Eyetracking

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Basic research methods

9/01/2020

Acknowledgement: Some of these slides were based on or inspired by slides for the previous editions of the same class by dr. Garret O'Connell and dr. Luke Tudge.

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LMatyjek

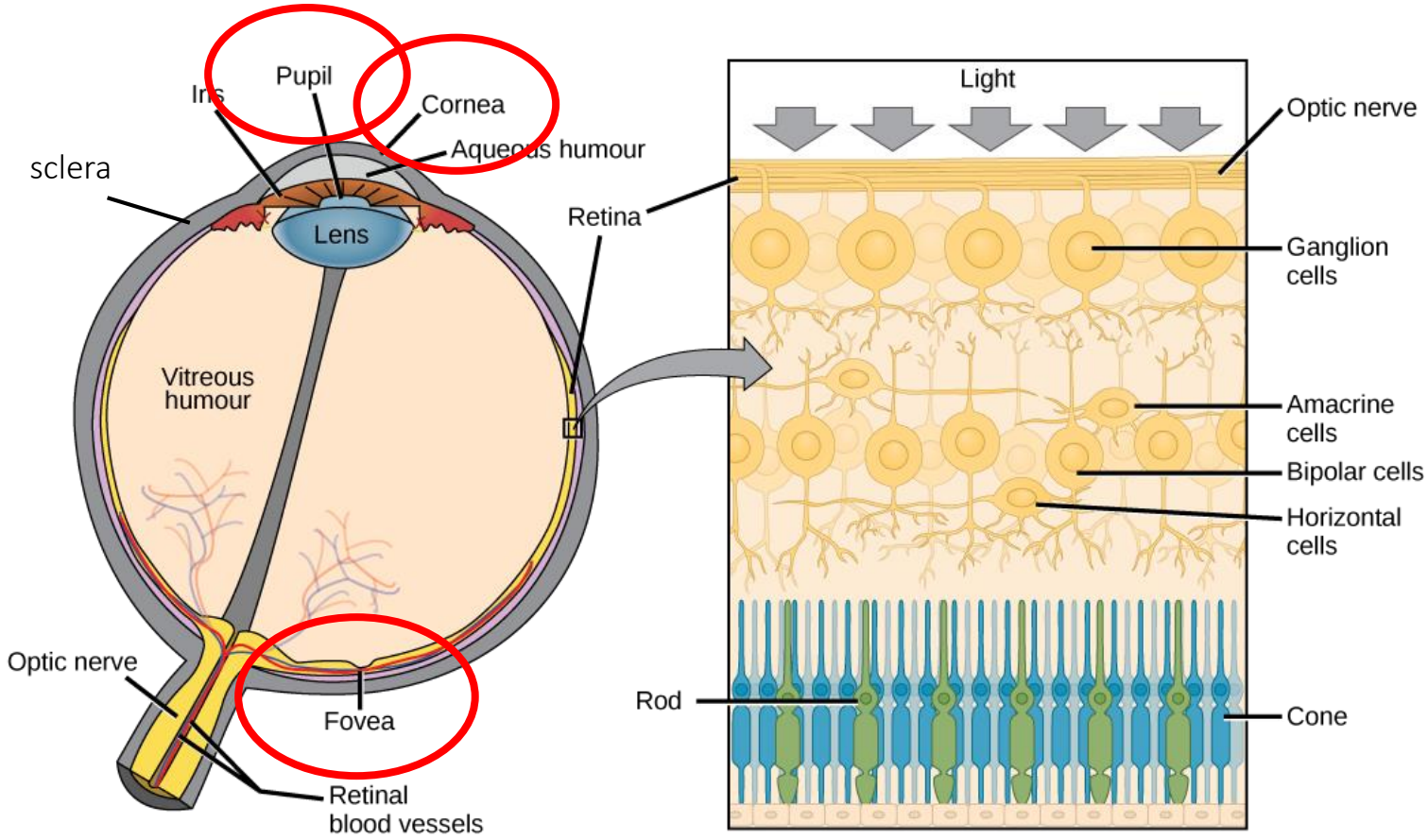
Introduction to eye tracking

Anatomy, history, technology, use, types and set-up

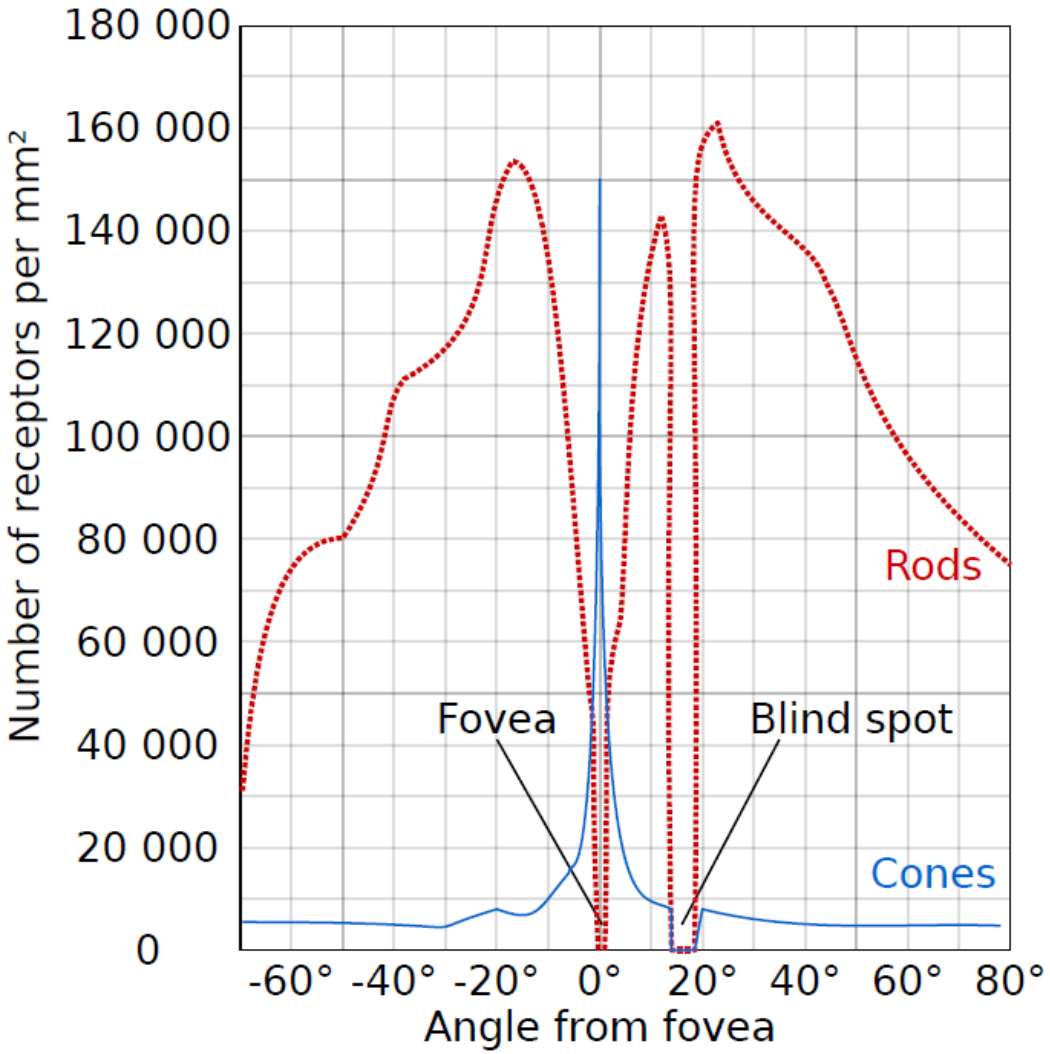
The Eye

- Why is the eye interesting for the Mind & Brain researchers?
  - Relationship between mental processes and the eyes' movements
  - Thoughts, attention, feelings, planning, etc.
  - Not only for vision researchers

Anatomy


Pupil
Iris
Cornea
Aqueous humour
sclera
Lens
Retina
Vitreous humour
Optic nerve
Fovea
Retinal blood vessels
Light
Optic nerve
Ganglion cells
Amacrine cells
Bipolar cells
Horizontal cells
Rod
Cone

