

Eyetracking

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Basic research
methods

20/01/2022

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.

Introduction to eye tracking

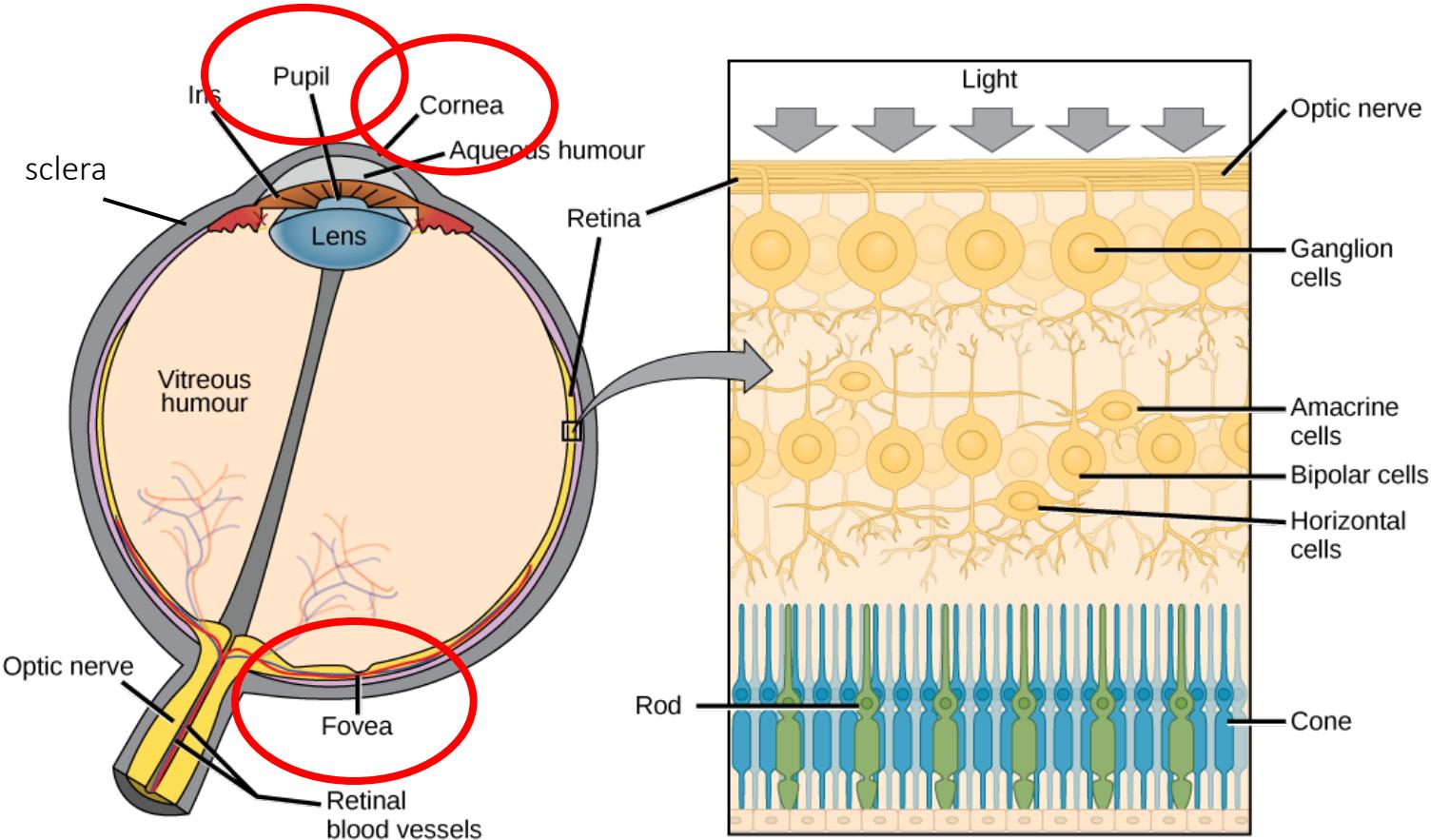
Anatomy, history, technology, use, types and set-up

