

Eye tracking basics

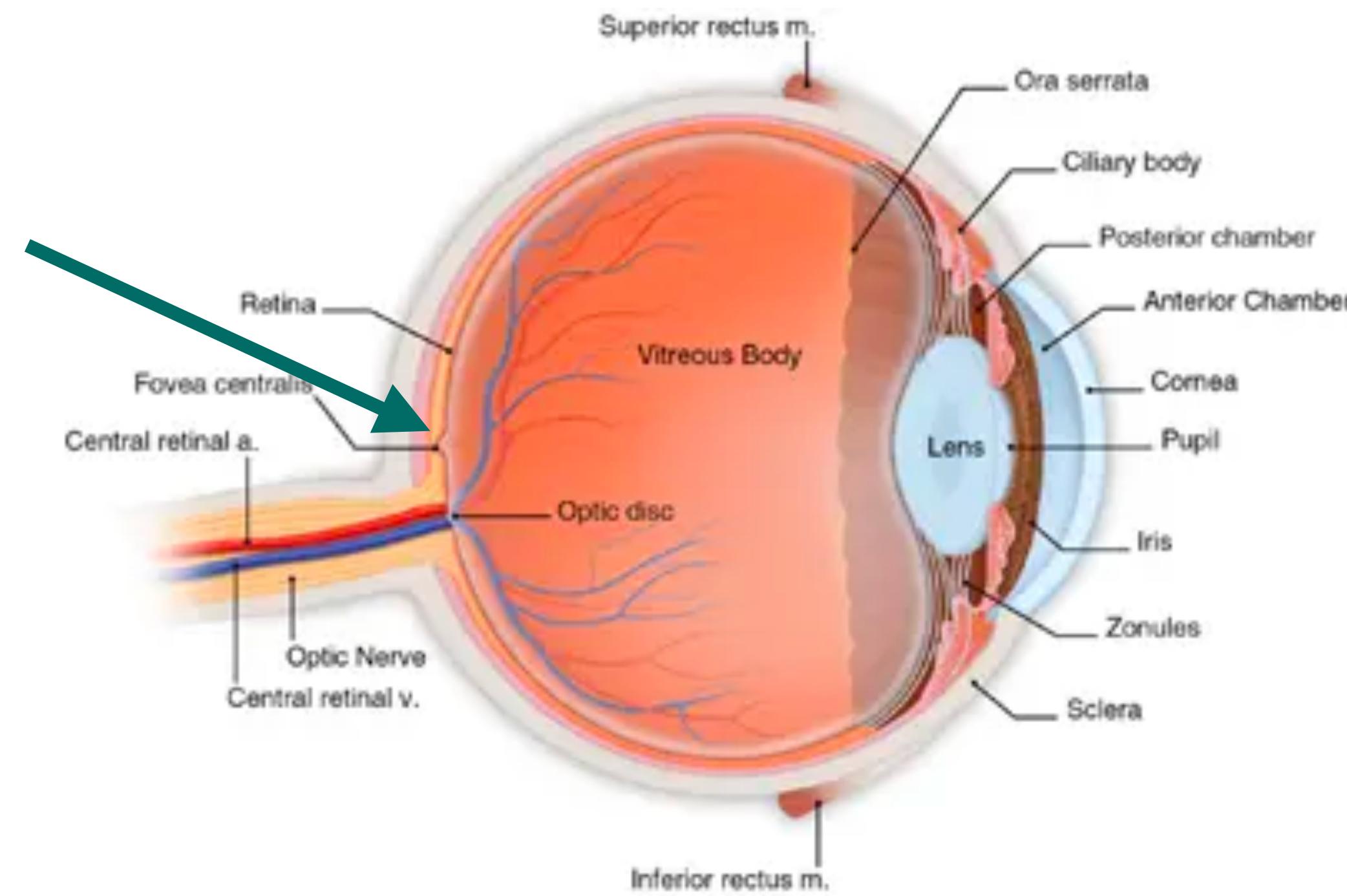
Maria Barrett 18.2.2022

I will be covering

- Very basic information about how the eye works
- Early eye movement research
- How modern eye trackers work
- A bit about low-cost eye trackers
- General notions about eye tracking features from reading

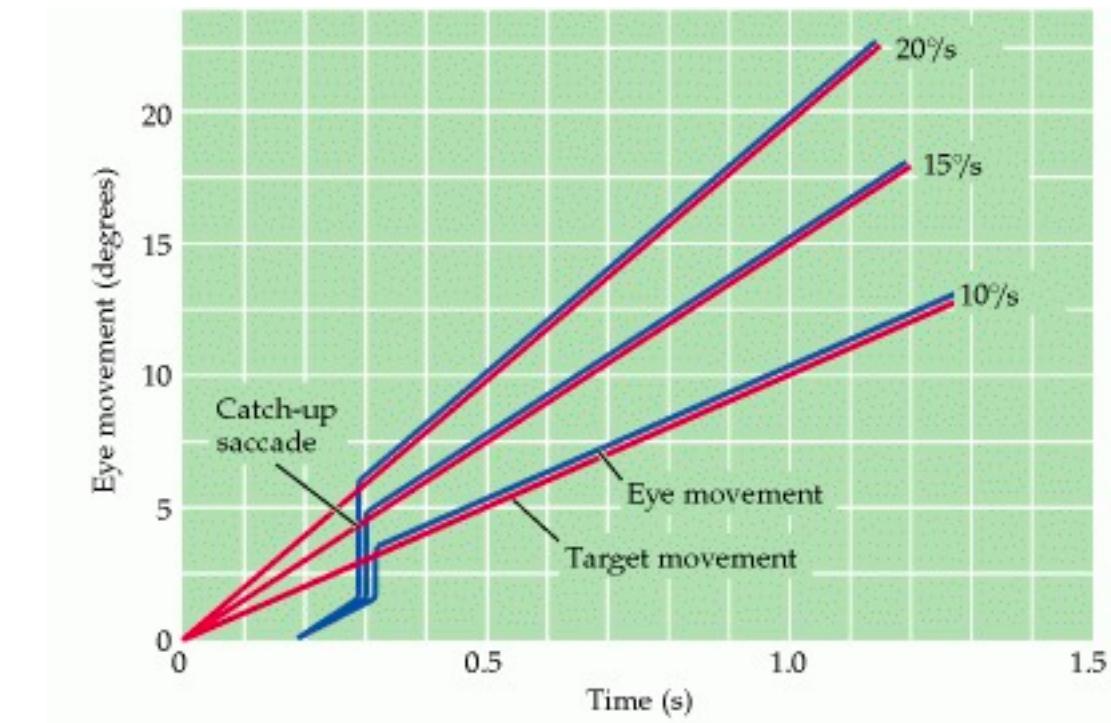
**Basic introduction to how the
eyes work**

