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CC BY

LEAD-ME Summer Training School Warsaw'21

Eye tracking in media accessibility research - methods, technologies and data analyses

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Leading Platform for European Citizens, Industries, Academia and Policymakers in Media Accessibility
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Introduction to experimental designs in eye tracking studies

Izabela Krejtz

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Eye Info by looking into eyes we can recognize their owner.

Whose eyes are these?

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Whose eyes are these?

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By analyzing eye movements we can tell what a person is doing and possibly infer their mental states

Duchowski et al. (2016)

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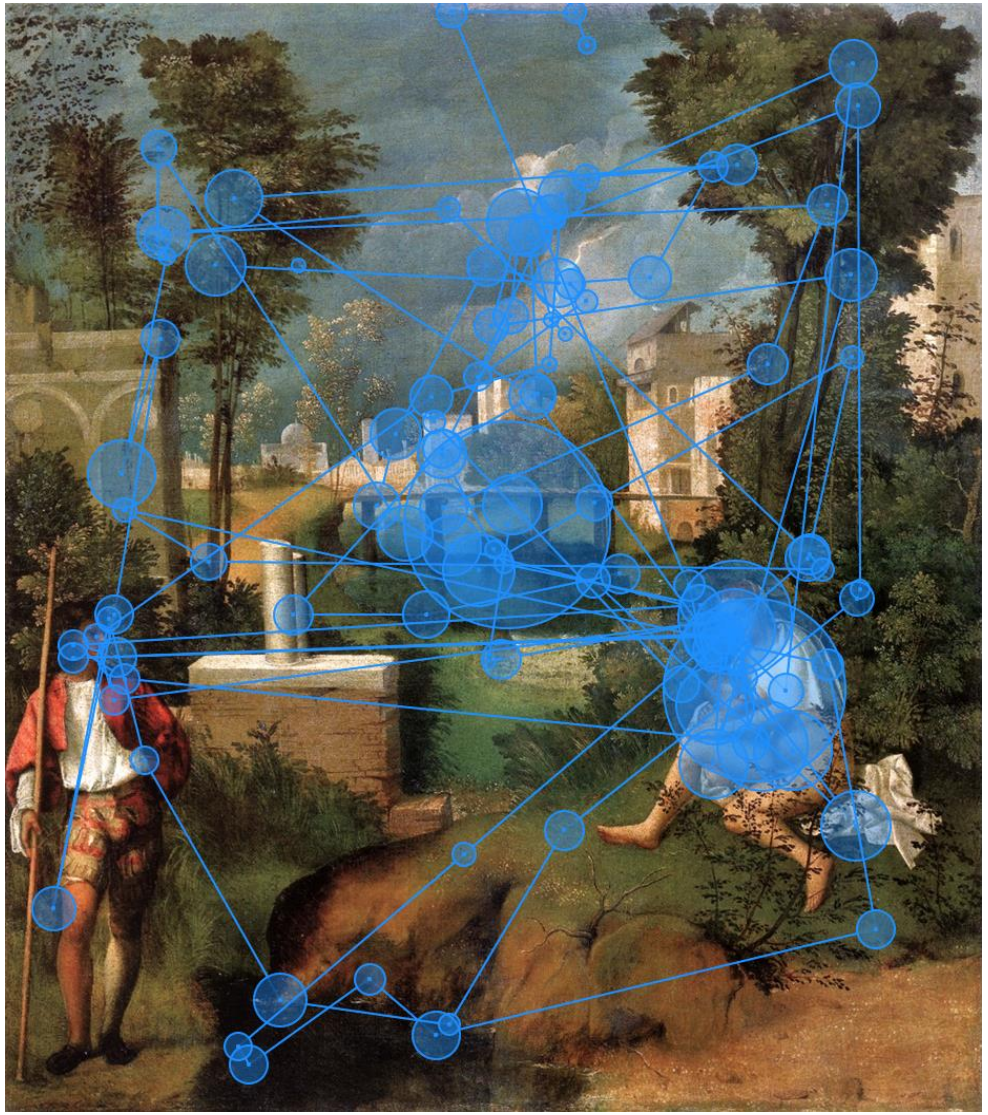
PROCESSING VISUAL INFORMATION

Viewing path for 1 person while viewing the image (30 sec.)

Fixations (circles) saccades (lines)



- Visual exploration from eye movements perspective is a consecutive sequence of fixations and saccades
  - Fixations
    - stabilise image on retina
    - low spatial disparity
  - Saccades
    - move eye towards a new location
    - high speed and amplitude

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Study design

what

who

how

- Before designing a study we need to decide:
  - What to study:
    Perception of emotions
  - Who will be participating:
    Deaf and hearing individuals
  - How will we test our prediction:
    Presentation of faces expressing emotions
- Do we have any predictions?

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HOW: Research designs

- correlational design
  - looking for relationship between two or more variables
- natural groups design (quasi-experimental)
  - independent variable is not manipulated
- experimental design
  - independent variable is manipulated
  - random allocation to groups
  - control of confounding variables

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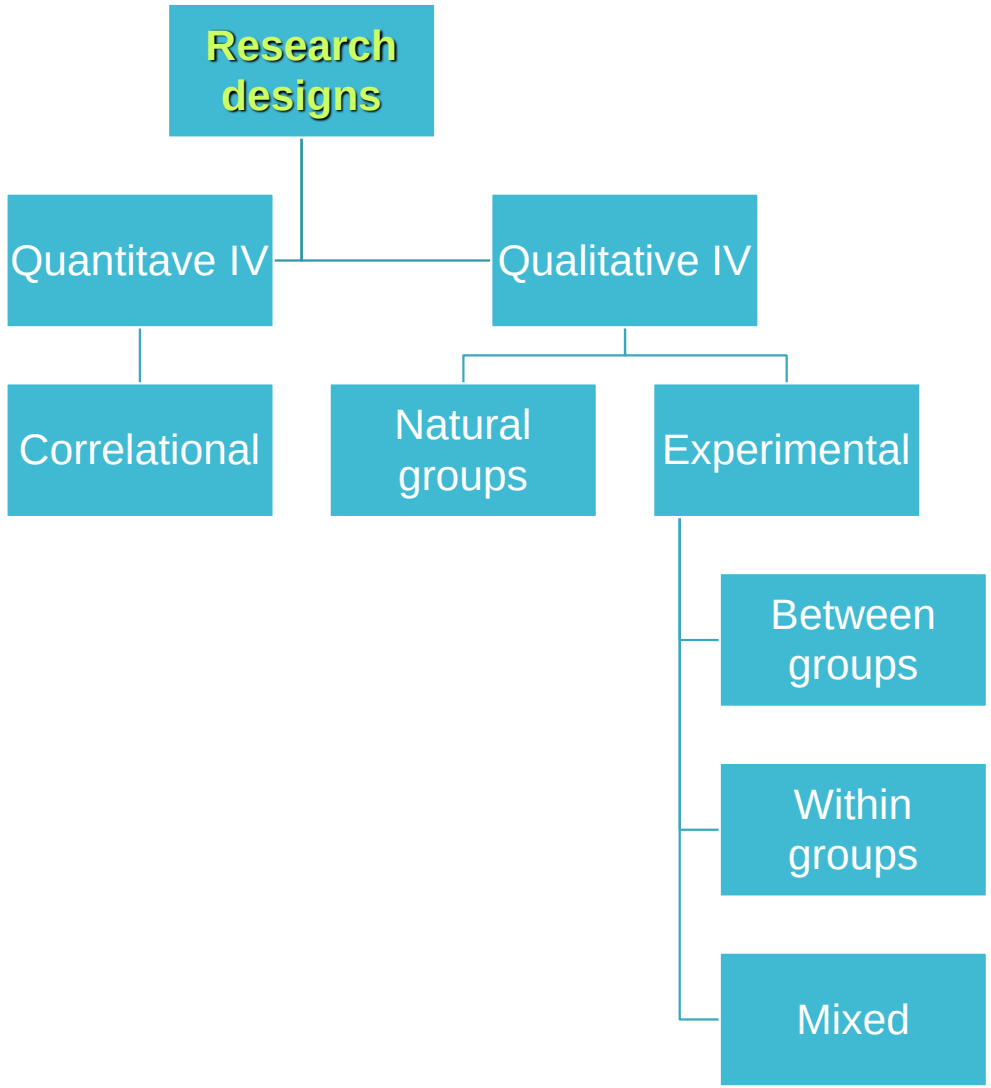
Decision tree



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Natural groups design quasi-experimental mixed-design

WHAT: Perception of emotions

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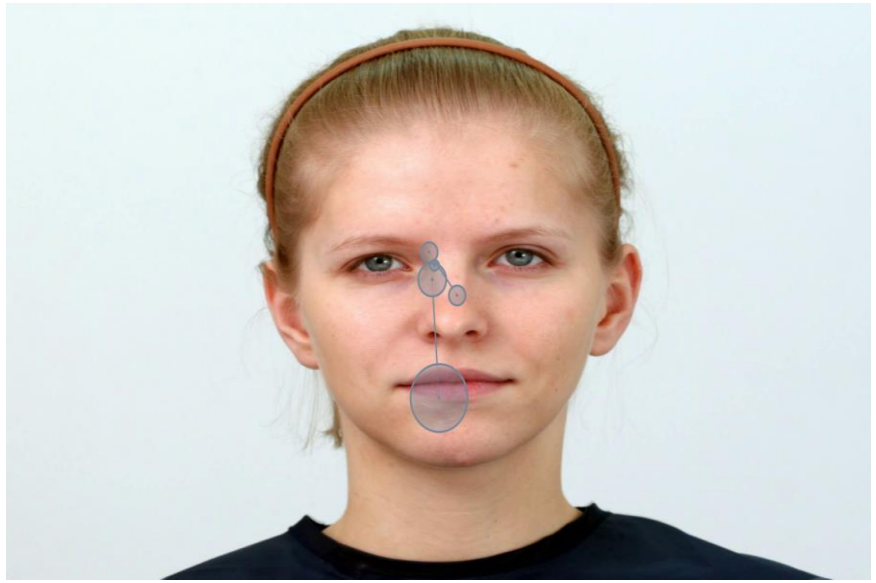
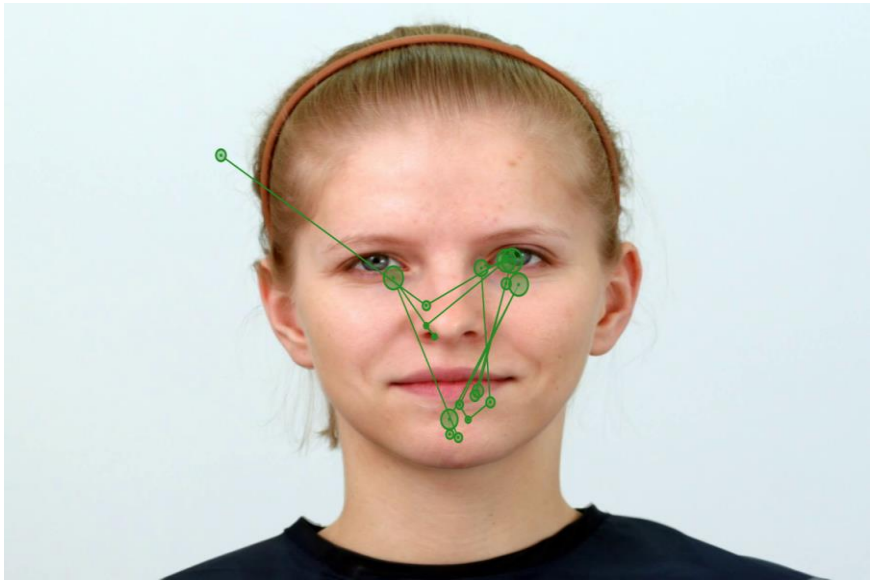
WHO

Group
Hearing vs Deaf

1st IV
independent
variable
not manipulated
between-
subjects





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HOW

Faces
Happy vs Angry

2nd IV
independent
variable
manipulated
within-subjects

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HOW

Visibility
Full vs Half face

3rd IV independent variable manipulated within-subjects

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Study design 2x2x2 mixed design

- So far, our study has 3 independent variables each on 2 levels
- Independent variables can be introduced as:
  - **Between-subjects designs** require more participants (around 20 per group) than within-subjects designs
  - **Within-subjects designs** require less participants because each participant is presented with the same set of stimuli
  - **Mixed design** has at least one within-subjects and one between-subjects independent variable
- We can complicate the design either by adding more levels to IVs or adding more independent variables

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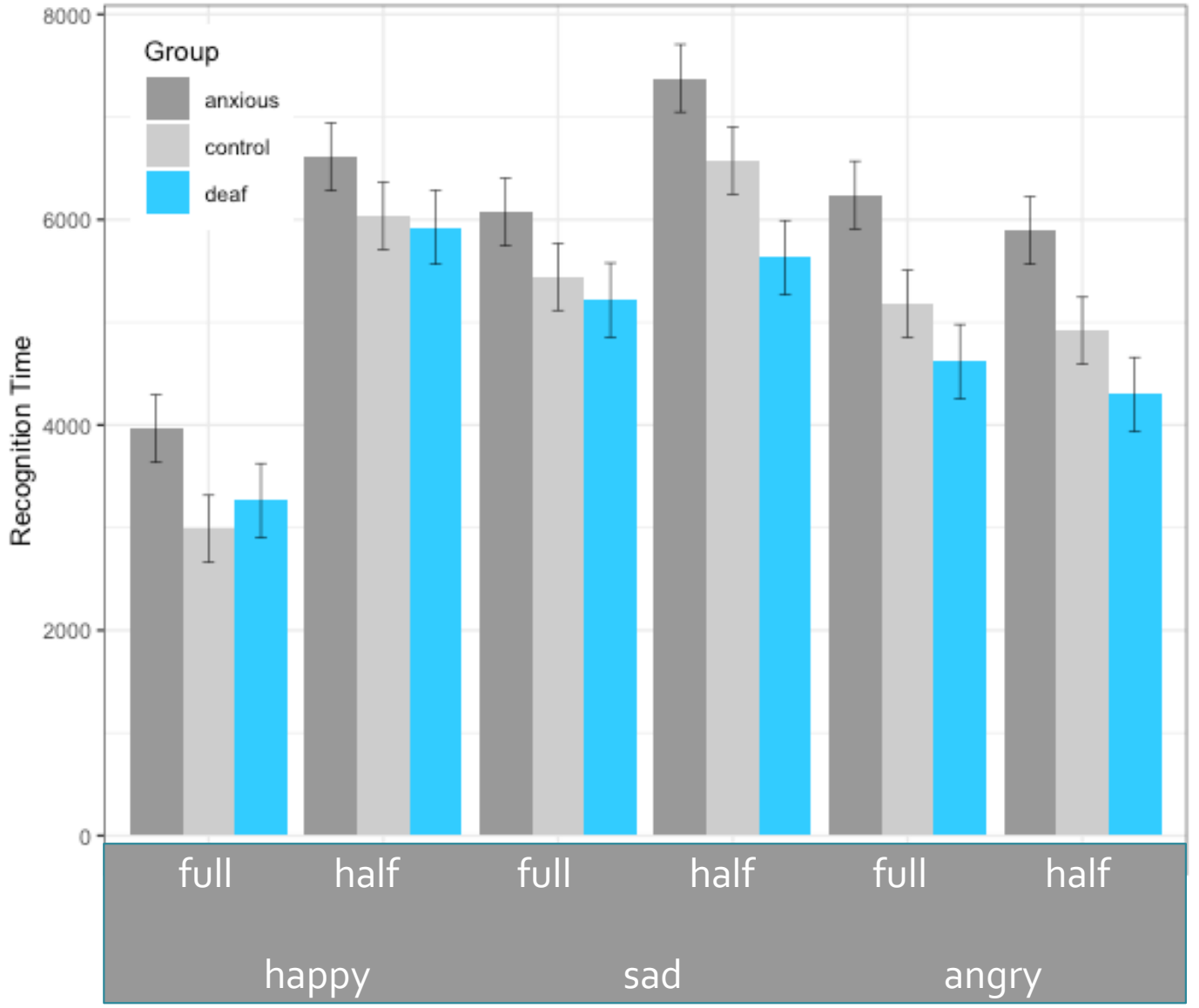
Final study design:

3x3x2 mixed design



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DESIGNING AREAS OF INTEREST

In eye tracking studies, areas of interests often create another within-subjects independent variable

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DRAWING AREAS OF INTEREST

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Each stimulus is a separate AOI

We may analyze:
The proportion of time spent looking at each of stimulus in relation to the rest of stimuli

$$FFD_{relative} = \frac{FFD_{positive}}{FFD_{positive} + FFD_{negative}}$$

FFD - First Fixation Duration
First Glance Duration
Total Dwell Time

Krejtz et al. 2018 Journal of Clinical Psychology

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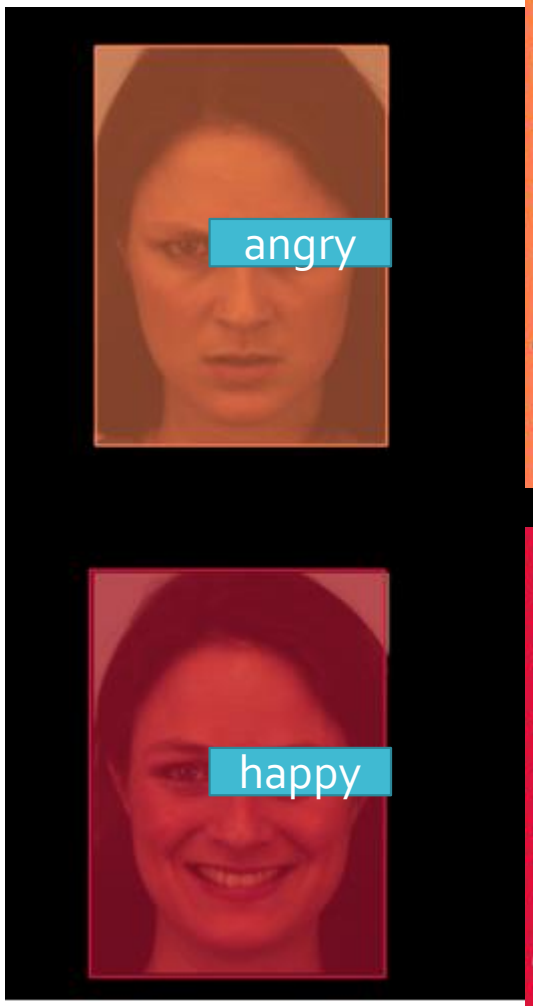
Other metrics



Sequence	2
Entry time	861.0 ms
Dwell time	2031.4 ms (20.3 %)
Hit ratio	50/50 (100.0 %)
Revisits	1.5
Revisitors	42/50
Average fixation	305.0 ms
First fixation	275.1 ms
Fixation count	6.6

Sequence	4
Entry time	2768.0 ms
Dwell time	2418.3 ms (24.2 %)
Hit ratio	50/50 (100.0 %)
Revisits	1.5
Revisitors	38/50
Average fixation	314.1 ms
First fixation	273.8 ms
Fixation count	7.8

Krejtz et al. 2018

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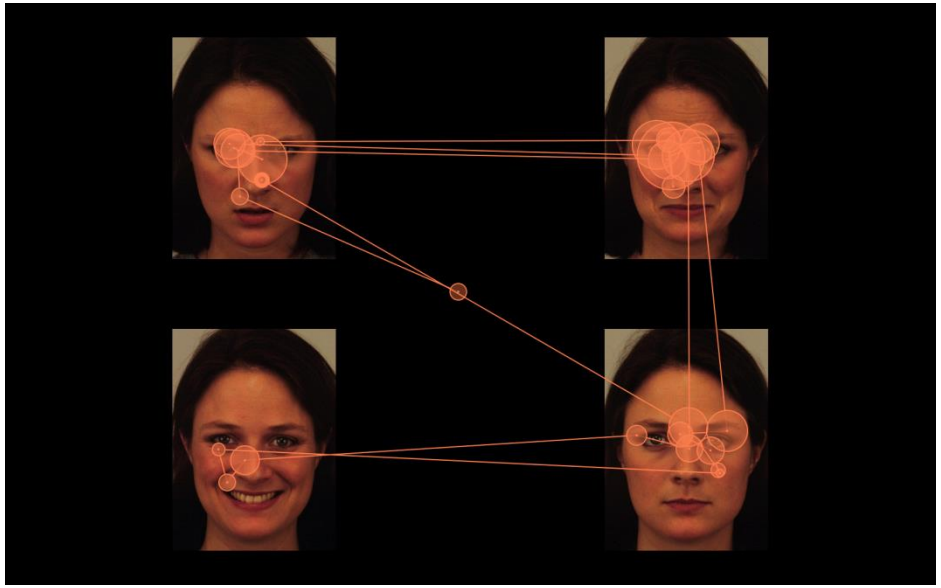
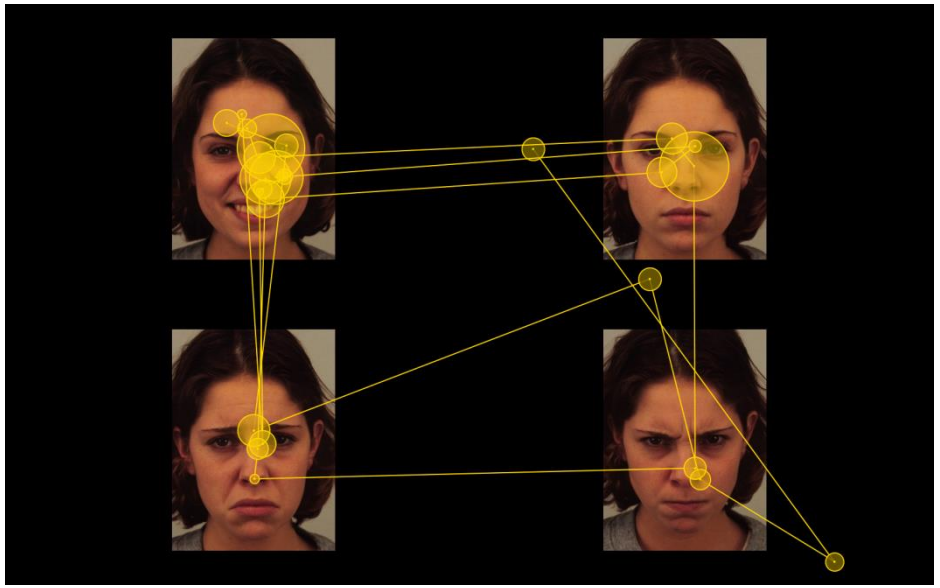
Examples of individual scanpaths





- Depressed before and after therapy (mindfulness training)

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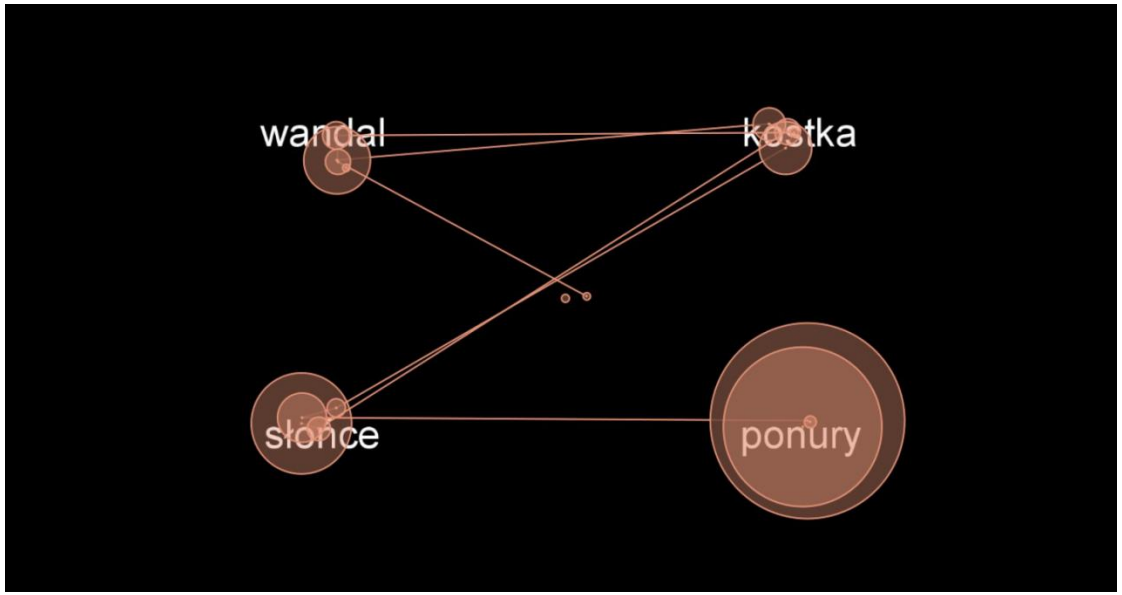
FOUR-WORD PROCEDURE

Eye tracking indices

- 12 slides with four words on each of them was shown to participants
- dysphoric
- aversive
- positive
- neutral



- simultaneously presented on a slide for 10 seconds
- indices of attentional bias: glances count and dwell time of dysphoric words

Ellis et al. 2011

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ET indicators and everyday functioning

Proportion of dwell time on negative words as a predictor of daily functioning of depressed individuals

DWELL TIME on DYSPHORIC WORDS

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Multilevel model

Day Level

$$Rumination_{ij} = \beta_{oj} + r_{ij}$$

Person Level

$$\beta_{oj} = \gamma_{oo} + \gamma_{o1} * (\text{Dwell Time}) + u_{oj}$$

Predictor of daily rumination:

dwell time on affective words

	dysphoric	*positive*	*aversive*	*neutral*
Rumination	.36**	.04	.63**	.20
Adjustment	-.21**	-.08	-.21*	-.14

Holas, Krejtz et al. 2019. Emotion and Cognition

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The effect of consumer confusion on attention to products placed in TV shows

Experimental mixed design 2x5:

1 Between-subjects independent variable (manipulated)

1 Within-subjects IV (epoch)

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Study design

Group 1: noise

Group 2: calm

3-min. video

5-min culinary program
"Advisor of taste" „Doradca smaku”

Grochowska, Kulig et al. (in prep.)

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BEKO

Prymat®

łaciate®

ZWIEGER haus & küche

Brands in the TV show

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Dynamical AOIs

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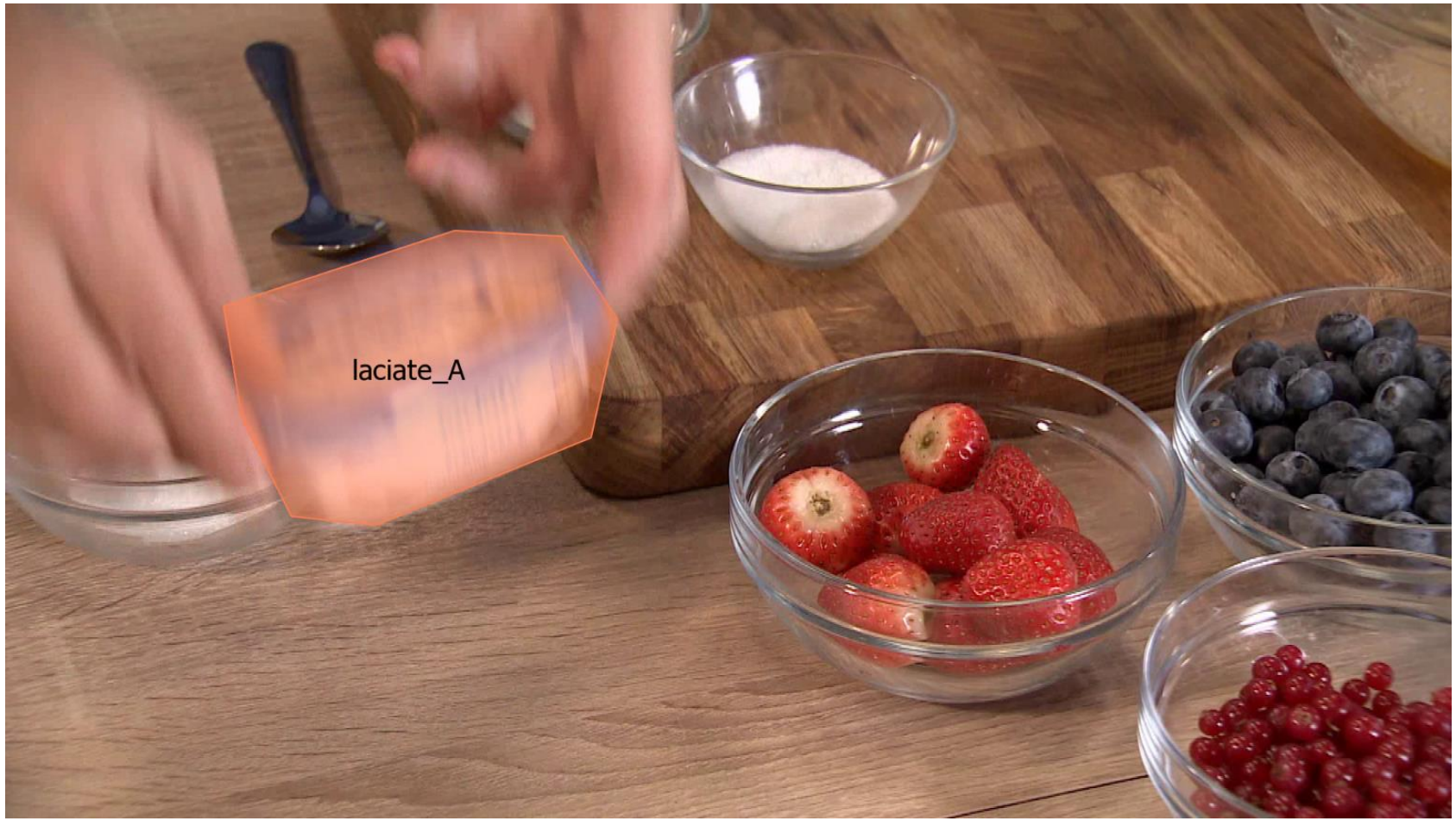