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

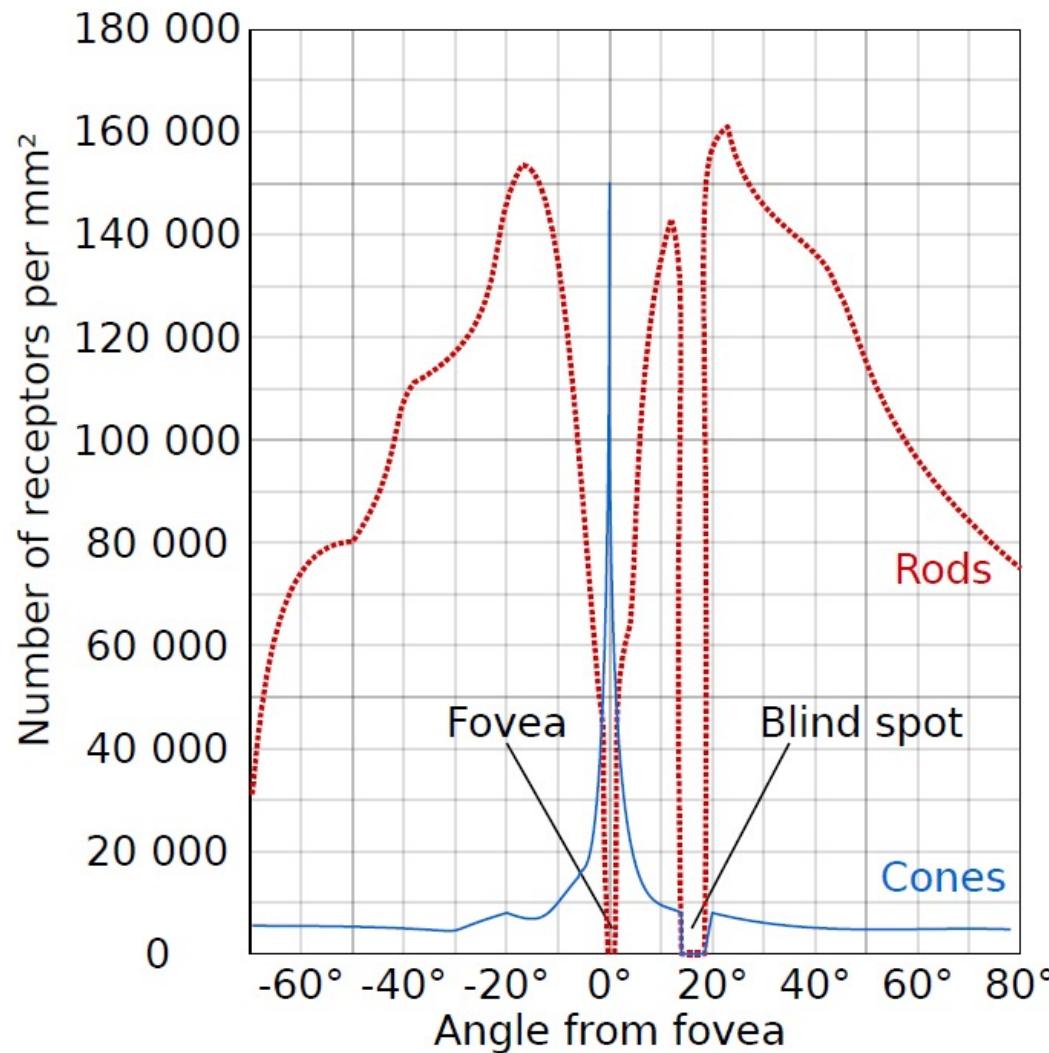


Cones & rods

Rod Stewart



Cone Stewart

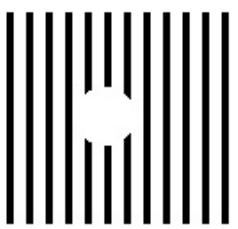


- **Cones:**

- 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



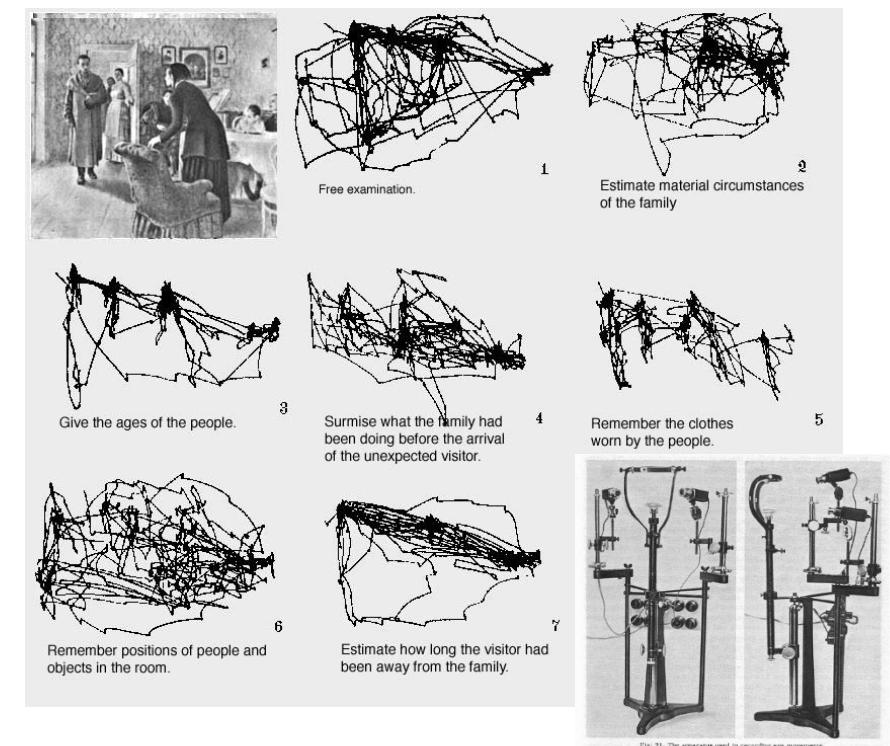
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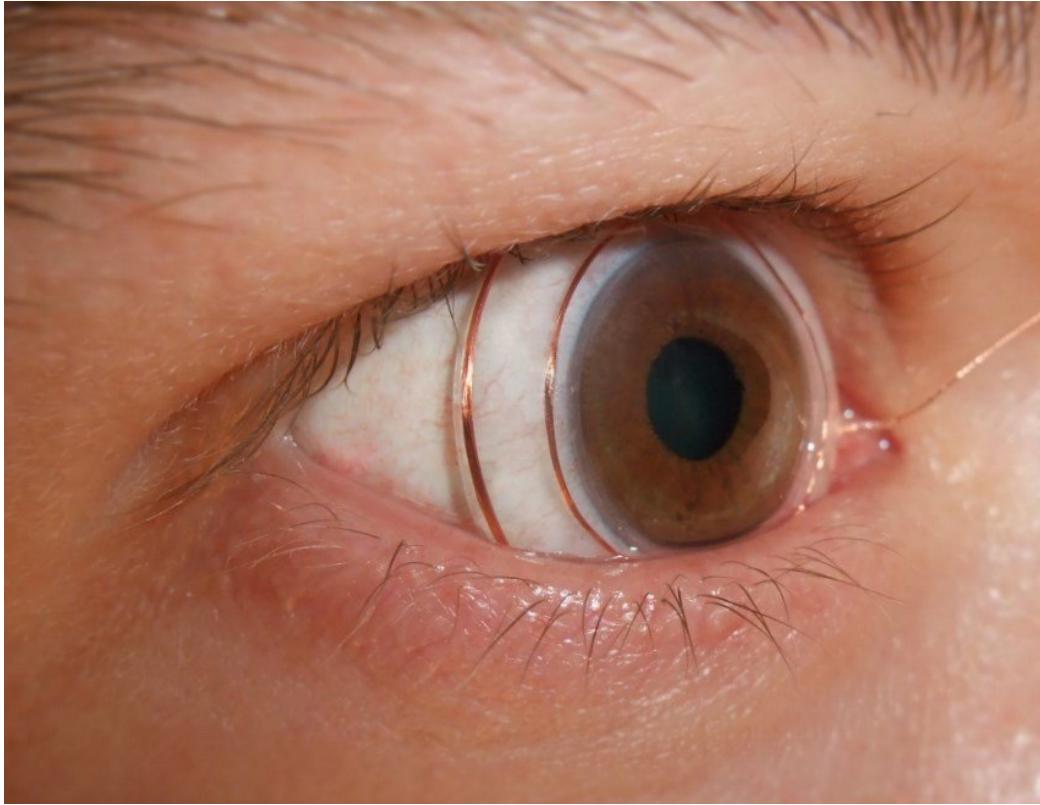
Eye tracking: history



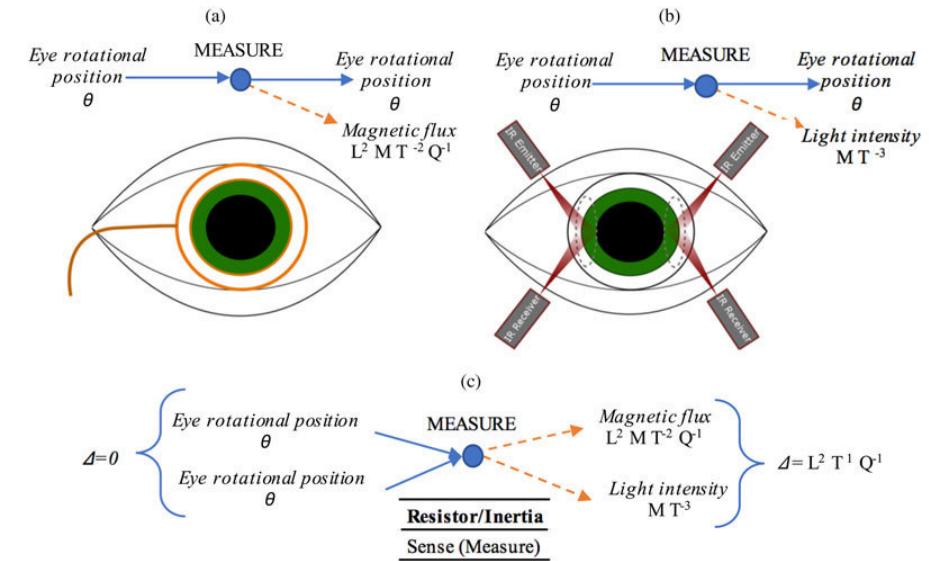
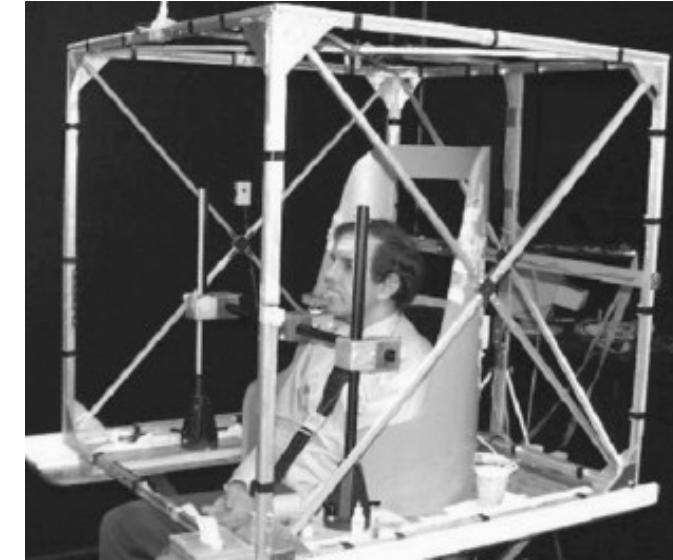
- **Javal, 1879:** reading („naked eye method“)
- **Huey, 1908:** first device
- **Yarbus, 50s & 60s:** saccades and fixations depend on the task and interests
- **Hunziker, 1970:** problem solving – tracking eyes through glass
- 70s & 80s: rapid progress
- 90s: marketing

