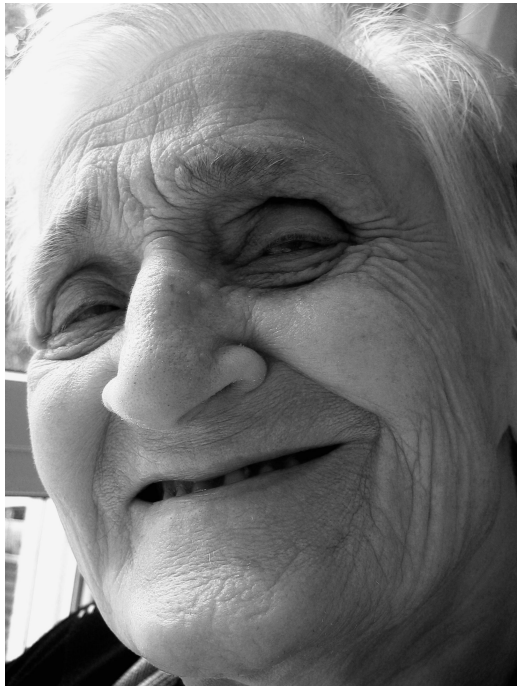
CNT Hackathon 2021

Jim Schwoebel

Pamel Kang

Jayant Arora

Alzheimer's: A Growing Problem



According to the World Health Organization (WHO), a new case of dementia is **diagnosed every 3 seconds.** That's **28,800 per day** or over **10 million people per year.**

- **Late diagnosis / poor outcomes -** AD is present up to 20 years before the disease is manifested.
- **Early treatment** is helpful to delay the progression to improve outcomes and lower costs.
- **Strong need to detect AD earlier on,** allowing for earlier therapies to slow decline of AD symptoms, improve treatment outcomes and ensure patients a greater quality of life.

Noninvasive Approaches for AD detection

Approach	Time	Cost	Cross-cultural?	Risk	Accuracy
Vocal Biomarkers 🗣️	Fast	Low (<$50)	Maybe	Low	Moderate
MMSE Exam ✍️	Moderate	Moderate (>$100)	Yes	Low	Moderate
MRI Image 🏥	Slow	High (>$1000)	Yes	Low	High
Spinal Fluid Test 💉	Slow	High (>$1000)	Yes	Moderate	High
Visual Biomarkers 👀	**Fast**	**Low (<$50)**	**Yes**	**Low**	**Moderate**

Table 1

Research on eye movements and Alzheimer disease on pubmed since 2013.