Cross section of the eye



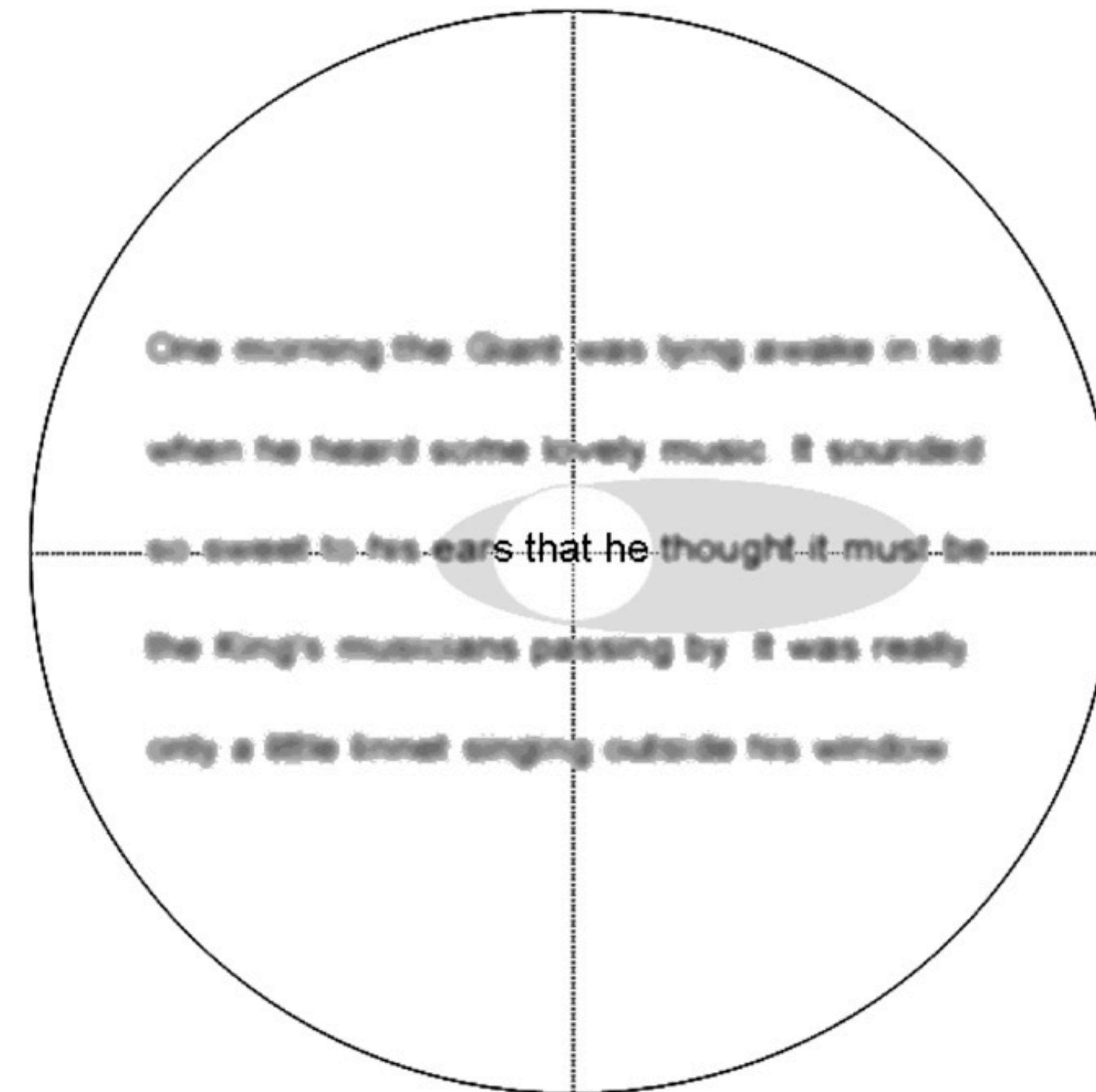
Basic types of eye movements

- Saccades
- Smooth pursuit
- Vestibulo-ocular movements
- Vergence



Smooth pursuit at different paces
From Purves et al. (2019)

The perceptual span during reading



during a saccade because the eyes are moving so
*

Normal Text

XXXXXX X XXXcade because the XXXX XXX XXXXXX XX
*

Moving Window

XXXXXX X XXXXXX XXXXXse the eyes are mXXXXX XX
*

Boundary

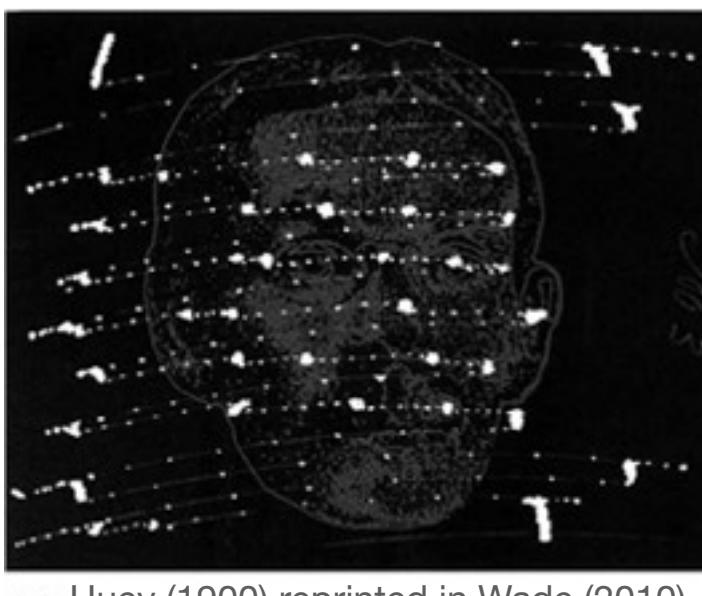
during a saccade because the dogs are moving so
*

during a saccade because the eyes are moving so
*

A history of modern eye movement research

Earliest studies of saccades during reading

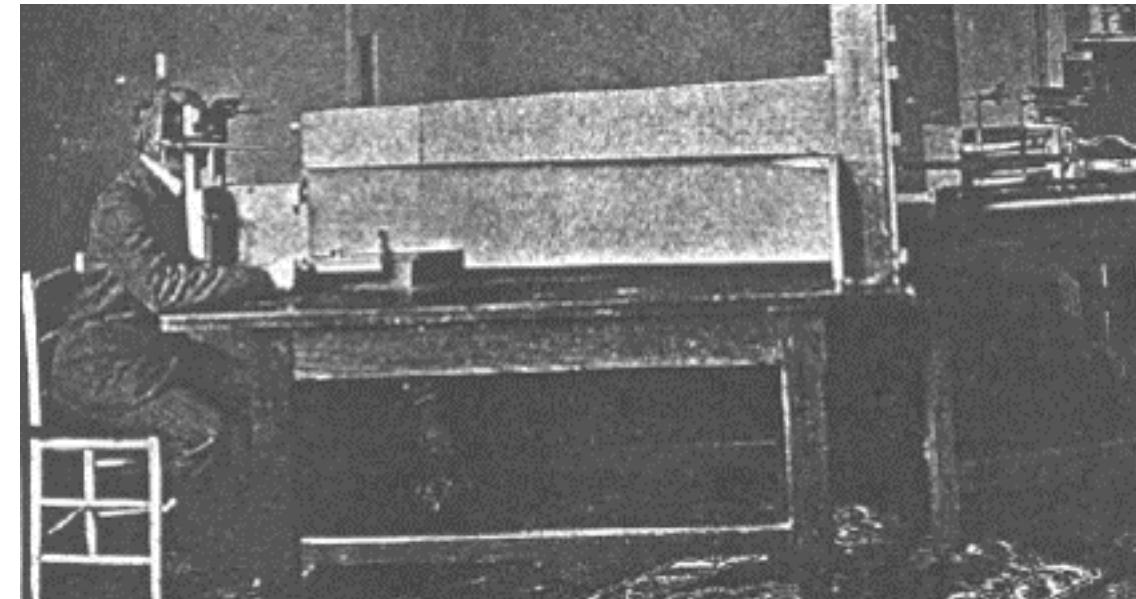
- Hering (1879) and Lamare (1892) listened to saccadic muscle contractions during reading.
- Javal also saw these movements with a mirror device and dubbed the jerky eye movements “saccades” in 1879.
- Huey (1900) Engraving of a photo of eye movements during reading with the first eye tracker



(a) Huey (1900) reprinted in Wade (2010)