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Distribution of attention

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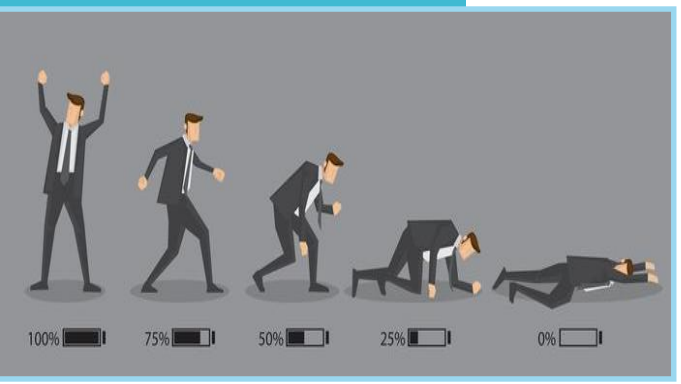
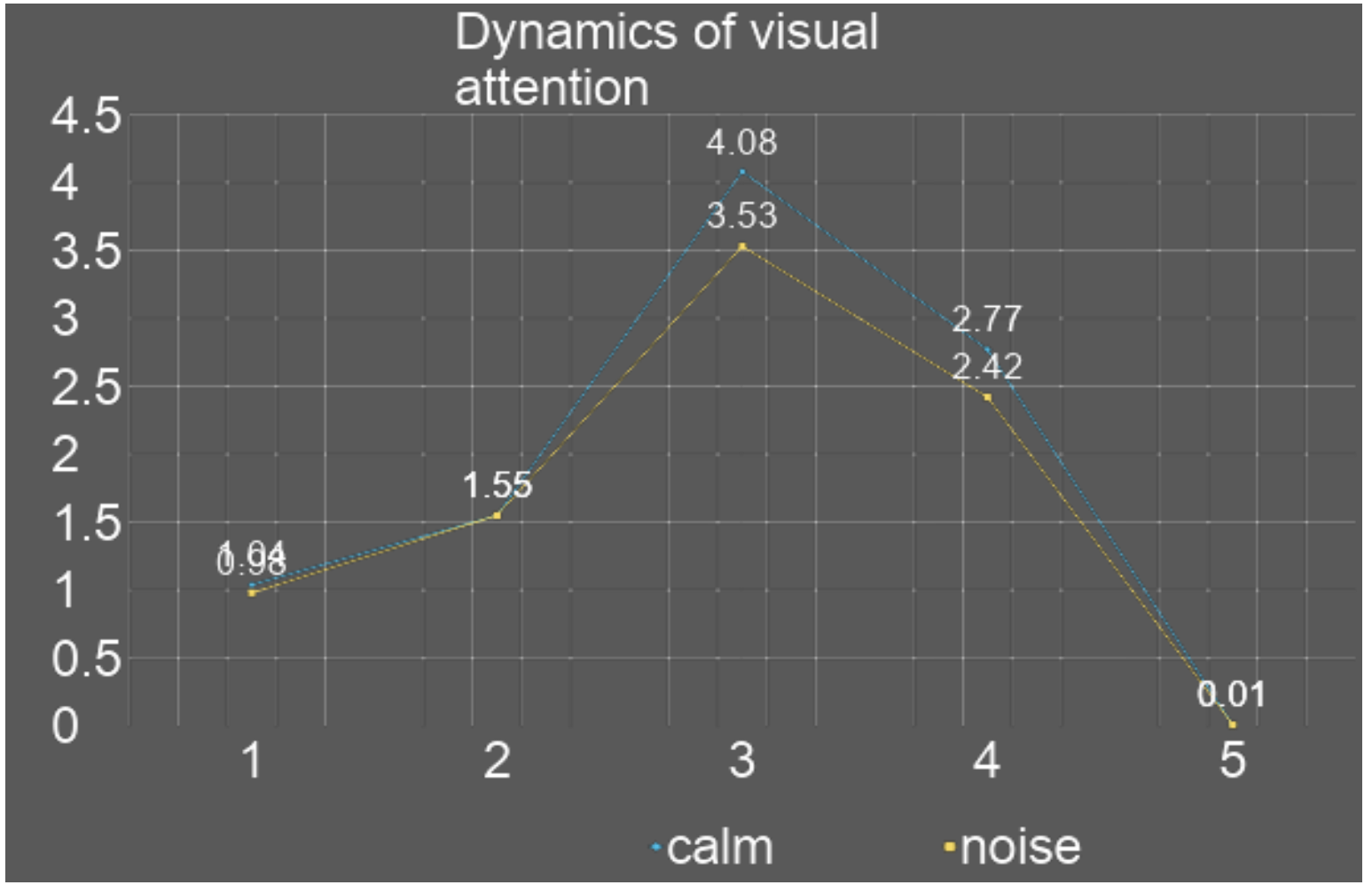
Number of fixations on the placed products





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Distribution of attention during perception of a sign language interpreter

2x3 within-subjects design:
1IV: lip movement
2IV: type of sign language

Abramczyk et al. unpublished

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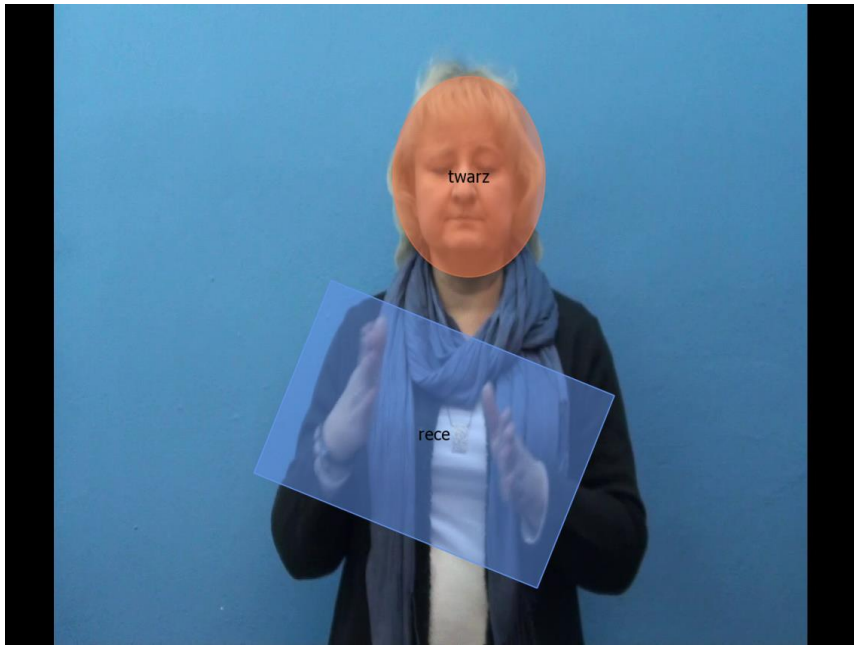
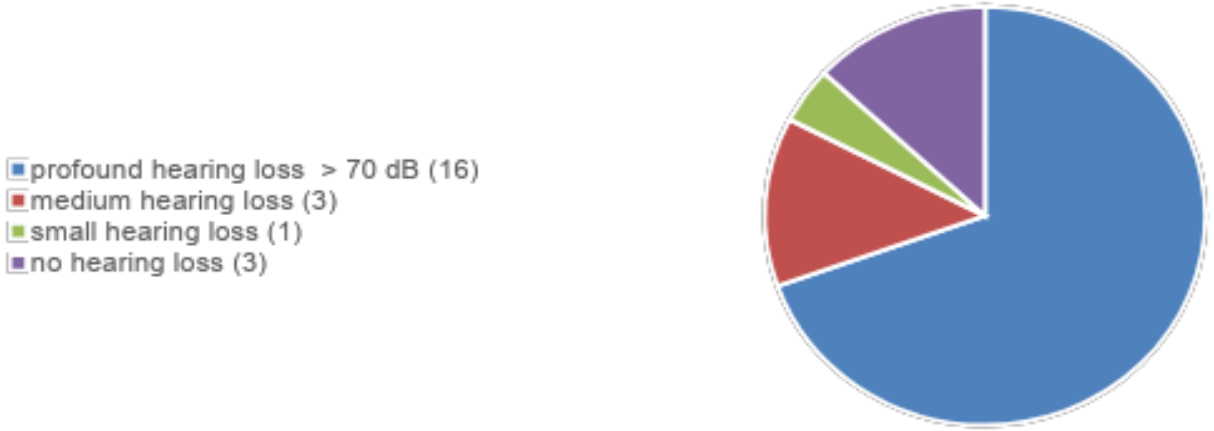
How attention is distributed between face and hands depending on sign language and lips movement



23 participants, Polish Association for the Deaf



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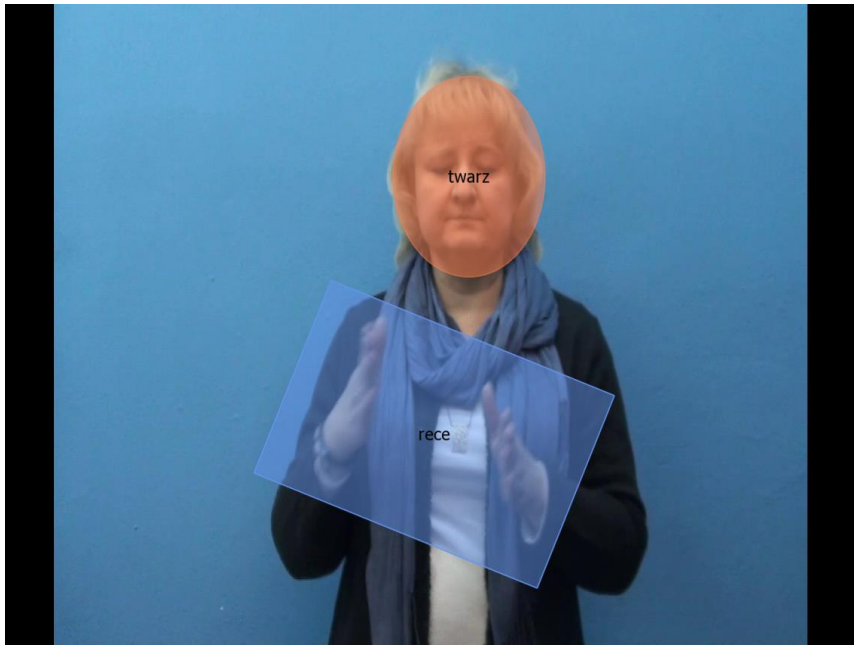
How attention is distributed between face and hands depending on sign language and lips movement



	Type of Sign Language		
	PSL	Hybrid	SLS
lips movement	yes	yes	yes
	no	no	no

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A little bit of a theory

- Theory of compensation – hearing impairment strengthens visual attention
  (Gibson et al., 1969)

- Deaf are more attentive to movements in their peripheral visual field than the Hearing
  - lack of support for the general enhancement of visual attention among Deaf
    (Armstrong et al. 2002; Pavani, Bottari, 2012)

source: http://www.ncbi.nlm.nih.gov/books/NBK92865/

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Guess which recording is from deaf participants and which one is a recording of hearing individuals fluent in sign language

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Long-term Music Education Fosters Attentional Control in Primary School Children

Mixed design:

Between-subjects independent variable (natural groups)

Within-subjects IV (experimental task)

Within-subjects IV (time of measurement)

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Music education and attentional control

Procedure:

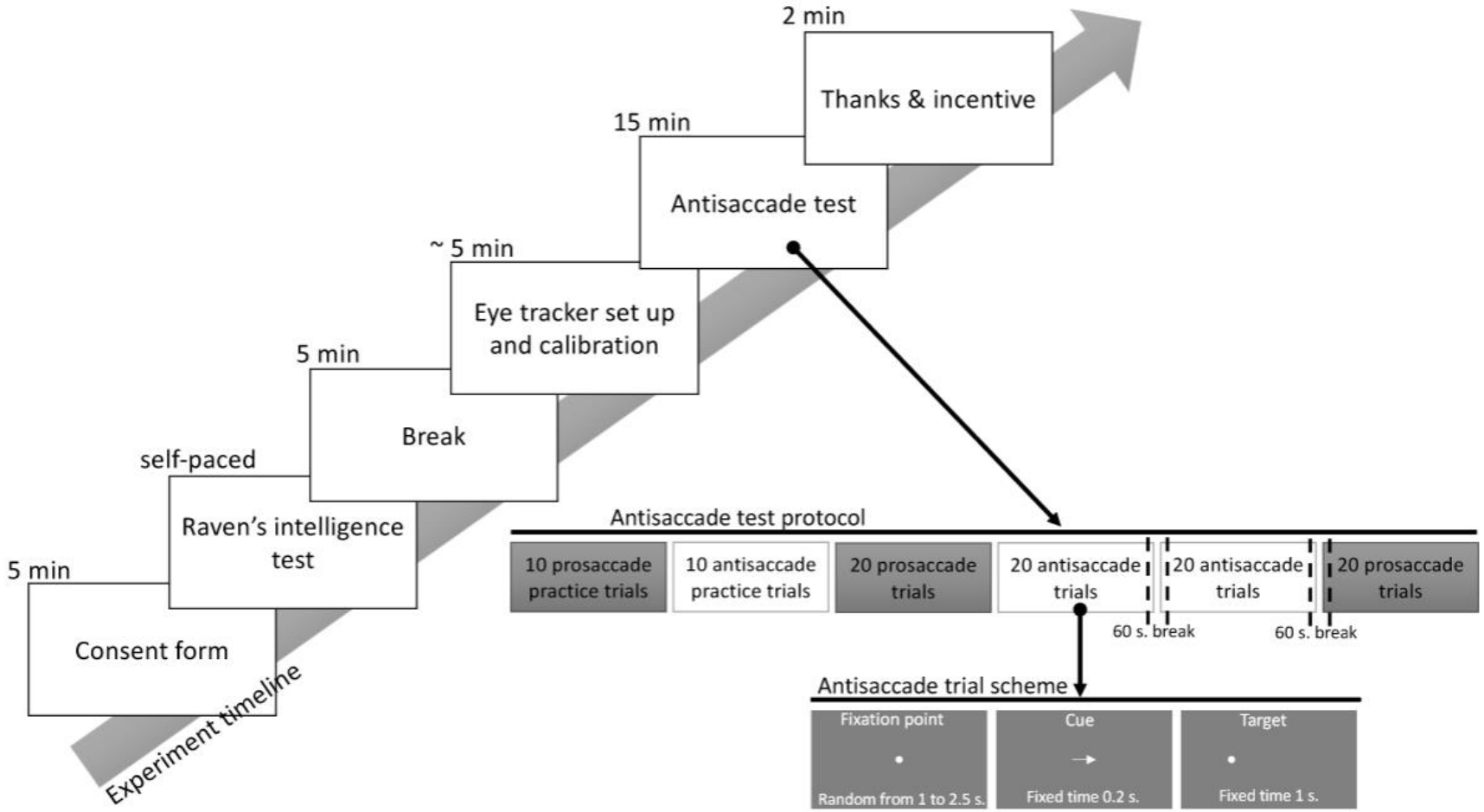

Figure 1

Experimental procedure, the antisaccade task, and the antisaccade trial schemes.

