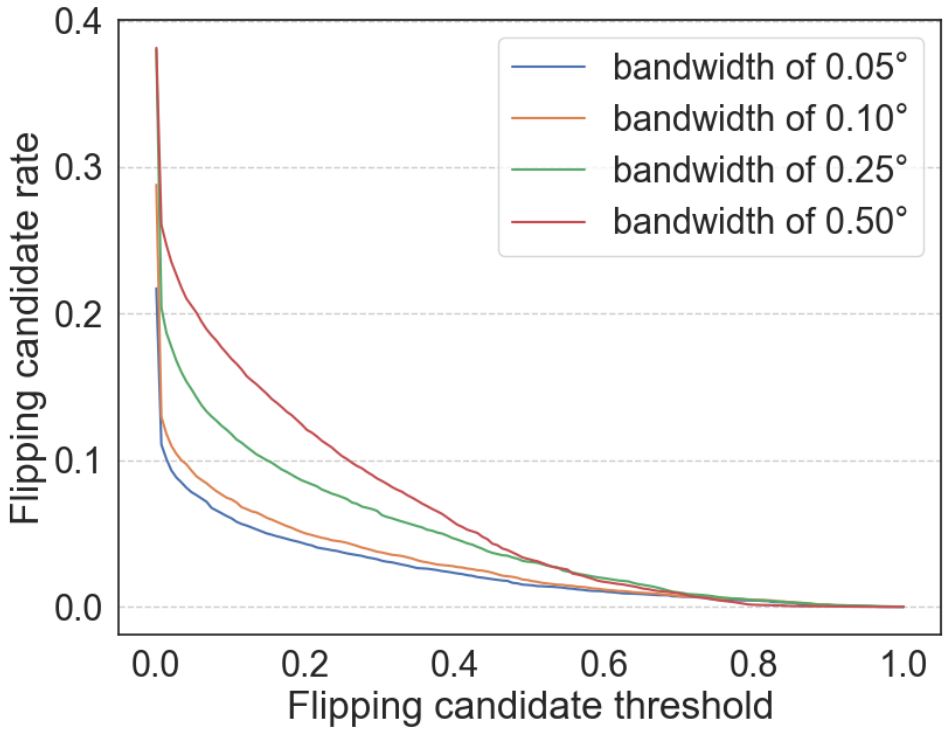
- FCR $= \frac{C}{N}$ of a scanpath

Flipping candidate threshold t: $max(s_j) > t, j \in \{2, 3, 4\}$

C: the number of flipping candidates