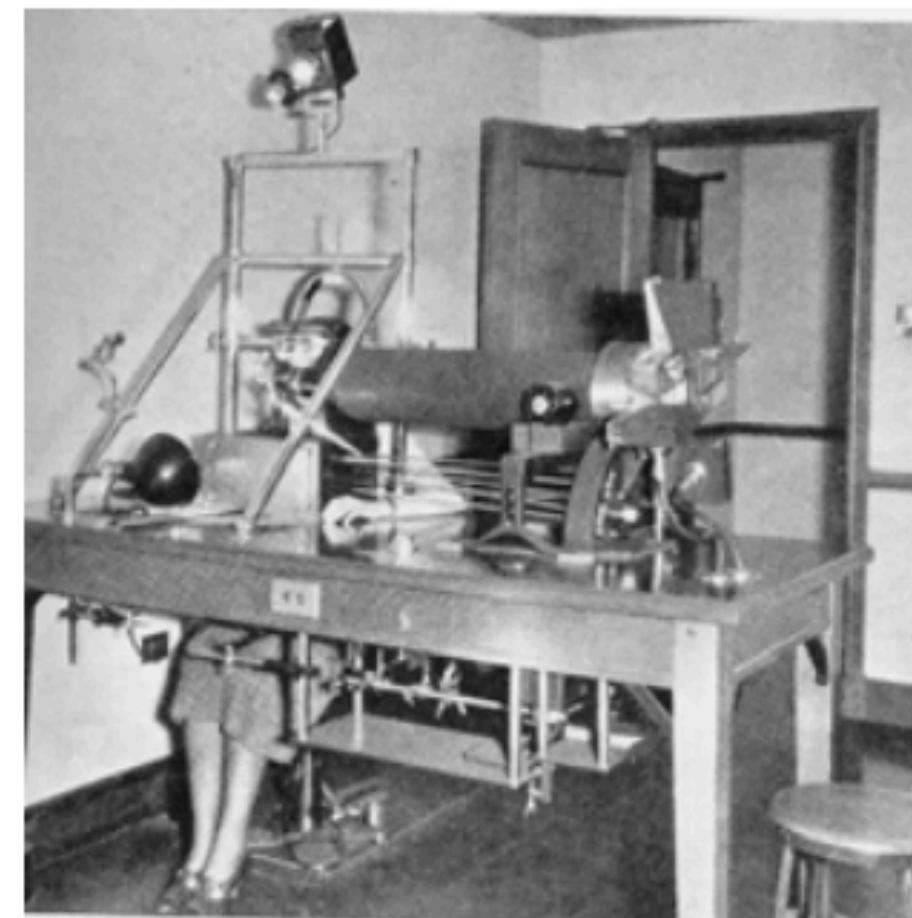
Non-invasive eye trackers

- Dodge and Cline invented the first non-invasive eye tracker in 1901

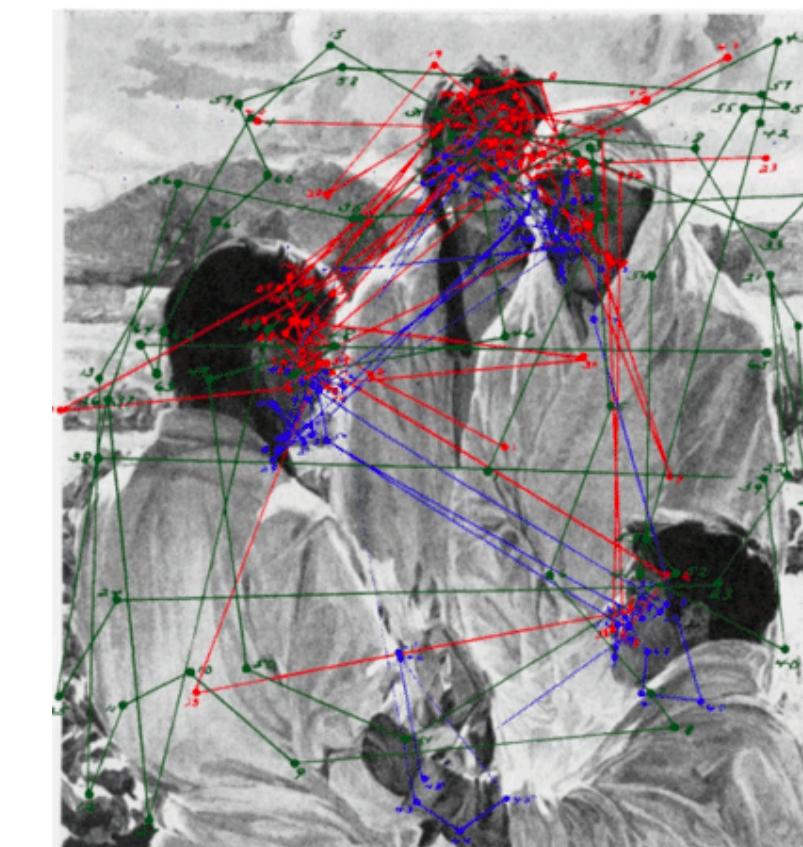


Early studies of eye movements during reading

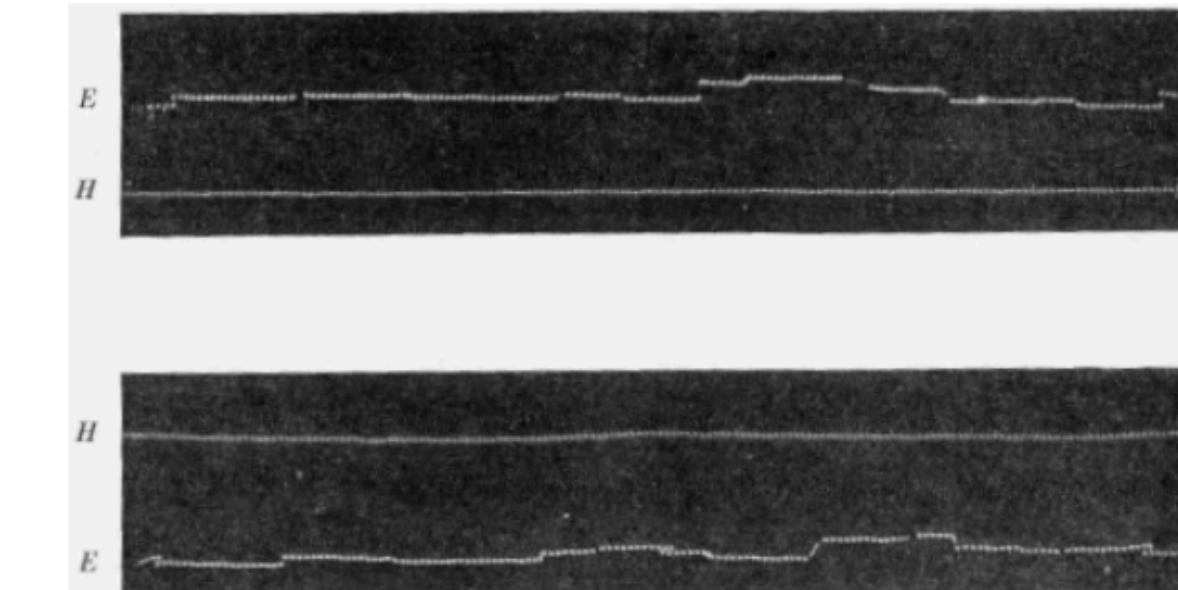
- Buswell performed a range of studies of eye movements during reading and picture viewing



Apparatus of Buswell (1935)