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



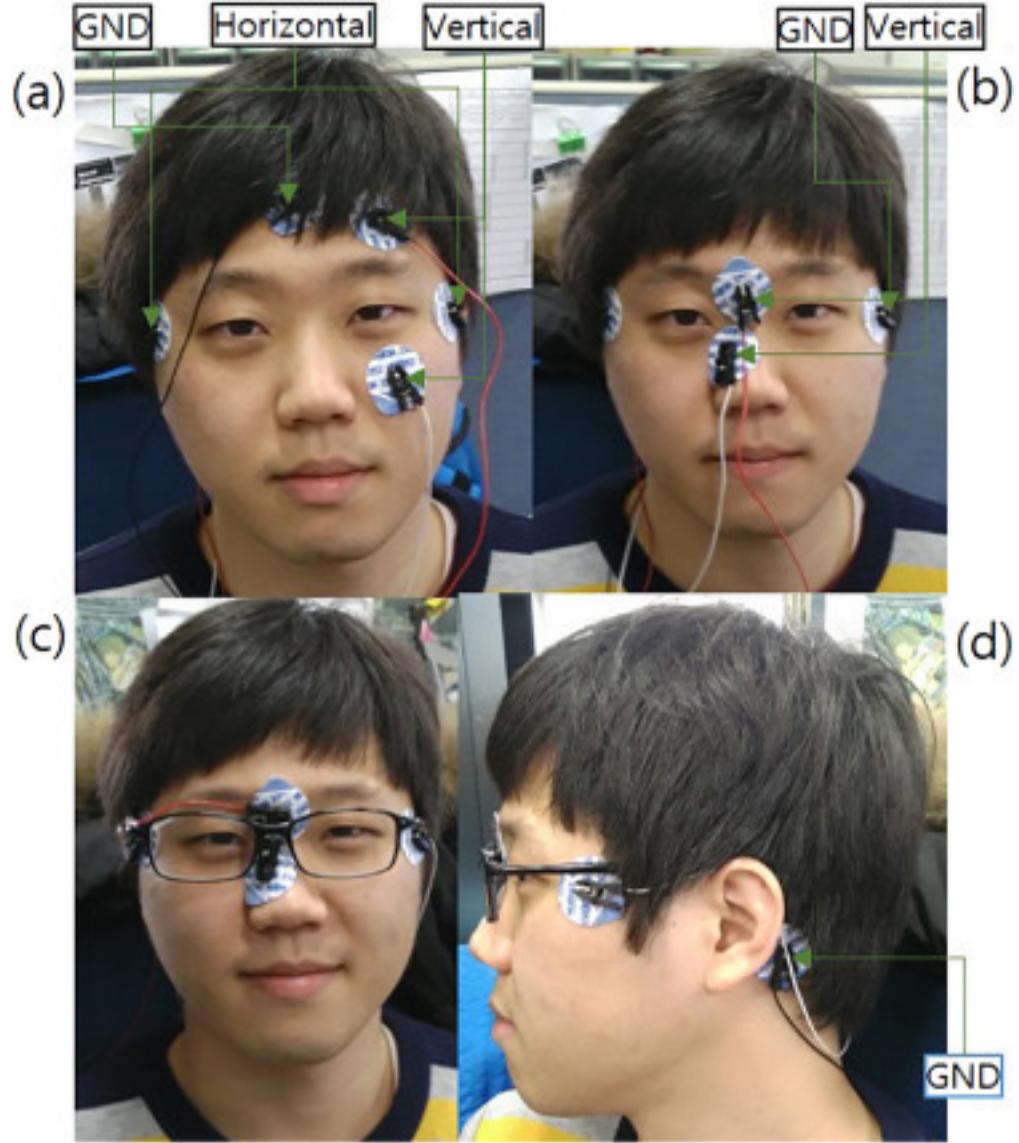


Invasive eye tracking: scleral search coil



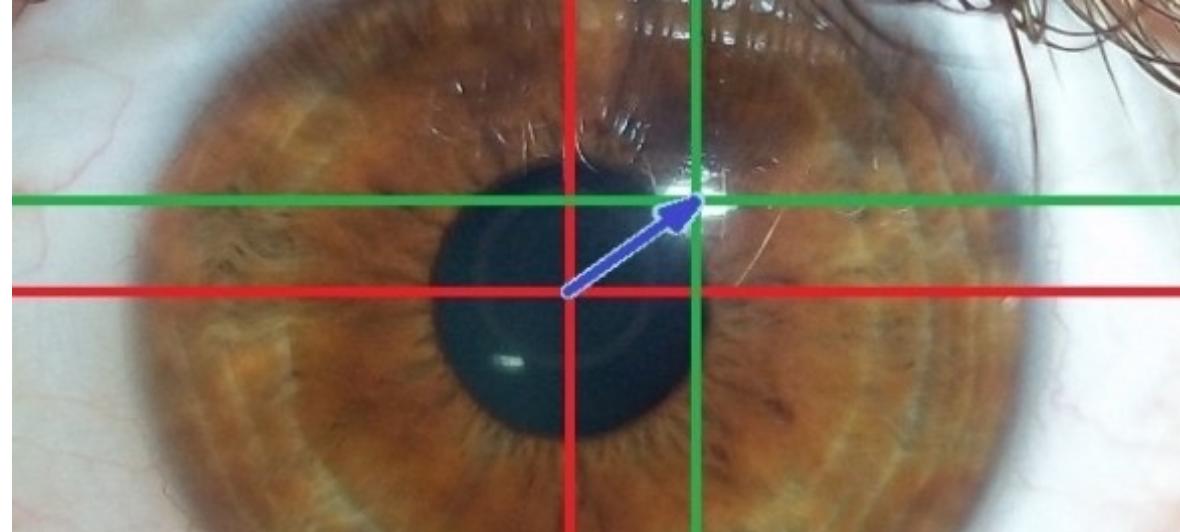
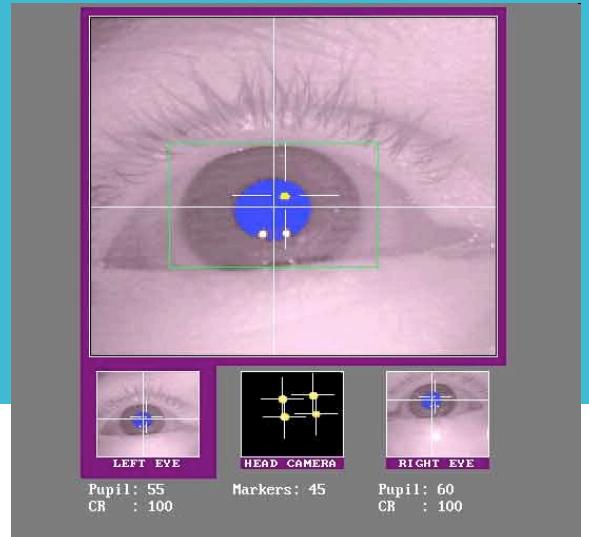
Electro-oculogram (EOG)

Measuring electric potentials
with electrodes around the eyes

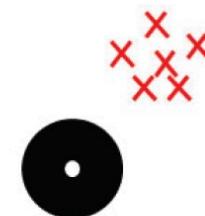


Ryu et al., 2019

Optical tracking



- Near-infrared technology & high-resolution camera
- Pupil
- Corneal reflection
- Pupil Centre Corneal Reflection (PCCR)
- Sampling rate: 30 – 2000Hz
- Price range: 100 – 100,000 USD
- Accuracy vs. Precision (calibration)



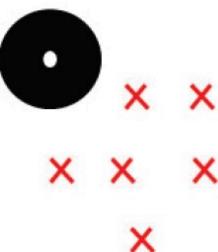
Good precision,
poor accuracy



Good accuracy,
poor precision



Good accuracy,
good precision



Poor accuracy,
poor precision

Set-up (for humans)

Fixed head

Best precision, bulky



Titz, Scholz, & Sedlmeier, 2018

Head mounted

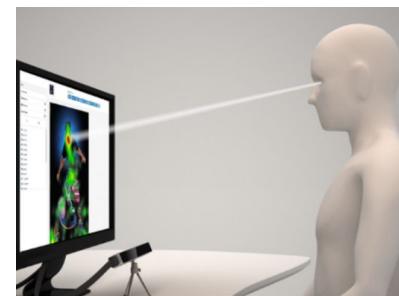
Open environment, bulky



sr-research.com

Remote (desktop, tower, arm)