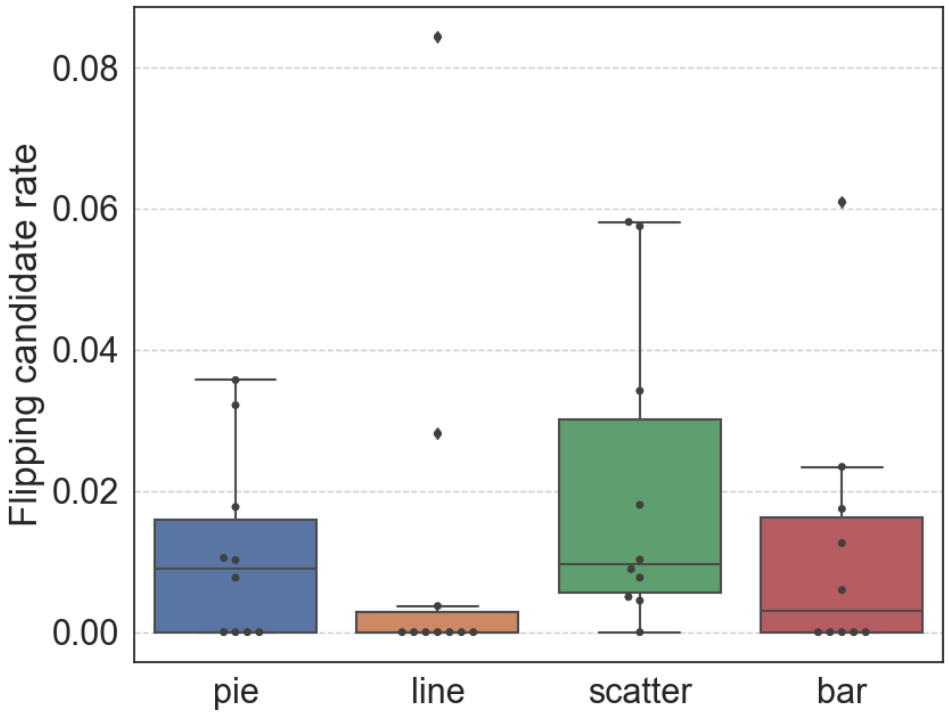
N: Scanpath length

Flipping Candidate Threshold



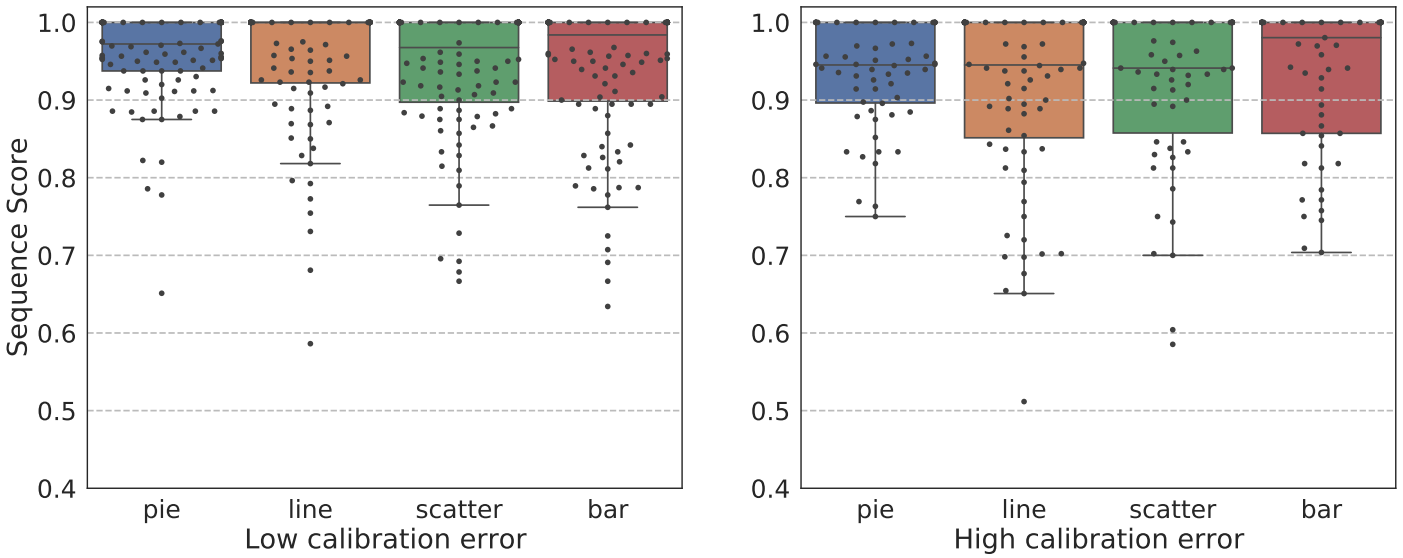
Average flipping candidate rate for different thresholds.

