ENABLING SACCADE LATENCY MEASUREMENTS WITH CONSUMER-GRADE CAMERAS

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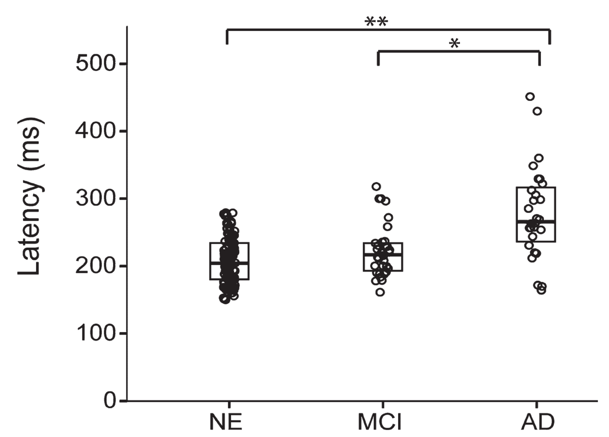
I. Motivation

- Current diagnoses of neurodegenerative diseases (e.g. Alzheimer's Disease) rely on subjective questionnaires and expensive brain imaging.
- Eye movement patterns are correlated with disease progression [1].
- They were measured using high-cost specialized equipment (high-speed high-quality camera, head rest, IR light).

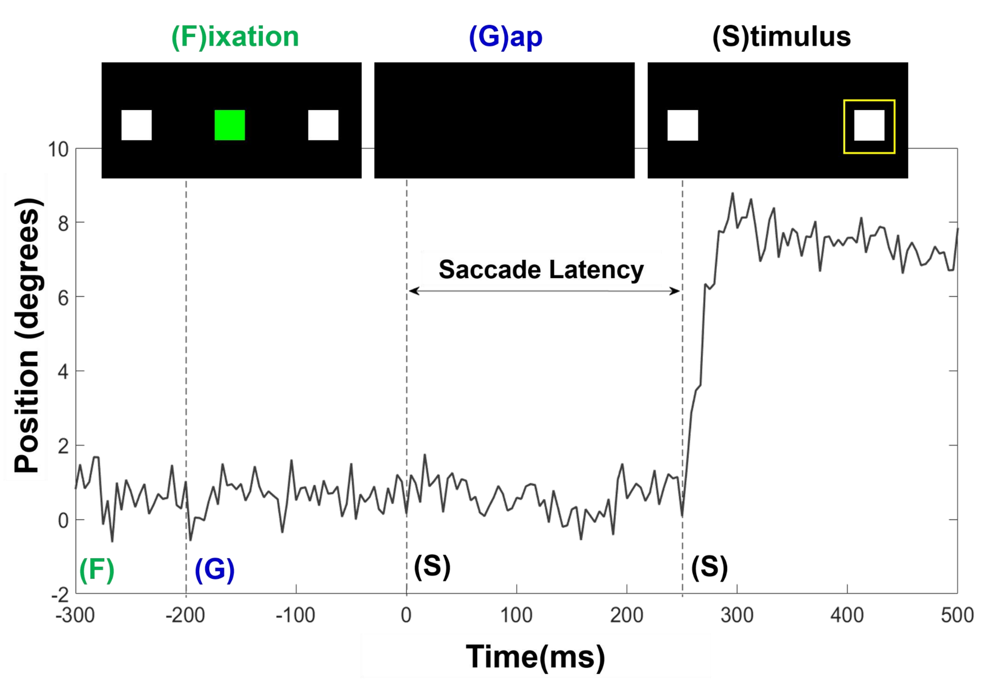


Can we make these clinical measurements more accessible?

We developed a pipeline to measure saccade latencies from smartphone cameras as an unobtrusive and quantitative method to track disease progression.

