On the use of eye tracking in man – machine interfaces

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Visegrad Fund

Developing a dialogue system to support psychiatry

Problems

The growing number of people suffering from various mental disorders, such as **depression**, **anxiety, phobias ...**

There are not enough psychotherapists or psychiatrists available ...

[https://img.wprost.pl/img/przymusowe-leczenie-psychiatryczne-przebieg-podstawa-prawna-odwolanie/2a/06/057af526ec5c9618fe8f47265c81.webp]

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Solutions

Using technologies: natural language processing (NLP), automatic speech recognition (ASR) etc. in a **dialogue system** can help in **therapy for mental illnesses.**

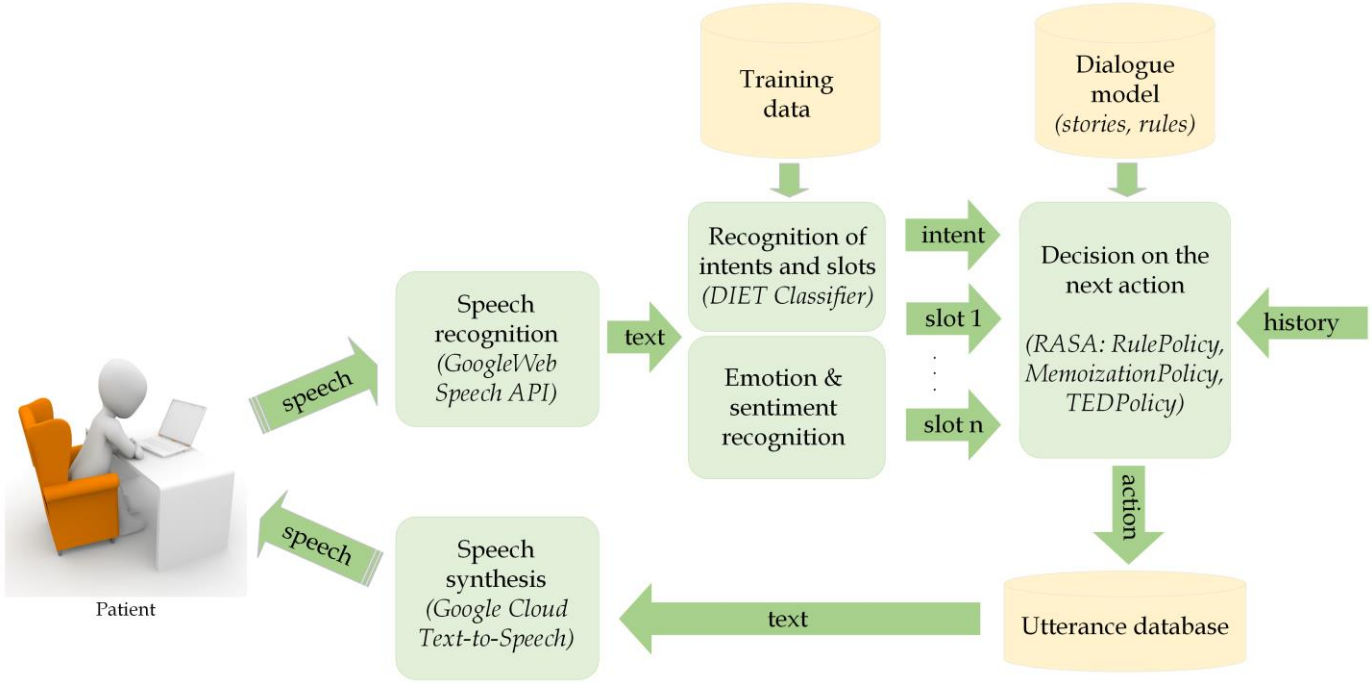
For example, patients suffering from complex, overwhelming emotions such as **anxiety, anger, shame** or frustration can learn to control them.

Development of a domain-specific dialogue agent - Terabot

Embodiment (user interface) - a film of a man wearing a hygiene mask.
He moves slightly, and his eyes blink naturally, gives impression that he is sitting in front of the computer during an online session like a therapist.

Development of a domain-specific dialogue agent – Terabot

Architecture - Terabot is a conversational system; goal–oriented, operating in the Polish language. Its aim is to complete a specific task through a conversation with the patient. It is enhanced with text-based emotion and intent recognition.

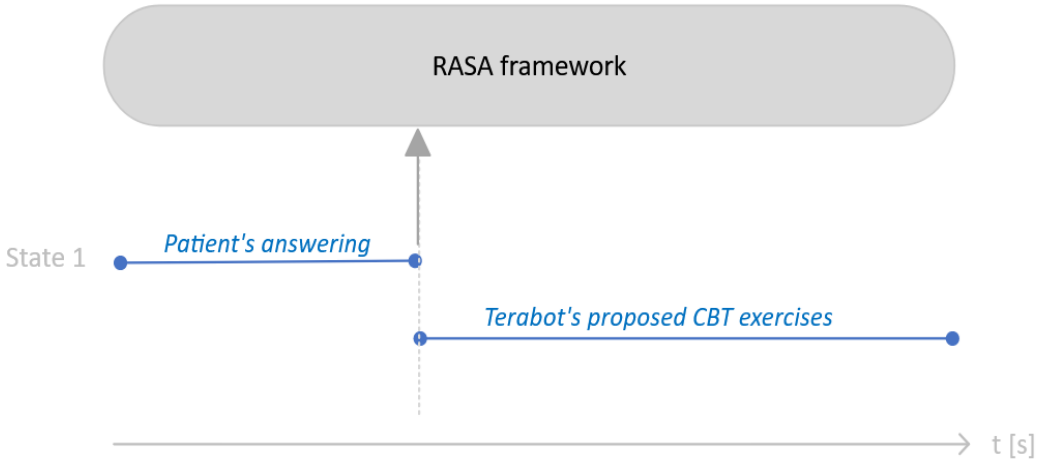


The **ideal flow** of the conversation should look like this:

Problems when conversing with the dialogue agent

Difficulties encountered when interacting with Terabot
(due to the different stages and symptoms of the schizophrenic patients):