Flipping Candidate Rate Across Vistypes



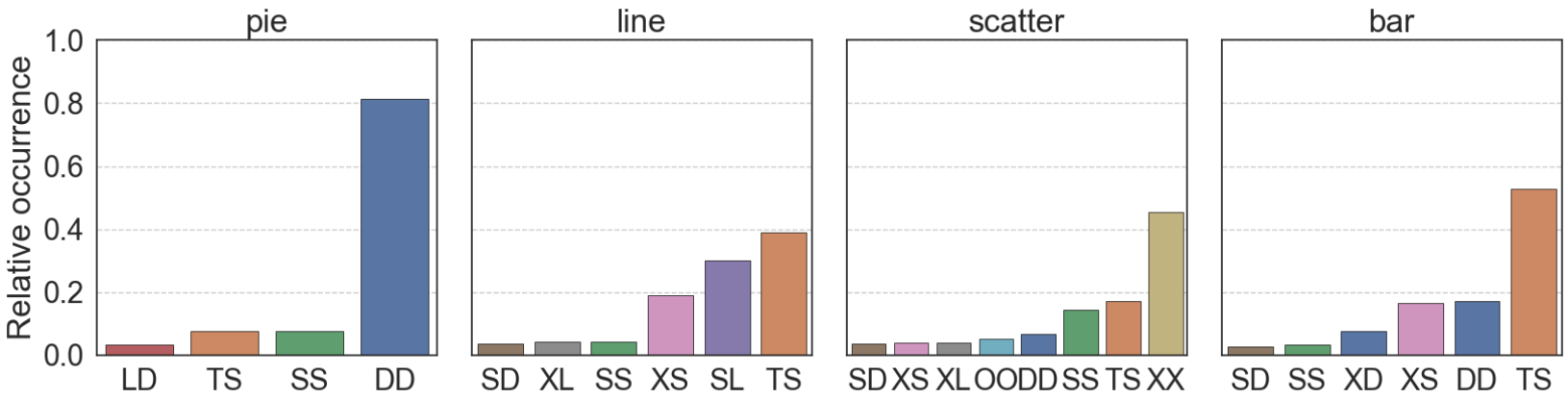
A flipping candidate threshold of 0.5, and a Gaussian bandwidth of 0.25 ° was applied.

Sequence Score of Flipped Scanpaths



- 0.5 ° as the criterion of low & high CE groups
- All flipping candidates are flipped to the second possible AOI

AOIs involved in Flipping Candidates



AOIs involved in flipping candidates of rank 2.

A: Annotation, D: Data, G: Graphics, L: Legend, O: Object, S: Source, paragraph, label, and header row text, denoted as Source etc., T: Title, X: Axis.

Impact of Gaze Uncertainty on AOIs in Information Visualisations

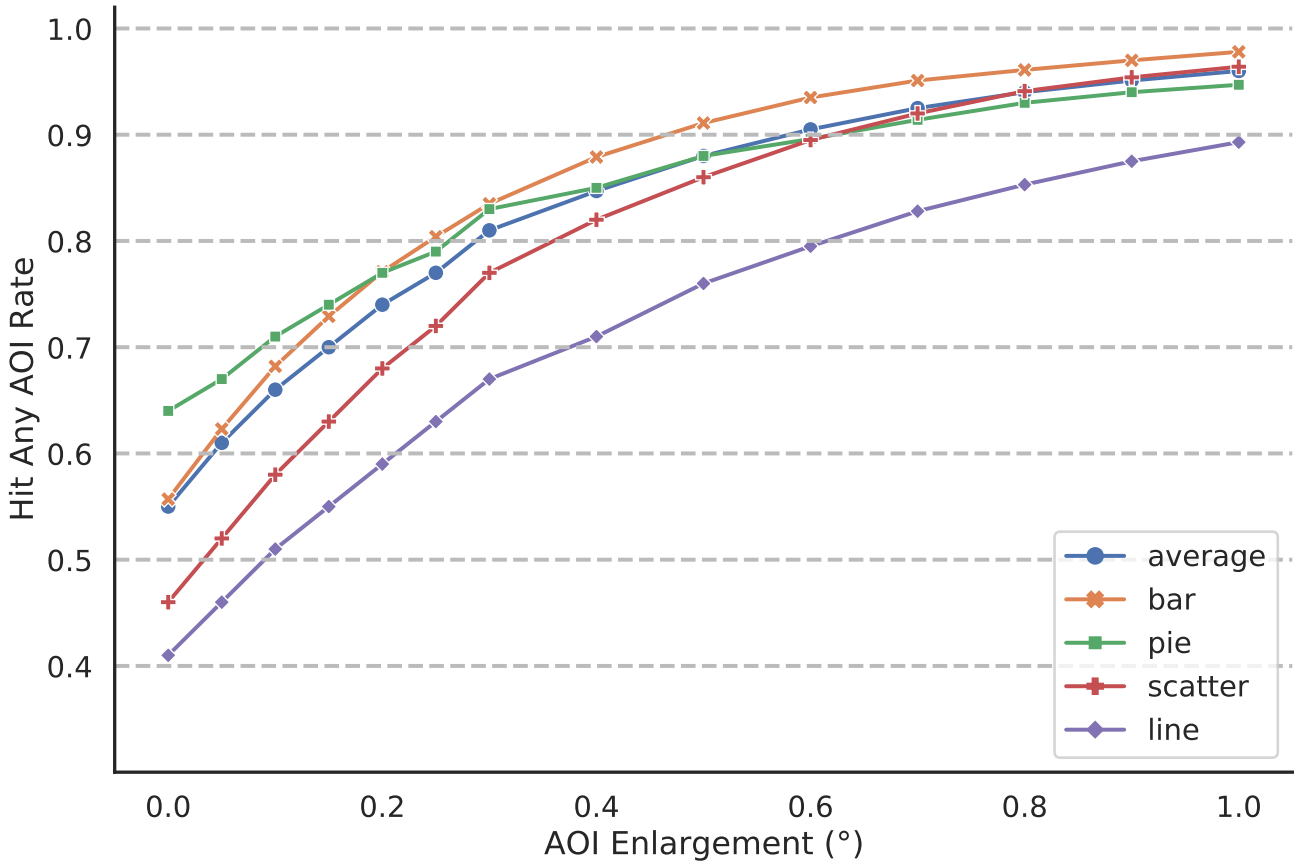
Hit Any AOI Rate (HAAR)