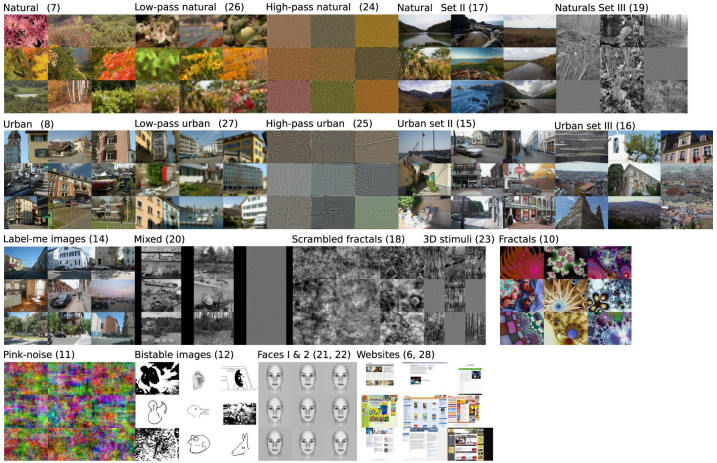
Cite	Methods	Findings	Participants/Apparatus
2016 [25]	Subjects responded to targets presented on a hemispherical screen with diverse eccentricity.	PwAD recognized less targets in the center. No difference was found with CG on the peripheral targets.	AD: 18 CG: 20 Apparatus: Hemispherical screen Octupus 900 with camera used for eye tracking.
2017 [26]	The King-Devick test (with saccadic and other movements) was applied to subjects.	The King-Devick test may a tool to detect cognitive impairment associated with AD.	AD: 32 CG: 135 MCI: 39 Apparatus: N/A
2016 [27]	Subjects looked a series of slides containing four images of different emotional themes.	PwAD with apathy had diminished attentional bias toward social-themed stimuli.	AD: 36 (Apathy: 17 Not apathy: 19) Apparatus: Binocular eye tracking system developed by EL-MAR Inc.
2016 [11]	Eye movements from subjects were examined during reading regular and high predictable sentences.	PwAD gaze was longer than CG gaze. CG decreased gaze duration with high predictable sentences suggesting reading enhancement using stored information.	AD: 35 CG: 35 Apparatus: EyeLink 1000. Chinrest to control eye movements.
2015 [28]	Subjects performed a variety of tasks: walking, through stairs, through a room with and without obstacles.	The Posterior Cortical Atrophy (PCA) patient had longer mean fixation durations than PwAD and CG. Mean fixation duration between PwAD and CG was similar.	AD: 1 CG:1 PCA: 1 Apparatus: SMI mobile eye tracker
2015 [29]	Eye movements from subjects were examined while read sentences.	PwAD had more fixations on regular and high predictable sentences. PwAD spend more time reading the sentence. CG had less frequent second pass fixation over sentences.	AD: 35 CG-elderly: 35 Apparatus: EyeLink 1000. Chinrest to control eye movements.
2015 [19]	Longitudinal study with Gap and overlap paradigms.	PwAD had slower reaction times than CG. Prosaccades did not deteriorate after the 12-month longitudinal study in AD.	AD: 11 CG elderly: 25 Apparatus: ExpressEye
2015 [30]	Subjects made saccadic movement to photographs to target instructed scenes (natural vs urban, indoor vs outdoor)	Were found differences between controls and PwAD on accuracy but not saccadic latency.	AD: 24 CG age-matched: 28 CG young: 26 Apparatus: Eye tracker (Red-M, Senso-Motoric Instruments)
2015 [23]	Eye movements from subjects were examined while read proverbs.	PwAD have less word predictability than CG.	AD: 20 CG: 40 Apparatus: EyeLink 1000. Chinrest to control eye movements.
2014 [31]	Eye movements from subjects were examined while read low and high predictable sentences.	CG have shorter gaze duration on high predictable sentences. PwAD have similar gaze duration on both low and high predictable sentences. PwAD gaze duration is longer than CG.	AD: 20 CG age-matched: 40 Apparatus: EyeLink 1000. Chinrest to control eye movements.
2014 [32]	Eye movements from subjects were examined while read sentences	PwAD have altered visual exploration and absence on contextual predictability.	AD: 18 HC age-matched: 40 Apparatus: EyeLink 2K. Chinrest to control eye movements.
2013 [33]	Eye movements from subjects were examined while read sentences	PwAD evidences marked alterations in eye movement behavior during reading.	AD: 20 CG age-matched: 25 Apparatus: EyeLink 1000. Chinrest to control eye movements.
2014 [12]	Subjects were asked to spot an animal target contained in Colored photographs along with other distracting items.	PwAD were significate less accurate than elderly controls. Elder were less accurate than young controls.	AD: 17 mild AD. CG elderly: 23 CG young: 24. Apparatus: Eye tracker (Senso-Motoric Instruments)
2014 [34]	Subjects were required to look to a small fixation cross for 20 seconds on the center of a screen.	CG and PwAD showed significantly differences of microsaccade direction.	AD: 18 MCI: 15 CG age-matched: 21 Apparatus: Eye See Cam
2013 [35]	Visual targets were presented to subjects in a dim room. Prosaccade and antisaccade trials.	The antisaccade taks performance serves as a measure of executive function on PwAD.	AD: 28 MCI: 36 CG elderly: 118 Apparatus: Dual Purkinje Image Tracker. Heads stabilized on a chinrest.
2013 [36]	Pro-saccade and anti-saccade tasks. Gap and overlap paradigms.	PwAD have an excessive proportion of uncorrected errors in the antisaccade test.	AD: 18 Parkinson disease: 25 CG-young: 17 CG elderly: 18. Apparatus: Head mounted device ExpressEye eyetracker.
2013 [37]	Horizontal and vertical saccades. Gap and overlap paradigms on a black computer screen.	A link between MMSE and saccade latency.	AD: 25 Amnestic MCI: 18 CG elderly: 30 Apparatus: Head mounted Eyeseecam

CG: Control Group; MCI: Mild Cognitive Impairment; MMSE: Mini Mental State Examination.