Cybulska et al. submitted

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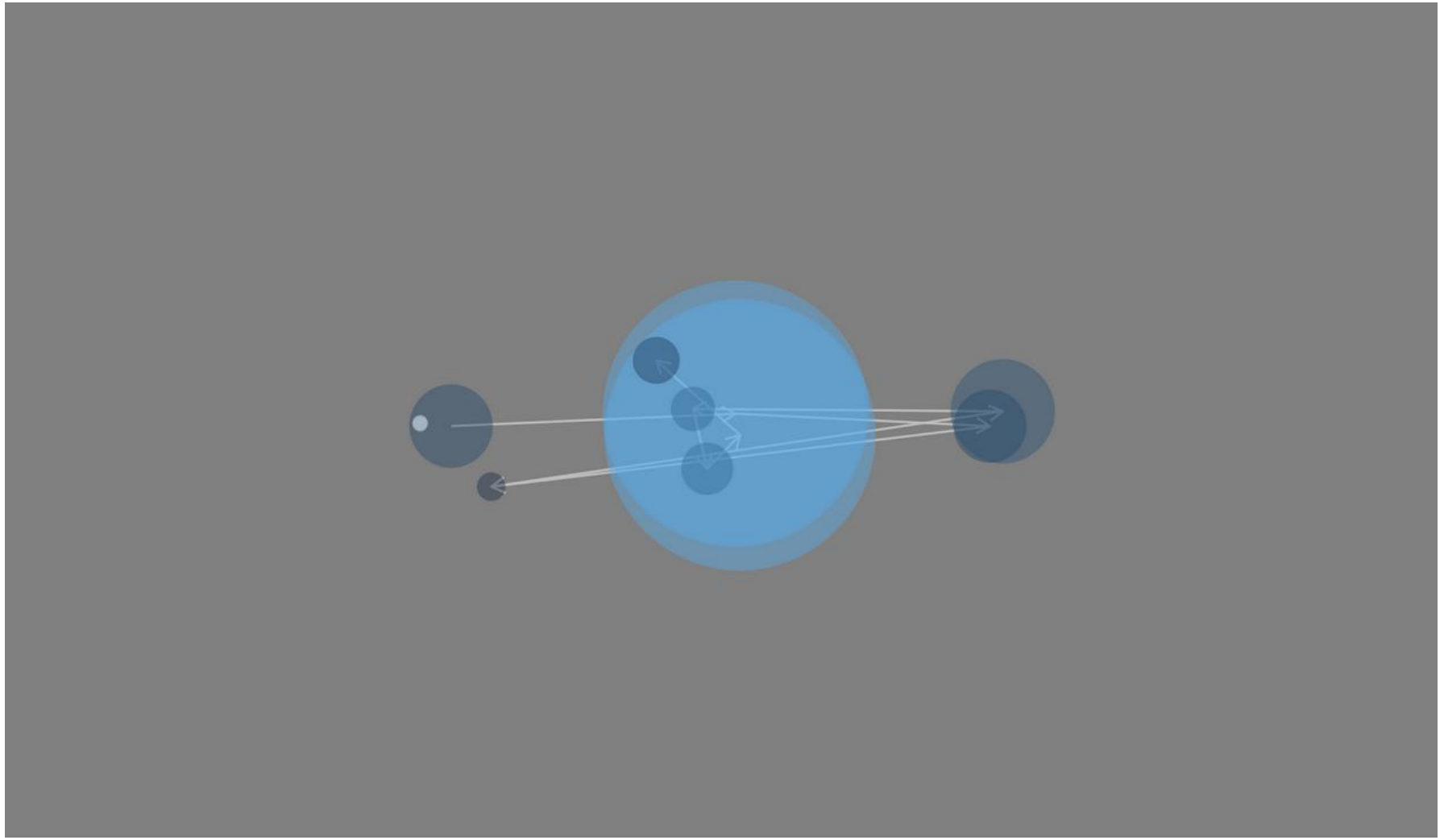
exemplary scanpath in antisaccadic trial



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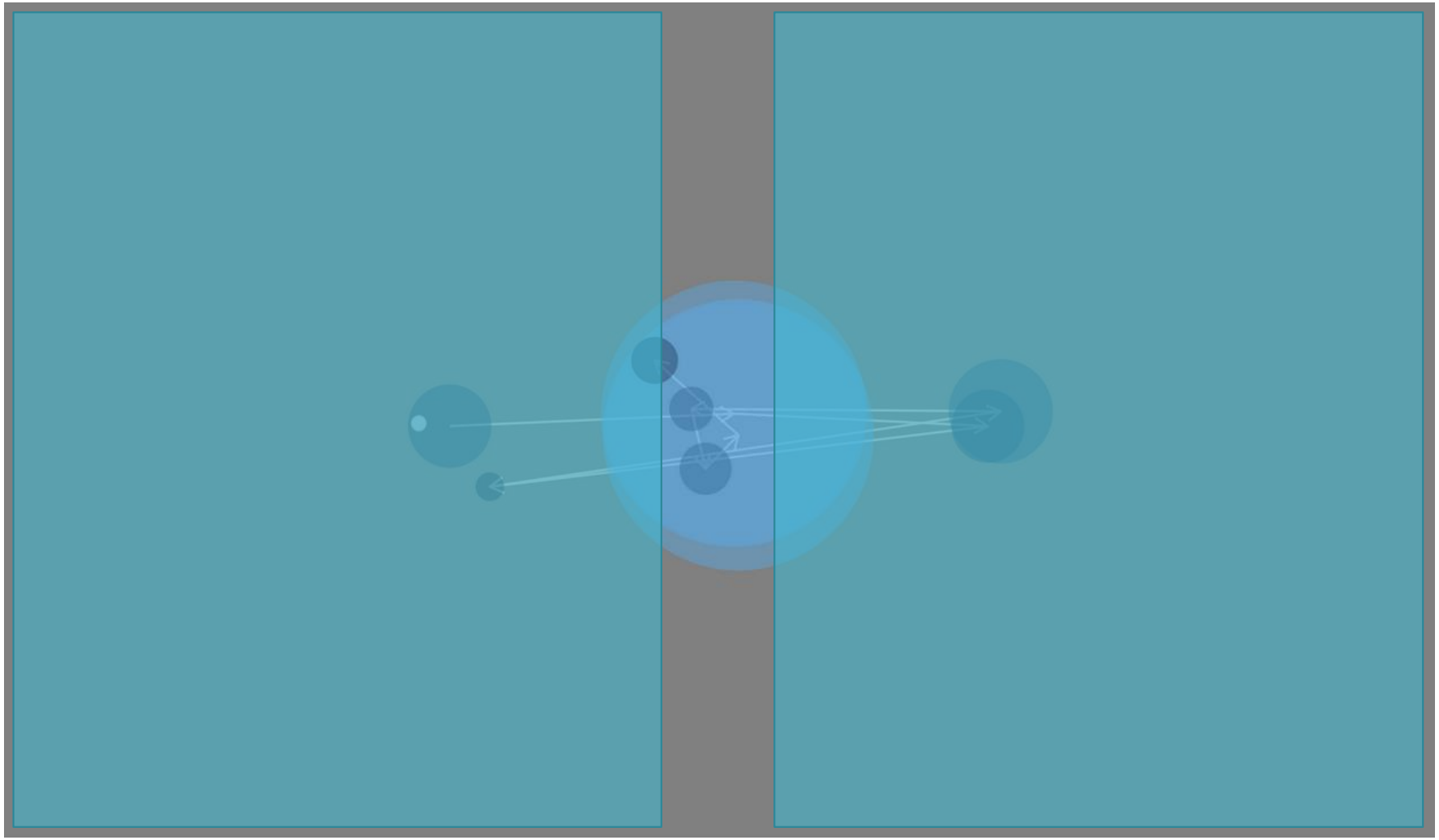
AOIs in antisaccade task



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Results:

significant decrease in reaction time

the linear trends are steeper for music children

due to a shorter latency of 1st saccade toward target

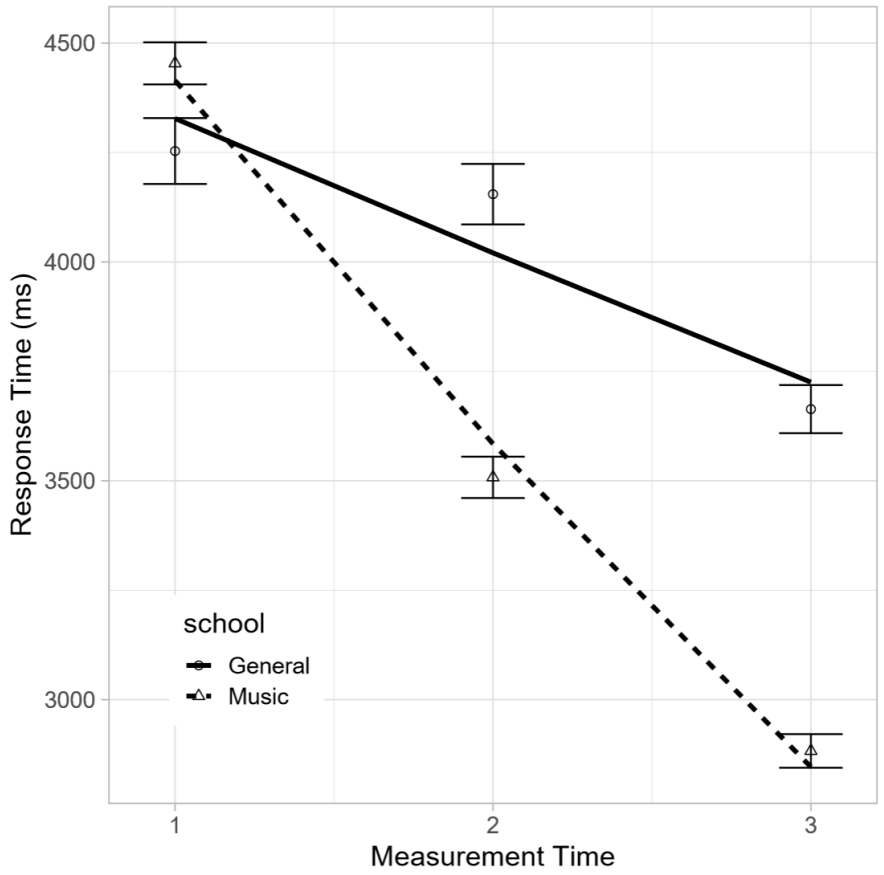
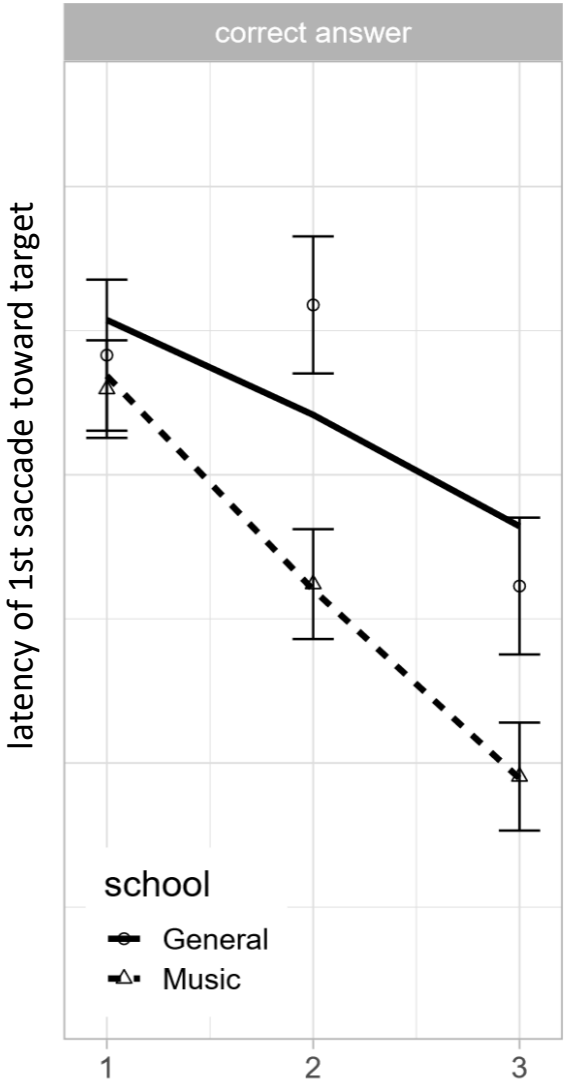


Figure 3

Reaction time of correct responses in antisaccade task depending on measurement time and school type. Interaction effect of time and school type.



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experimental design
2x2
effect of word characteristic on cognitive effort

Evaluating Cognitive Effort With Pupillary Activity When Reading

Evidence from Eye Movements of Primary School Children

AGATA CYBULSKA, IZABELA KREJTZ, and KRZYSZTOF KREJTZ, SWPS University of Social Science & Humanities, Poland
ANDREW T. DUCHOWSKI, Clemson University, USA

(a) long and frequent (b) long and infrequent (c) short and frequent (d) short and infrequent

Fig. 1. Exemplary scanpaths (circles indicate fixations of relative duration, larger radii are longer) when reading sentences with different embedded keywords: (a) long and frequent, (b) long and infrequent, (c) short and frequent, and (d) short and infrequent.