Lack of knowledge about patient behavior during relaxation exercise



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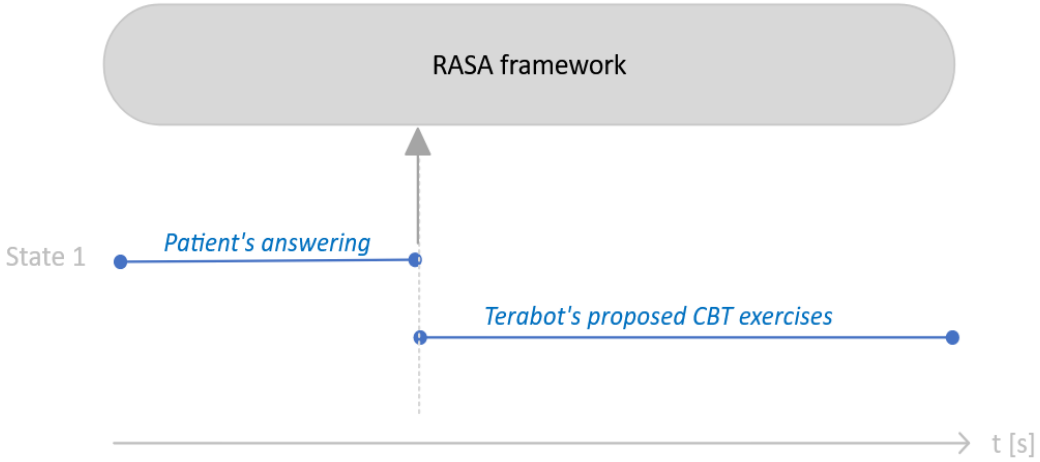
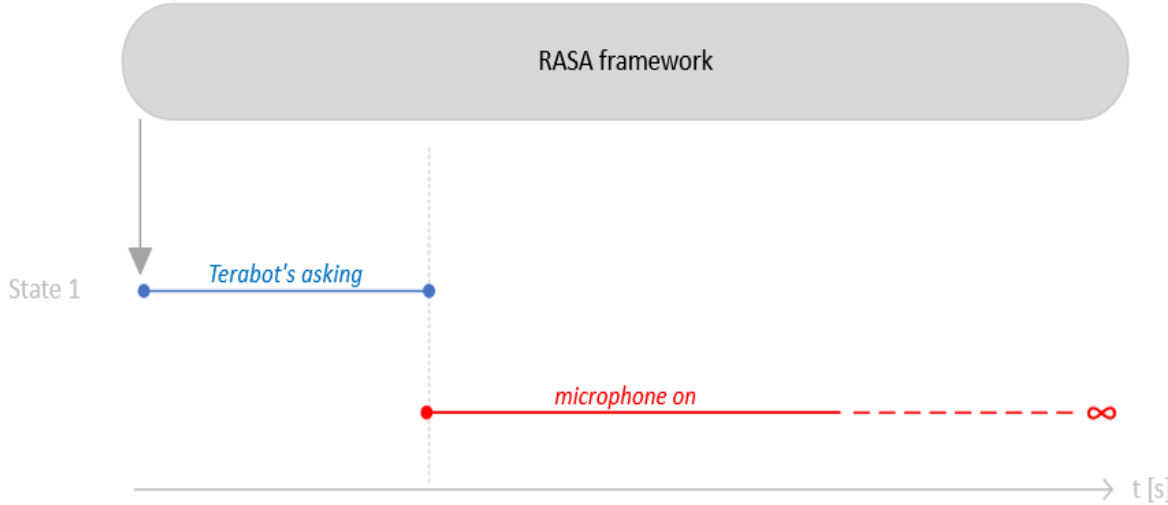


Waiting too long for the patient's answer



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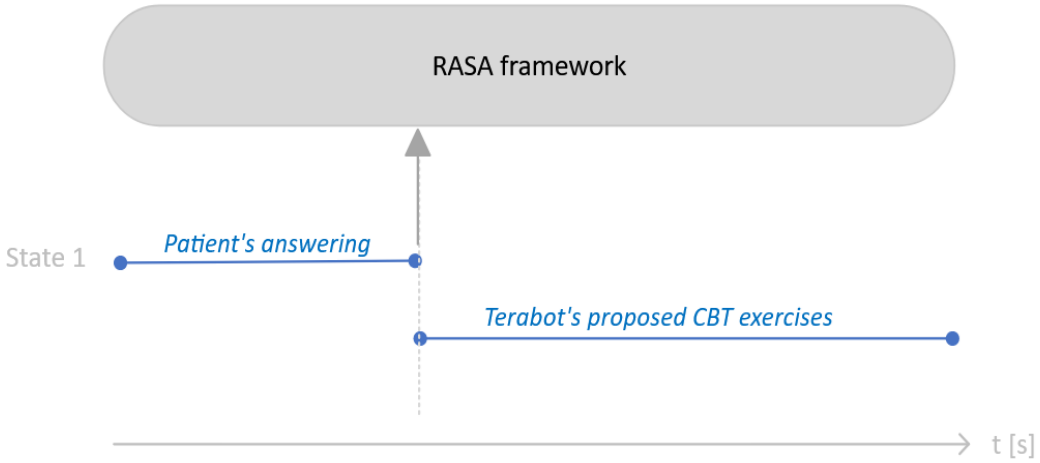

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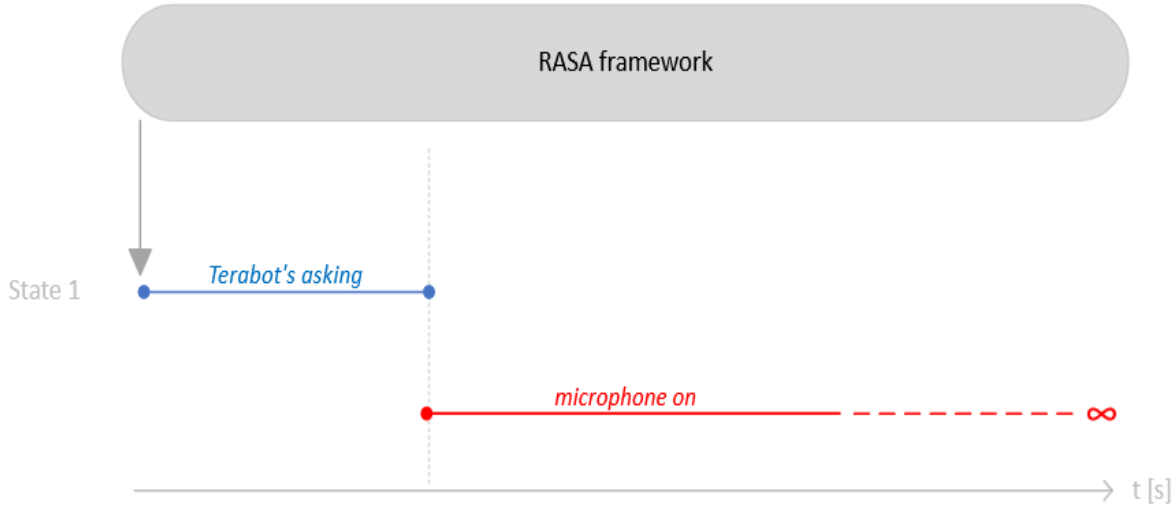

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What other modality could be beneficial for a dialogue system?

Speech + _____ ?

Facial expressions?

Gesture recognition?