Cones & rods

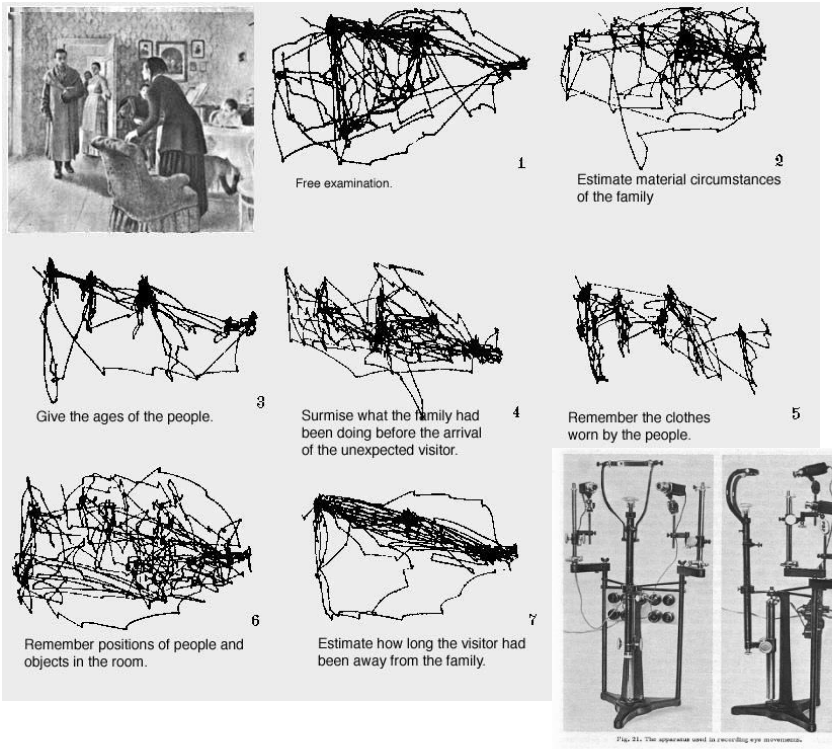


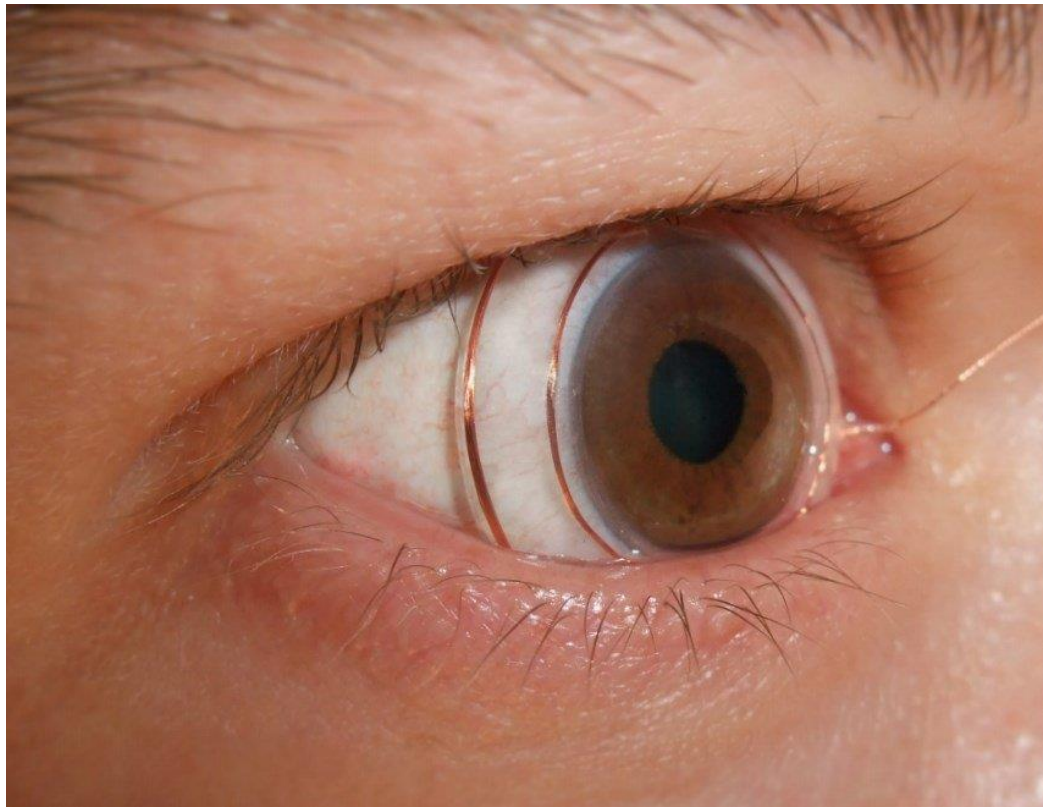
- **Cones**:
  - Less sensitive to light
  - Of 3 types:
    - S – blue
    - M – green
    - L – red
  - Faster than rods
  - Sharp vision
- **Rods**
  - More sensitive to low intensity of light (night vision) and movement
  - Specific for one colour (blue-green)
  - Slower than cones

https://medium.com/@eyesee/eye-tracking-through-history-b2e5c7029443

Eye tracking: history

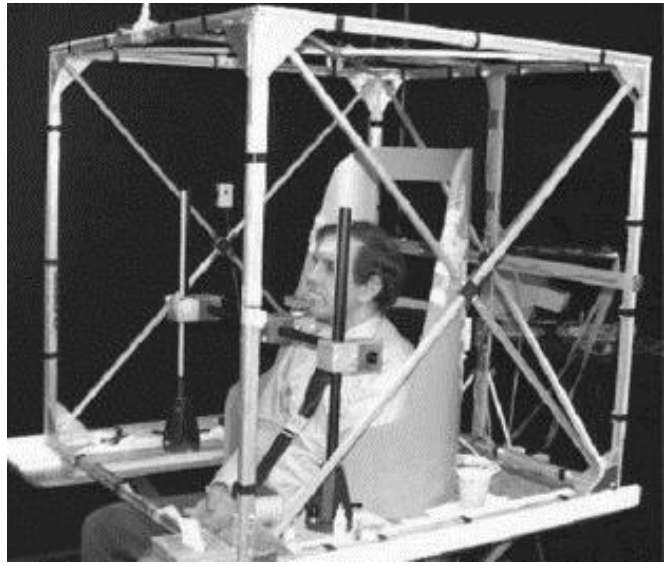
- **Javal,** 1879: reading („naked eye method")
- **Huey,** 1908: first device
- **Yarbus,** 50s & 60s: saccades and fixations depend on the task and interests
- **Hunziker,** 1970: problem solving – tracking eyes through glass
- 70s & 80s: rapid progress
- 90s: marketing