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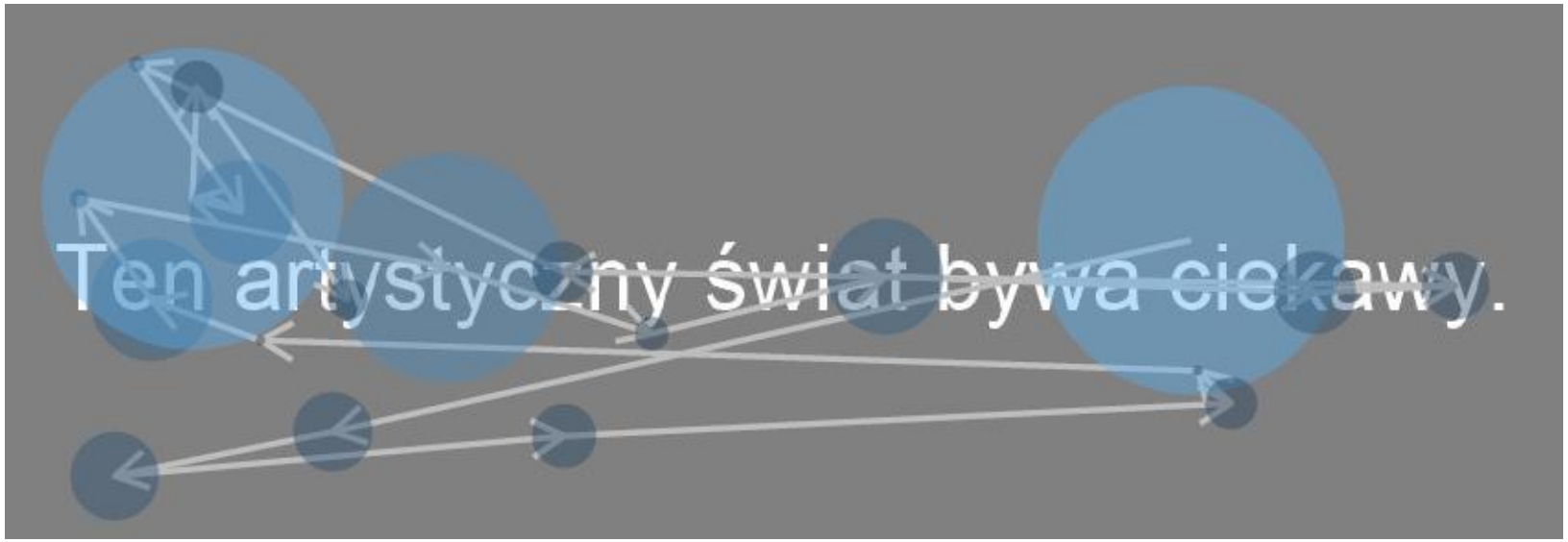
Exemplary scanpaths



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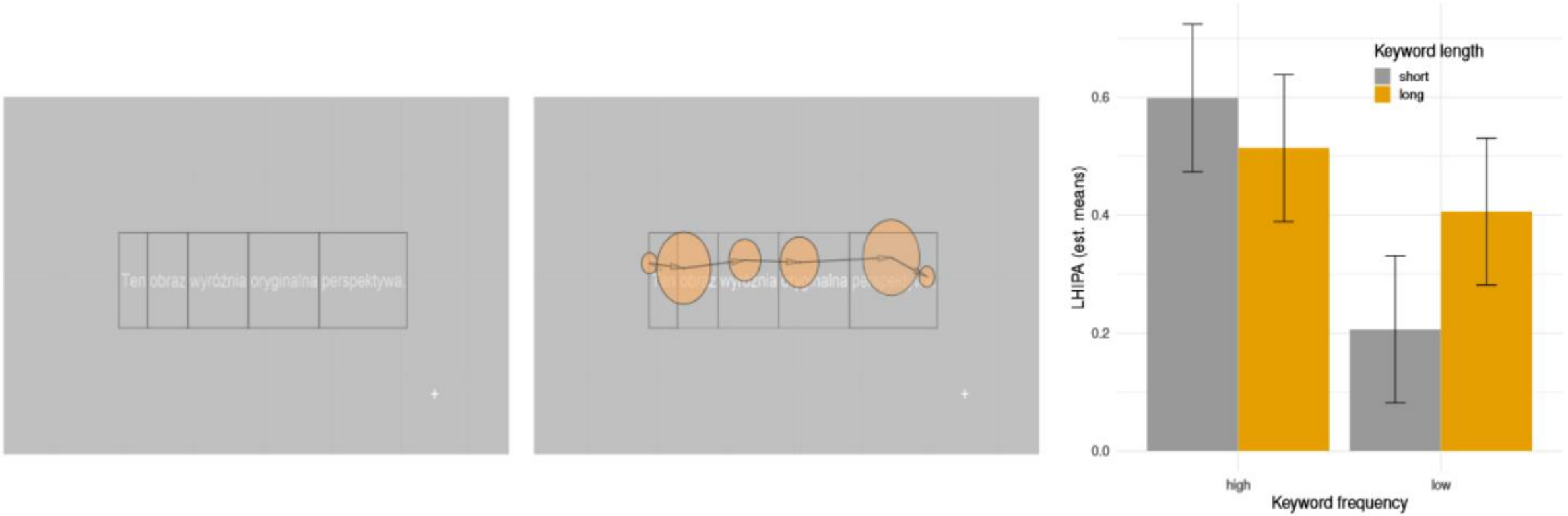

(a) AOI definitions (b) fixations (circles) within AOIs (c) LHIPA for correct answers

Fig. 2. Example scanpath processing: (a) Areas Of Interest (AOIs) are defined so that only (b) fixations detected within AOIs are processed further via statistical analysis, e.g., fixation count or (c) LHIPA while reading sentences with different types of keywords. *Note:* Error bars represent ±1 *SE*.

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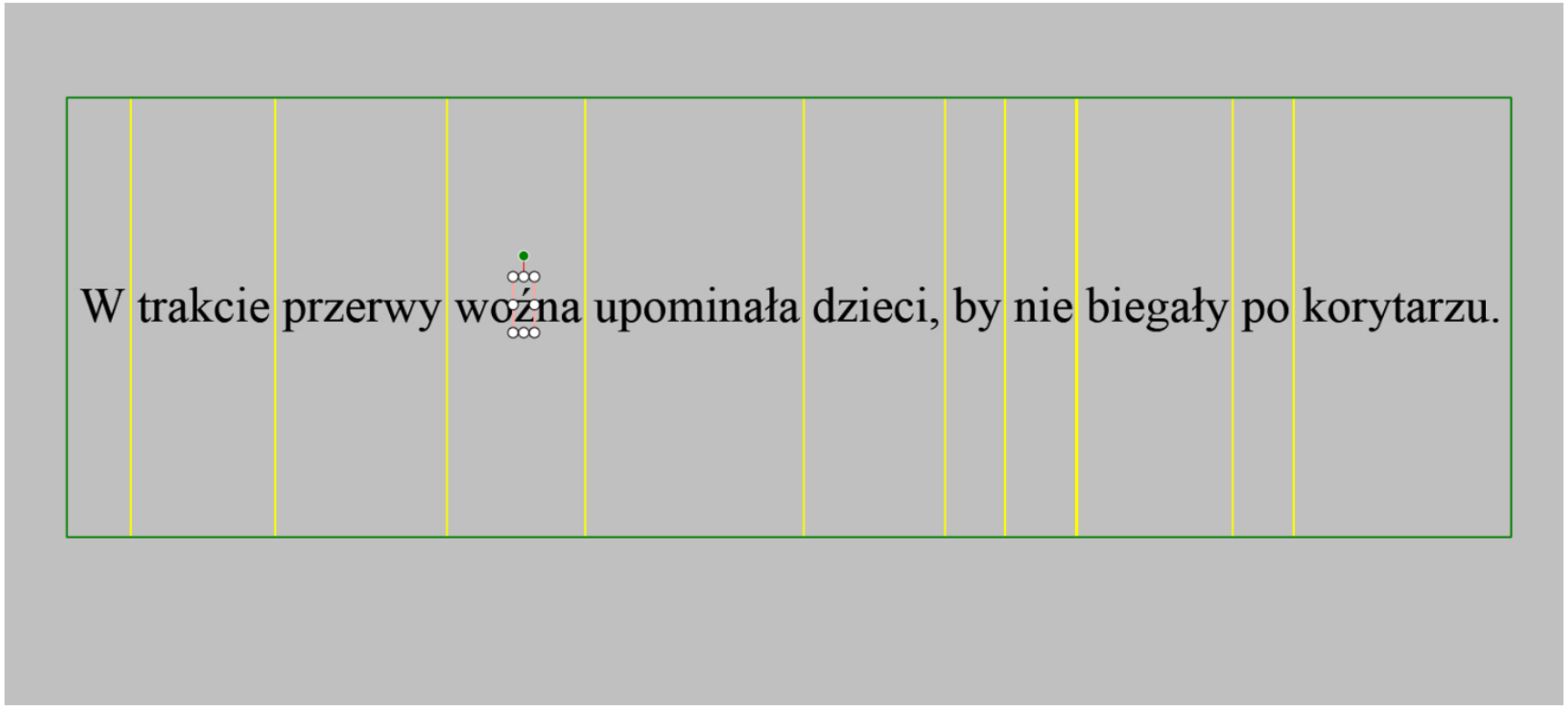
UNITS OF ANALYSIS IN READING STUDIES



We may analyze eye movements over:
whole text, paragraph, sentence, word, syllable, letter

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AOIs IN READING RESEARCH

A more common method of determining AOI

Used for longer texts

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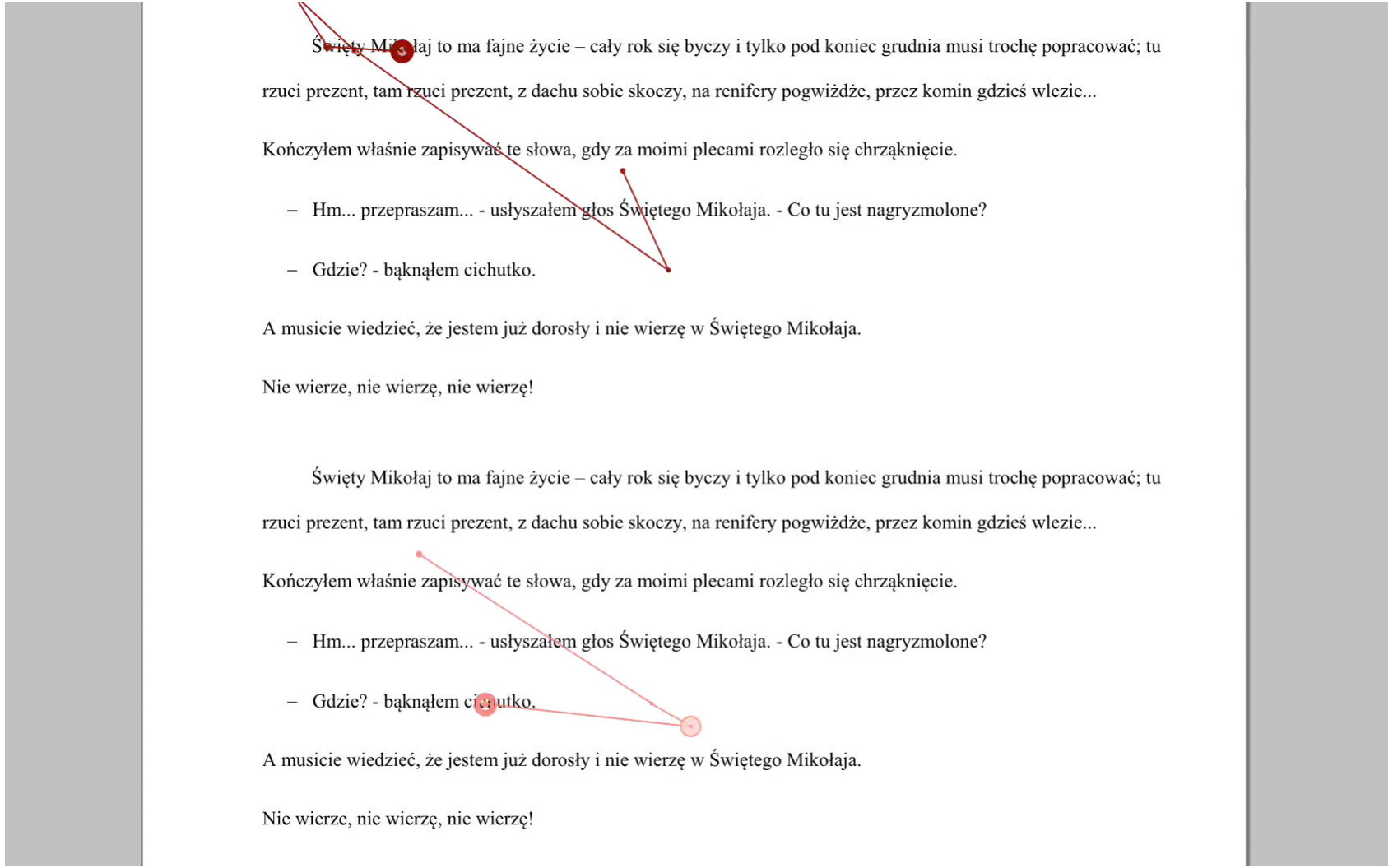
A comparative reading study

reading in typically developing and dyslexic children

fixation, regressions, refixations, skipping



Święty Mikołaj to ma fajne życie – cały rok się byczy i tylko pod koniec grudnia musi trochę popracować; tu rzuci prezent, tam rzuci prezent, z dachu sobie skoczy, na renifery pogwiżdże, przez komin gdzieś wlezie...

Kończyłem właśnie zapisywać te słowa, gdy za moimi plecami rozległo się chrząknięcie.

– Hm... przepraszam... - usłyszałem głos Świętego Mikołaja. - Co tu jest nagryzmolone?

– Gdzie? - bąknąłem cichutko.

A musicie wiedzieć, że jestem już dorosły i nie wierzę w Świętego Mikołaja.

Nie wierze, nie wierzę, nie wierzę!

Święty Mikołaj to ma fajne życie – cały rok się byczy i tylko pod koniec grudnia musi trochę popracować; tu rzuci prezent, tam rzuci prezent, z dachu sobie skoczy, na renifery pogwiżdże, przez komin gdzieś wlezie...