Many papers validating visual biomarker approaches

Across a range of tasks:

- Passage reading
- Images
- Videos



User interviews

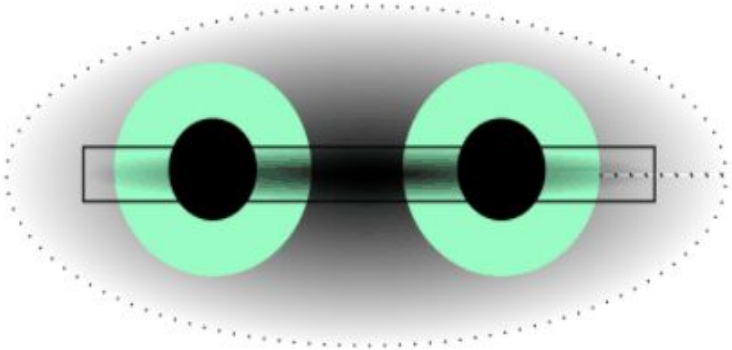
Courtney's Grandmother

- iPad games (Los Vegas, Word Chumps)
- Stimulating to the brain
- VR ➔ Motion sickness, uncomfortable
- Memories and photographs are significant

Wilmer, 75

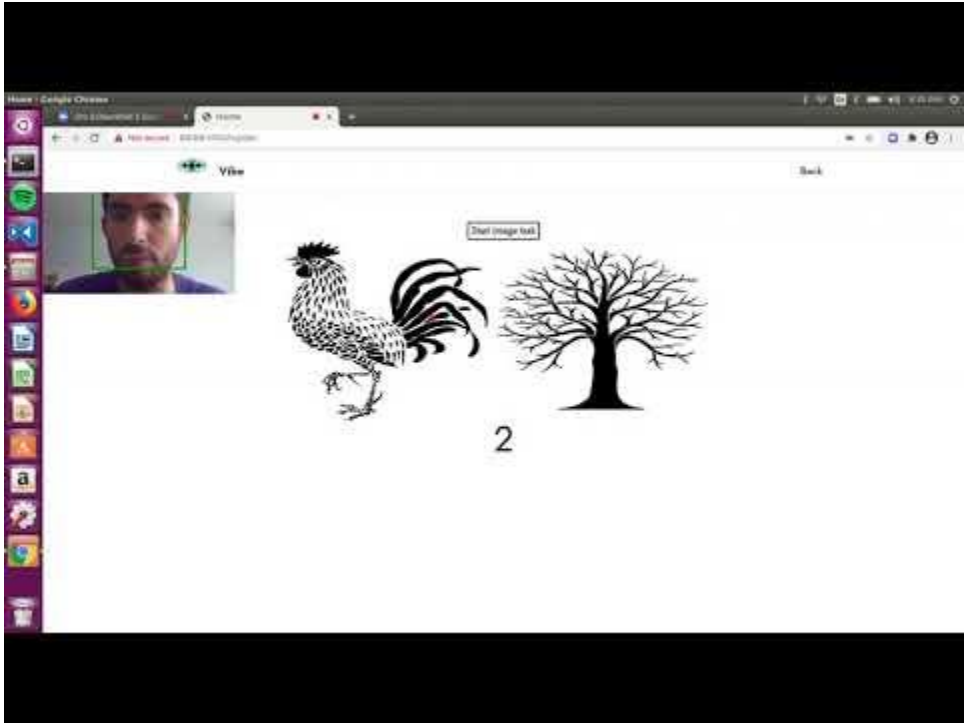
- Uses a lot less technology but plays Word Chumps
- Not up to date of VR world
- Avoids using over complicated devices
- Real pictures are a lot more important compared to photos on her phone

We present to you...