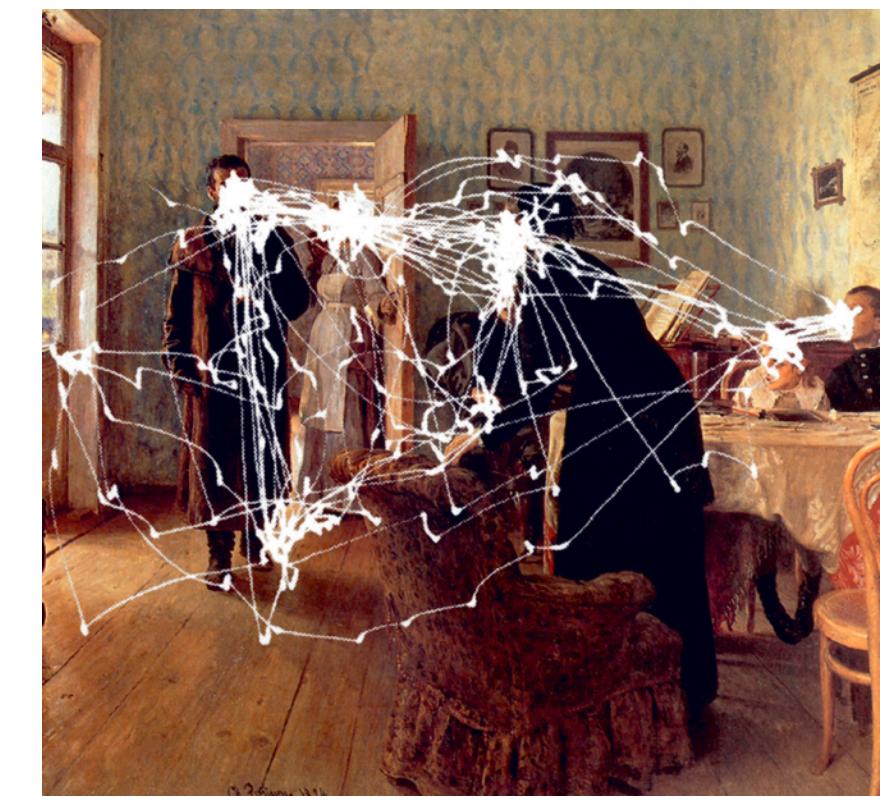
Overlay of three subjects eye movements when viewing a picture from Buswell (1935), adapted by Wade (2020)



Sample of eye movement records Buswell (1935)

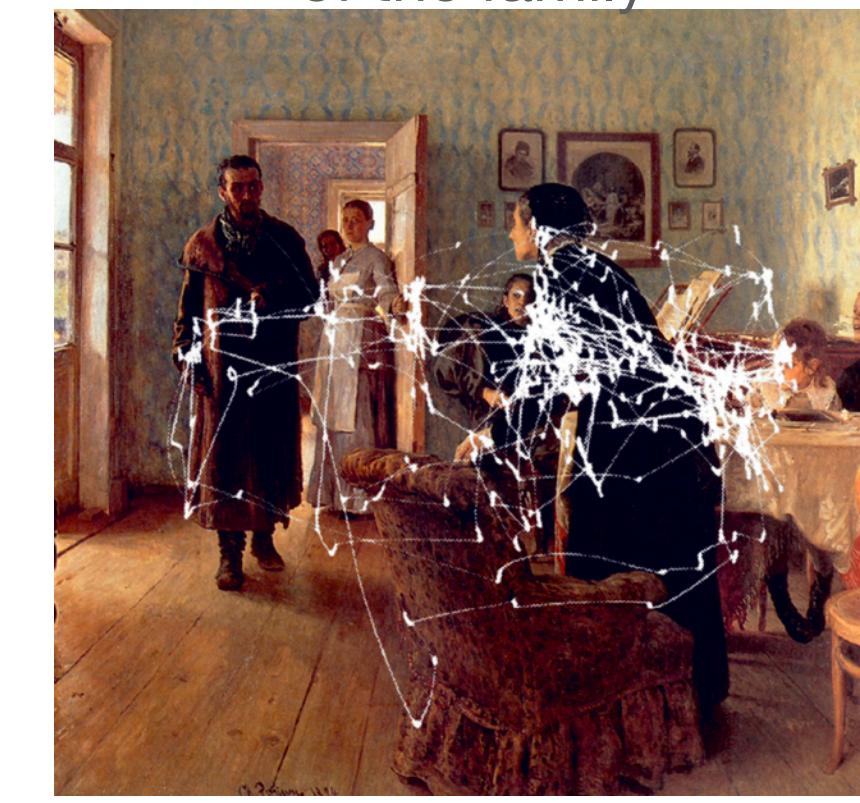
A side note about eye movements during picture viewing

Confirmation of findings by Bushwell (1935)



Free exploration

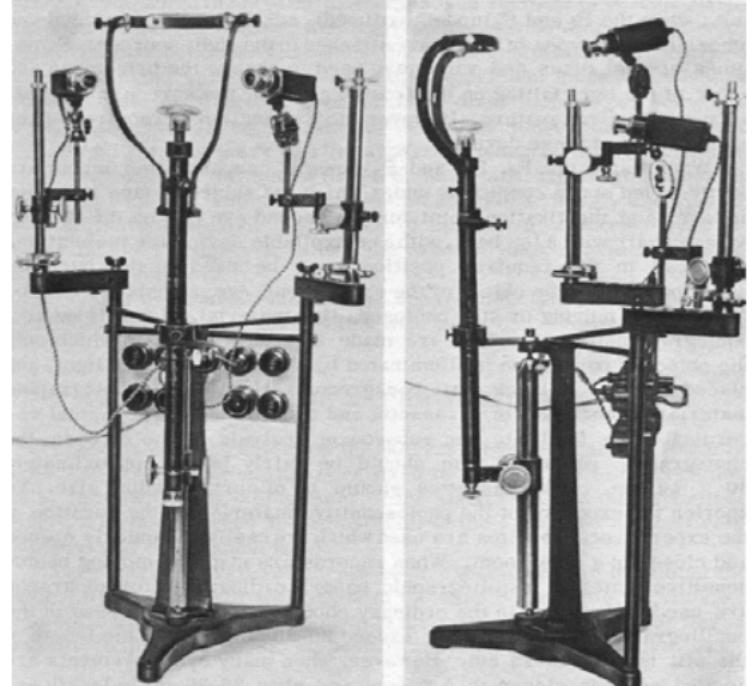
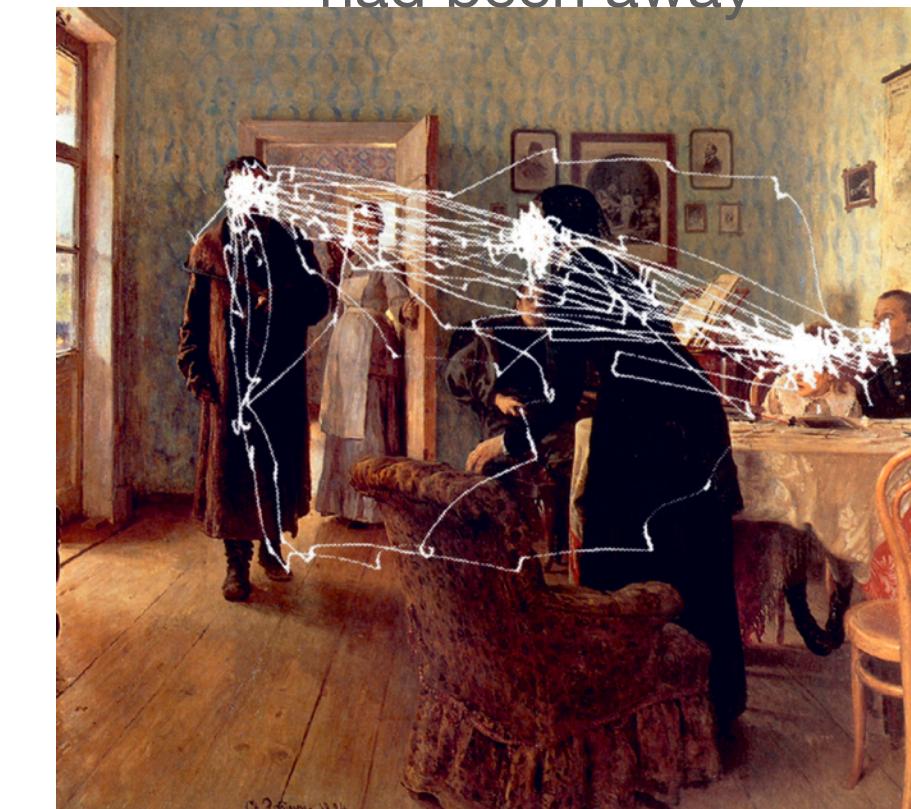
Estimate the material circumstances
of the family