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Facial expressions? ✗

Gesture recognition? ✗

Biomedical signals? → Electroencephalography (EEG)

↓ Heart rate (HR)

↘ Galvanic skin response (GSR) = Electrodermal Activity (EDA)

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Eye gaze

Biomedical signals? →

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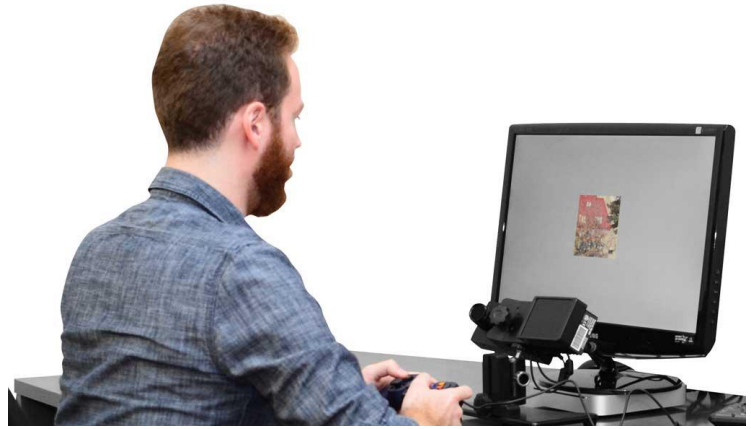
General information on eye tracking

Different types of eye trackers – design

Pupil Labs - Neon

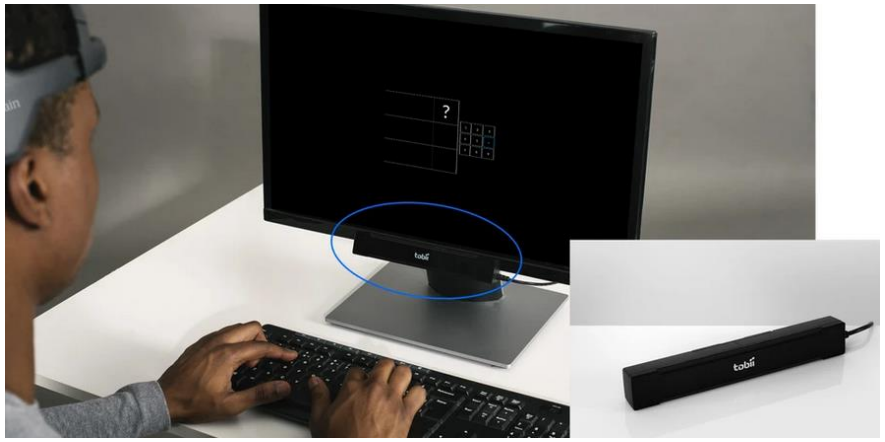


EyeLink 1000 Plus

Different types of eye trackers available....

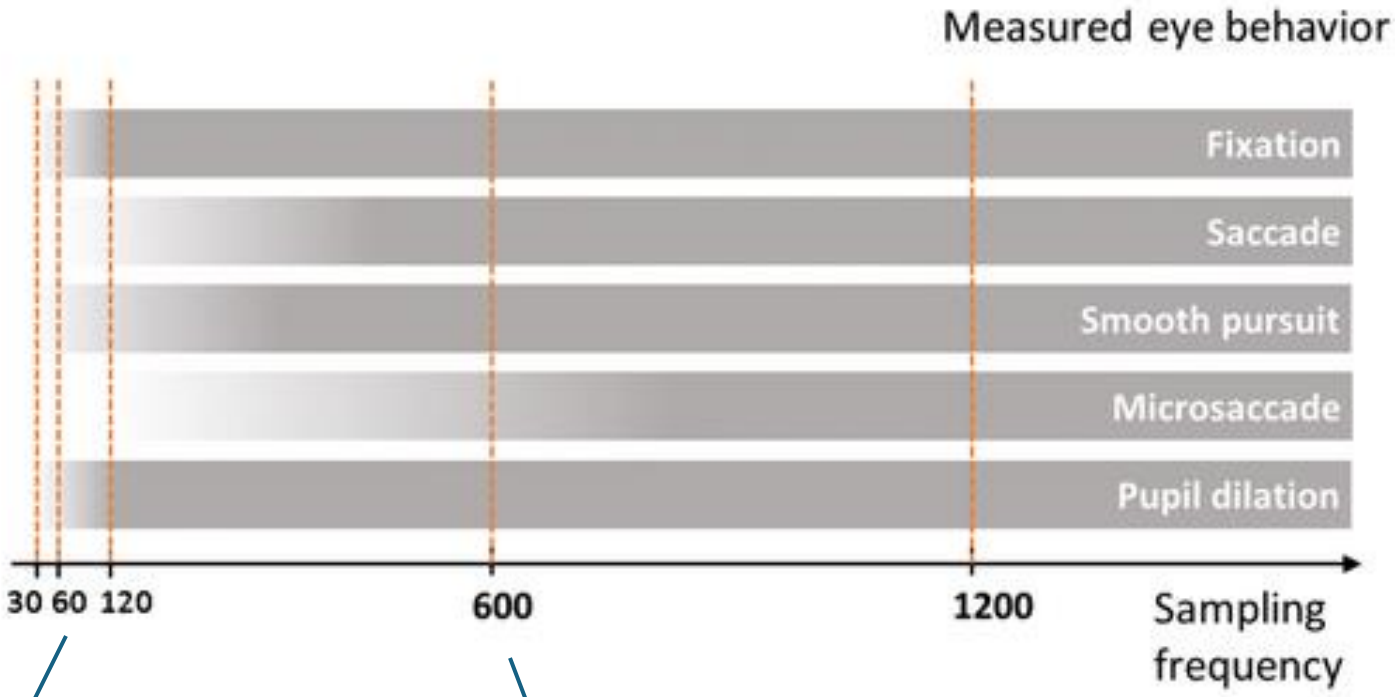
the choice depends on the **purpose & features** of the environment in which they will be used!

Pupil Labs - Neon



Tobii Pro X2-30

Different types of eye trackers – sampling frequency



Already sufficient for analyses
in, e.g., **Human-Computer Interaction**

Minimum for diagnostics
of **neurodegenerative diseases**!