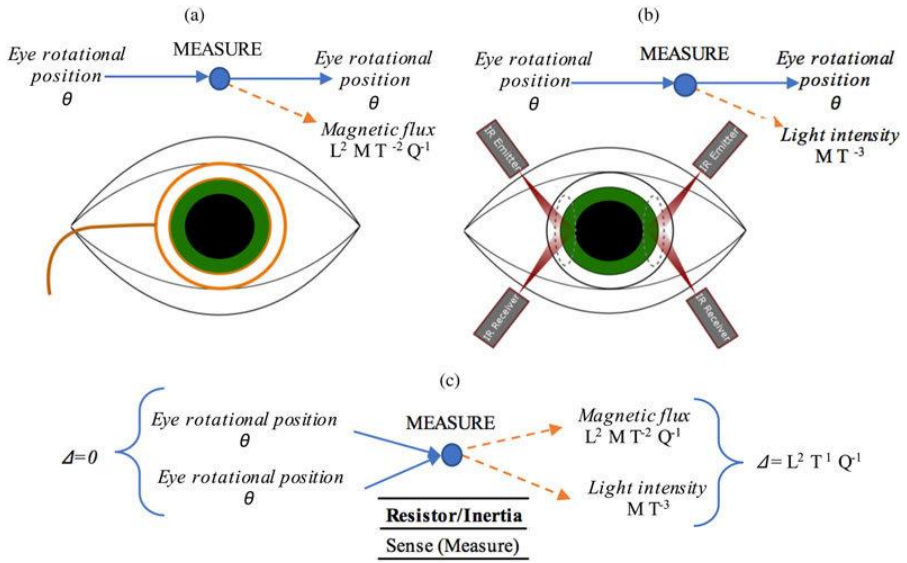




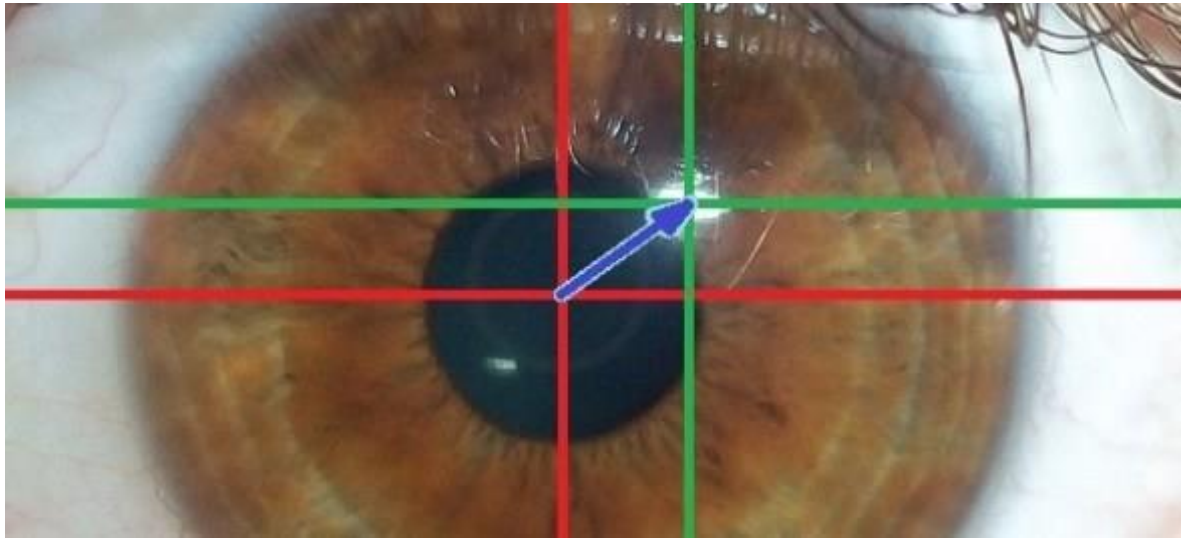
Invasive eye tracking:

scleral search coil

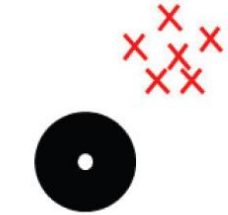




Optical tracking



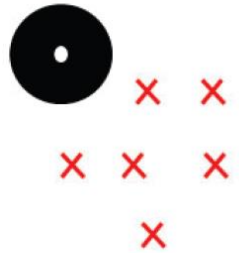
- Near-infrared technology & high-resolution camera
- Pupil
- Corneal reflex
- **Pupil Centre Corneal Reflection (PCCR)**
- Sampling rate: 30-2000Hz
- Price range: 100 – 50.000 USD
- Accuracy vs. Precision (calibration)



Good precision, poor accuracy

Good accuracy, poor precision

Good accuracy, good precision



Poor accuracy, poor precision

Set-up

Fixed head

Best precision, bulky

Titz, Scholz, & Sedlmeier, 2018

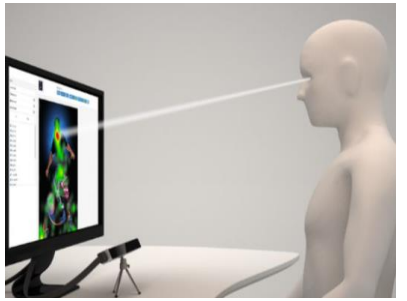
Head mounted

Open environment, bulky

sr-research.com

Remote

Ok precision, not bulky



theeyetribe.com

Glasses

Poor precision, open environment

tobiipro.com

Eye tracking - applications

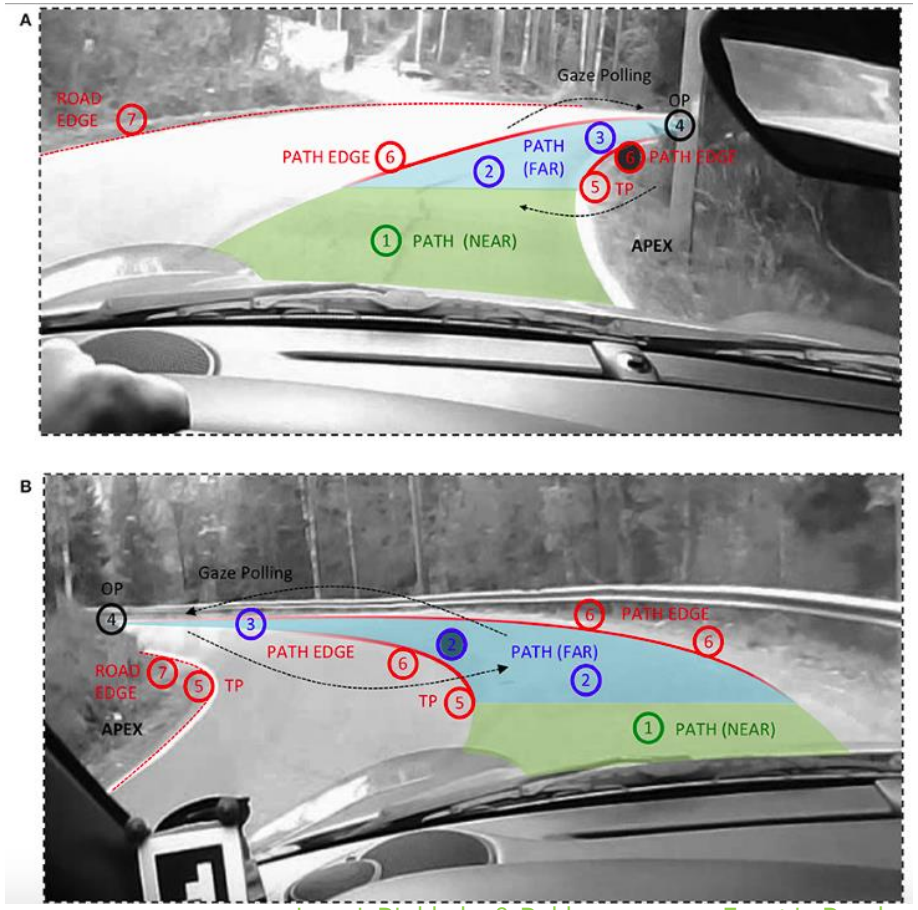
What can we measure?

Eye activity:

- where we look
- what we look at
- how much time we spend looking at it
- how our pupils respond
- when we blink

Use outside of research:

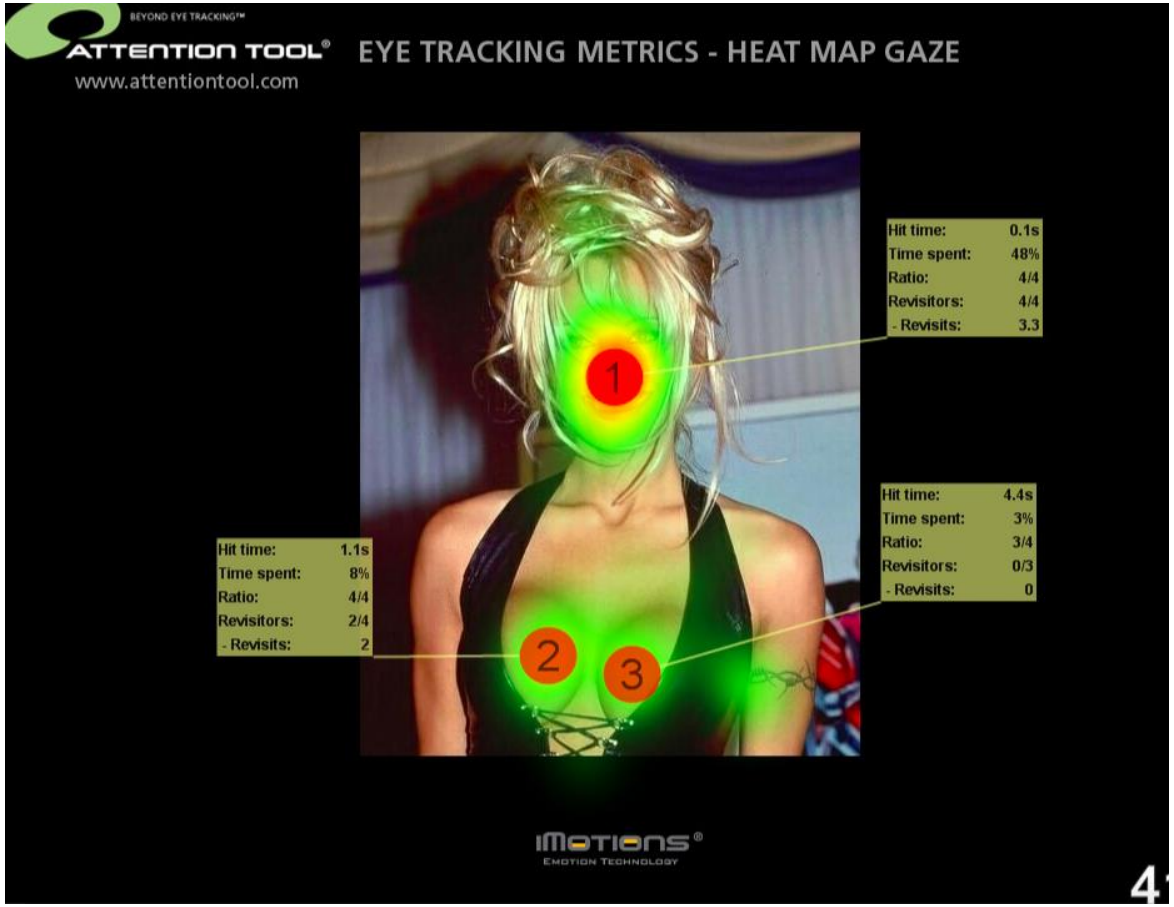
- as a **means of communication** for disabled people who can use only their eyes for input;
- in **ophthalmology**, for better understanding of eye movements to prevent, diagnose and treat abnormalities;
- **gaming**, as a controller or a way to increase immersive experinece;
- for testing **usability** of websites, software, computer games, mobile devices, etc.
- **marketing**