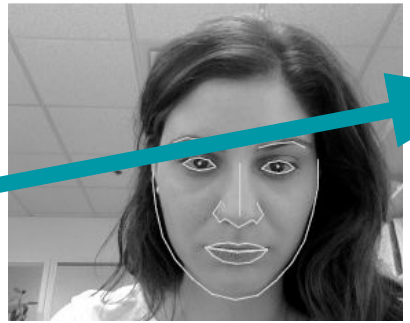
Vibe

Check me out @ https://github.com/nostalgia-cnt/vibe


Vike
Back
Start image task
2

Design considerations: trade-offs

Eyegazer.js
Oculumatic
Eyeware
TOBII
Custom OpenCV pipeline



Used in many applications

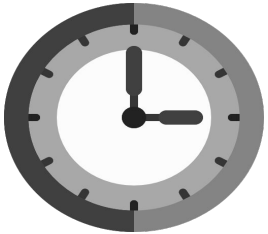
- Can distribute easily and broadly in research studies.
- Removes hurdle to reach proper demographics.
- Helps to scale patient care; addresses neurologist shortage.

Eyegazer.js chosen due to speed and accuracy on most consumerized devices (e.g. laptops). ***All others require custom software/hardware setups and are less scalable.***

Advantages: of approach

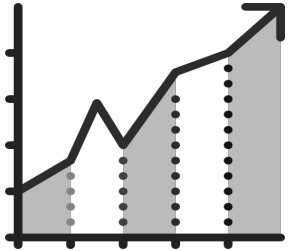
Low cost

<$10/screen



< 5 minutes

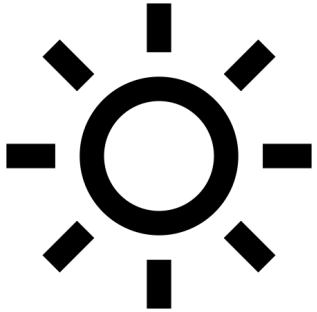
any device



Accurate

70-80%

Limitations: potential confounds



Brightness

Dark settings can reduce accuracy.

Distance

Far-field face detection can reduce accuracy.

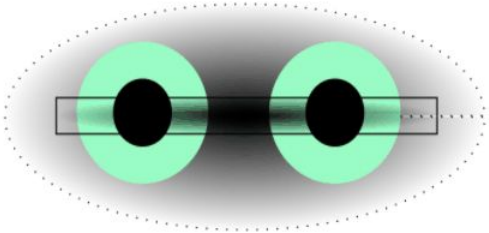
Aging

Rx time and oculomotion changes with age.

Future Work

Online Web app - Digitalocean (python flask)

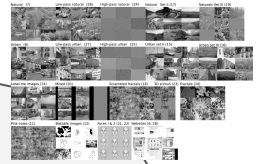
Publish a large open source vision biomarker datasets for eye tracking in AD



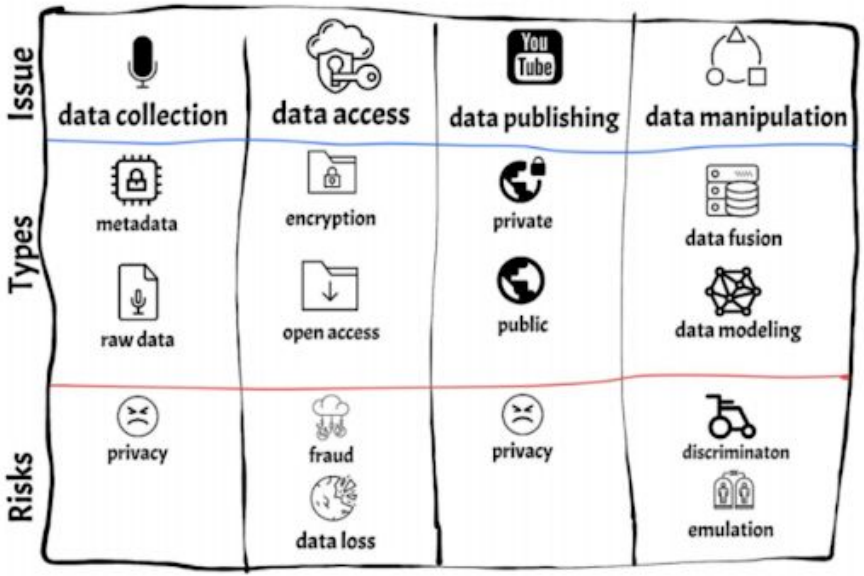
VR/AR and drug effects pre/post therapy.