[https://www.tobiipro.com/learn-and-support/learn/eye tracking-essentials/eye tracker-sampling-frequency,
[„Effect of Sampling Frequencies on Computation of the Maximum Velocity of Saccadic Eye Movements" M.Juhola, V.Jantti, I.Pyykko; „Sampling frequency and eye tracking measures: how speed affects durations, latencies, and more" R. Anderson]

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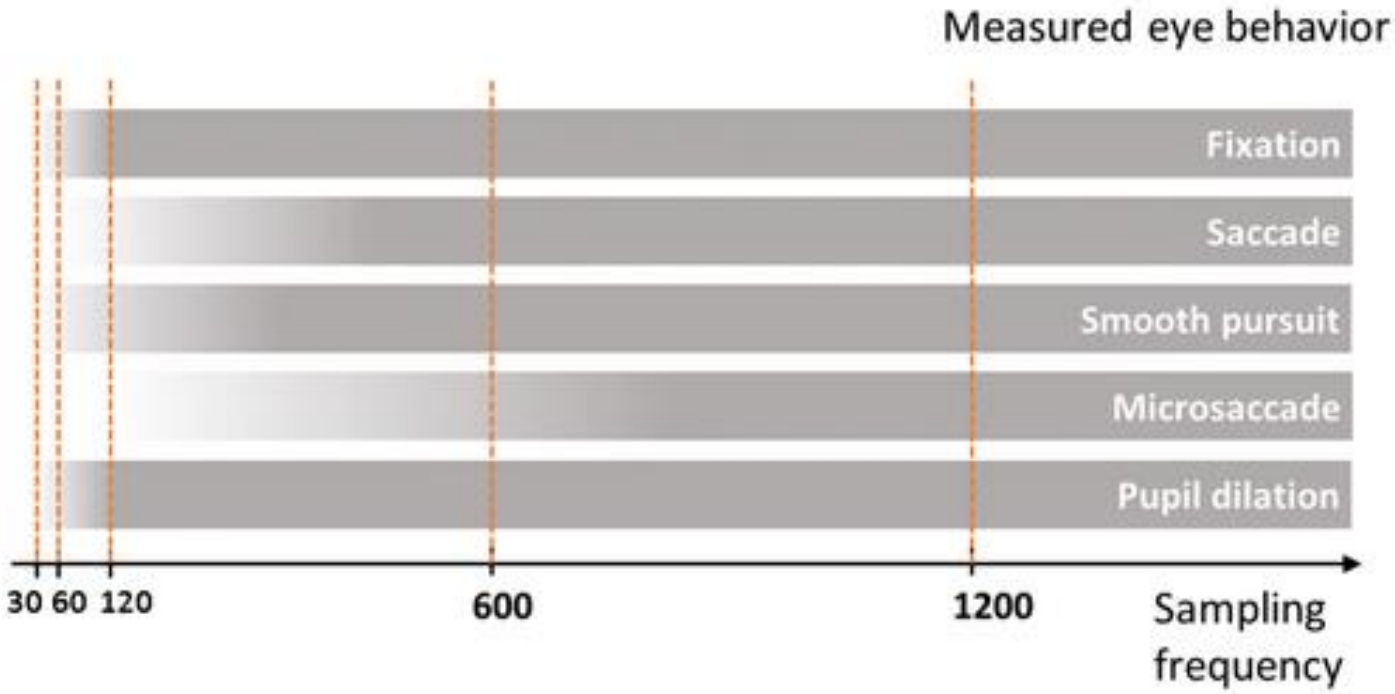


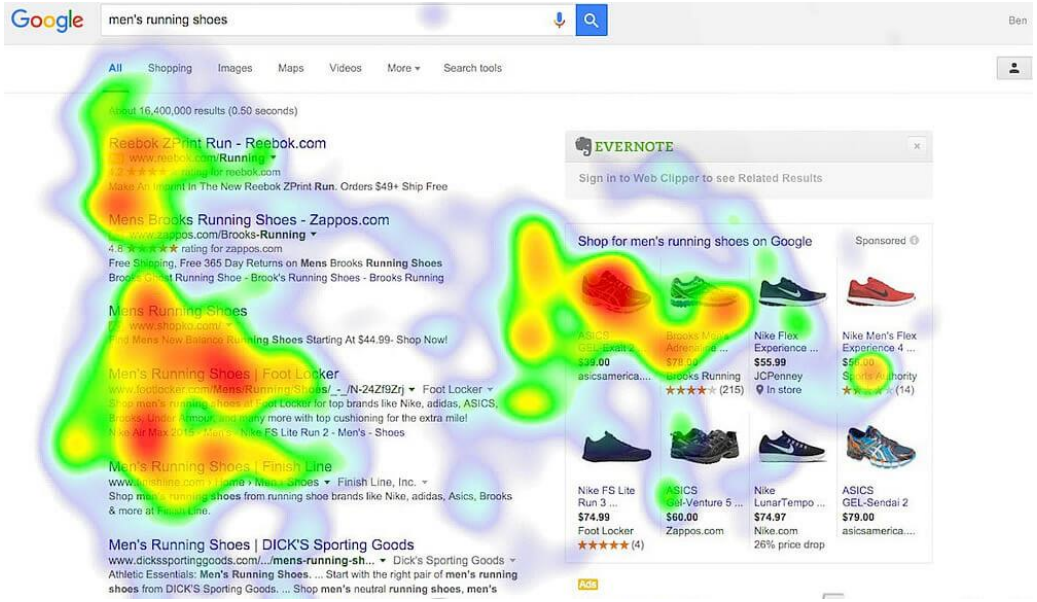
- A high sampling rate (typically 600–1000 Hz) is essential for **capturing rapid eye movements**, such as **saccades and microsaccades**. Lower sampling rates might miss these subtle dynamics, reducing necessary diagnostic accuracy.
- **The sampling frequency of min. 400/600 Hz** allows analyses for early diagnostics topics.

[https://www.tobiipro.com/learn-and-support/learn/eye tracking-essentials/eye tracker-sampling-frequency, „Effect of Sampling Frequencies on Computation of the Maximum Velocity of Saccadic Eye Movements" M.Juhola, V.Jantti, I.Pyykko; „Sampling frequency and eye tracking measures: how speed affects durations, latencies, and more" R. Anderson]

Eye tracking – data

How does it look like?

visualisations made automatically by software,
e.g., heatmaps, fixation points, etc.