Ok precision, not bulky



theeyetribe.com

Glasses

Poor precision, open environment



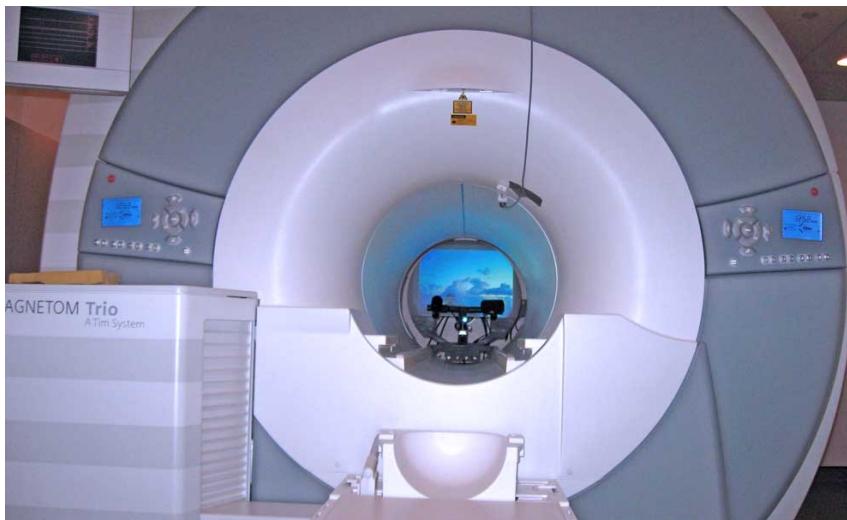
tobii.com

Integration with other methods



fNIRS

(f)MRI



EEG

MEG



Eye tracking - applications

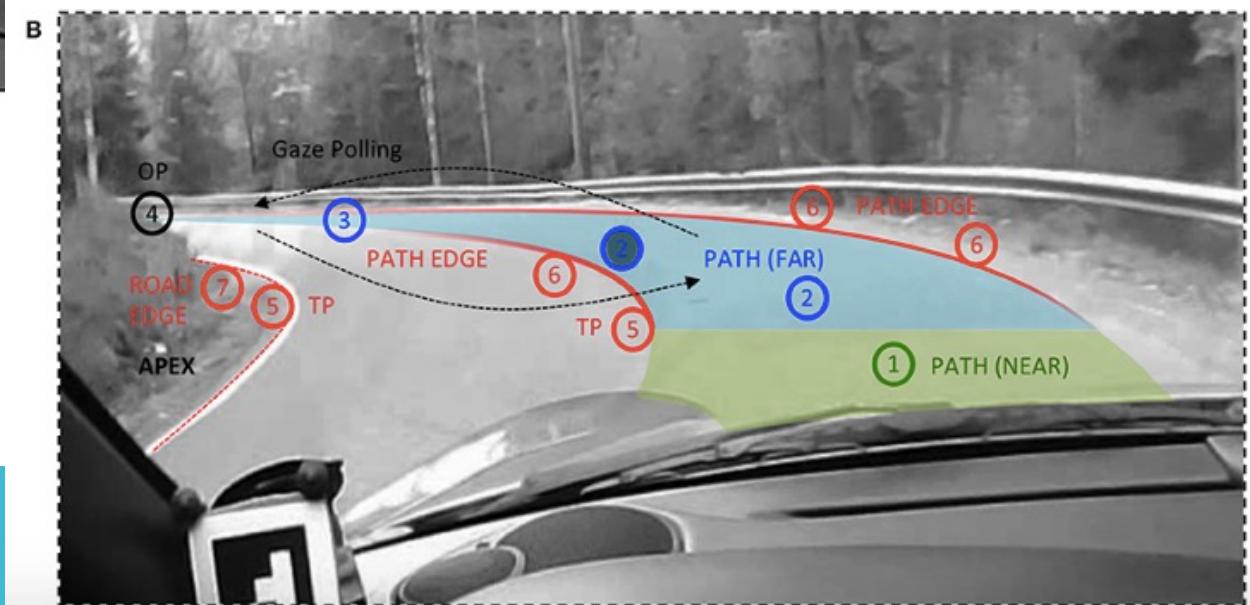
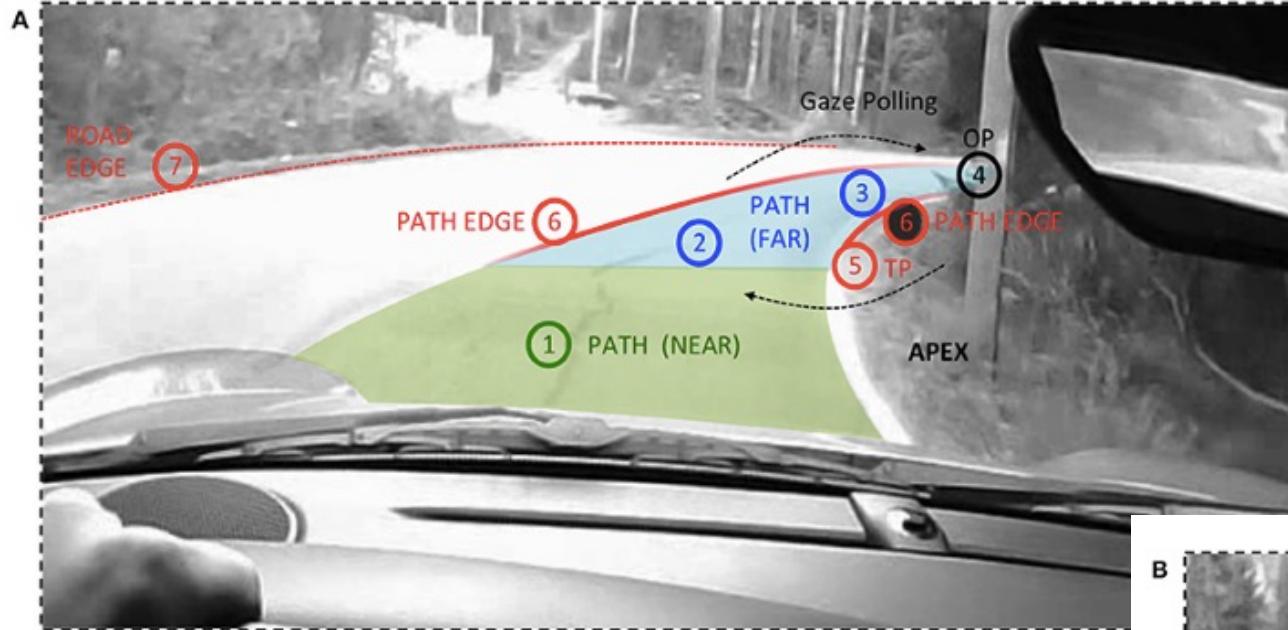
What can we measure?

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:

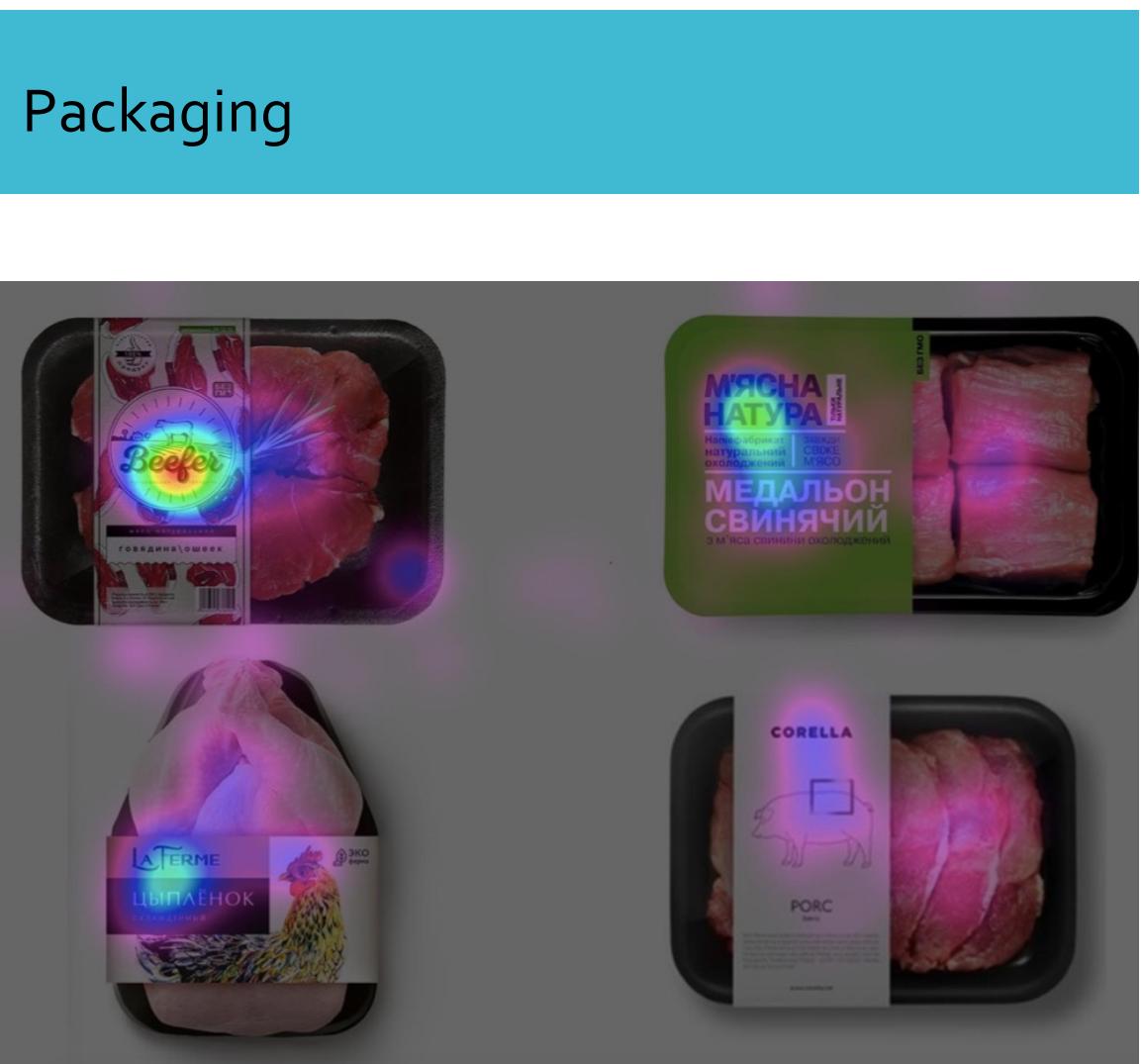
- as a **means of communication** for disabled people who can use only their eyes for input;
- in **ophthalmology**, for better understanding of eye movements to prevent, diagnose and treat abnormalities;
- **gaming**, as a controller or a way to increase immersive experience;
- for testing **usability**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