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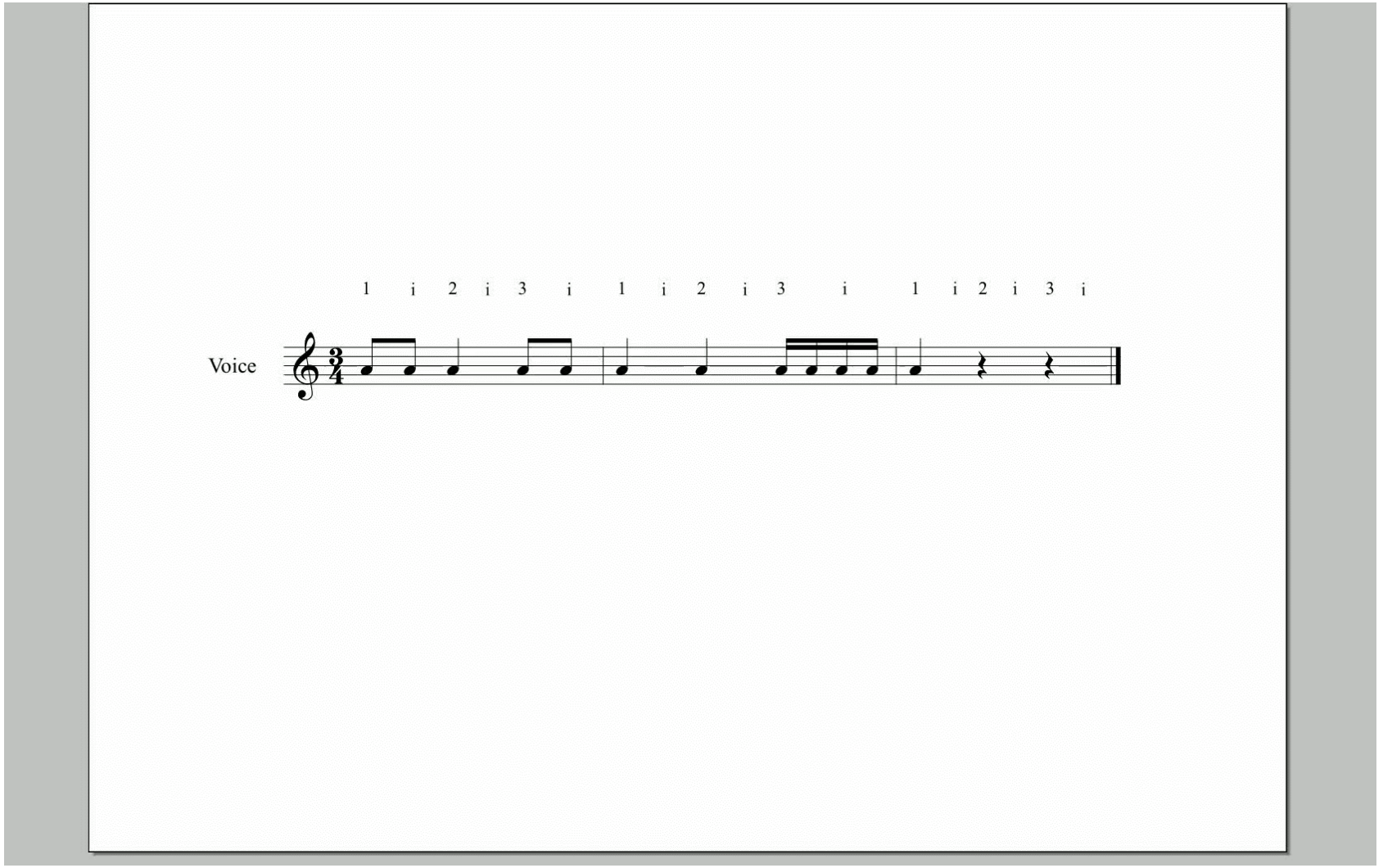
Reading music notes



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Transitions between AOIs

Reading film subtitles

Krejtz, Szarkowska et al. 2016

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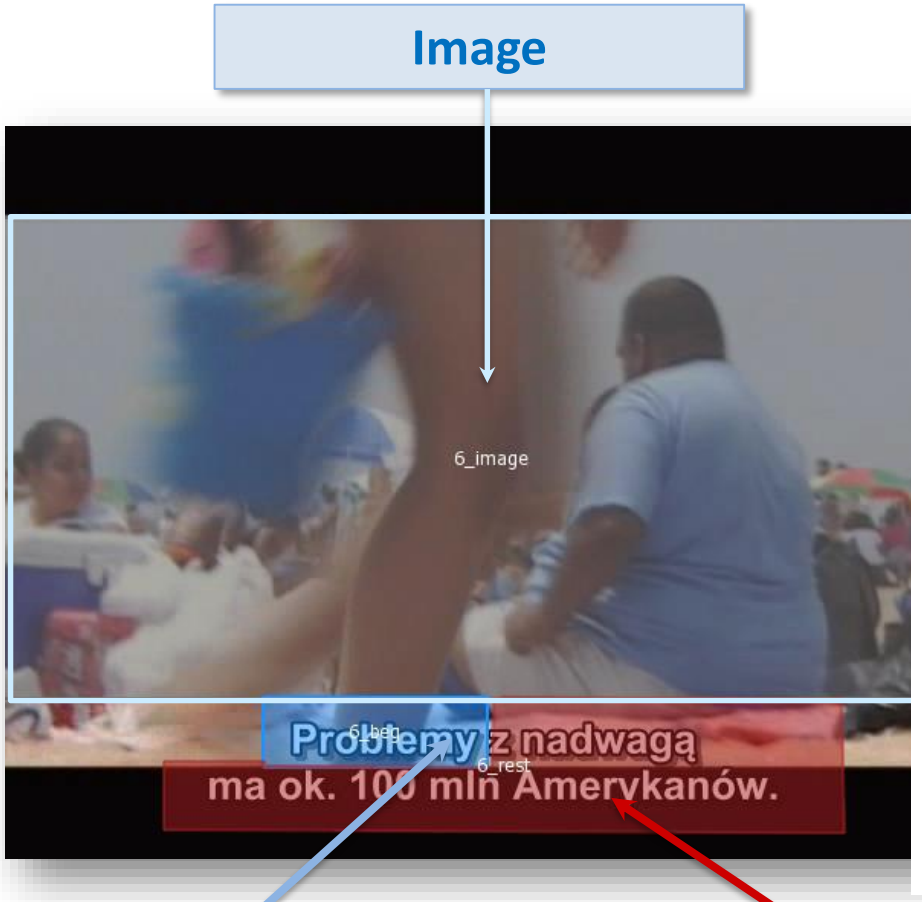
Transition matrix: analysis of the probability of switching between AOIs



TO

FROM

FROM \ TO	IMAGE	BEGINNING	REST
IMAGE	0.6	0.17	0.23
BEGINNING	0.15	0.34	0.51
REST	0.21	0.18	0.61

Krejtz, Szarkowska & Krejtz, 2013

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EYE TRACKING RESEARCH CENTER ESTABLISHED IN 2014

24 VIDEO EYE TRACKERS
11 GAZE POINTS, 60 Hz
4 GAZE POINTS, 150 Hz
1 SMI RED, 120 Hz
7 PUPIL LABS, 120Hz
1 EYELINK 2000 Hz

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gazepoint

Biometrics | Hardware

AdHawk microsystems

VIVE

SR Research EyeLink®

tobii

Pupil Labs

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Eye tracking in the wild

Joint collaboration project

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Joint attention in collaboration

project of Katarzyna Wisiecka, PhD candidate

Mobile eye tracking with PupilLabs eyetrackers

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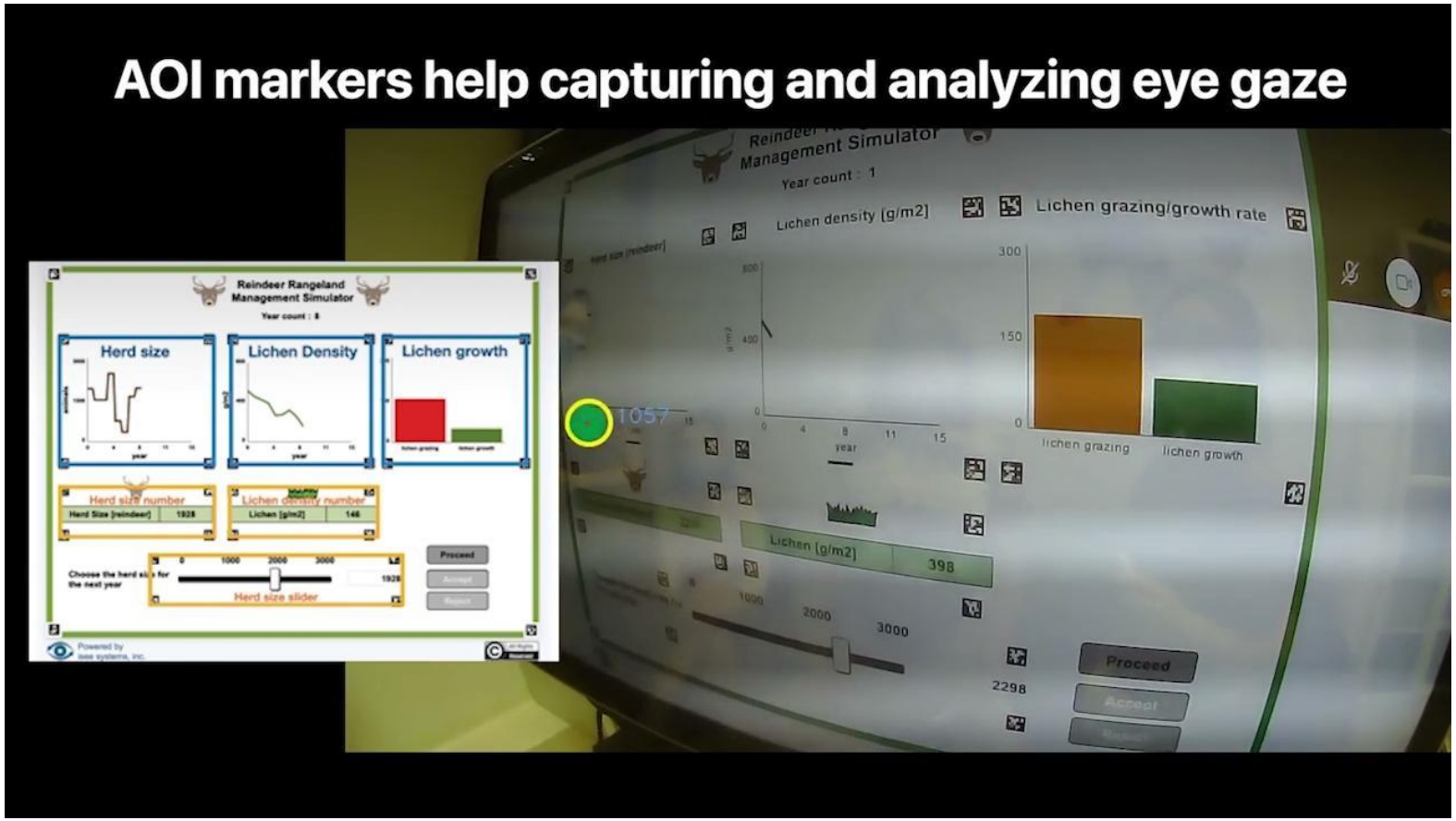
Joint attention in collaboration

Mobile eye tracking with PupilLabs



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Joint attention in collaboration

Mobile eye tracking with PupilLabs eyetrackers

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precision and accuracy

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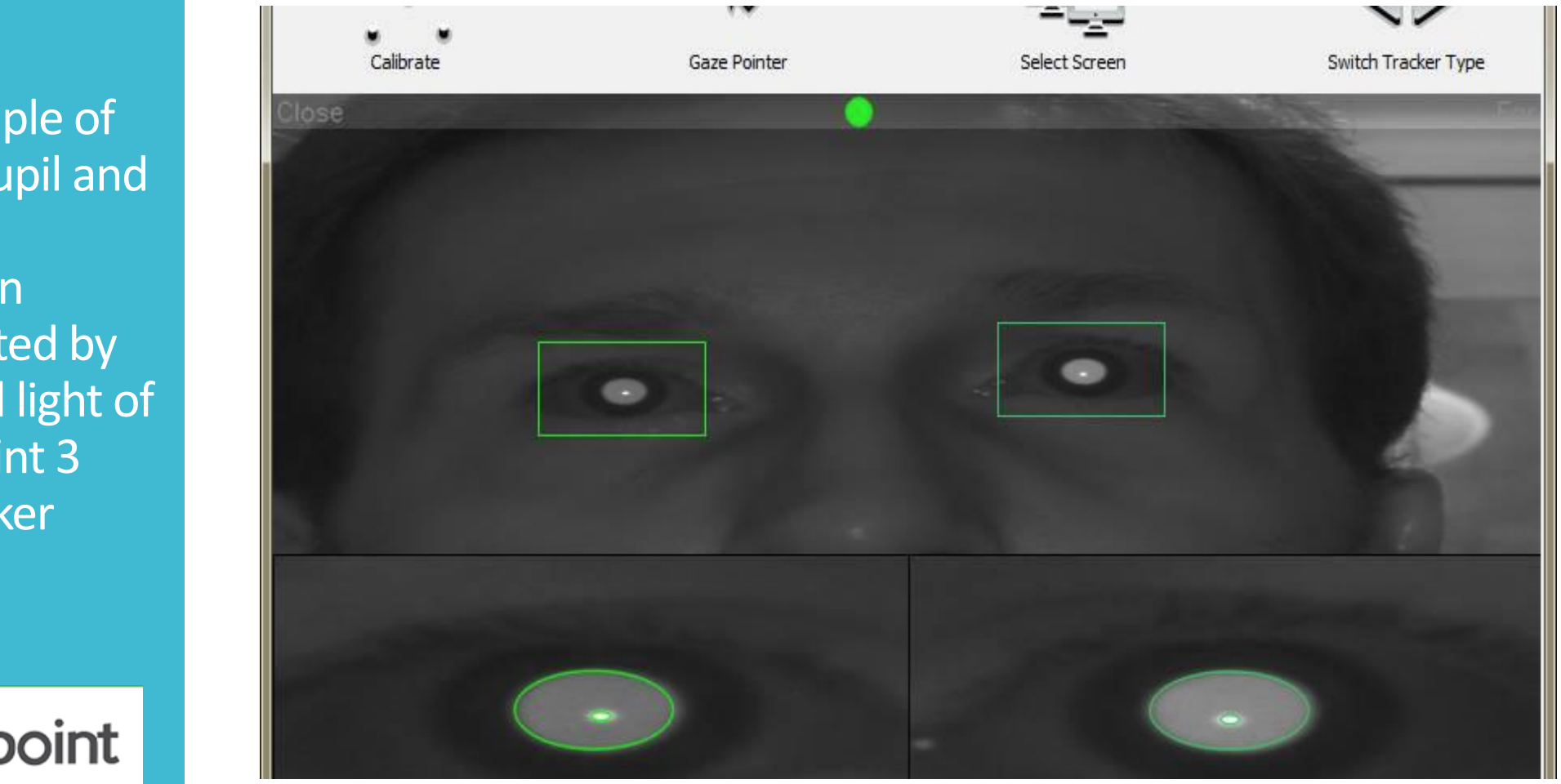
an example of bright pupil and corneal reflection illuminated by infra-red light of Gaze Point 3 eye tracker