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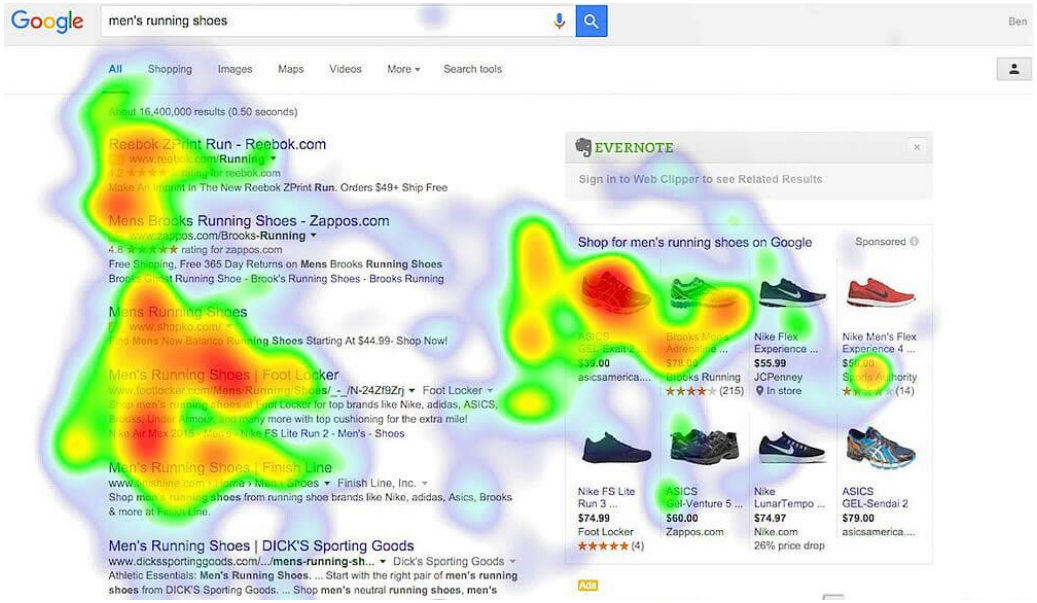
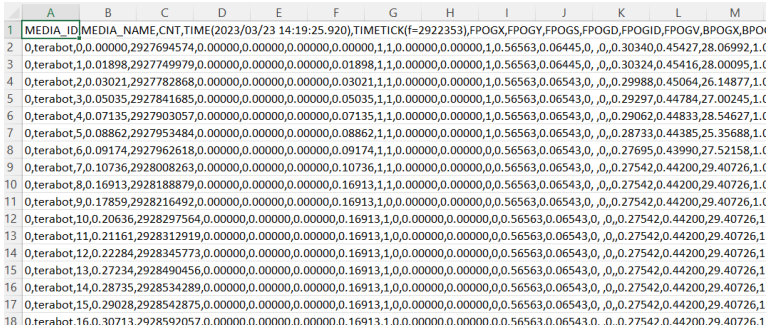
raw data





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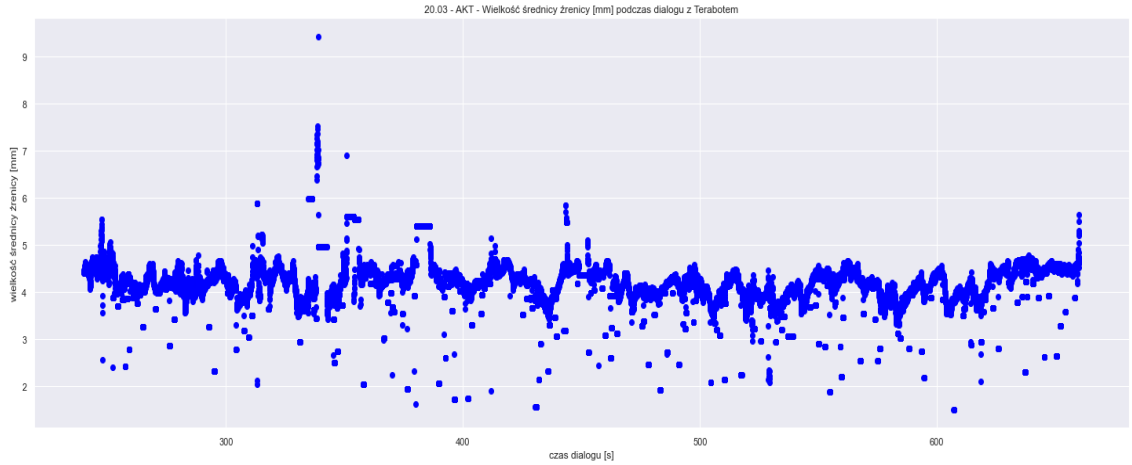

Some facts about eye tracking

An eye tracker is a device that allows you to track eye movements; it uses the light spectrum in the near-infrared range (NIR: 700-1000nm).

The eye tracking parameters:

- pupil diameter [mm],
- parameters for eye movement:

fixations – moments when the eyeball is in the phase of immobility and

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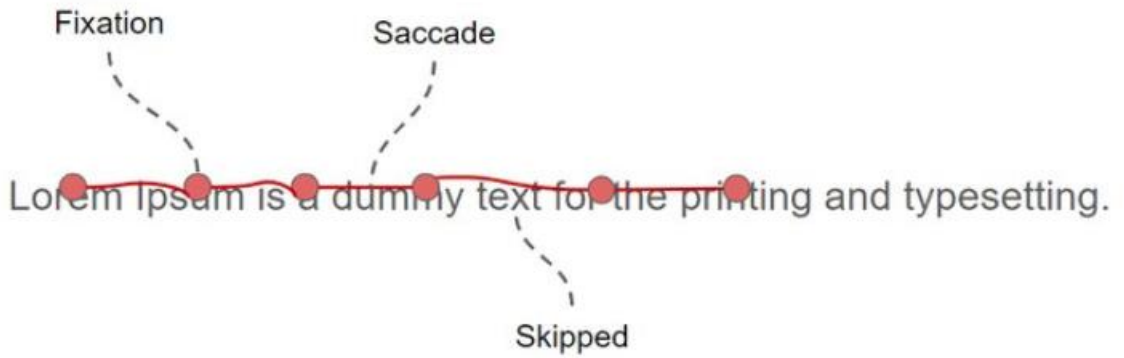

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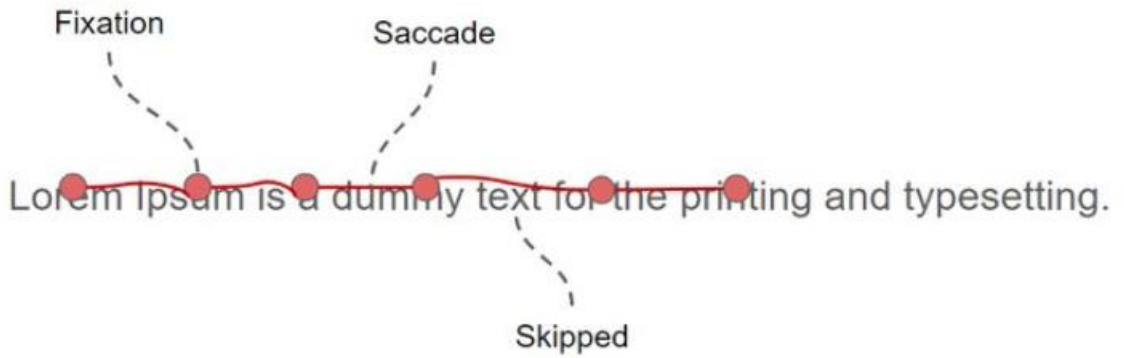
- the duration of the fixation/saccade [s];
- the magnitude/direction of fixations;
- many others (e.g., TTFF – time to first fixation).