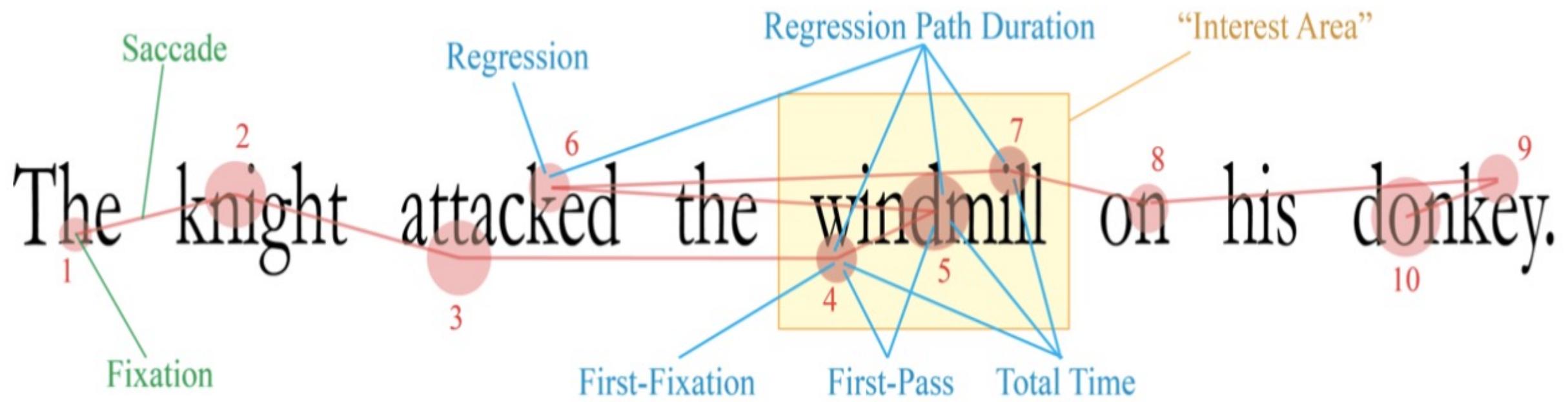
Expertise



Marketing



<http://consulting.md/>



Reading comprehension

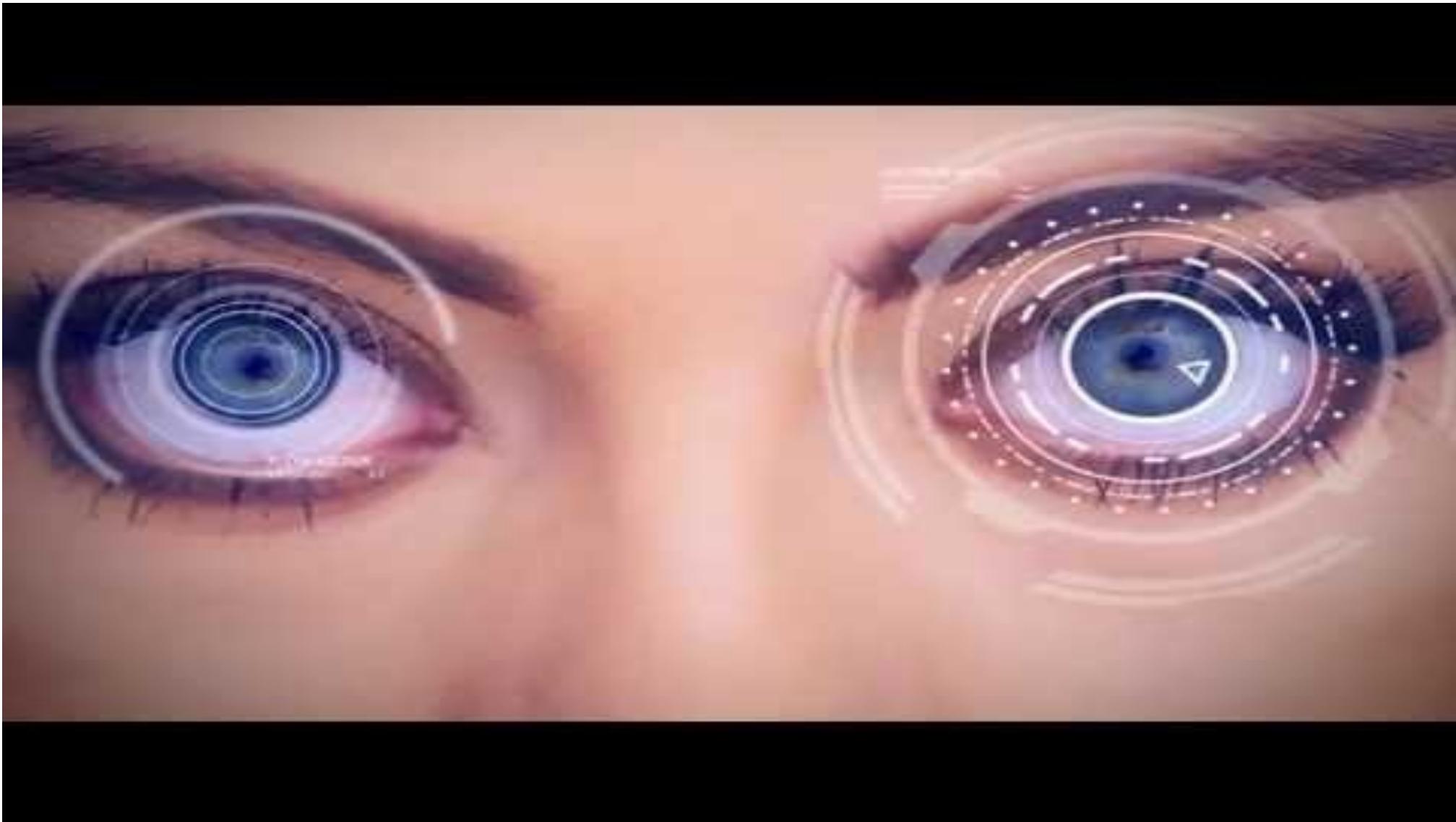


Look at a horde of zombies, they will become aware of your presence and come towards you.



Look to a light source – the environment will dim or brighten up simulating your eyes' adaptation to different lighting scenarios

Gaming



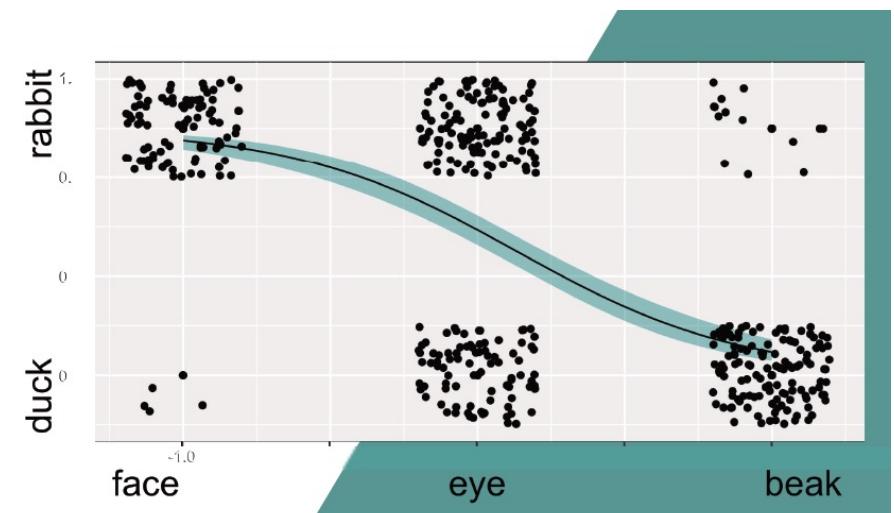
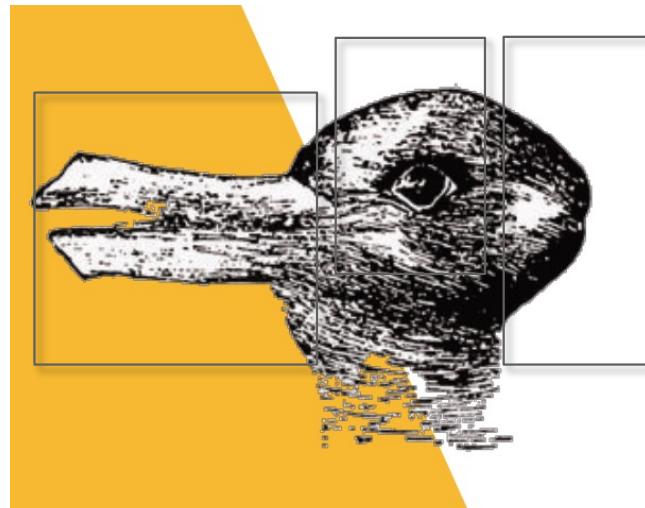
- Eye tracking glasses
- Gaming
- Marketing
- Heat-maps
- Real-life, natural recording
- Means of communication

Research

What kind of data can we collect with eyetracking technology?