Guess the age of the characters

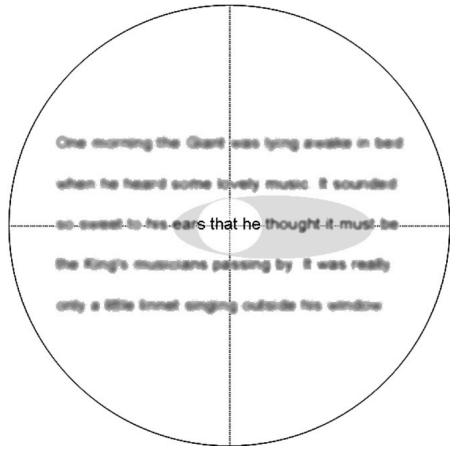


Guess how long the man
had been away



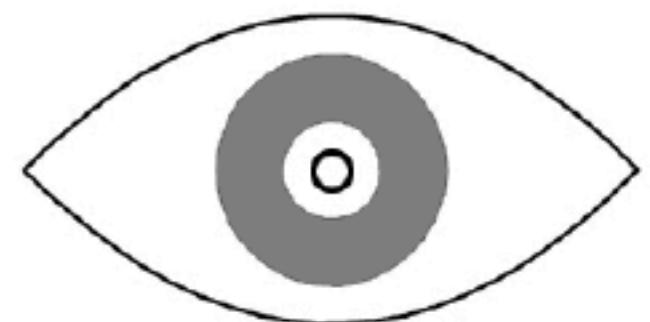
Highlights from later reading research (1970-present)

How the eyes move during reading is guided by a complex interplay of at least

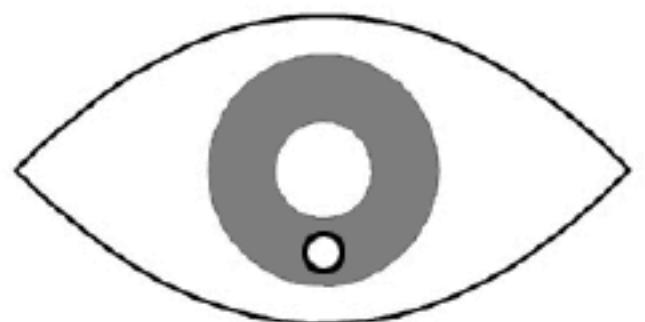


- **Low level processing** How much the eye can see and encode during a fixation *in parallel with a*
- **Higher-level processing** “fixation time is shorter when the word is easy to identify and understand” (Clifton et al., 2007)
 - Word length, word frequency, word predictability from context + smaller factors that interacts with the following:
 - A basic syntactic and semantic parsing system
 - This system sometimes backing off to a different system
- Individual characteristics of a reader (e.g. working memory capacity, reading experience)