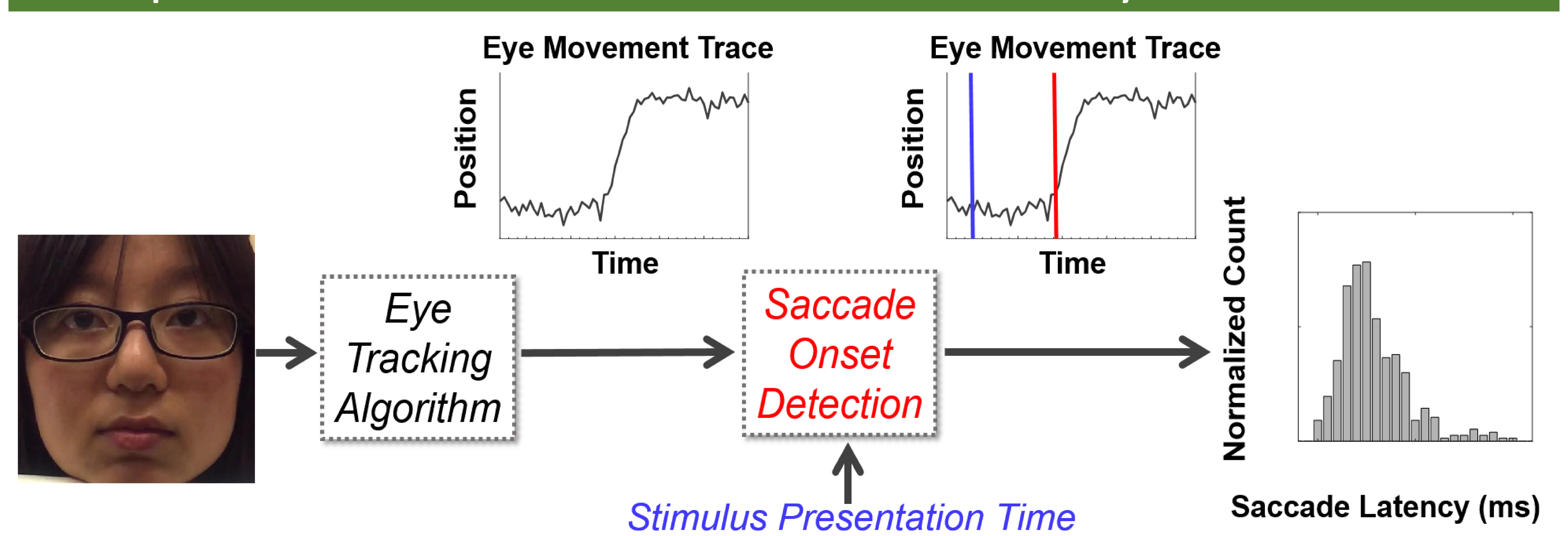
II. Visual Stimulus and Saccade Latency

Subjects were recorded with a smartphone camera while performing a visual fixation/stimulus task displayed on a laptop.



Saccade latency is the time delay between the appearance of a visual stimulus and the eye movement towards the stimulus.

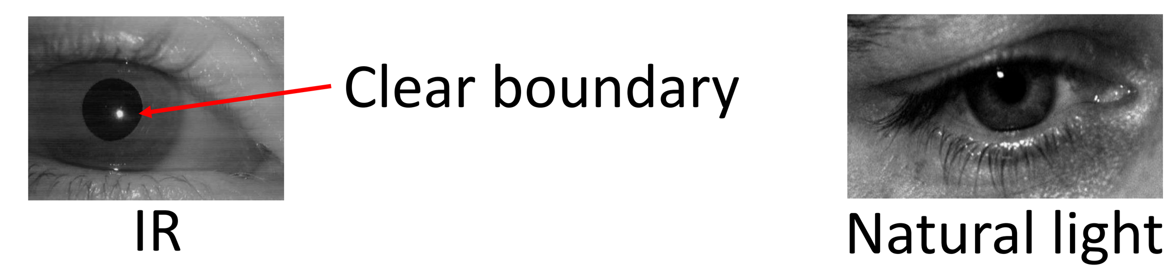
III. Pipeline for Calculation of Saccade Latency



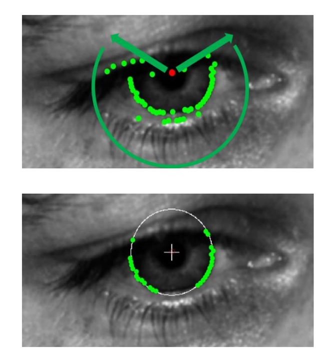
IV. Eye Tracking Algorithms

Goal: Find a robust eye tracking algorithm that can present clear saccade onsets from recordings under natural light condition.

- Starburst [2] was developed for a head-mounted IR-based system.