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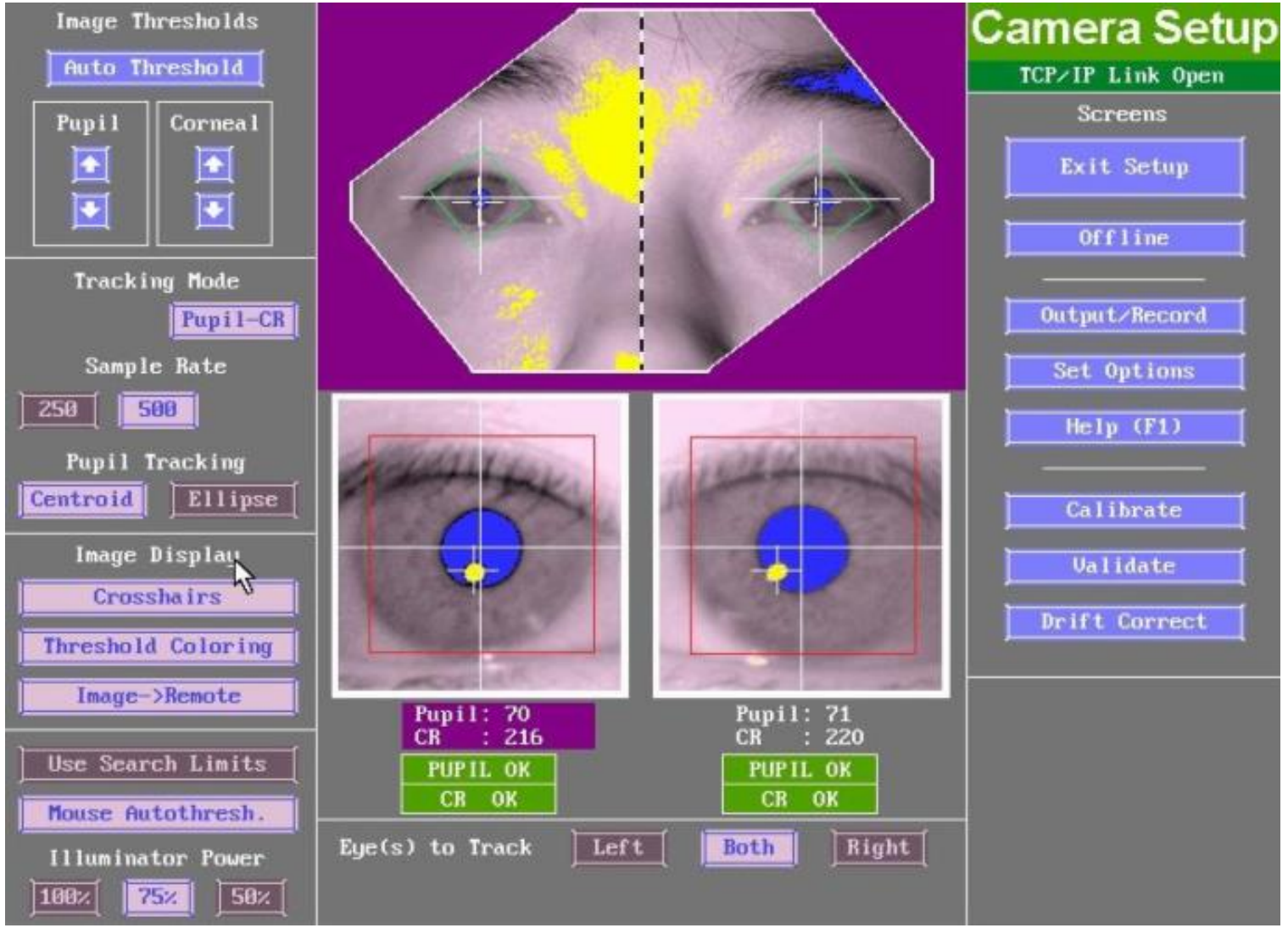
PUPIL AND CORNEAL REFLECTION FOR BOTH EYES



SR Research EyeLink®

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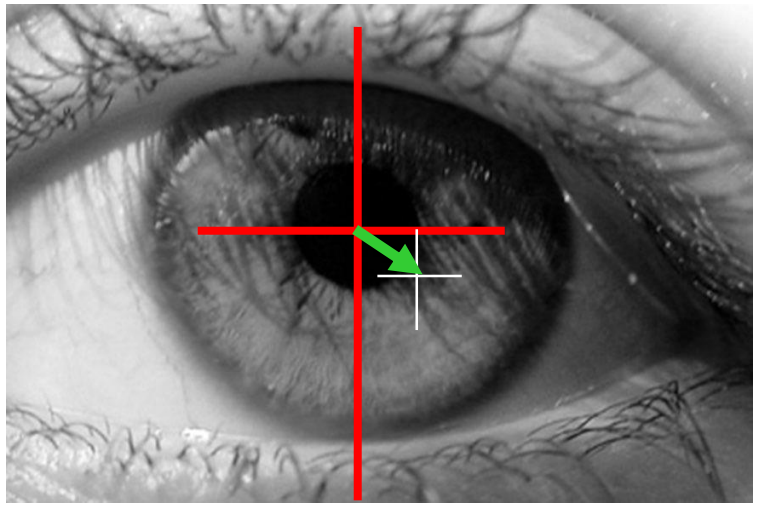
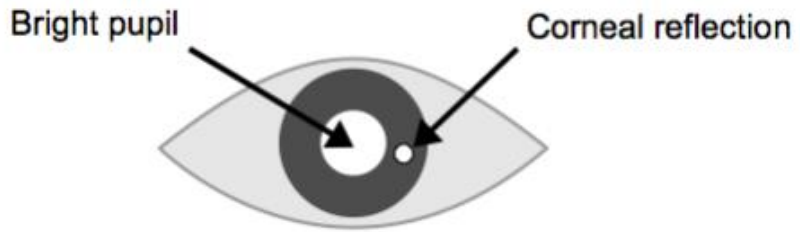
HOW DOES IT WORK?

The corneal reflection of the infrared light source is measured relative to the location of the pupil center



Corneal reflections known as PURKINJE images



Mantiuk et al..

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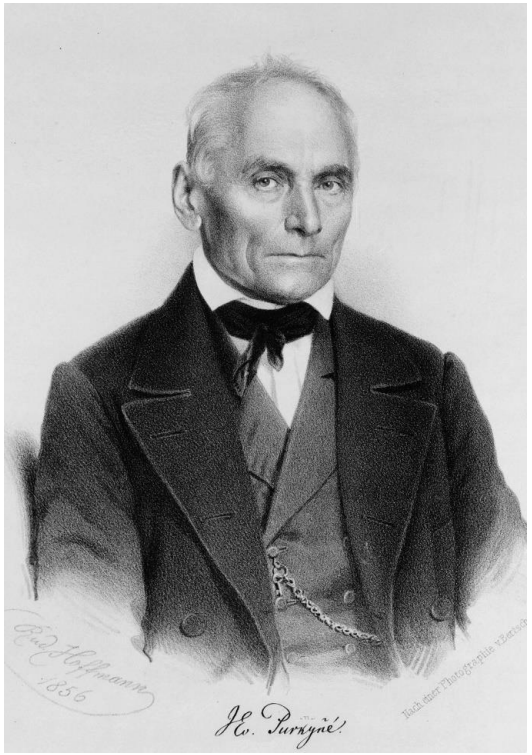
JAN EVANGELISTA PURKYNĚ 1787-1869



Chech anatomist and physiologist
One of the founding fathers of physiology.
He established the first Department of Physiology in the world at the University of Breslau– in Prussia (now Wrocław, Poland) in 1839.

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How does video-based eye tracker work?

Capture eye image by video camera

↓

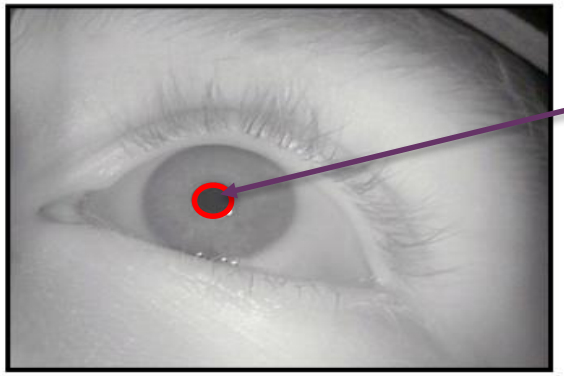
Pupil detection

↓

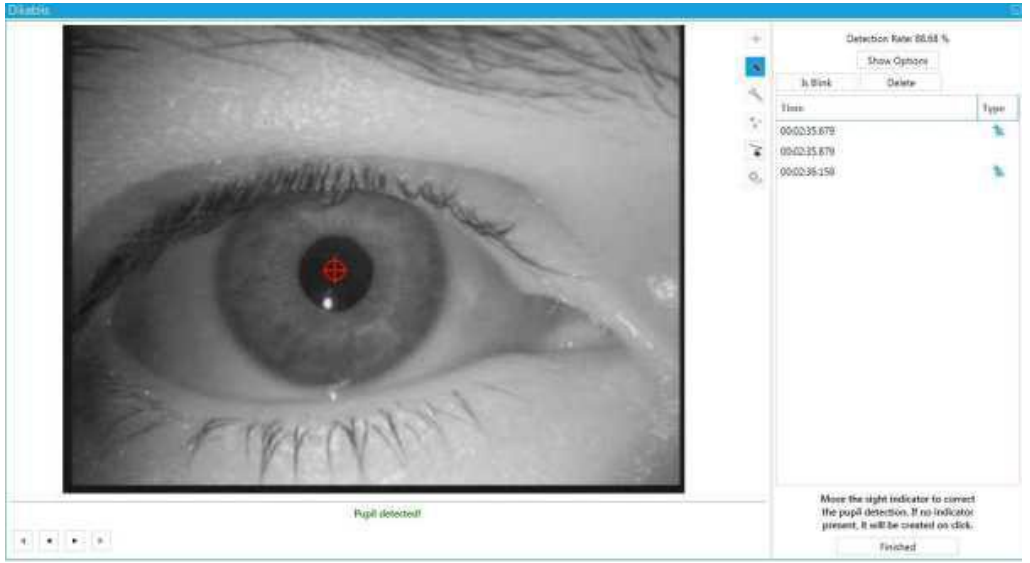
Mapping the coordinates of visual scene onto the camera image (callibration)

↓

Eye position estimation



Infrared light
=
better pupil distinguishability



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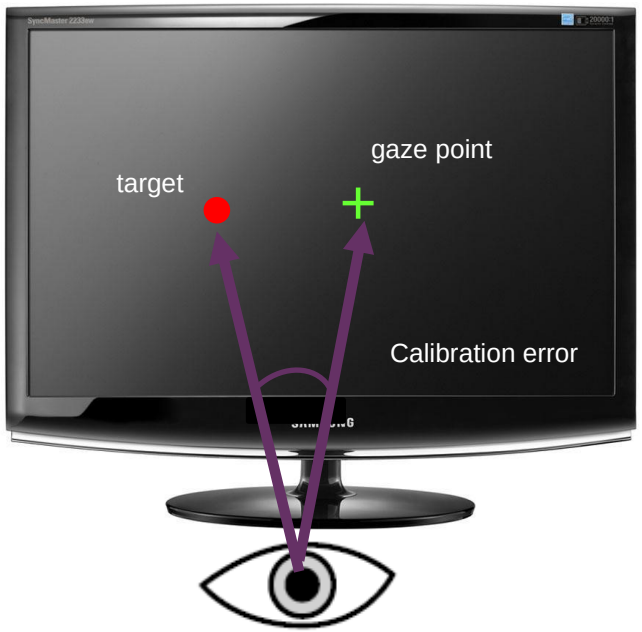
THE ACCURACY OF THE EYE TRACKER



- defined by the distance between the target and the eye fixation
- (typically expressed in angular degrees)

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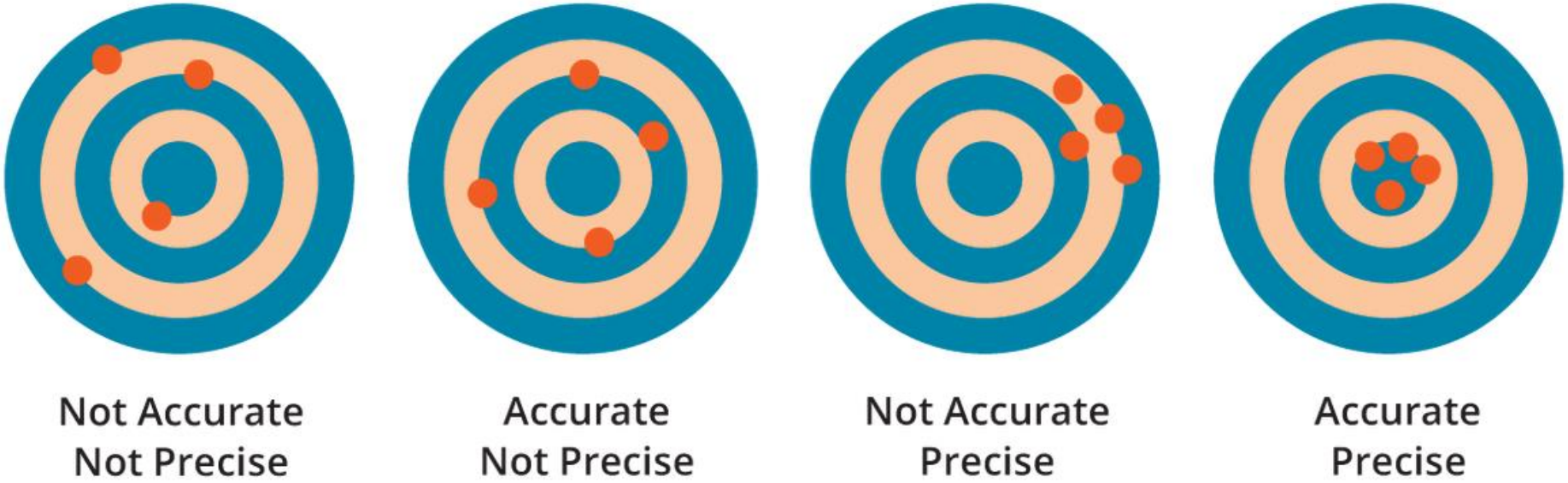
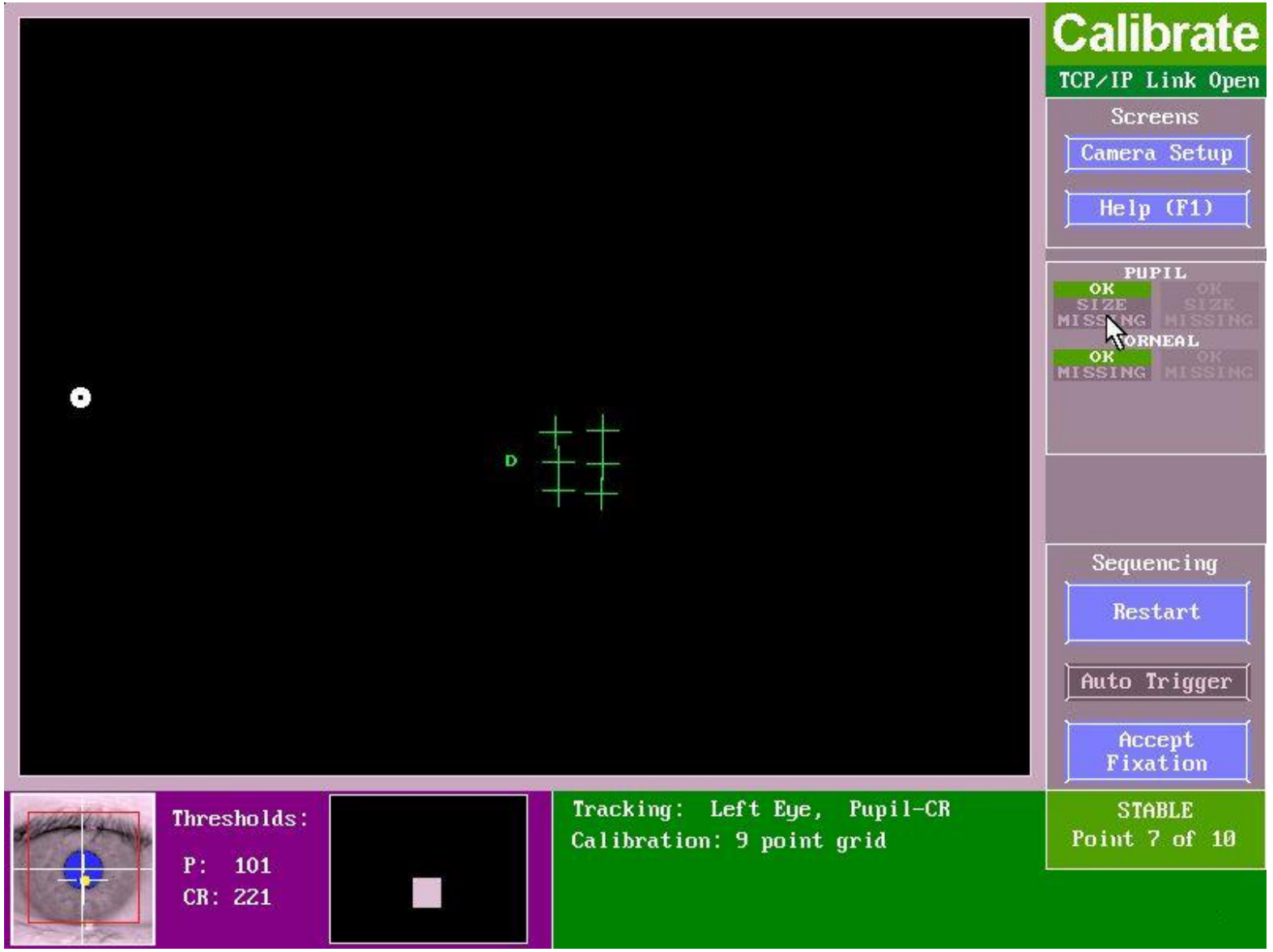
Accuracy and precision



https://www.filamentlearning.com/backyard-engineers-lesson-3-accuracy-and-precision