Feature pipeline create new vision biomarker pipelines

New survey designs / optimize the protocol



Ethical Considerations



How we fit into the CNT mission?

The CNT's mission is to develop innovative neural devices and methods for directing **engineered neuroplasticity in the brain** and spinal cord, which will improve sensory and motor function for people with spinal cord injury, stroke and other neurological disorders. Engineered neuroplasticity is a new form of rehabilitation that uses engineered devices to restore lost or **injured connections in the brain**, spinal cord and other areas of the nervous system.

- **Assisting** with debilitating neurological conditions (Alzheimer's)
- **Benefitting** and improving quality of life of patients
- **Measuring** engineered neuroplasticity for those affected by memory disorders

Contact Us

Jim Schwoebel

jim@schwoebel.me

www.linkedin.com/in/jimschwoebel/

Jayant Arora

jayant23arora@gmail.com

www.linkedin.com/in/jayant-arora-0709541b7

Pamel Kang

pamelk@uw.edu

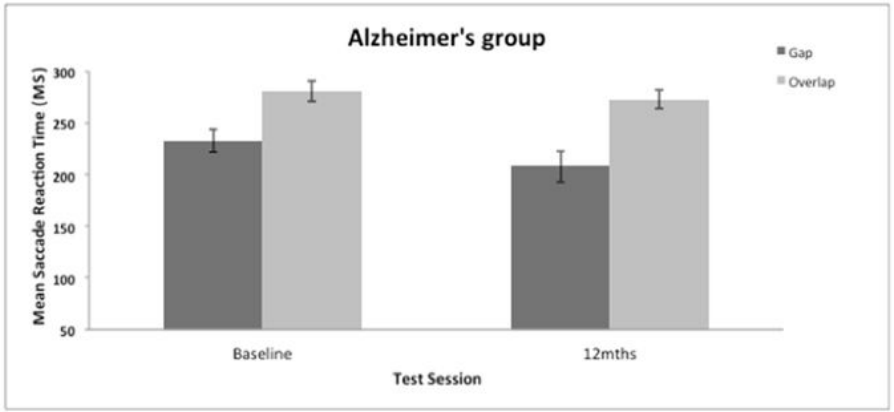
www.linkedin.com/in/pamelkang/

References

- Alzheimer’s facts and figures.
- Open source datasets for eye tracking (Nature).
- Eye tracking review paper for Alzheimer’s disease.
- Eyegazer.js repository.
- MMSE exam / interview.
- Voice ethics framework through Neuroethics blog.
- Vibe framework on GitHub.
- The disengagement of visual attention in Alzheimer's disease: a longitudinal eye-tracking study.
- Digital biomarkers for AD detection (Nature).