Our algorithm, **Starburst-phone,** works under natural light by



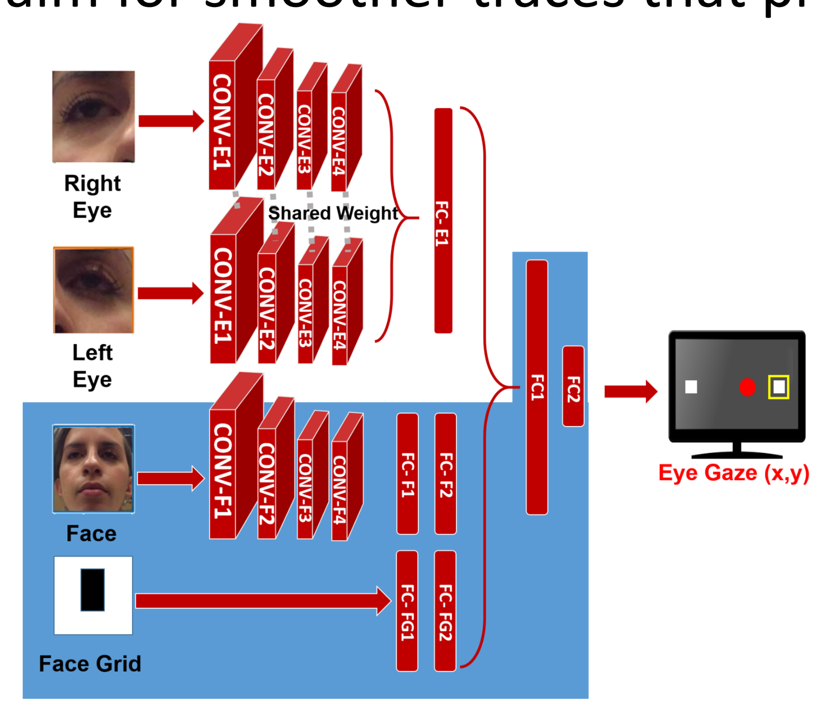
(i) Iris contour detection that avoids the upper eyelid.

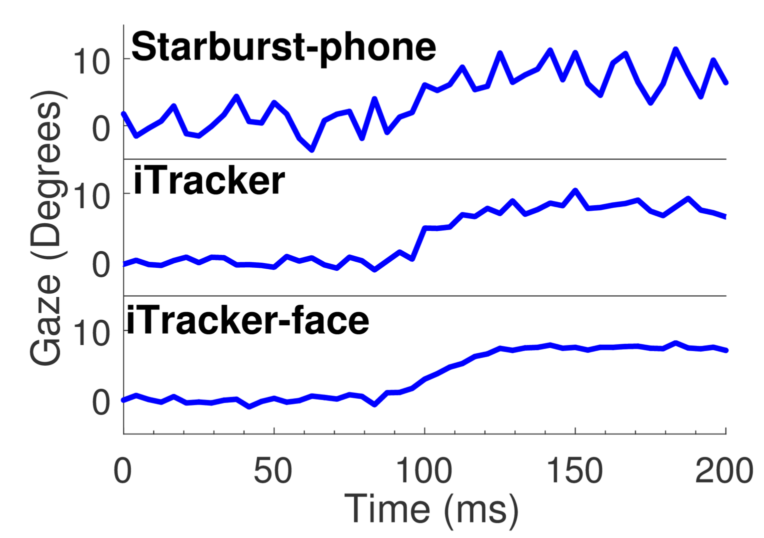
(ii) Iris model fitting using RANSAC.

- **iTracker** [3] is a convolutional-neural-network (CNN)-based gaze estimator trained on data from iPhones/iPads at 30fps.

We need 240fps to accurately measure saccade onsets.

- We propose **iTracker-face** (which removes the eye-related CNN) to aim for smoother traces that present clearer onsets.





Evaluate the robustness: compare numbers of good saccades (clear onsets) by visual inspection

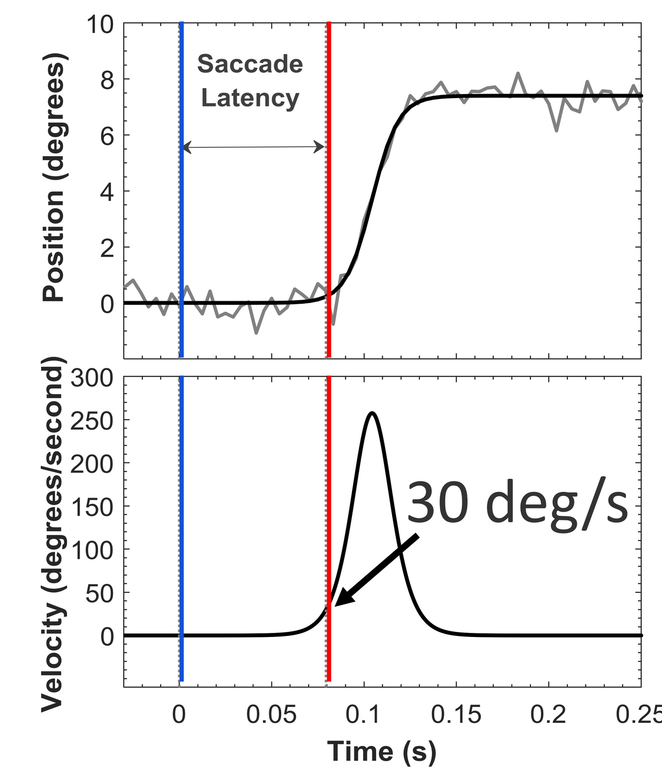
Eye Tracking Algorithm	Glasses (out of 200)		Ext. Illumination (out of 40)		
	No	Yes	No	Low	Max
Starburst-phone	136	22	17	38	35
iTracker	153	100	29	37	35
iTracker-face	177	181	36	39	35

iTracker-face is the most robust algorithm.