General overview of main parameters gained of the eye tracker

(using the example of Gazepoint GP3 eye tracker)

Parameter group, regarding:	Parameter group description
Eye movements	Fixations (number, duration, *X*/*Y*-coordinates of the fixation on the screen (*FPOGX/Y*))
	Saccades (number, duration, direction, magnitude)
Blinks	Identifier of a blink
	Duration of the blink [ms]
Pupils	Right pupil size (in mm or pixels) (*RPMM*)
	Quality flag of the right pupil—valid or not valid (*RPV*)
	Left pupil size (in mm or pixels) (*LPMM*)
	Quality flag of left pupil—valid or not valid (*LPV*)

Application of eye tracker in research areas

- **medicine** (e.g., supporting early diagnosis of mental and neurodegenerative diseases),
- **psychology** (e.g., emotional state),
- **education** (e.g., supporting teacher decisions),
- **marketing** (e.g., eye focus on website elements),
- **Human – Computer Interaction** (e.g., assisting dialogue agents)

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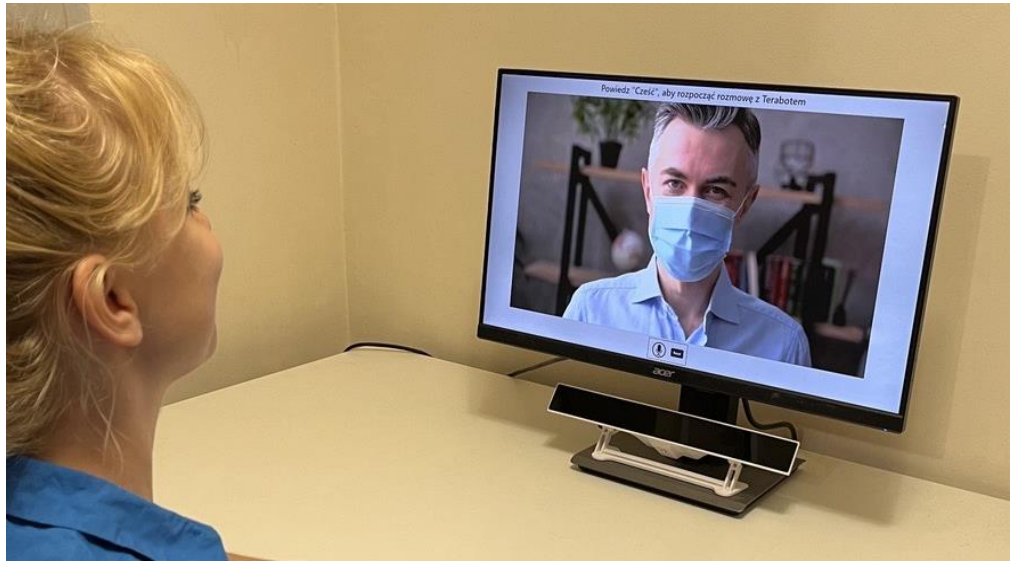
We applied eye tracking into a therapeutic dialogue system ``Terabot'' to gain additional data from the patient

Eye tracking and dialogue system combined

Fixation data from specific Areas of Interest (AOIs)



Can the fixation parameter provide us with the necessary non-verbal information?

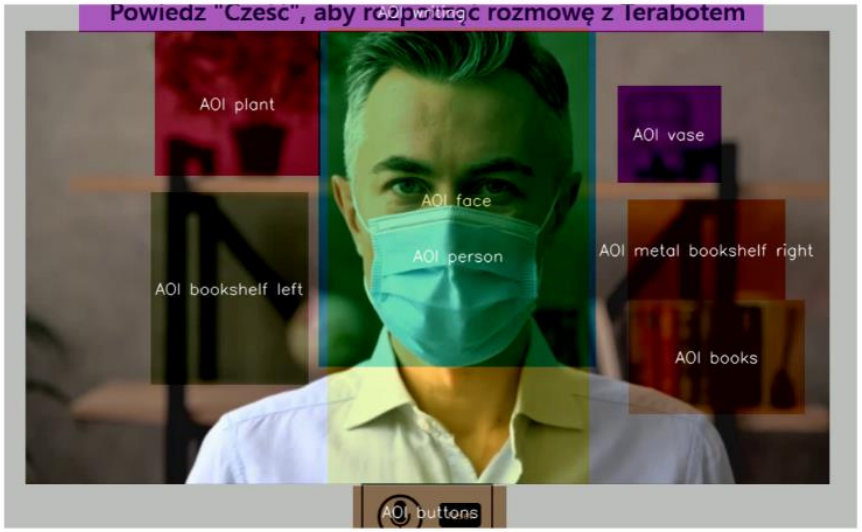
When answering the Terabot's questions, we looked at **where the patients gazed and for how long.**

We devided Terabot’s visual interface into **areas of interest (AOIs)**. We did this **to have information about the fixation. parameters in these selected regions**.

Fixation data from specific Areas of Interest (AOIs)

Area of interest (AOI)	No. of fixations	average fixation duration [s]	max. fixation duration [s]
AOI face and AOI person	**5519**	0.45	**3.68**
AOI person	**2821**	0.54	**2.0**
AOI bookshelf left	564	0.37	1.13
AOI buttons	347	0.42	1.8
AOI writing	309	0.34	0.9
other AOIs	209	0,21	0,53

Fixation data from specific Areas of Interest (AOIs)



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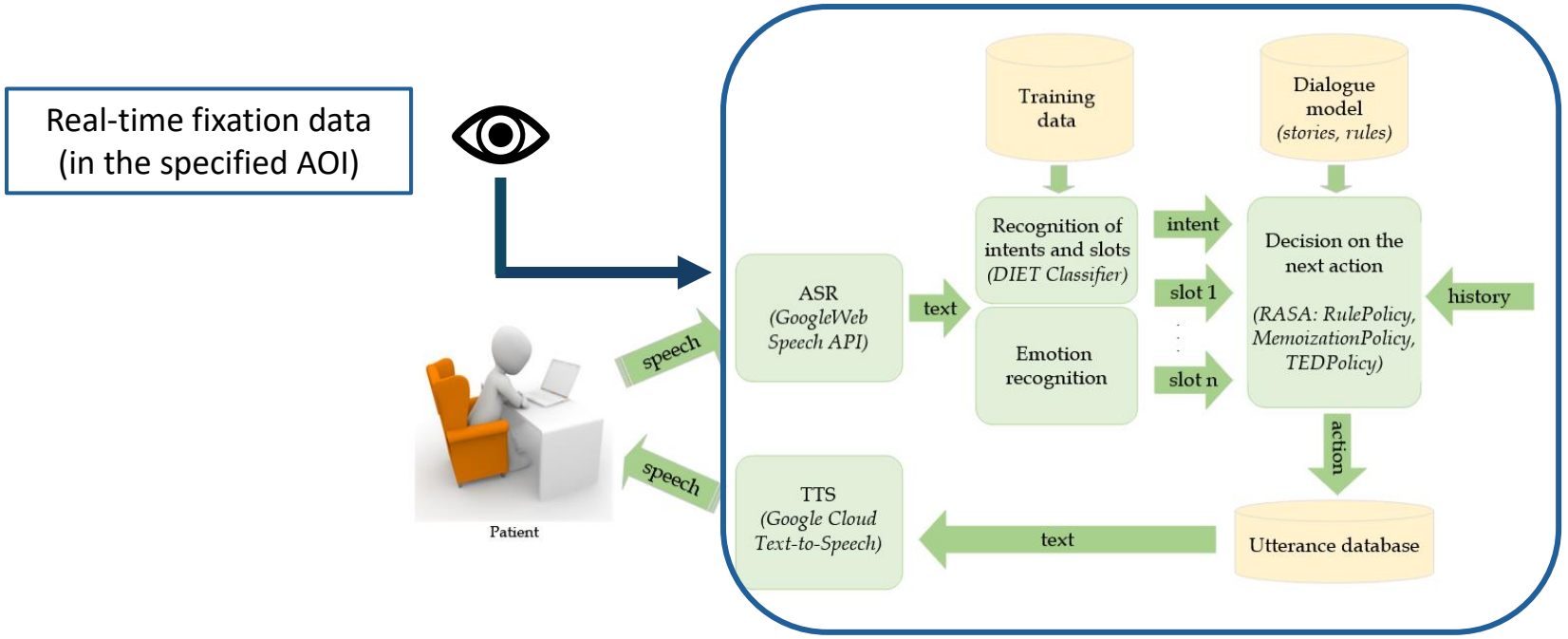
AOI face and the AOI person is important from the perspective of our dialogue system.