Appendix Slides

A



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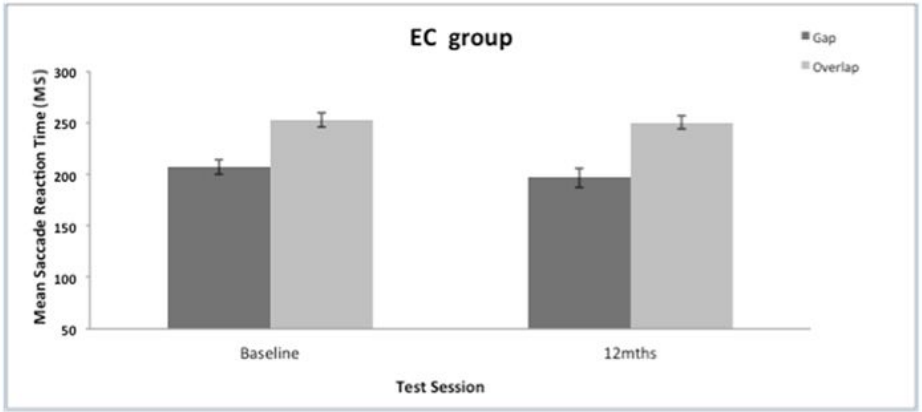
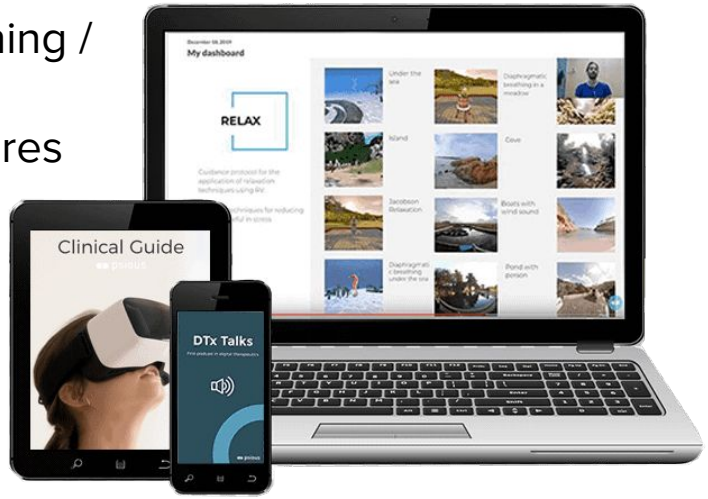
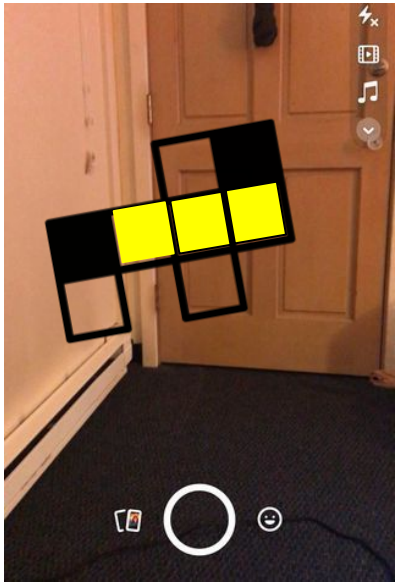


AD were slower to generate a saccadic eye movement towards the target in comparison to the control group (mean = 226 ms, *SE* = 4.97); AD group {mean = 249 ms, *SE* = 7.4; [$F_{(1, 35)} = 6.43$, $p = 0.016$]}

Future Work:
Personalized & Immersive VR/AR Therapy

- Personal VR-enabled messages
- Collection of photographs
- Memory games for brain training / enhancement
- Crossword puzzles with pictures