V. Saccade Onset Detection and Pipeline Automation

Goal: Find a saccade onset detection method and a way to automatically detect bad saccades.

- Saccade onset detection can be achieved by **tanh fitting**.



(i) Avoid high-frequency noise caused by differentiation.

(ii) Normalized root-mean-square errors (NRMSE) can be used to reject bad saccades.

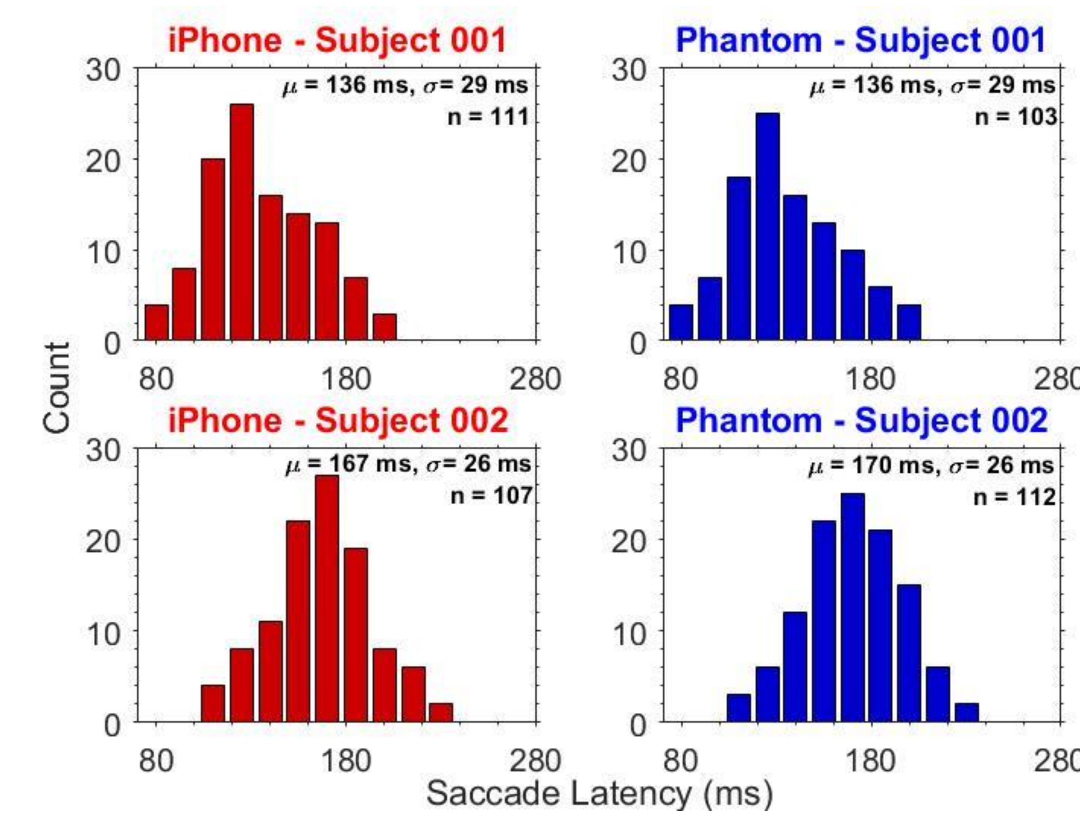
By considering every trace with an NRMSE larger than a proper threshold as bad saccades, **we achieved an average true-positive rate of 0.95 and an average false-positive rate of 0.05.**

VI. Pipeline Evaluation with a Research-Grade Camera

Consumer grade camera
iPhone 6,
cost <$1k,
720p resolution, 240 fps

VS.

High-speed high-quality camera
Phantom v25-11,
cost $100k,
720p resolution, 500 fps



We are able to attain almost the same saccade latency statistics.

Over 11000 saccade latencies using this pipeline [4].

Conclusion: Accurate and Robust Saccade Determination is Feasible using Consumer-Grade Cameras.

[1] H.W. Heuer et al. *Neuro* 81(14), 2013.; [2] D. Li et al. *IEEE CVPR- Workshops*, 2005.; [3] K. Krafka et al. *IEEE CVPR*, 2016.; [4] G. Saavedra-Peña et al. *IEEE EMBC,* 2018.