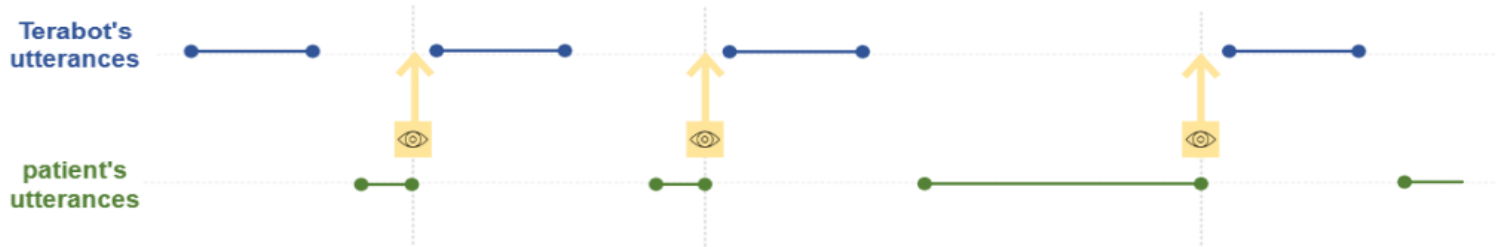
- This may be an indication, considering that these calculated fixations only occurred when the patient finished speaking and waited immediately.

- We can assume that these **fixation parameters in specific AOIs** in concrete timing can serve as a **helpful parameter to the dialogue system**.

Results – a new multimodal dialogue agent (speech & fixations)



Considering the combined multimodal dialogue agent, we expect an **improvement of dialogue flow.** **When considering** the application of real-time fixation data of specified AOI in Terabots interface, the flow should go as follows:



What does that information give us?

- Depending on whether or not the fixation parameter is present in the AOIs,
  Terabot can **activate the corresponding utterance** to encourage the patient towards answering**.**

- Based on the **presence of this real-time data in** the experimentally determined **AOIs**, it will be able to **modify the dialogue flow** so that Terabot's response is better suited to the patient’s behavior.

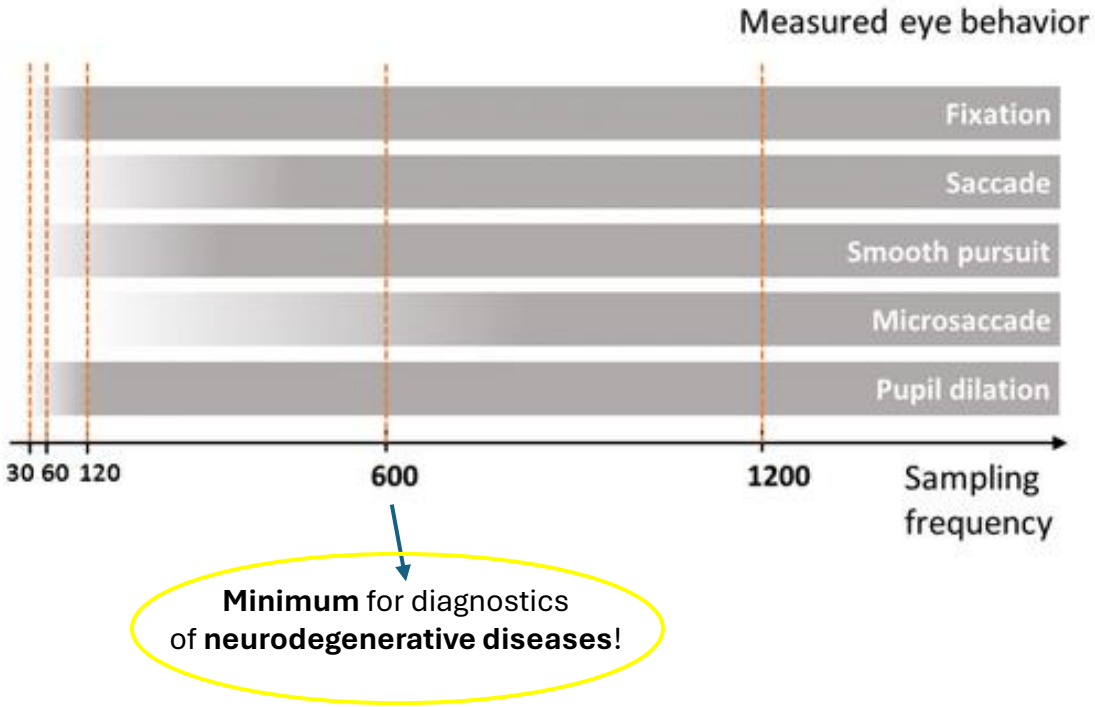
eye tracking can improve the
behavior of a dialogue system

Eye tracking can be used to make the conversations more human-like.

Eye tracking as early stage diagnosis tool for Alzheimer’s Disease

Application of eye tracker in early diagnostics of AD

Diagnostics – special requirements of eye tracker



➡ A high sampling rate (typically 600–1000 Hz) is essential for **capturing rapid eye movements**, such as **saccades and microsaccades**. Lower sampling rates might miss these subtle dynamics, reducing necessary diagnostic accuracy.