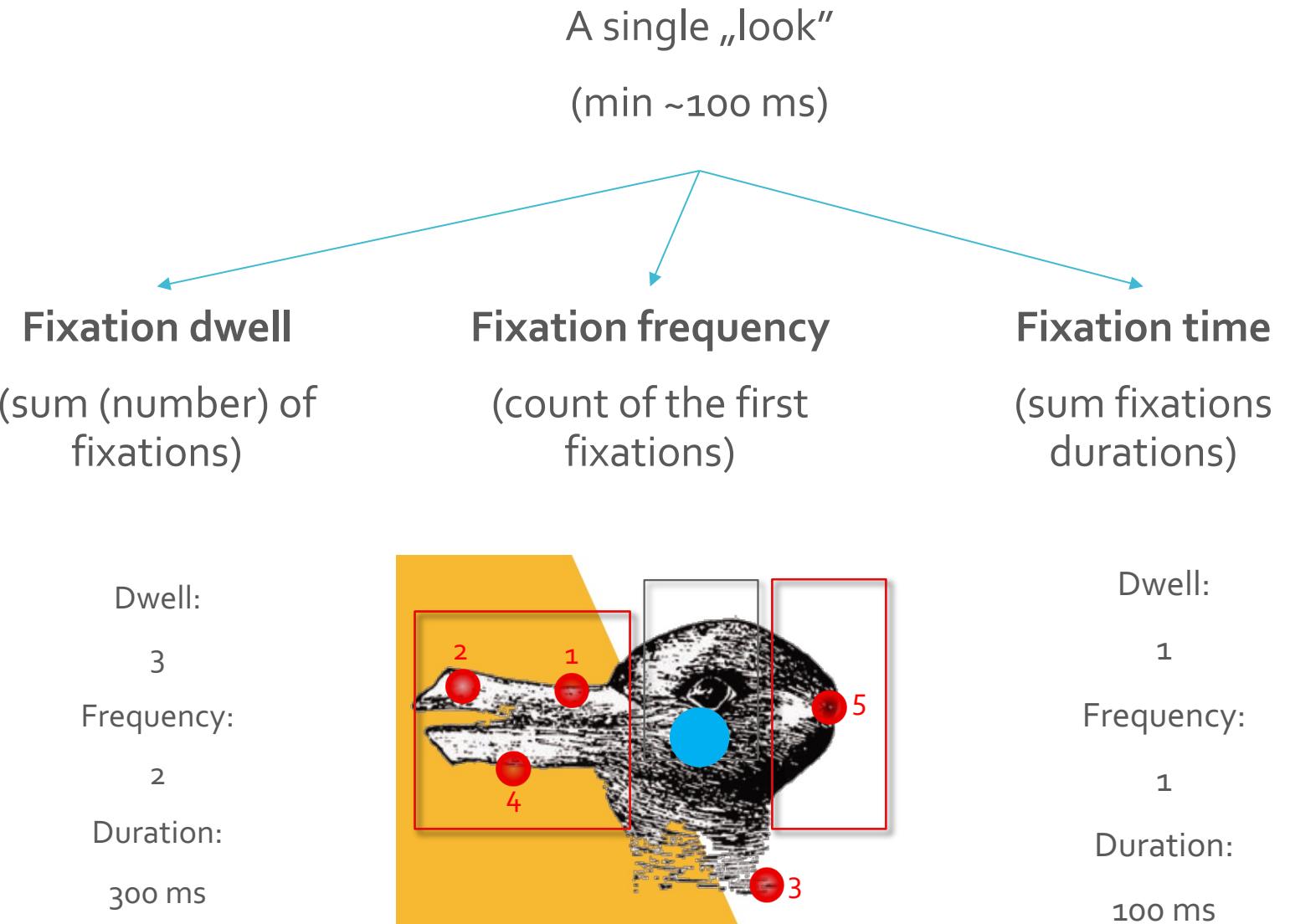
AOI

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



Matyjek et al., 2016, unpublished

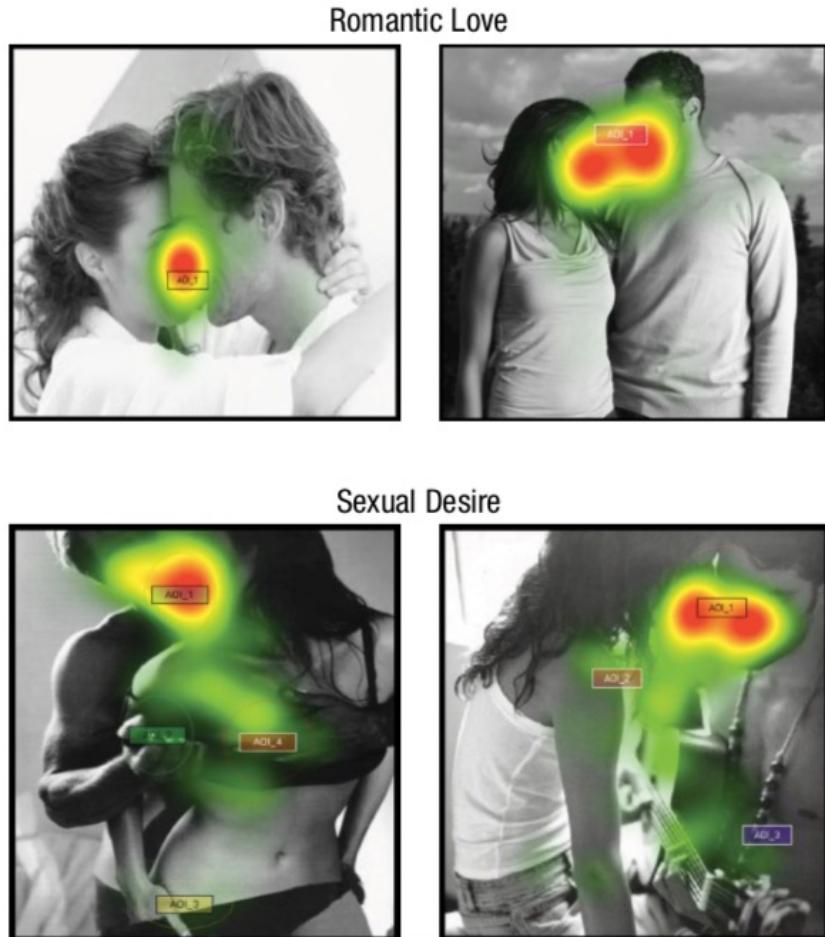
Fixations popular measures



Heat maps

An AOI-free way of visualising fixation dwell

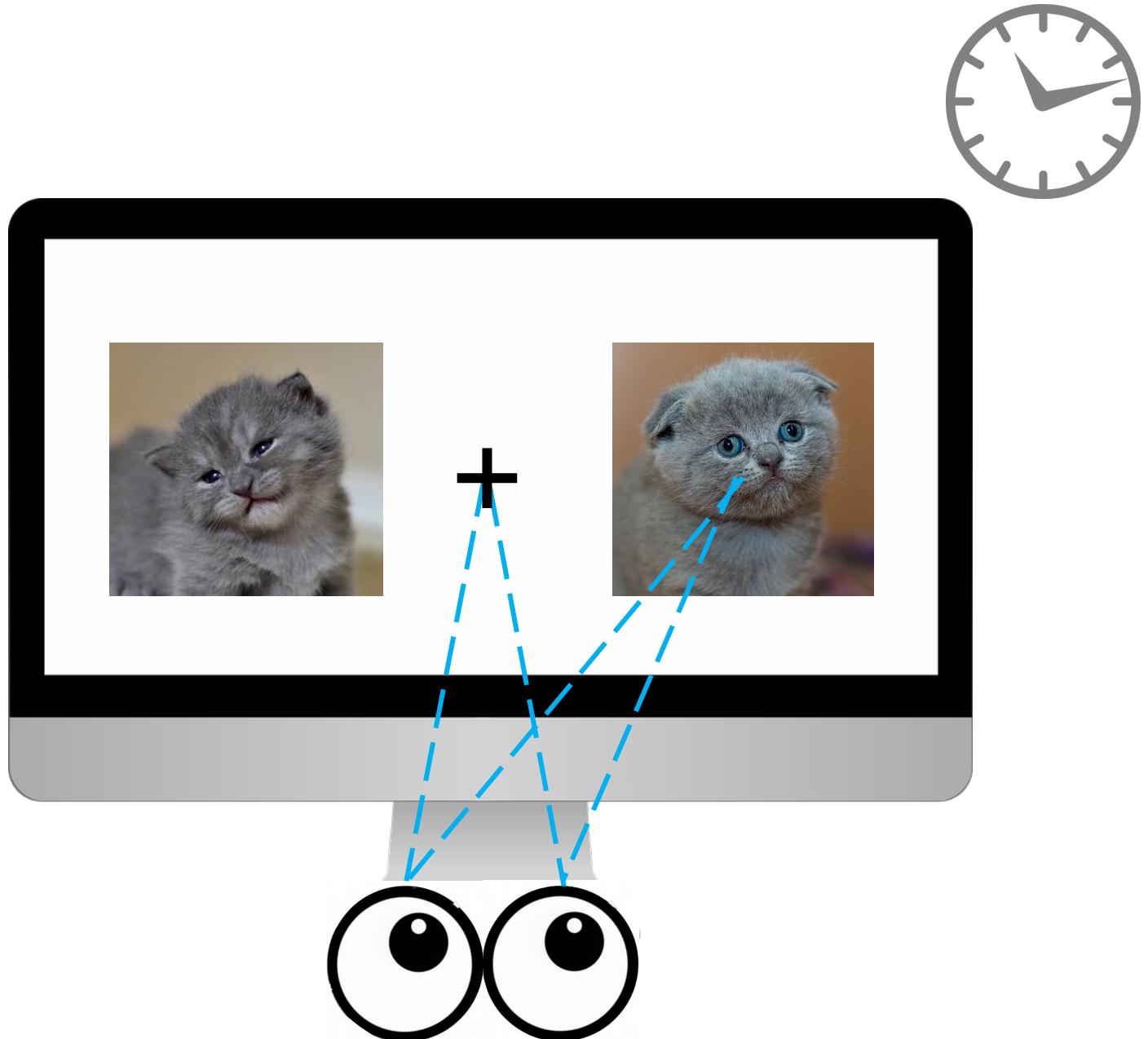
- fixation density sometimes weighted by duration
- averaged over participants



Bolmont, Cacioppo, & Cacioppo, 2014, Psych Science

Latency

Time until the first fixation



Saccades

Movements between fixations

Include:

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

DANS, KÖN OCH JAGPROJEKT

På jakt efter ungdomars kroppsspråk och den "synkretiska dansen", en sammansmältning av olika kulturers dans har jag i mitt fältarbete under hösten fört mig på olika arenor inom skolans värld. Nordiska, afrikanska, syd- och östeuropeiska ungdomar gör sina röster hörda genom sång, musik, skrik, skratt och gestaltade känslor och uttryck med hjälp av kroppsspråk och dans.