Metric II — Hit Any AOI Rate (HAAR)

- The raw gaze data are not accessible in most public information visualisation datasets *Borkin et al. [2015]; Zheng et al. [2018]*
- Human attention is not naturally drawn by low saliency regions such as white spaces *Matzen et al. [2017]*
- HAAR $= \frac{HIT}{HIT+OFF}$

HIT: the number of fixations that hit at least one AOI
OFF: the number of fixations that do not land on any AOI

HAAR Across Visualisation Types



AOI enlargement factor by visual angle ° and the Hit Any AOI Rate (HAAR).

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Take-home Messages

- If only fixations are available (no raw gaze data), only HAAR is applicable
- In practice, a smaller flipping candidate threshold (0.2 - 0.5) and an enlargement factor (around 1 °) are desired
- Scatter and bar plots are most commonly designed in a way that causes more uncertainty than line and pie plots

Thanks for your attention!

Questions?

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www.perceptualui.org

References i

M. Barz, A. Bulling, and F. Daiber. Computational modelling and prediction of gaze estimation error for head-mounted eye trackers. Technical report, German Research Center for Artificial Intelligence (DFKI), 2016.

M. A. Borkin, Z. Bylinskii, N. W. Kim, C. M. Bainbridge, C. S. Yeh, D. Borkin, H. Pfister, and A. Oliva. Beyond memorability: Visualization recognition and recall. *IEEE Transactions on Visualization and Computer Graphics*, 22(1):519–528, 2015.

G. Drusch, J. Bastien, and S. Paris. Analysing eye-tracking data: From scanpaths and heatmaps to the dynamic visualisation of areas of interest. *Advances in Science, Technology, Higher Education and Society in the Conceptual Age: STHESCA*, 20 (205):25, 2014.

L. E. Matzen, M. J. Haass, K. M. Divis, Z. Wang, and A. T. Wilson. Data visualization saliency model: A tool for evaluating abstract data visualizations. *IEEE Transactions on Visualization and Computer Graphics*, 24(1):563–573, 2017.

J. L. Orquin and K. Holmqvist. Threats to the validity of eye-movement research in psychology. *Behavior Research Methods*, 50(4):1645–1656, 2018.

Q. Zheng, J. Jiao, Y. Cao, and R. W. Lau. Task-driven webpage saliency. In *Proceedings of the European conference on computer vision (ECCV)*, pages 287–302, 2018.