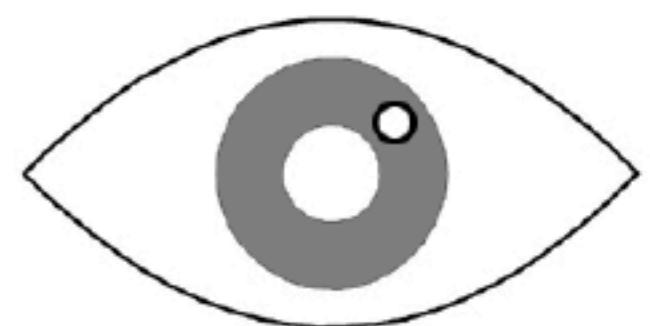
How modern eye trackers work



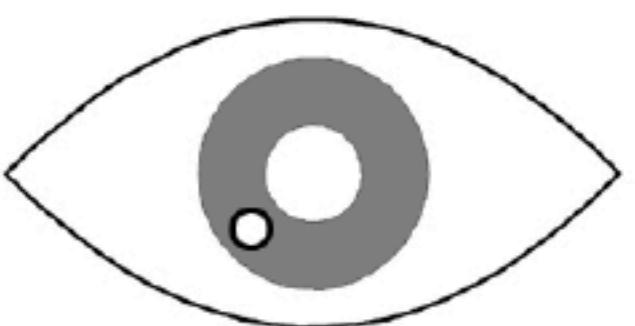
Directed at the camera



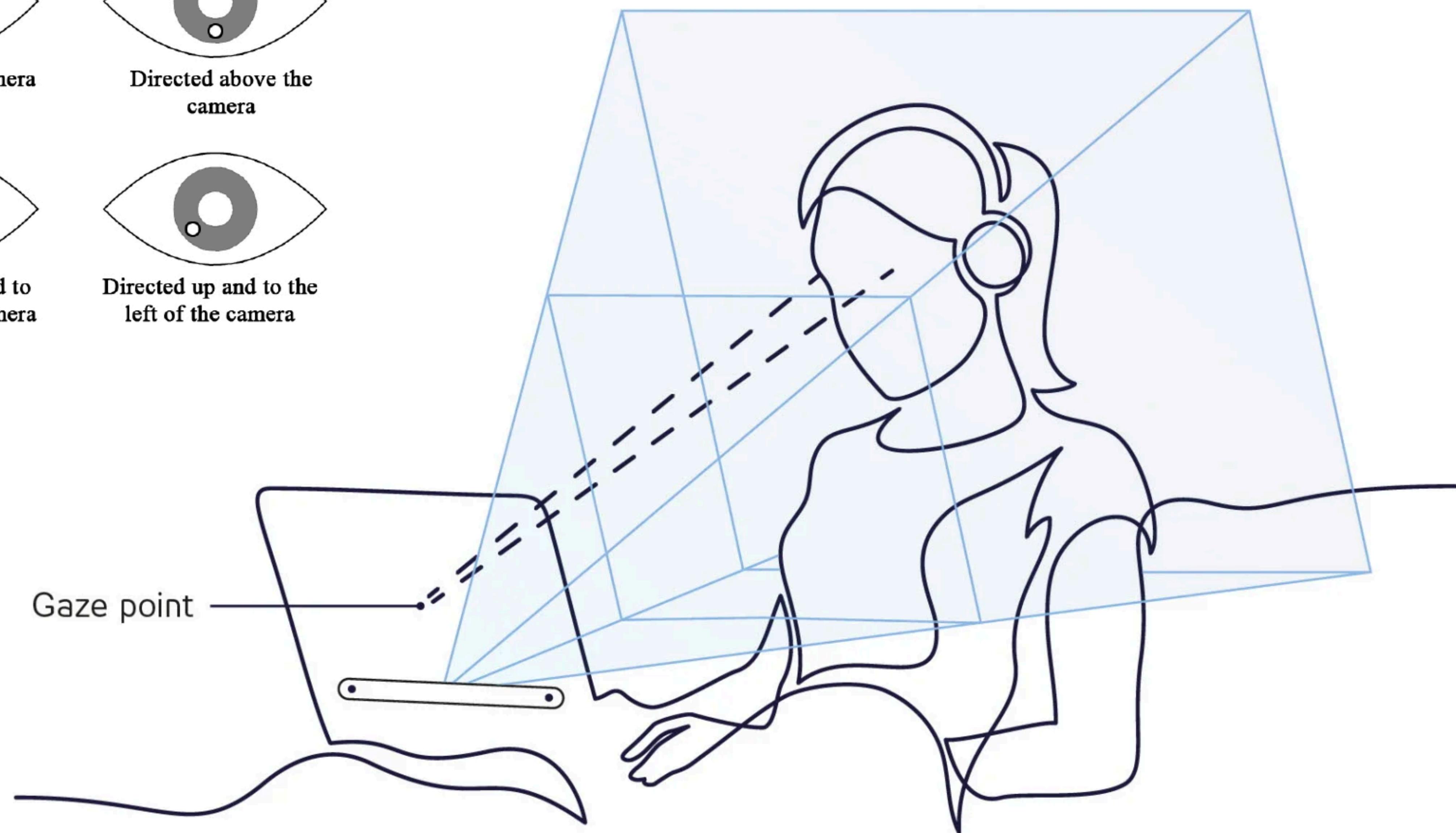
Directed above the camera



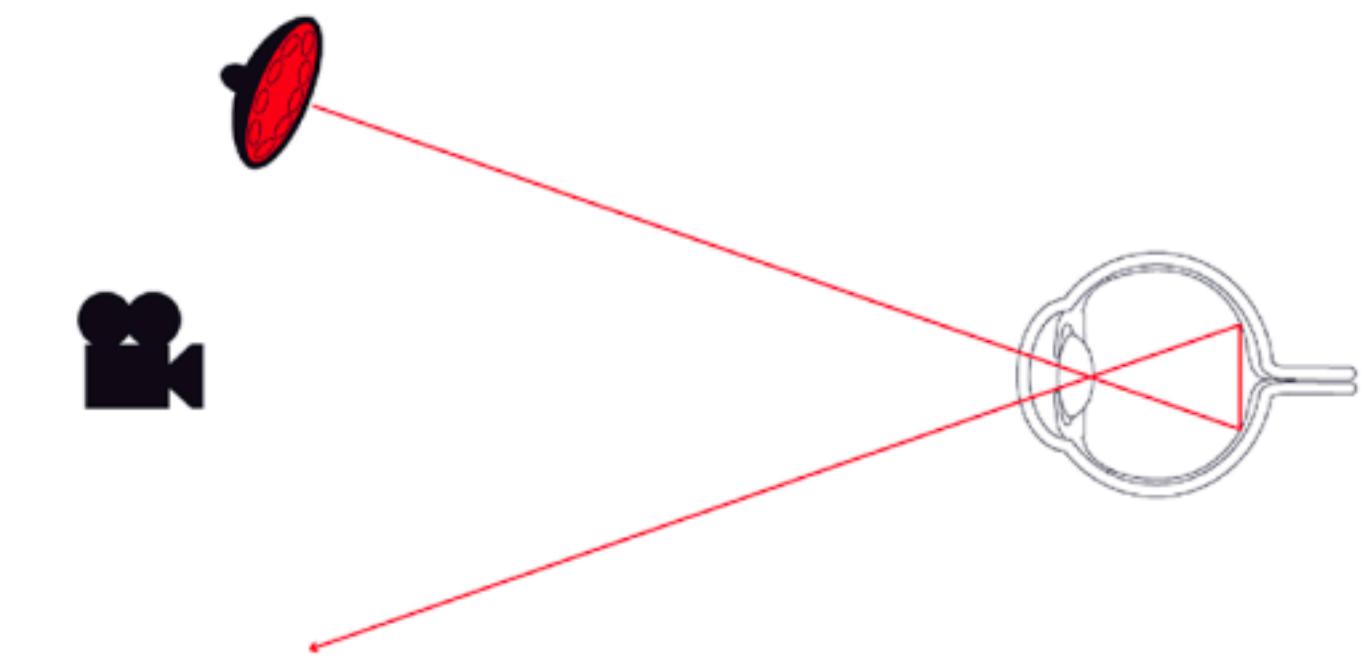
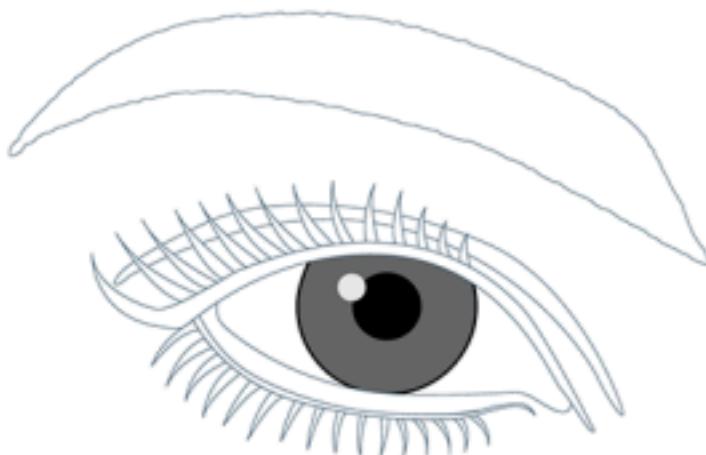
Directed down and to the right of the camera



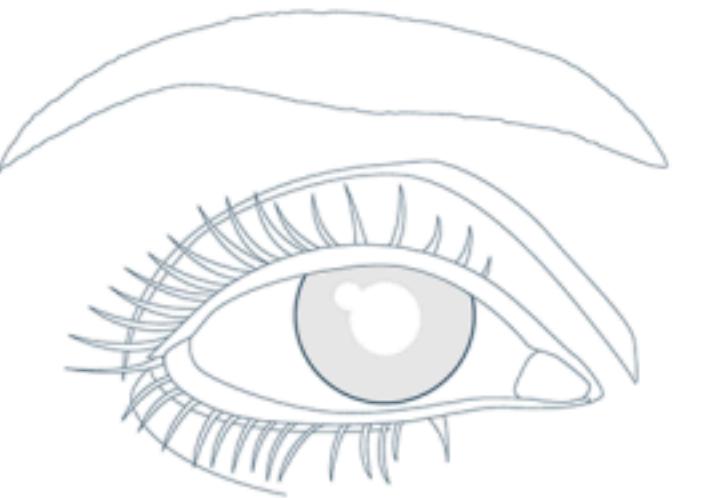
Directed up and to the left of the camera