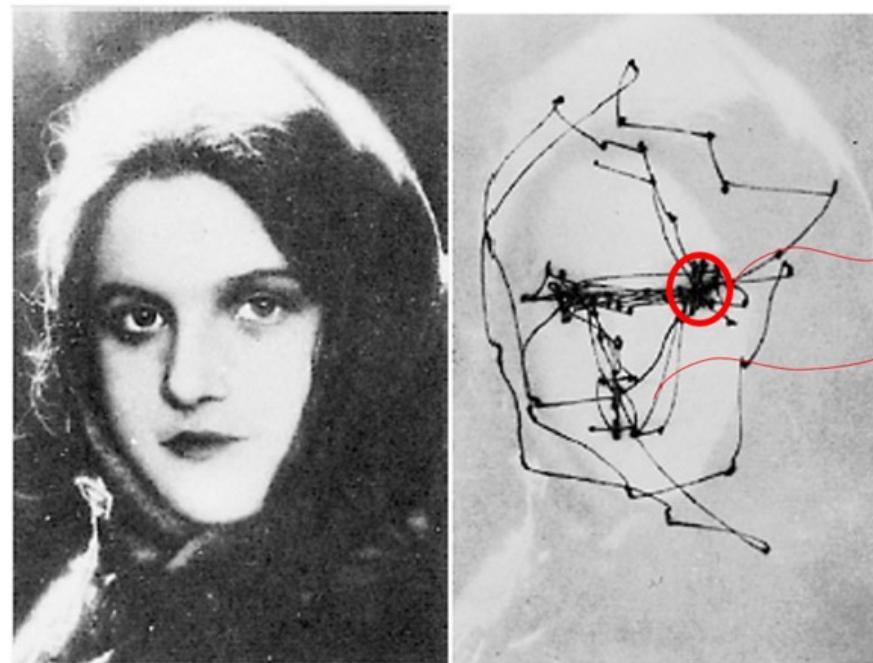
Den individuella estetiken framträder i kläder, frisyrer och symboliska tecken som förstärker ungdomarnas "jagprojekt" där också den egna stilens i kroppsrörelserna spelar en betydande roll i identitetsprövningen. Uppehållsrummets funktioner som offentlig arena där ungdomarna spelar upp sina performance liknande kroppsspråk

Microsaccades

small, Involuntary, jerk-like movements within a fixation

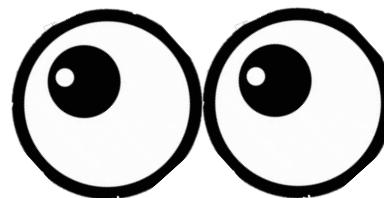
Unclear function:

- 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**?

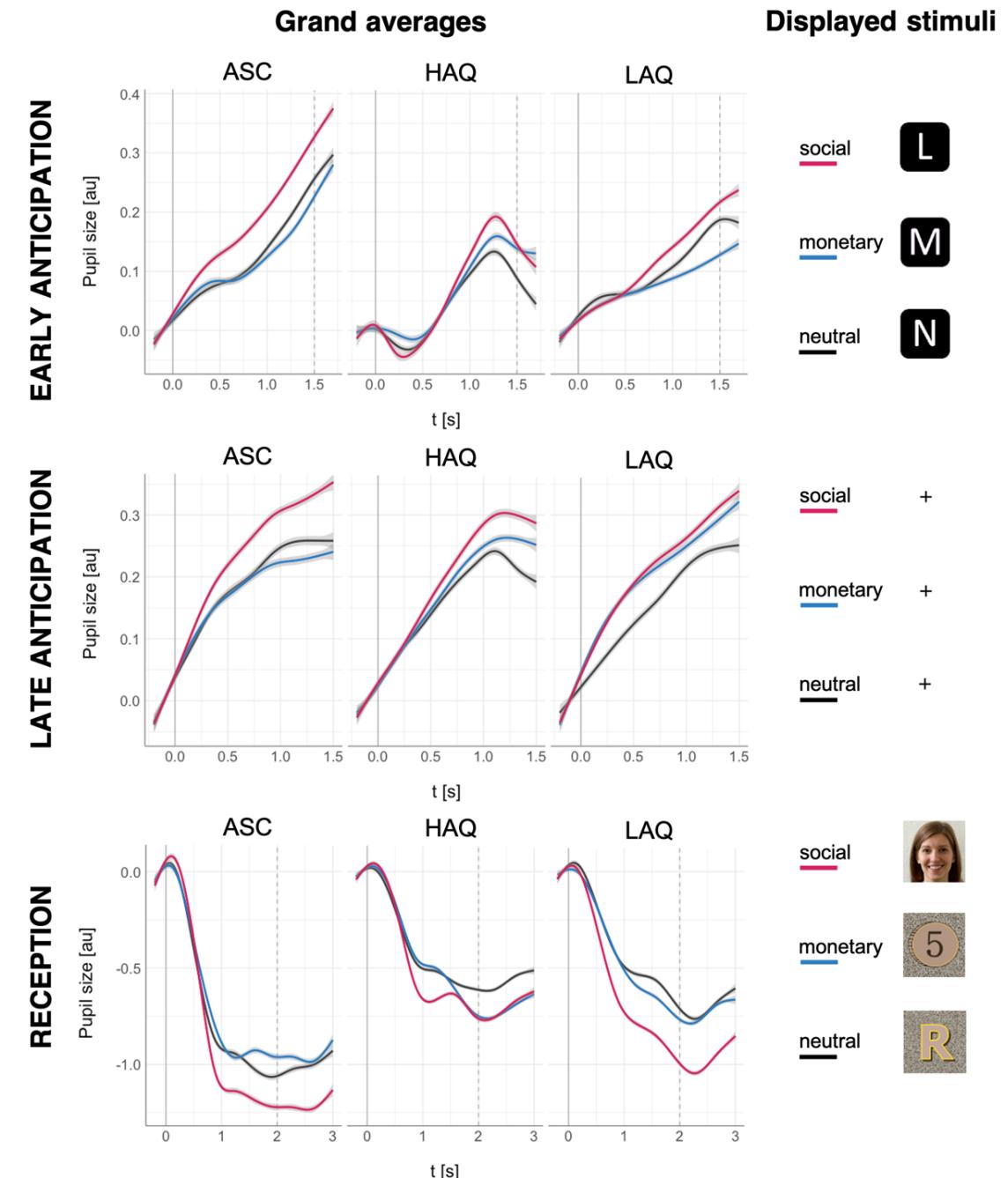
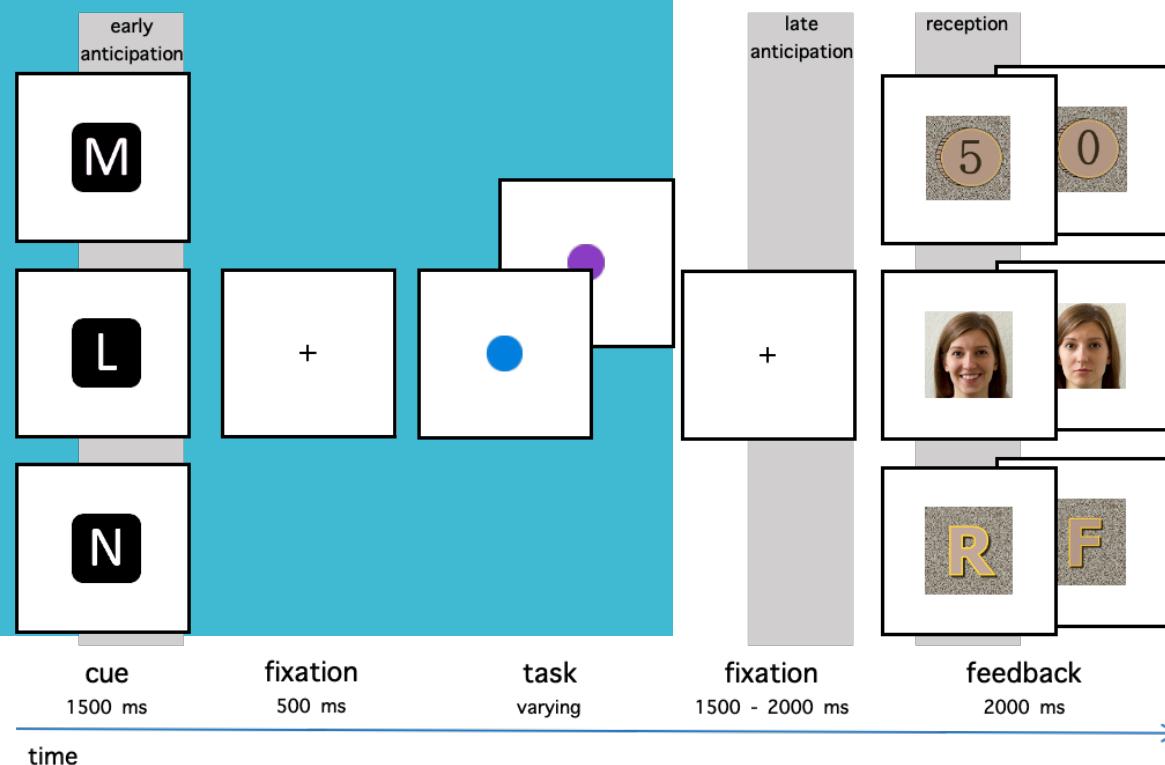
- Pupillary light reflex (PLR)
- Other low-level equiluminant changes in stimuli (colour, motion) – reorienting pupil constrictions: selective attention?
- Tonic constriction when executing a well-learned task

Example: clinical psychology

Reward processing in autism and autistic traits

3 groups:

- Autism (ASC)
- Low autistic traits (LAQ)
- High autistic traits (HAQ)



