A Comparative Evaluation of Eye-Movement Detection Algorithms

Jonathan Nir[1], Leon Y. Deouell[1,2]

[1] Edmond and Lily Safra Center for Brain Sciences, The Hebrew University of Jerusalem, Jerusalem 9190401, Israel
[2] Department of Psychology, The Hebrew University of Jerusalem, Jerusalem 9190501, Israel

Introduction

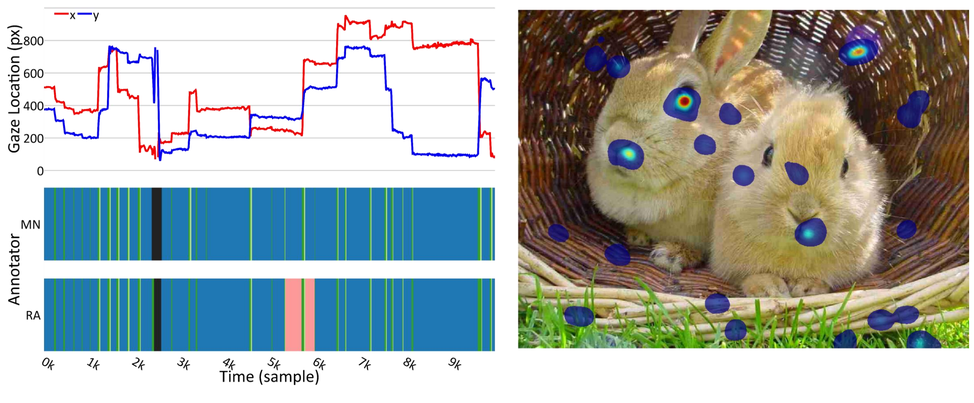
- Eye-tracking (ET) provides insights into multiple cognitive processes.
- Detection and classification of eye movements (EM) from ET signal is difficult and costly to achieve manually.
- Automated algorithms, *detectors*, vary significantly in methodology, sensitivity, and accuracy.
- We provide a software package to compare threshold-based detectors for fixation and saccade detection.

Method

- Dataset: 20 publicly available eye-tracking recordings of free-viewing of images ([1]).
- Ground Truth (GT): annotations by two independent raters (*RA* & *MN*).
- Detectors: Four fixed-threshold and three adaptive-threshold.
- Evaluation Procedures: Sample-by-sample agreement (Cohen's Kappa, [2]) and event-boundary detection sensitivity (d') as a function of time windows around GT events.

The pEYES package

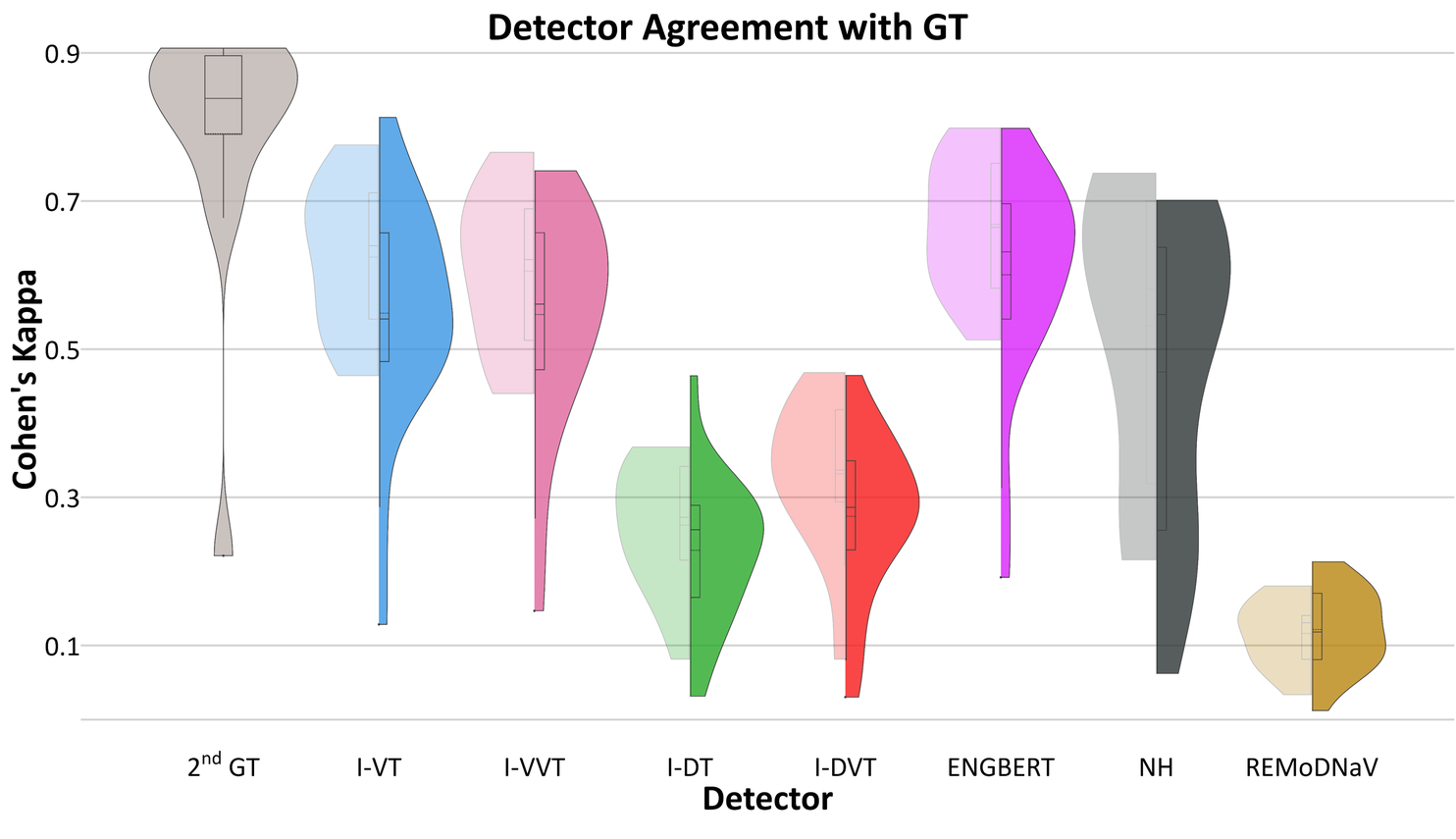
- Self-developed open-source Python package designed to facilitate EM detection, evaluation and analysis.
- Provides implementations for multiple threshold-based detection algorithms, along with "classic" visualization and analysis tools.
- Enables quantitative evaluation of detection performance compared to GT.
- Freely available for public use.