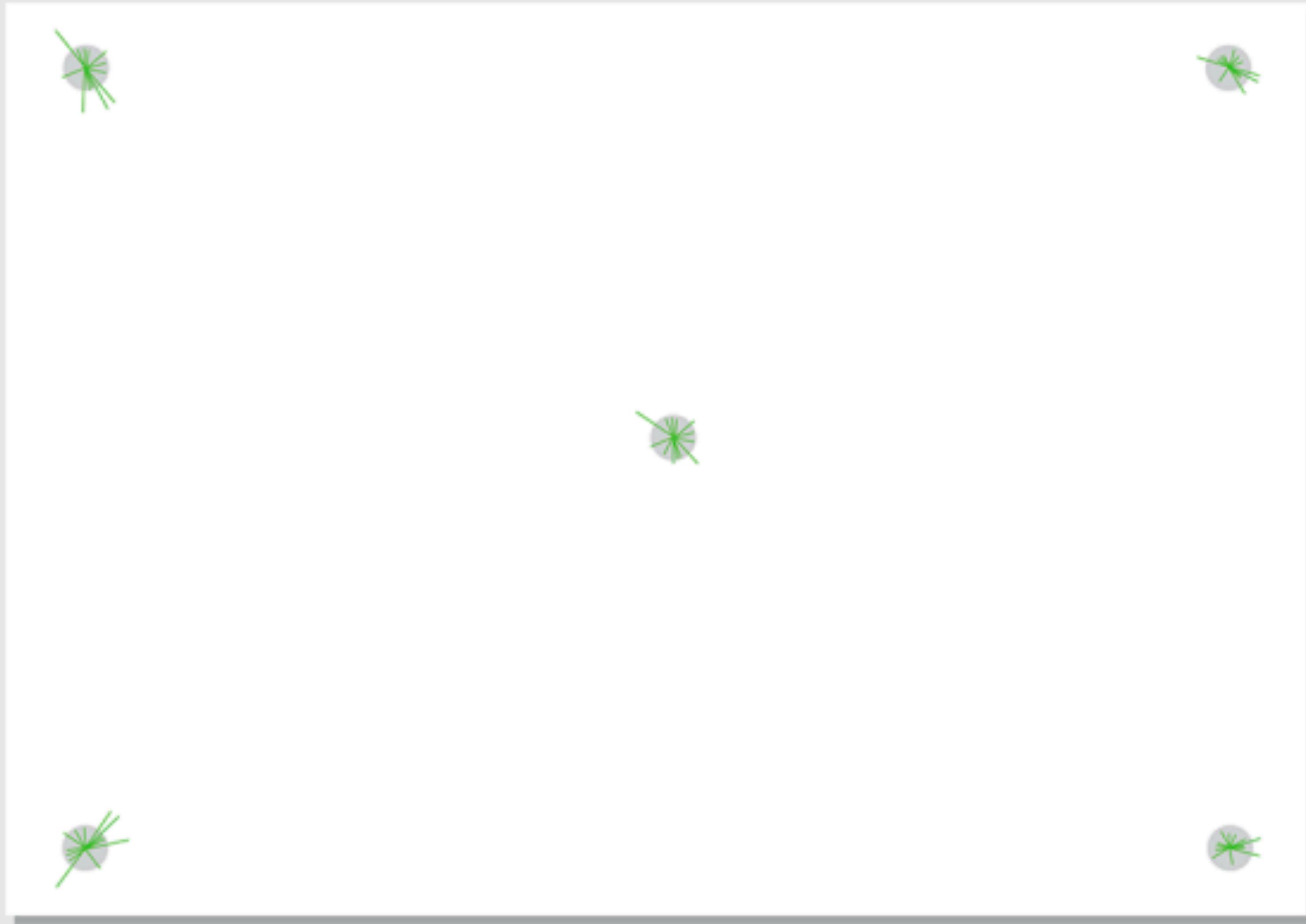
Dark pupil effect



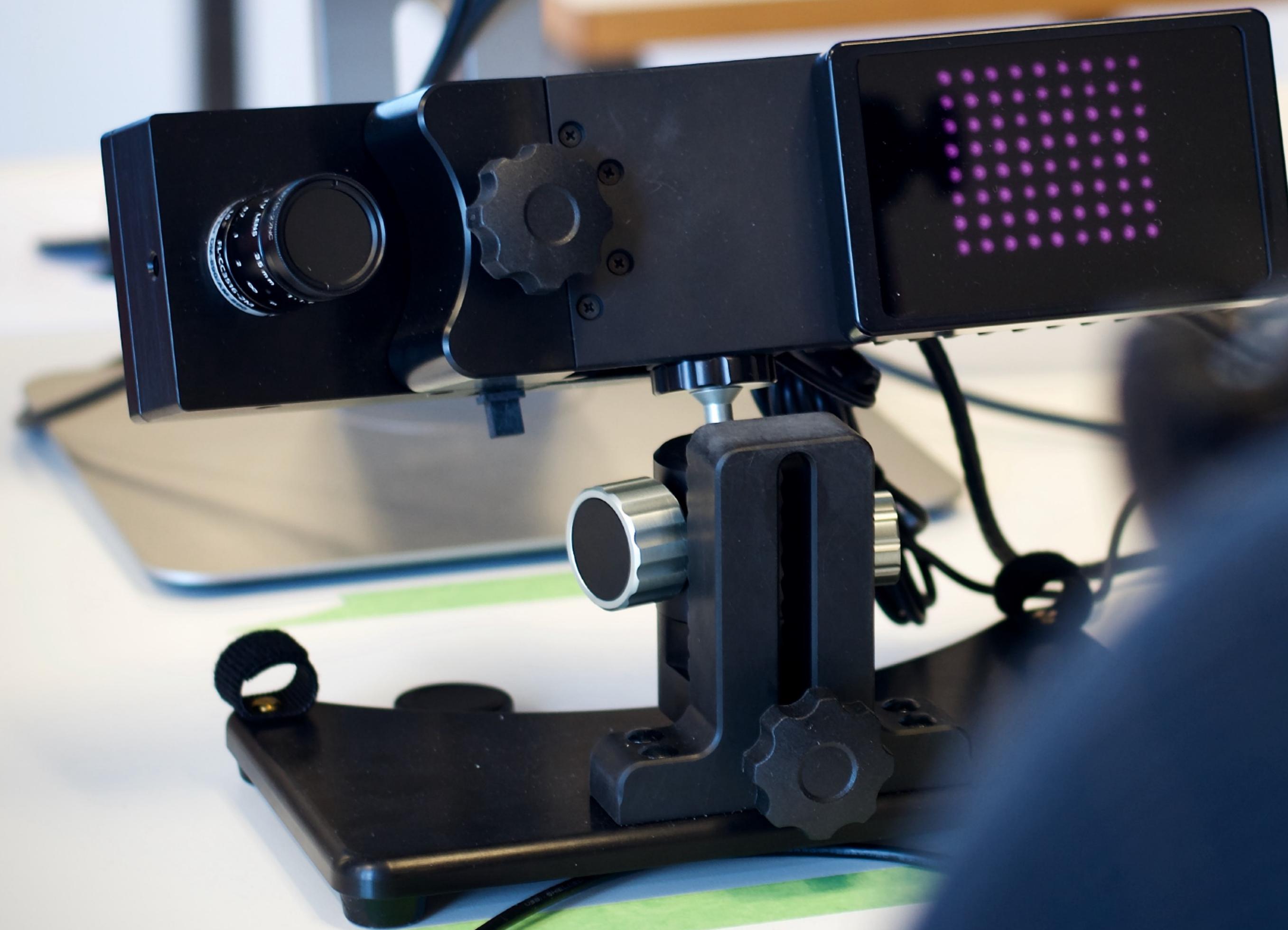
Bright pupil effect



Left Eye



DELL

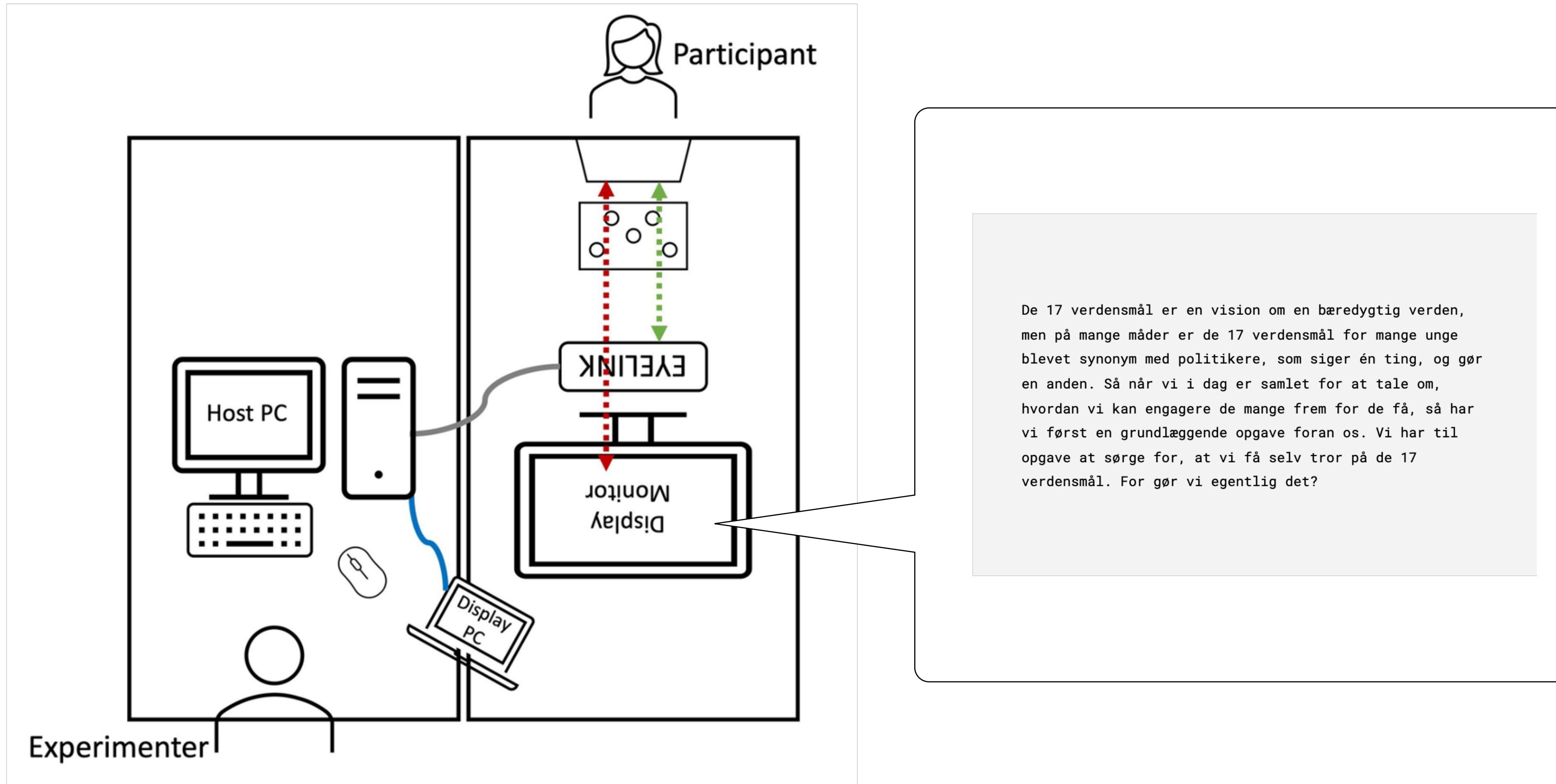


Kære Alle

Mit navn er Andrea Rygg Karberg, og jeg startede 1. juni som ny direktør for Nivaagaards Malerisamling. Mine første 23 dage har været forrygende travle, skægge og glade. Jeg har set frem til at opleve også denne her smukke Nivaagaard-tradition, som blev meget bæret. jeg blev bedt om at holde årets båltale. En båltale er jo sådan en slags frit emne, så jeg har haft mange forskellige ideer - og jeg med at ville tale om en række H'er: Sankt Hans - hedenskab - hekse - og Holger Drachmann.

DELL

Copco experimental setup



Experiment setup
Eye tracking laboratory setup

Output from reading experiments

Når vi endelig bryder ud af skabet og for alvor viser og siger det, der ikke passer i det normative skab, kan vi godtopleve negative reaktioner - men
så sandeligt også positive - for vi er jo slet ikke alene!

●

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Eye tracking output from reading experiments

The Dundee Corpus (Kennedy, Hill and Pynte, 2003)

- Word-level trajectory from subject reading the sentence:
 - As ever, market trends are against the way of life of a marginalised community.

WORD	TEXT	LINE	OLEN	WLEN	XPOS	WNUM	FDUR	DBLP	WDLP	LAUN	TXFR
ever,	1	1	5	4	4	2	270	1	1	0	38
market	1	1	6	6	13	3	192	4	4	-9	19
trends	1	1	6	6	21	4	206	5	5	-8	1
against	1	1	7	7	32	6	160	5	5	-11	36
way	1	1	3	3	42	8	238	3	3	-10	58
a	1	1	1	1	54	12	259	0	0	-12	1434
community.	1	1	10	9	69	14	208	0	0	-15	10
marginalised	1	1	12	12	63	13	203	7	7	6	1
of	1	1	2	2	44	9	185	1	1	19	1757
against	1	1	7	7	34	6	274	7	7	10	36
against	1	1	7	7	28	6	248	1	1	6	36
marginalised	1	1	12	12	62	13	98	6	6	-34	1
community.	1	1	10	9	74	14	159	5	5	-12	10

Which eye tracking features for word-level analysis

All can be aggregated

- **Early processing features**

- first fixation duration
- First gaze duration - first pass reading

- **Late processing features**

- Total fixation duration
- Number of refixations
- Second pass+ reading duration
- number of regressions to
- number of regressions from