Lappi, Rinkkala, & Pekkanen, 2017, Front in Psych

Expertise

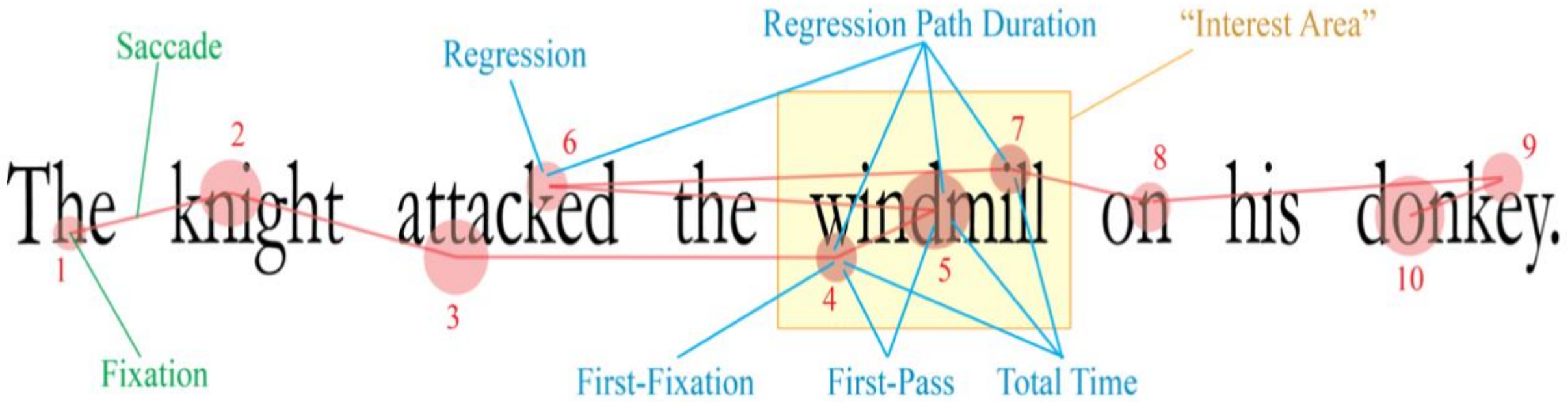
Attention pointer



Marketing

Packaging

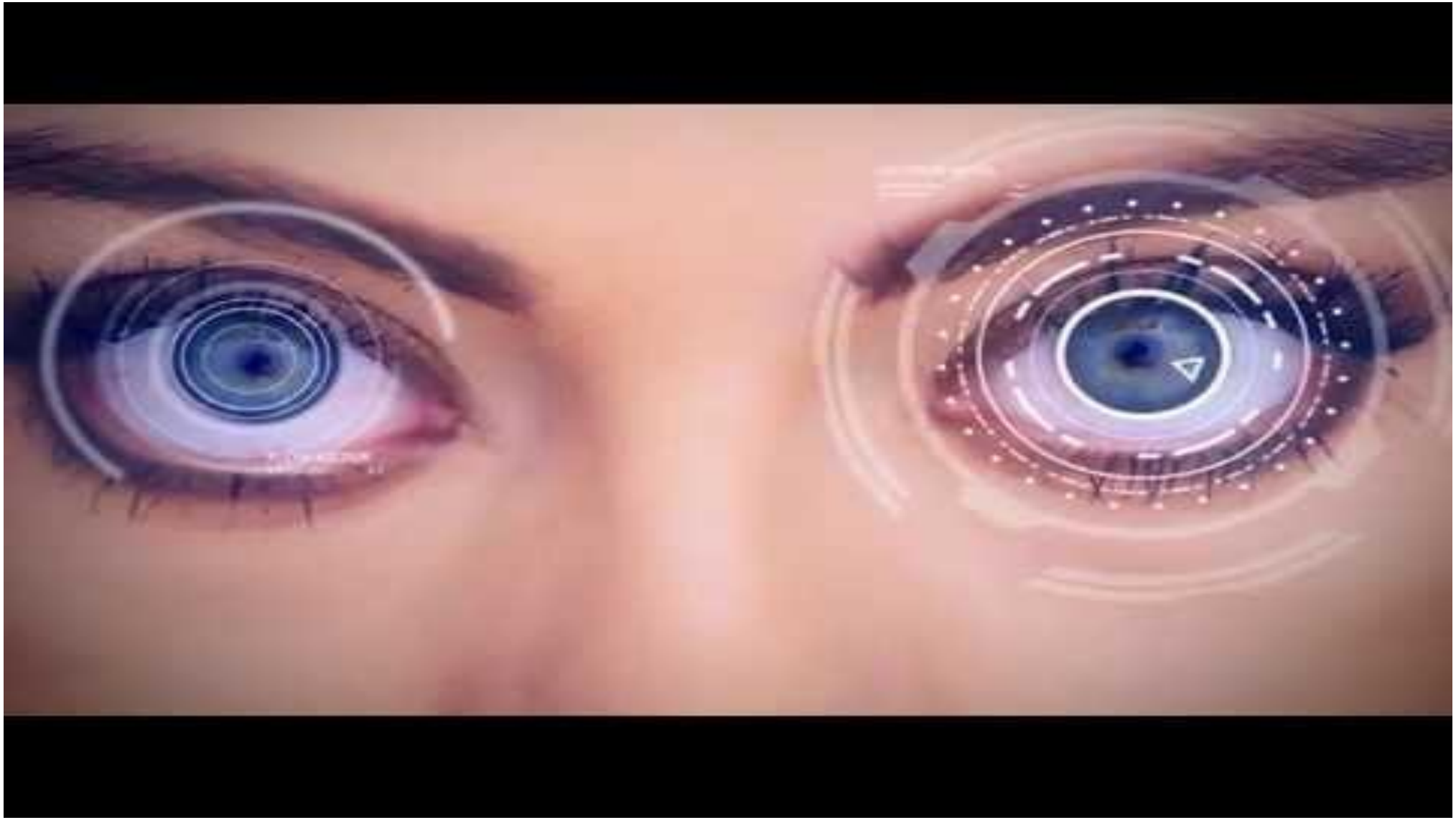
http://consulting.md/



Reading comprehension

Gaming

https://tobii.github.io/UnitySDK/eyetracking-features



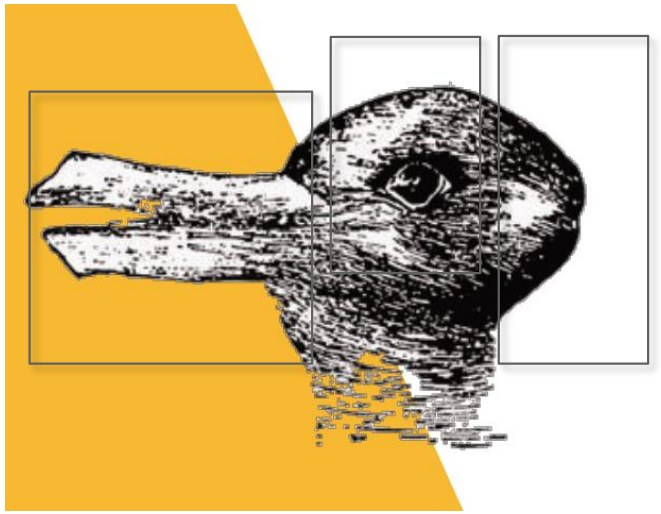
- Eye tracking glasses
- Gaming
- Marketing
- Heat-maps
- Real-life, natural recording
- Means of communication

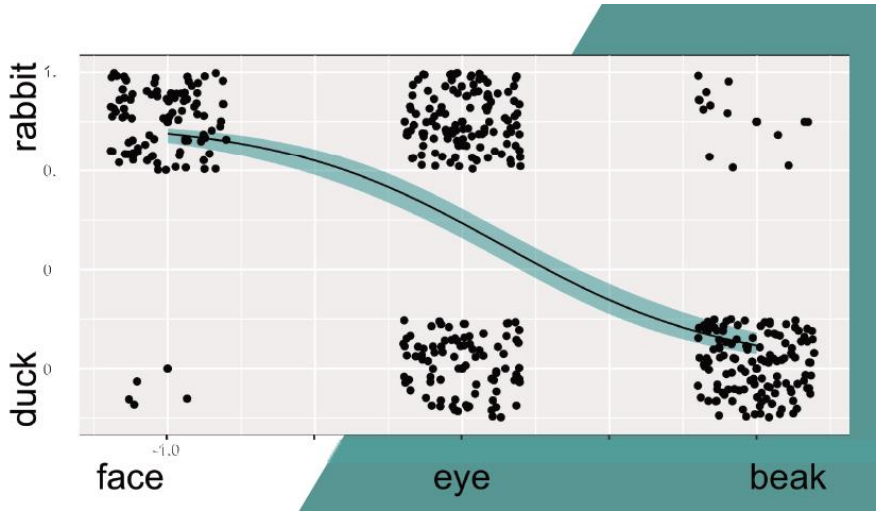
Research

What kind of data can we collect with eyetracking technology?

AOI

- Stimulus location defined by area-of-interest (AOI)
- Choosing the right size is important!
- Consideration: sample rate





Matyjek et al., 2016, unpublished

Fixations

A single „look”

(min ~100 ms)

Fixation dwell

(sum (number) of fixations)

Fixation frequency

(count of the first fixations)

Fixation time

(sum fixations durations)

Dwell:

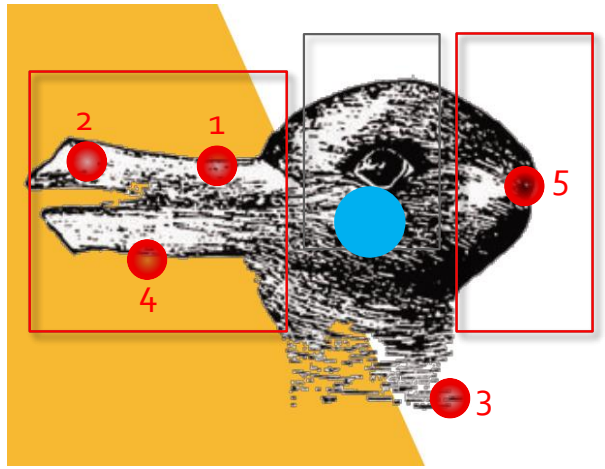
3

Frequency:

2

Duration:

300 ms



Dwell:

1

Frequency:

1

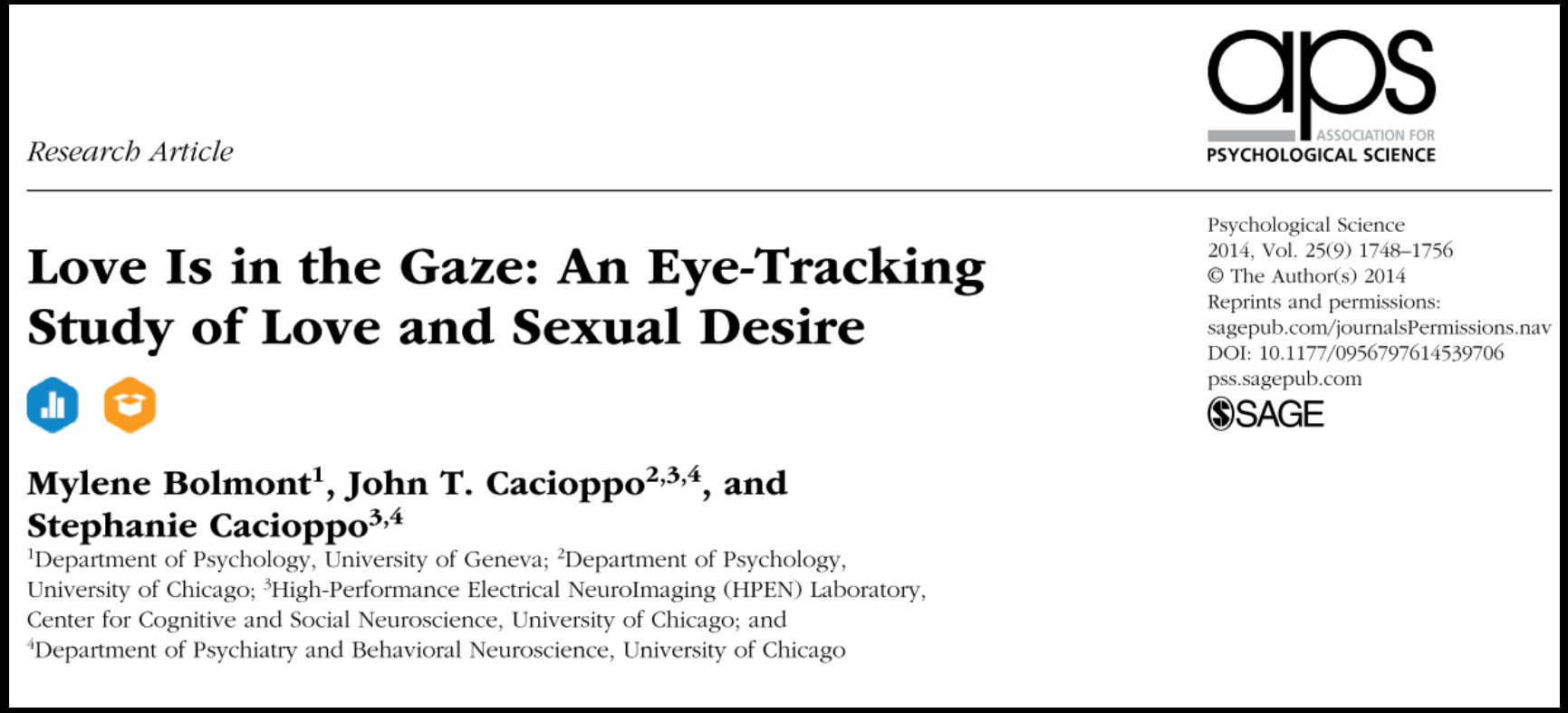
Duration:

100 ms

Heat maps

An AOI-free way of visualising fixation dwell
- fixation density sometimes weighted by duration
- averaged over participants

Bolmont, Cacioppo, & Cacioppo, 2014, Psych Science



Research Article

aps ASSOCIATION FOR PSYCHOLOGICAL SCIENCE

Love Is in the Gaze: An Eye-Tracking Study of Love and Sexual Desire

Psychological Science
2014, Vol. 25(9) 1748–1756

DOI: 10.1177/0956797614539706
pss.sagepub.com
SAGE

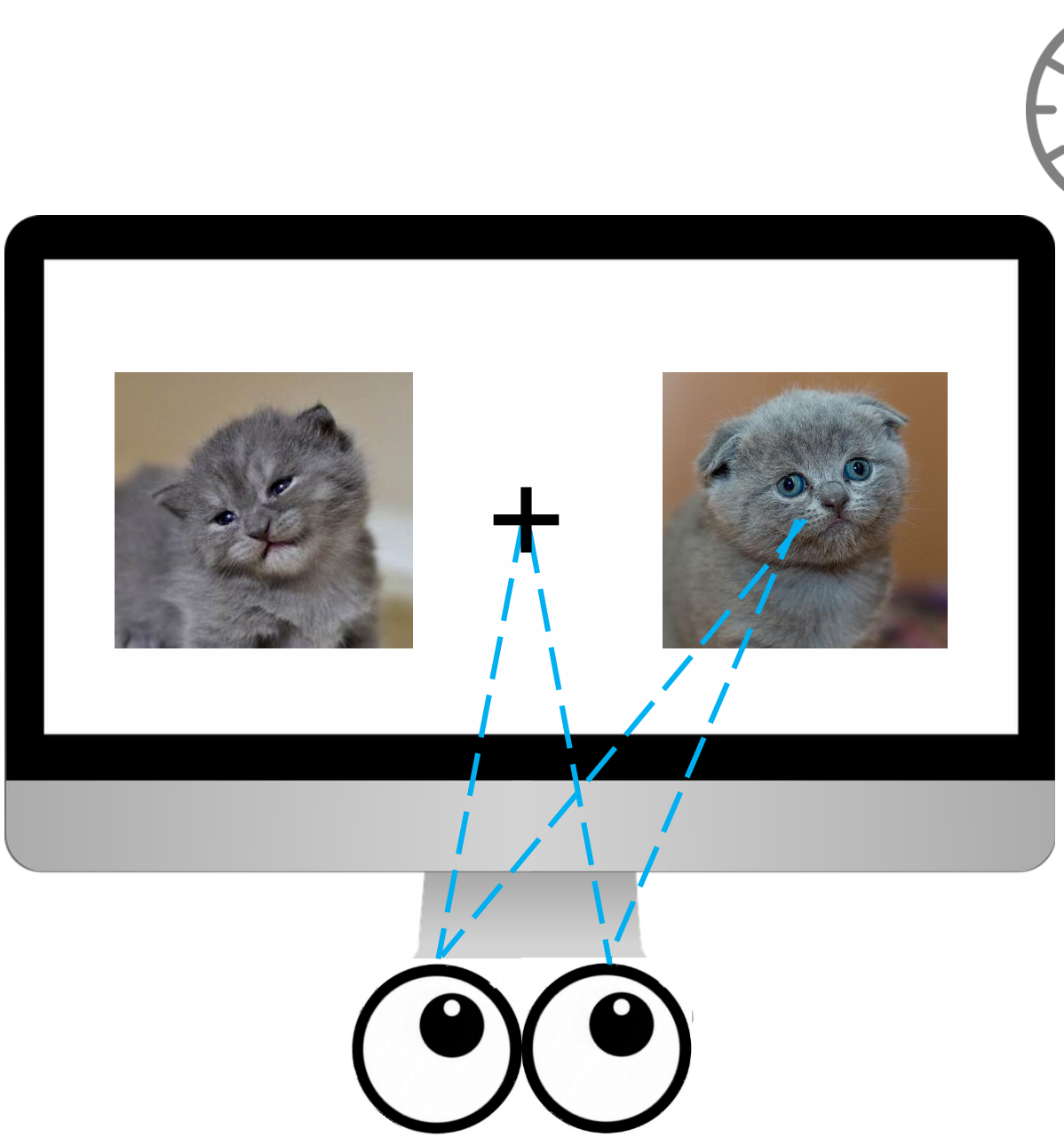
Mylene Bolmont[1], John T. Cacioppo[2,3,4], and Stephanie Cacioppo[3,4]

[1]Department of Psychology, University of Geneva; [2]Department of Psychology, University of Chicago; [3]High-Performance Electrical NeuroImaging (HPEN) Laboratory, Center for Cognitive and Social Neuroscience, University of Chicago; and [4]Department of Psychiatry and Behavioral Neuroscience, University of Chicago

Student presentation

Latency

Time until the first fixation

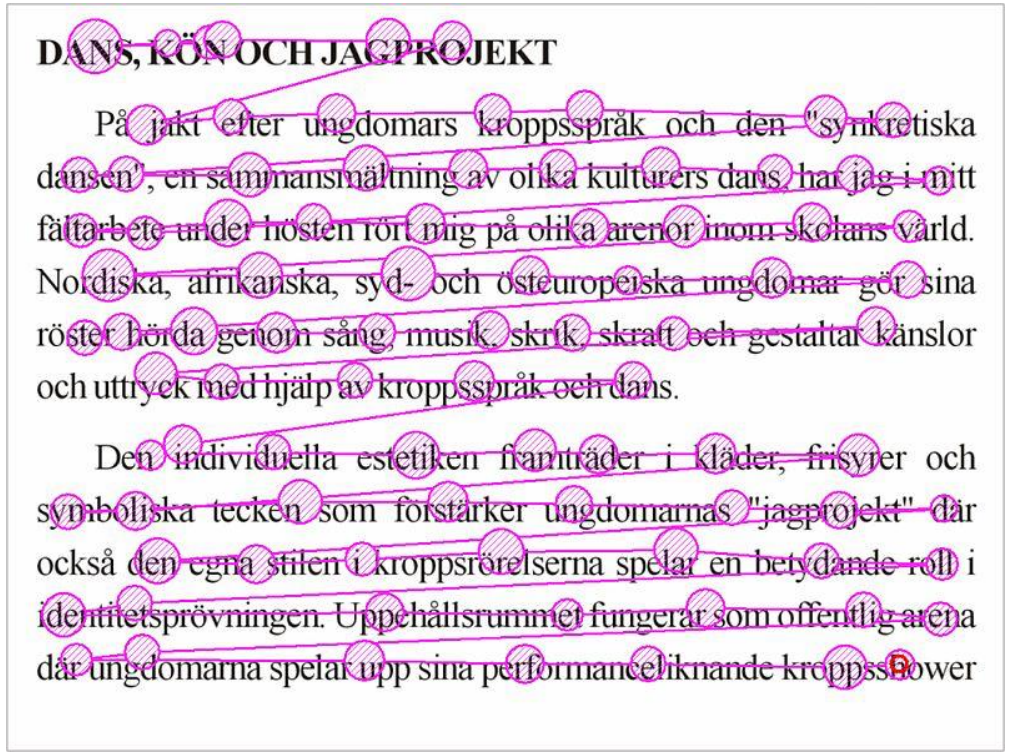


Saccades

Movements between fixations

Include:

- Start and stop position
- Latency
- Duration
- Speed
- Pattern / trajectory

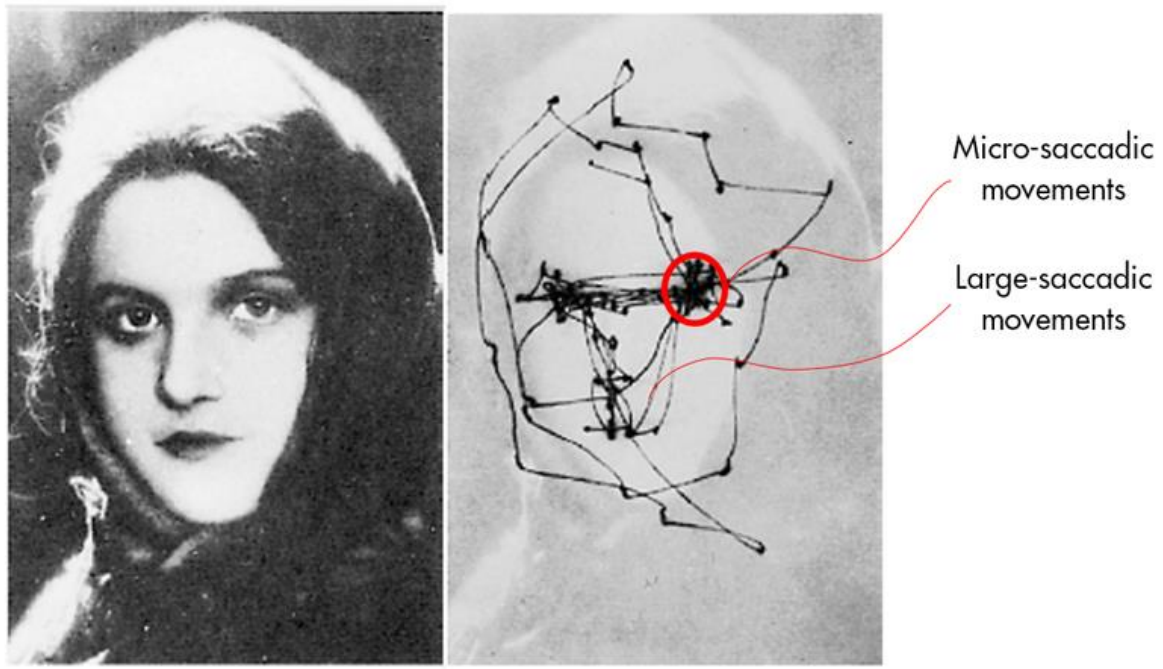


Microsaccades

small, Involuntary, jerk-like movements within a fixation

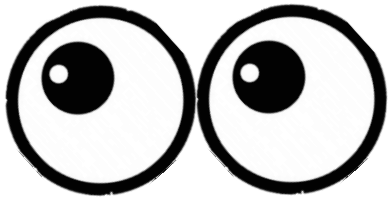
Unclear function:

- Enhancing spatial vision (correcting drifts)?
- Prevent retinal image from fading? - memory
- Conscious perception?
- Modulating neural responses (moving a stationary stimulus in and out of a neuron's receptive field)



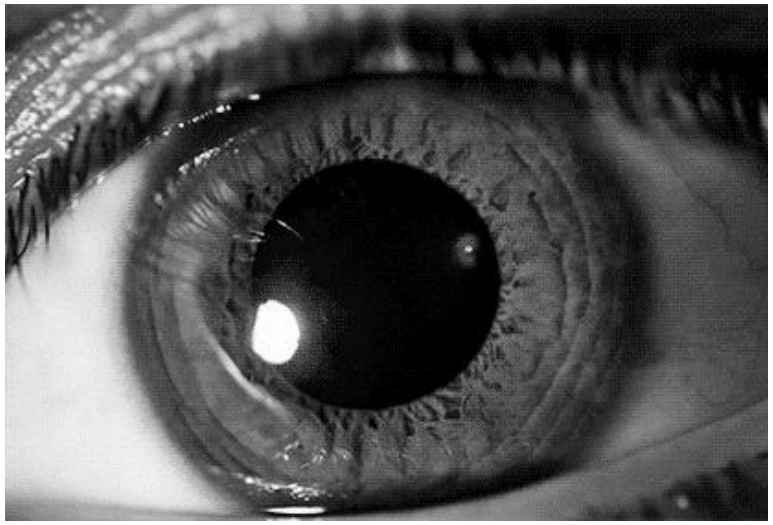
Smooth pursuit

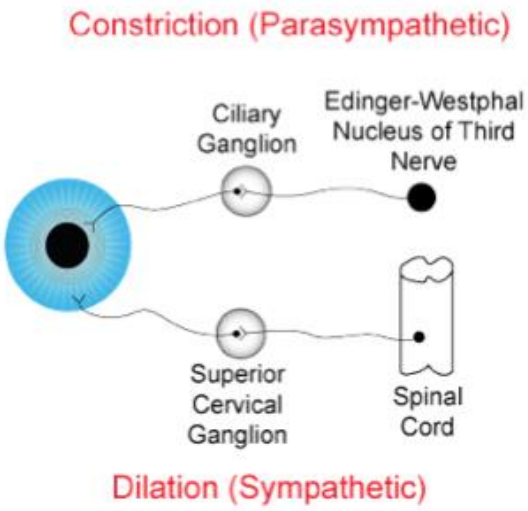
The path of eye gaze following a moving stimulus



Pupillometry

diameter of the pupil, pupillary light reflex (PLR) – in humans ~700 ms





Pupillometry - meaning

- **Medicine**
  - Critical care: pupil size, light reflex, equality of two pupils

- **Psychology** – research
  - Arousal (sexual, emotional) - pupil dilation response (PDR)
  - Cognitive load, PDR
  - Memory load, PDR
  - Long-term memory (encoding, retrieval), PDR
  - Surprise, motivation, emotion, exploration, etc.

But what about **constrictions**?

- Pupillary light reflex (PLR)
- Other low-level equiluminant changes in stimuli (colour, motion) – reorienting pupil constrictions: selective attention?
- Tonic constriction when executing a well-learned task

Ebitz & Moore, 2019, Frontiers in Neurology

Journal of Vision (2013) 13(6):8, 1–9 http://www.journalofvision.org/content/13/6/8 1

Pupil constrictions to photographs of the sun

Paola Binda Department of Psychology, University of Washington, Seattle, WA, USA
Department of Physiological Sciences, Universita' di Pisa, Pisa, Italy

Maria Pereverzeva Department of Psychology, University of Washington, Seattle, WA, USA

Scott O. Murray Department of Psychology, University of Washington, Seattle, WA, USA

Student presentation

Data analysis

Exemplary data

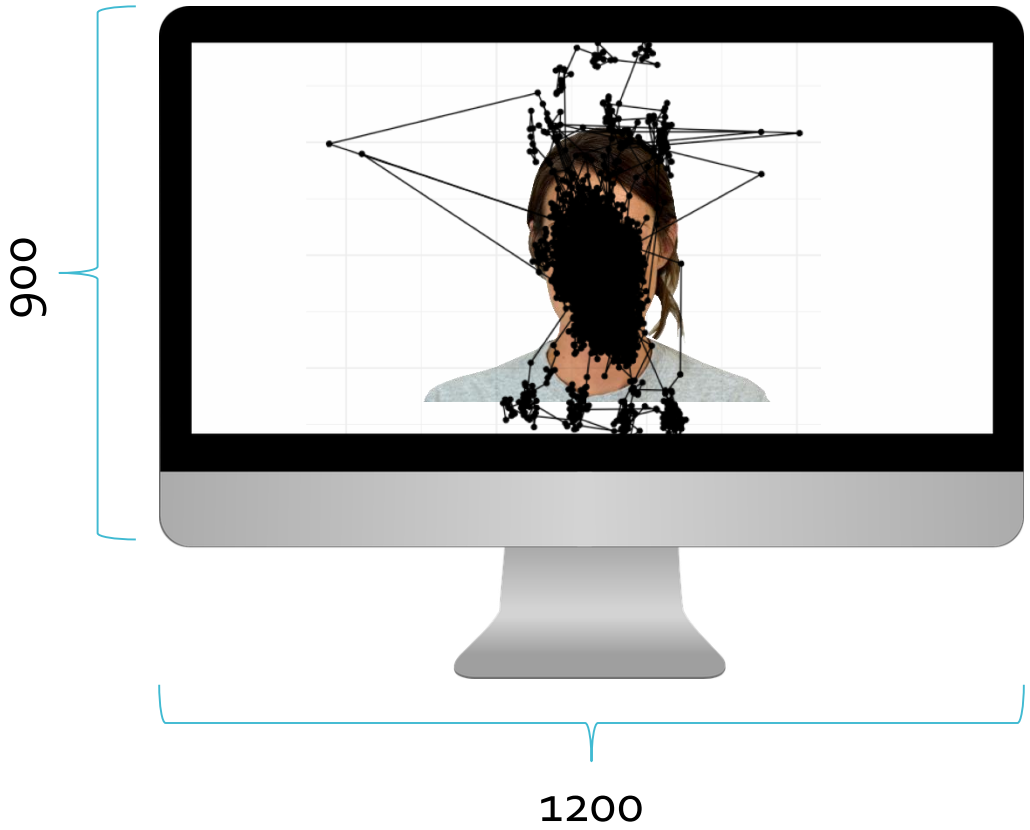
	timestamp	time	rawx	rawy	psize
1	MSG	2019-12-10 13:13:59.933	NA	NA	NA
2	2019-12-10 13:13:59.931	800784123	530.0952	565.9204	19.73470
3	2019-12-10 13:13:59.948	800784140	537.7161	564.1823	19.86985
4	2019-12-10 13:13:59.964	800784156	561.0669	529.8452	19.73450
5	2019-12-10 13:13:59.981	800784173	562.8224	553.5091	20.18605
	:59.997	800784189	557.0399	522.8593	19.33275
	:00.014	800784206	561.5466	575.9089	19.84775
	:00.031	800784223			90
	:00.047	800784239			25
10	2019-12-10 13:14:00.064	800784256			15
11	2019-12-10 13				65
12	2019-12-10 13		532.6516	649.2690	20.04245
13	2019-12-10 13		531.5295	667.4310	20.11490
14	2019-12-10 13		536.2996	635.7606	20.03630
15	2019-12-10 13:14:00.180	800784372	532.0245	664.2655	19.78350
16	2019-12-10 13:14:00.197	800784389	545.0134	677.5048	20.01395
17	2019-12-10 13:14:00.214	800784406	540.5254	671.4240	19.97145