Tasks chosen / plots

Screenshot them in here

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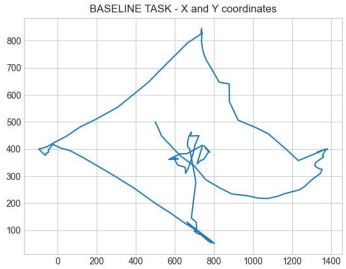
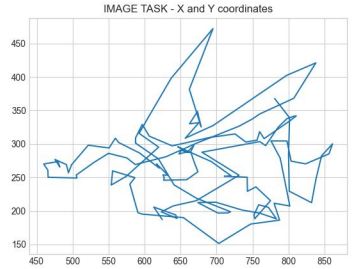
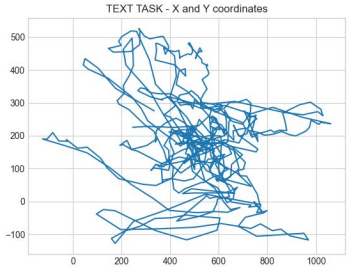
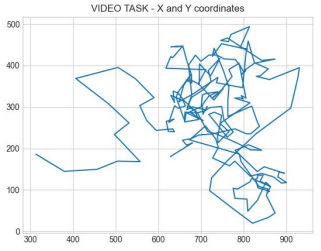
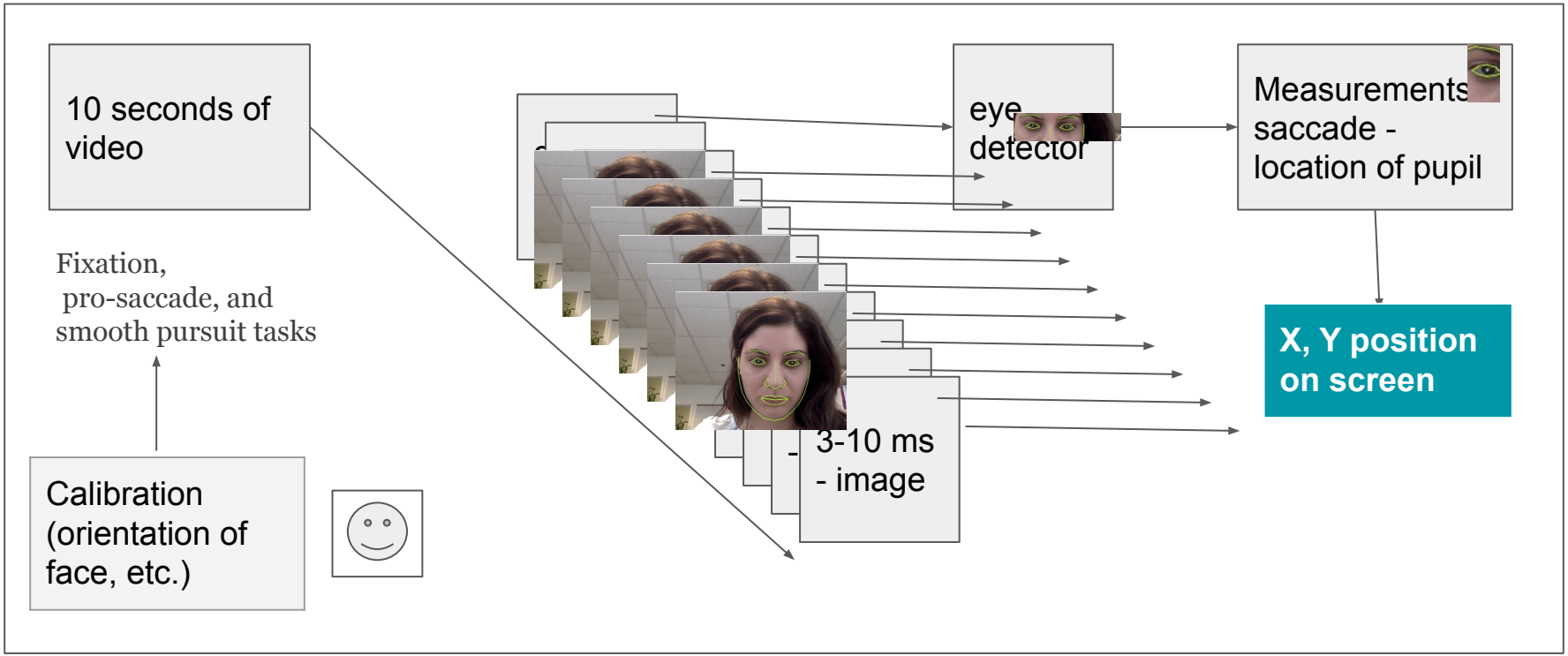








How it works


10 seconds of video
Fixation, pro-saccade, and smooth pursuit tasks
Calibration (orientation of face, etc.)
eye detector
Measurements saccade - location of pupil
X, Y position on screen
3-10 ms - image