- **Low level processing features**

- Saccadic latency
- Word length

Low cost eye trackers





The worlds first 99\$ eye tracker





WHAT'S IN THE BOX?

Just everything you need.

- ✓ Tobii Eye Tracker 5
- ✓ USB extension cable
- ✓ Two magnetic flat mounts
- ✓ One flex mount
- ✓ Warranty and safety documentation
- ✓ How to get started

EyeJustRead

Reading analysis for children with reading difficulties with a low cost eye tracker

References

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Larger, English eye tracking corpora and NLP task annotations

Name	Reference	Text source	Annotations	Subjs.	Tokens	Coverage
GECO	Cop, Dirix, Drieghe, and Duyck (2017)	novel	named entities (Hollenstein and Zhang, 2019) multiword expressions (Rohanian, Taslimipoor, Yaneva, and Ha, 2017), referential uses of <i>it</i> (Yaneva, Evans, Mitkov, et al., 2018)	14	68606	95%
Dundee	Kennedy, Hill, and Pynte (2003)	newspaper articles	POS, Universal Dependencies (Barrett, Agić, and Søgaard, 2015), named entities (Hollenstein and Zhang, 2019), Anaphora (Seminck and Amsili, 2018)	10	58598	94%
CFILT-Sarcasm	Mishra, Kanojia, Nagar, Dey, and Bhattacharyya (2016a)	movie reviews	Sentiment	7	23466	85%
CFILT-Sentiment	Joshi, Mishra, Senthamilselvan, and Bhattacharyya (2014)	movie reviews	Sentiment	5	21076	82%
ZuCo	Hollenstein, Rotsztein, et al. (2018)	Wiki/Sentiment	NER, Sentiment, Relations	12	13465	90%
CFILT-Scanpath	Mishra, Kanojia, Nagar, Dey, and Bhattacharyya (2017)	Wikipedia/simple Wikipedia	Reading difficulty scores	16	3677	89%
Provo	Luke and Christianson (2018)	miscellaneous domains	POS	470	2689	95%
CFILT-Coreference	Cheri, Mishra, and Bhattacharyya (2016)	MUC-6 dataset	Coreference	14	2210	95%

Table 1

Overview of eye tracking resources with normal, skilled reading for English by native speakers. Annotations column: annotations useful for NLP, if no reference is provided, the annotations are from the authors of original publication. Coverage = X% of vocabulary in corpus occurs in British National Corpus list^a of most frequent English words (occurring more than 5 times). "CFILT" prefix denotes corpora from the Center for Indian Language Technology

^a<https://www.kilgarriff.co.uk/bnc-readme.html>