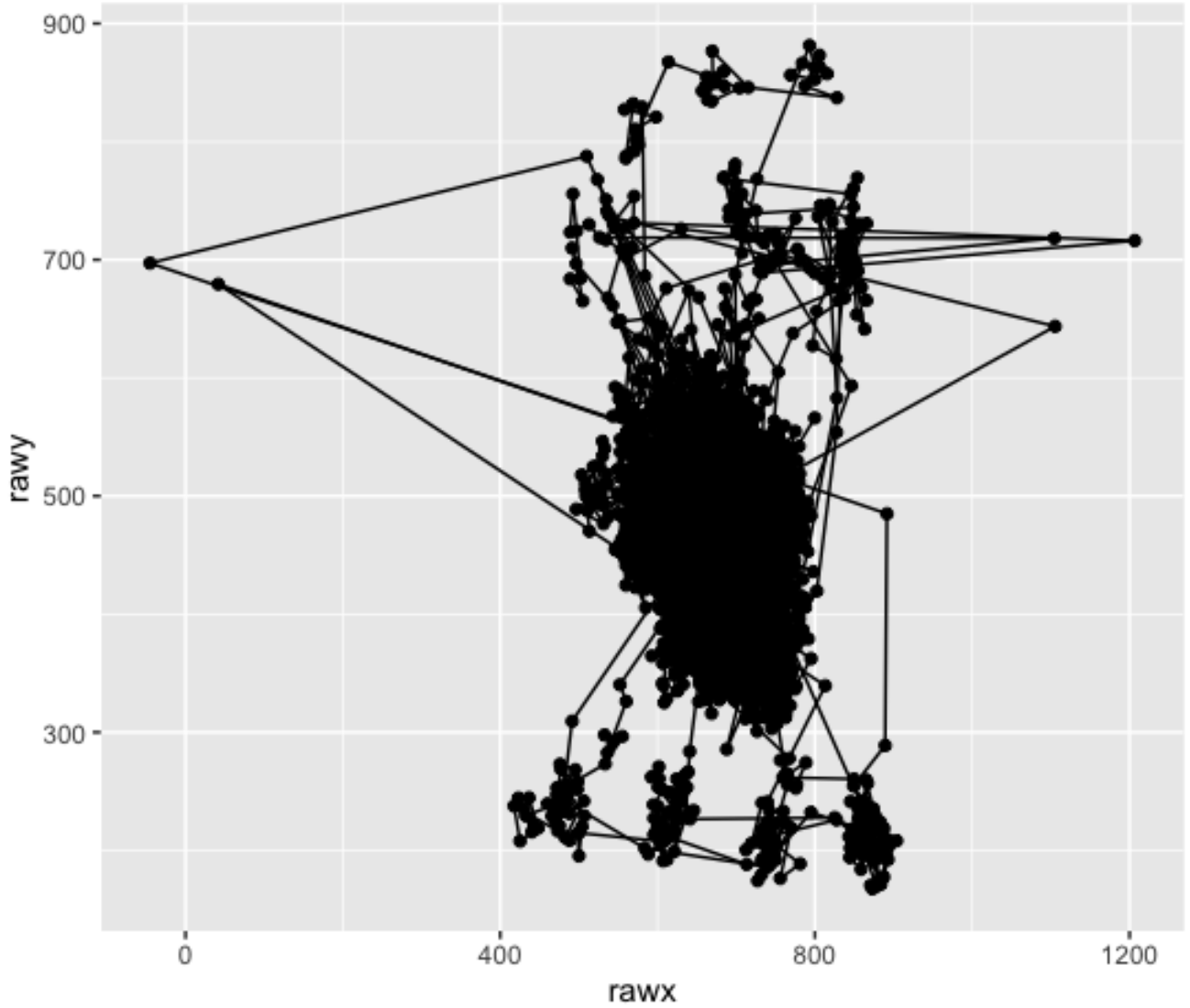
Showing 1 to 19 of 30,587 entries, 5 total columns

When?
timestamp(s)

Where?
coordinates

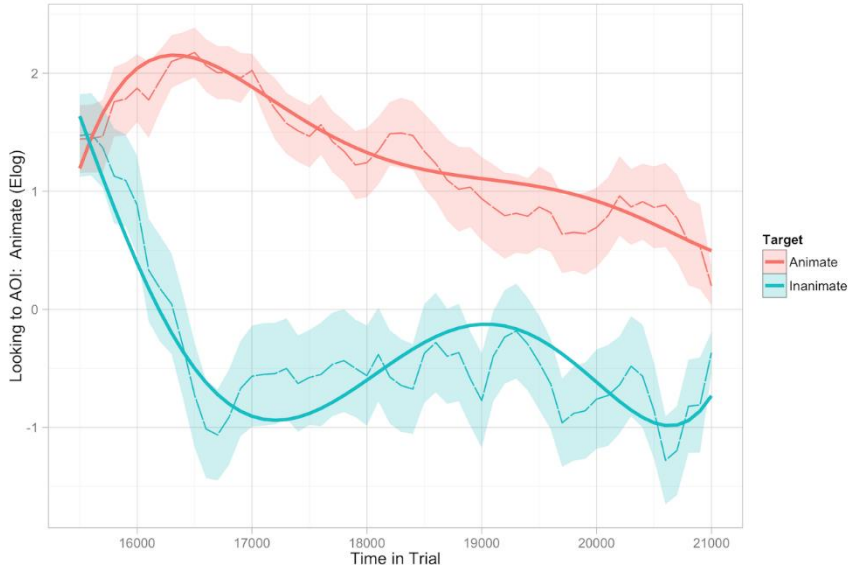
Pupil size


900
1200


900
700
500
300
rawy
0
400
800
1200
rawx

Preprocessing

- Remove or interpolate eye-blinks, bad quality data
- Filtering
- Smoothing data
- Average left and right eye position and pupil diameter
- Event detection e.g. fixations, saccades



http://www.eyetracking-r.com/

Questions / comments?

Tomorrow:

- hands-on data collection with pupillometry – emotional and neutral pictures
- 2 volunteers for eye trackign calibration needed!
- recording pupil sizes from those interested
- wear contact lenses instead of glasses if possible
- don't wear eyeliner, if possible (mascara is ok)

@ magdalena.matyjek@hu-berlin.de LMatyjek