Data analysis

Exemplary data

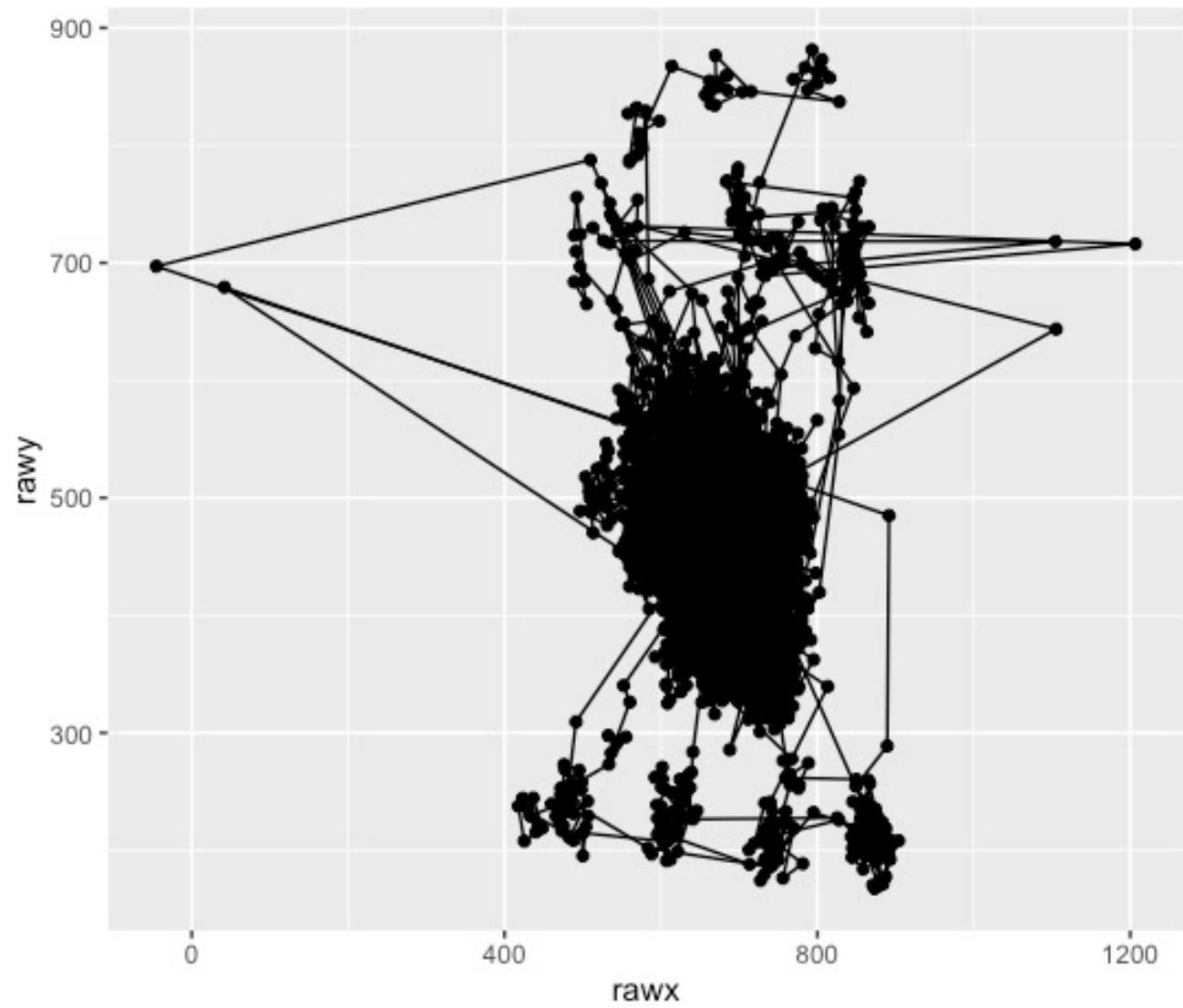
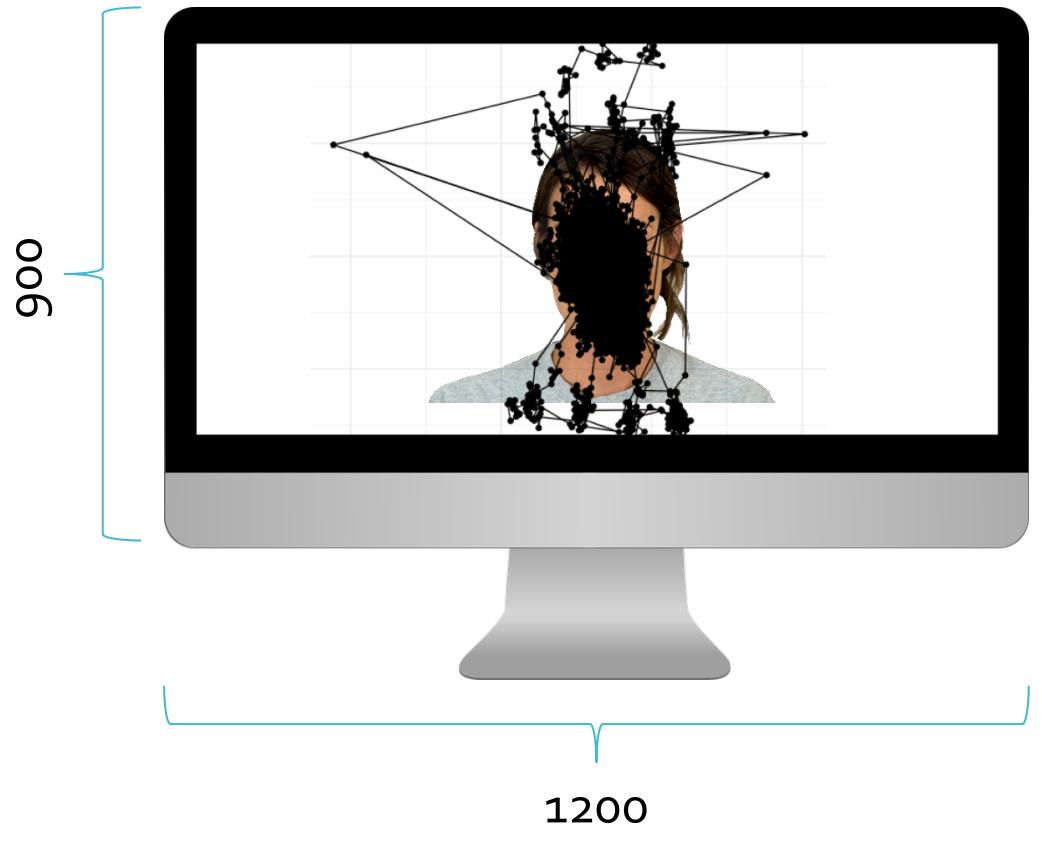
| | timestamp | time | rawx | rawy | psize |
|----|-------------------------|-------------------------|----------|----------|----------|
| 1 | MSG | 2019-12-10 13:13:59.933 | NA | NA | NA |
| 2 | 2019-12-10 13:13:59.931 | 800784123 | 530.0952 | 565.9204 | 19.73470 |
| 3 | 2019-12-10 13:13:59.948 | 800784140 | 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 13:14:00.081 | | | | 65 |
| 12 | 2019-12-10 13:14:00.098 | | | | |
| 13 | 2019-12-10 13:14:00.115 | | | | |
| 14 | 2019-12-10 13:14:00.132 | 800784273 | 532.6516 | 649.2690 | 20.04245 |
| 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)

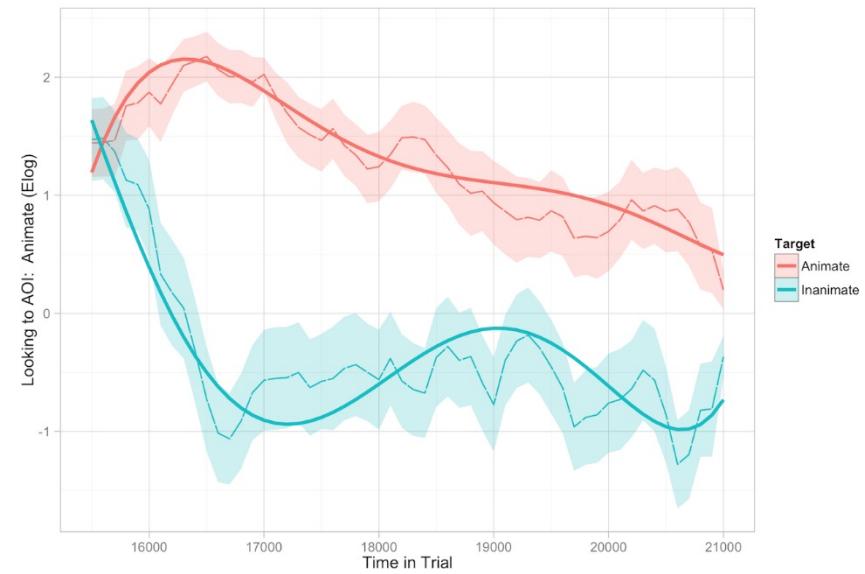
Where?
coordinates

Pupil size



Preprocessing

- Remove or interpolate eye-blanks, 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?

Lecture and tutorial slides are available at:
https://github.com/lenamatyjek/ET_class_2022



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