CALIBRATION - EXAMPLE



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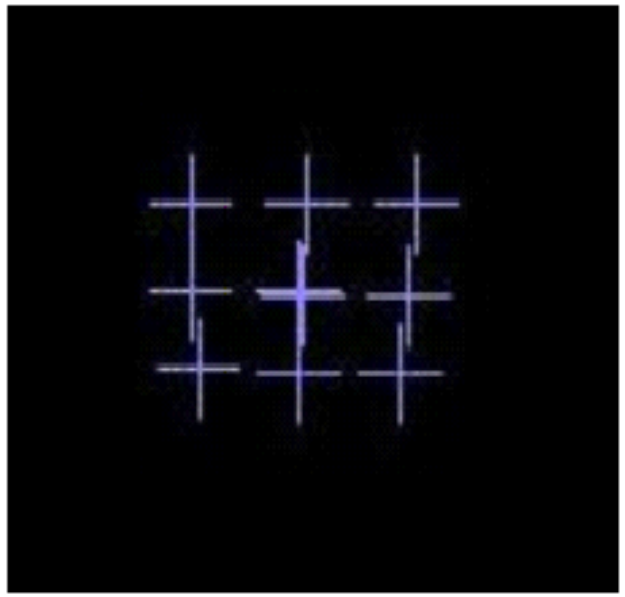
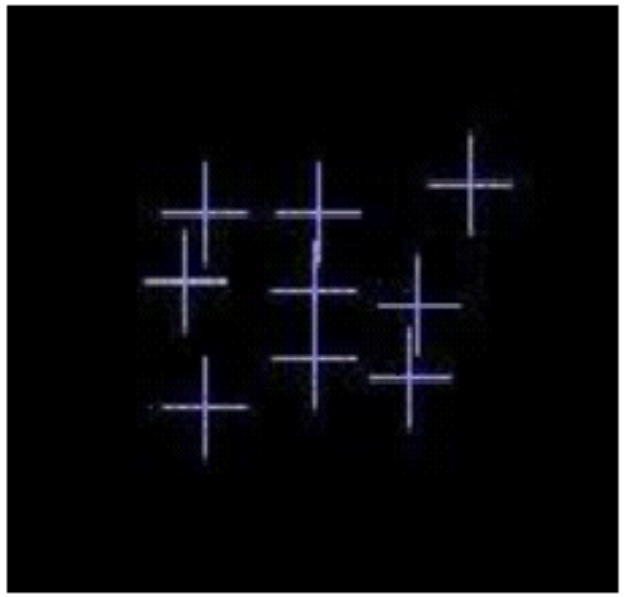
CALIBRATION EXAMPLES





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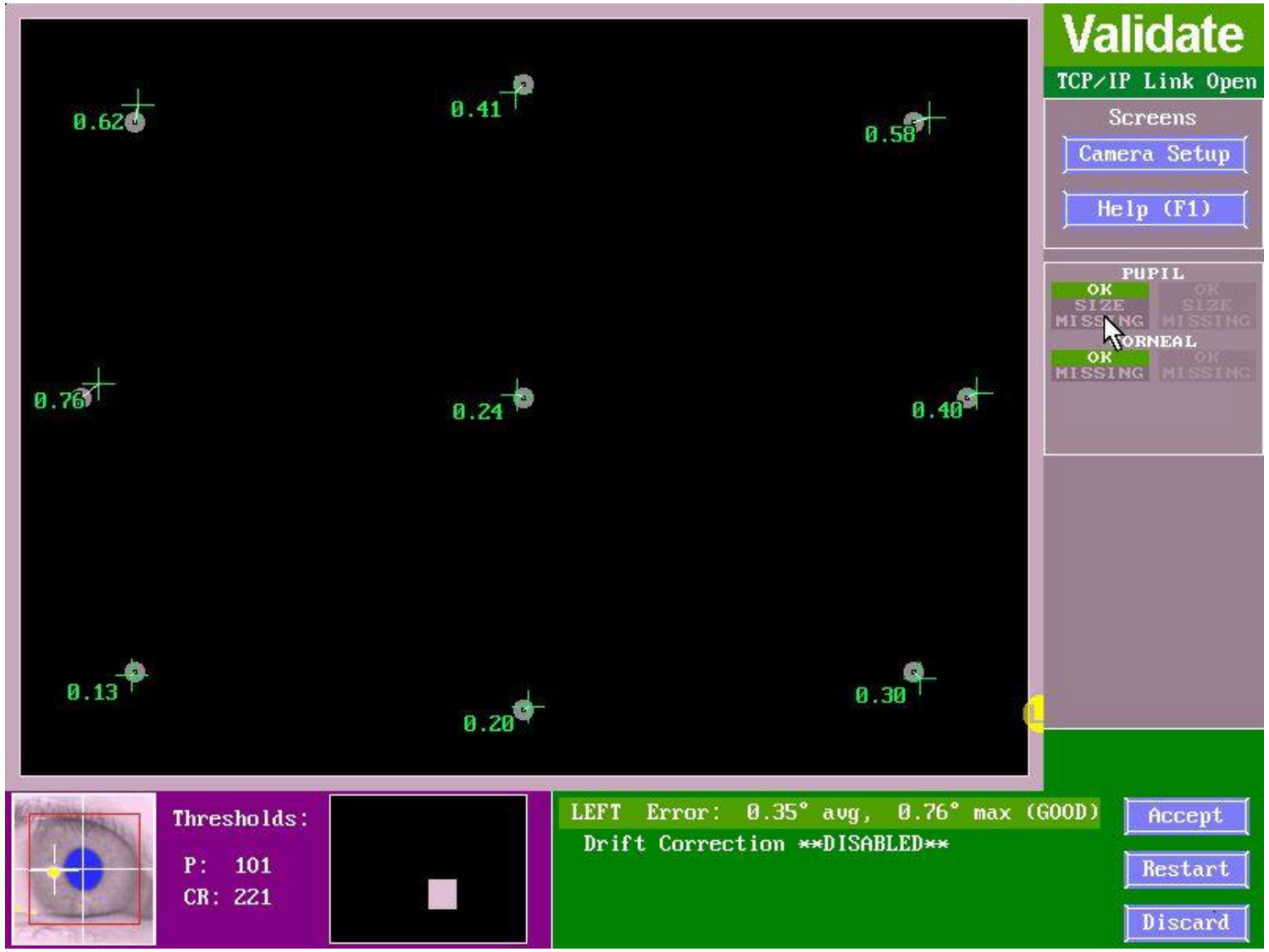
VALIDATION



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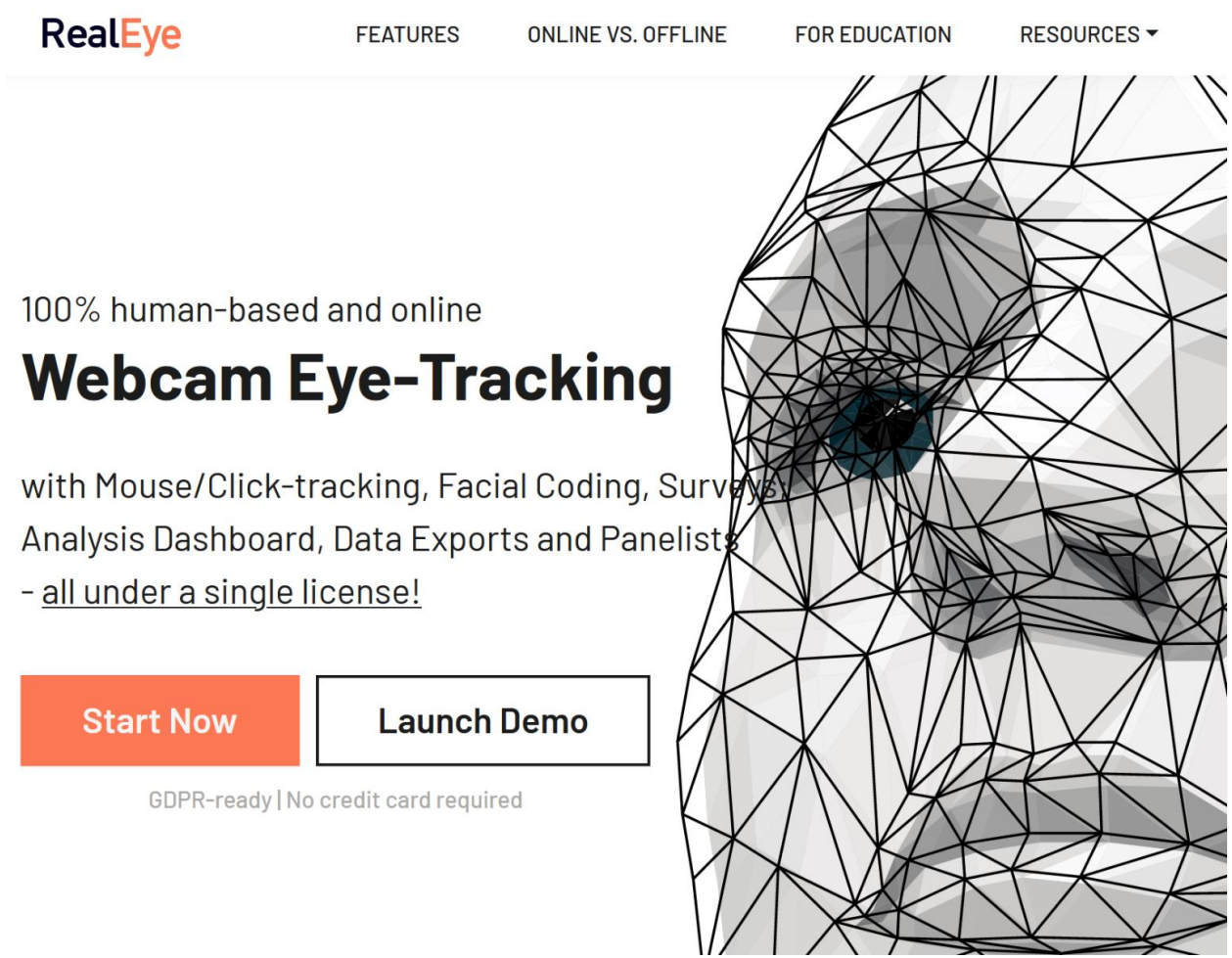
online eye tracking

https://www.realeye.io/



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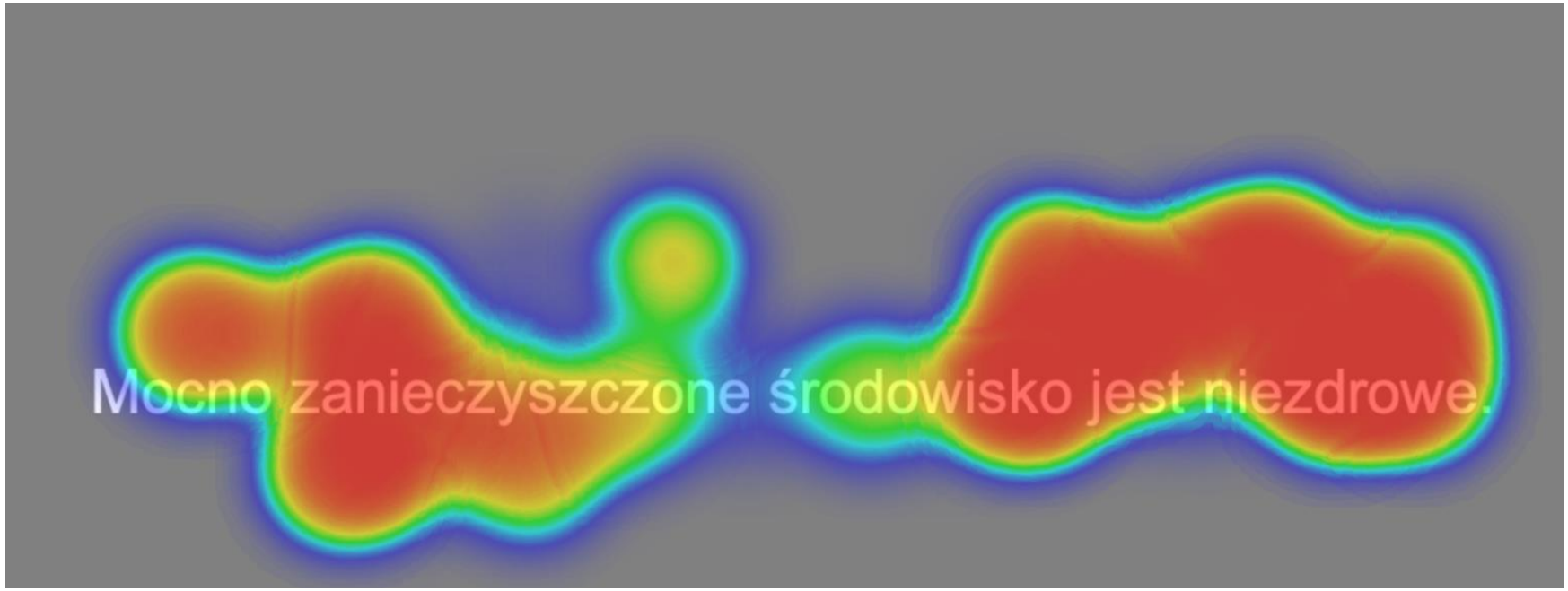
Visualization of attention distribution



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OBO

OŚRODEK BADAŃ OKULOGRAFICZNYCH