Results

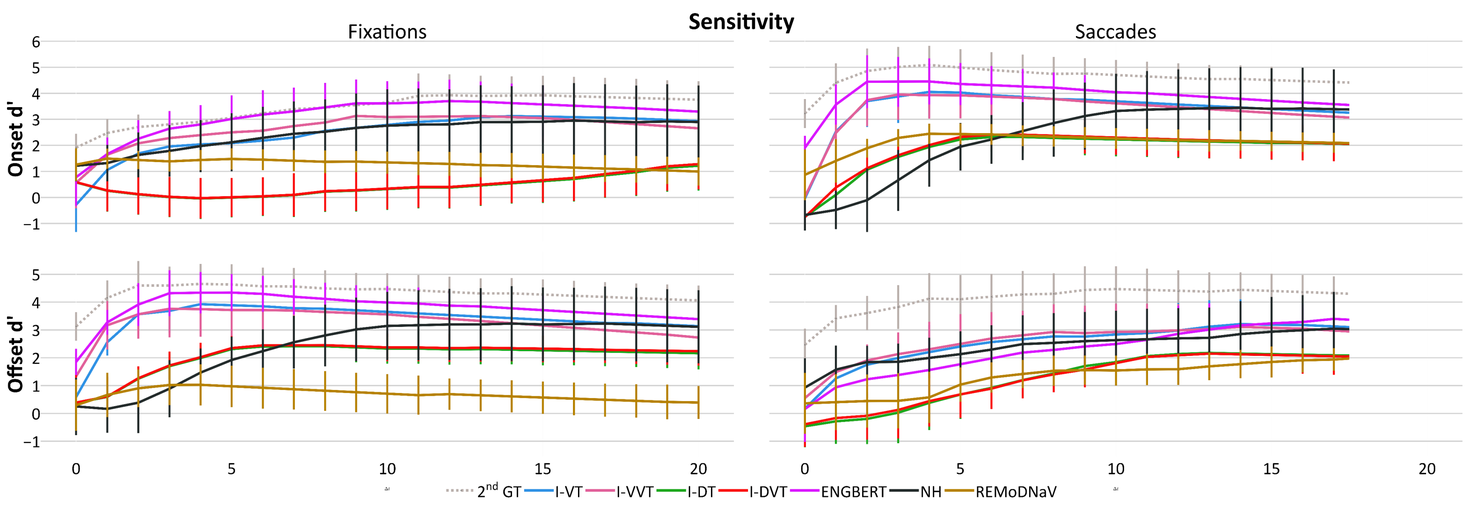
Agreement with GT

There was high labelling agreement between the human annotators. Detectors agreement with GT significantly differed ($p < 0.001$), with *Engbert* detector ([3]) performing comparably or better than the other detectors.

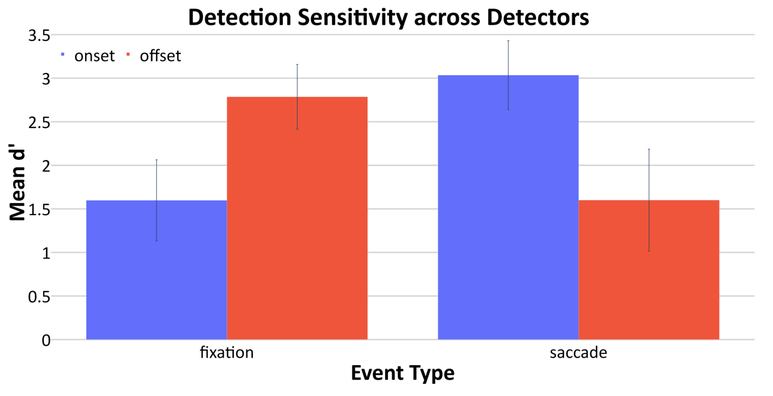


Detection Sensitivity

Across time windows, the *Engbert* detector outperforms other detectors in detection sensitivity (d'), approaching human-level performance.



Overall, detectors are better at detecting saccade onsets (fixation offsets) than saccade offsets (fixation onsets).



Conclusions

1. Detection performance varies significantly between different detection algorithms.
2. The *Engbert* detector is the optimal algorithm for detecting fixations and saccades during free viewing of static image stimuli.
3. Saccade offsets & fixation onsets is significantly harder than detecting their complements.
4. pEYES provides a framework for assessing detectors in different settings, given reference annotations.

References

[1] Andersson, R., Larsson, L., Holmqvist, K., Stridh, M., & Nyström, M. One algorithm to rule them all? An evaluation and discussion of ten eye movement event-detection algorithms. *Behavior research methods*, 2017.
[2] Startsev, M., & Zemblys, R. Evaluating eye movement event detection: A review of the state of the art. *Behavior Research Methods*, 2023.
[3] Engbert, R., & Kliegl, R. Microsaccades uncover the orientation of covert attention. *Vision research*, 2003.