[„Effect of Sampling Frequencies on Computation of the Maximum Velocity of Saccadic Eye Movements" M.Juhola, V.Jantti, I.Pyykko; „Sampling frequency and eye tracking measures: how speed affects durations, latencies, and more" R. Anderson]

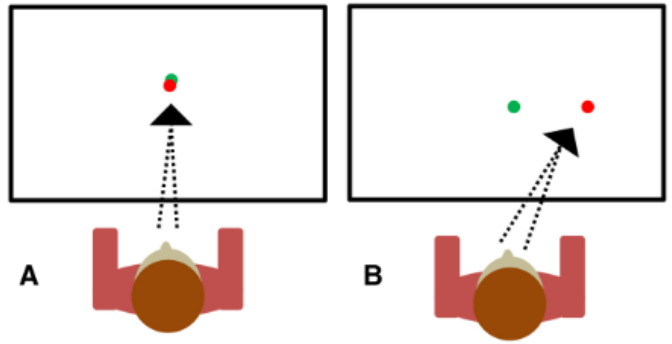
Application of eye tracker in early diagnostics of AD

Diagnostics – special visual tasks for participants:

Pro-saccade task:

A - Starting point – looking at the center at 2 points

B – Trying to **look just after** the moving red point

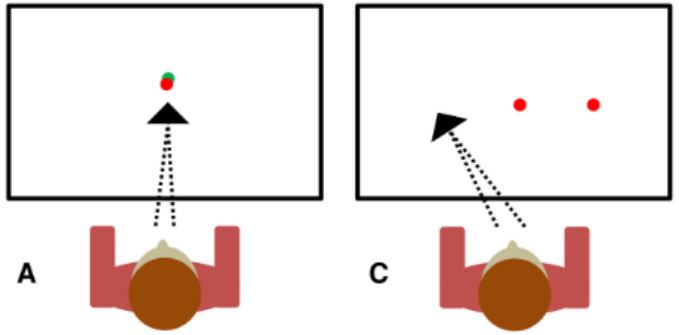


Anti-saccade task:

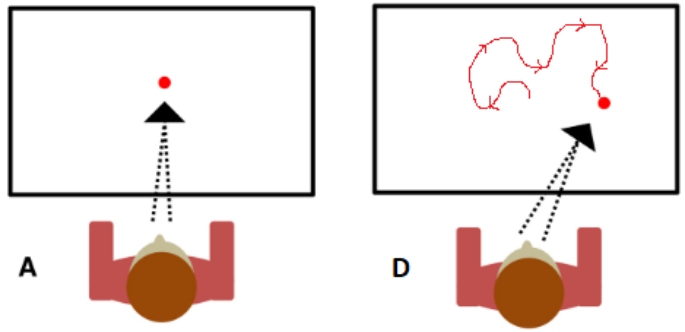
A - Starting point – looking at the center, at 2 points

C – Trying to **look away in the opposite direction** from the moving red point

Purpose: monitoring the involving inhibitory behavior by patients' eyes



Smooth pursuit task:



A - Starting point – looking at the center at main point

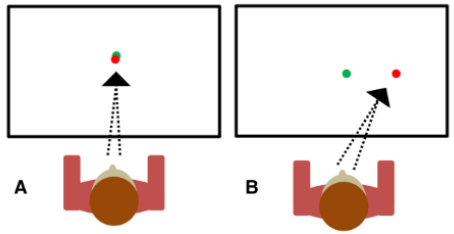
D – Trying to **gaze after the constantly moving (in random directions) red point**

Purpose: to access sustained object tracking by patients' eyes

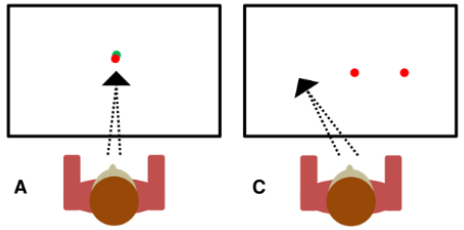
Application of eye tracker in early diagnostics of AD

Diagnostics – special visual tasks for participants

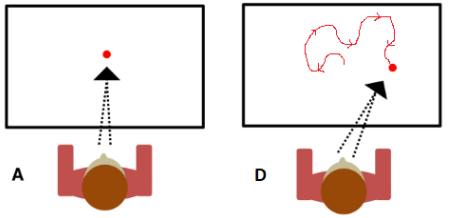
Pro-saccade task:



Anti-saccade task:



Smooth pursuit task:



What data is analysed for the early stage AD diagnostics?

- **Saccades and the latencies** between the appearing or moving point and the patient's saccade which appeared as it was following / unfollowing it;
- Peak reaction times, average reaction times [ms]
- Peak and average saccadic velocity [^{0}/s]
- Smooth pursuit acceleration [^{0}/s^{2}] and other

→ Analysing and modeling the behavior of saccades, latencies etc. for healthy participants and early stage AD patients

Example of a specific eye tracker – also for early stage AD diagnosis

Saccadometer & LATER model (Carpenter, Ober)

The Saccadometer system & device:

- is the result of scientific cooperation between Prof. Carpenter from UK (opthalmologist) and Ober Consulting Poland

  (Prof. Ober from Poland, Silesian University of Technology)

- provides device & software for eye movement measurement;
- includes the possibility of individually modifying the research experiments;
- provides fast statistical analysis of the results of a research and their presentation.

[source: www.ober-consulting.com/product/saccadometer/]

Research concerning neurodegenerative diseases diagnosis – a few years back…

Article	Number of patients + control group	Disease	Device	What is measured?	Methodology
[1]	10 + 11	**Alzheimer's disease**	model 3000, Applied Science Laboratories, Waltham, Mass	saccades	…
[2]	9 + 0	**Parkinson's disease**	miniaturised IR 1kHz saccadometer, with 12 bit resolution (Ober Consulting)	Saccades - their latency	LATER model
[3]	22 + 27, 15	Parkinson's disease	saccdometer (Ober Consulting)	Saccades -their latency	LATER model
[4]	18 + 17 + 18	Alzheimer's disease	'Express Eye' (Optom, Freiburg, Germany)	saccades	…
[5]	11	Parkinson's disease	saccdometer (Ober Consulting)	Saccades – their latency	LATER model
[6]	30	**Cranial surgery – neurological damage**	saccdometer (Ober Consulting)	Saccades – their latency	LATER model
[7]	60 - Alcoholism, 18 – Alzheimer's, 21 - opioid dependence, 12 - Parkinson's, and 29 – Schizophrenia → data from the 2012 International Joint Conference on Neural Networks	**6 types of psychiatric conditions (Alcoholism, Alzheimer's d., opioid dependence, Parkinson's disease and Schizophrenia)**	portable saccadometer, head-mounted, 1kHz sampling rate	Saccades - latencies	LATER model
[8]	35 + 35	**cirrhosis patients with cognitive defect** (Covert Hepatic Encephalopathy)	saccadometer (Ober Consulting)	Saccades – their latency	LATER model
[9]	19 Richardson's, 24 Parkinson's., 26 healthy controls	Parkinson's d. & progressive supranuclear palsy (**Richardson's syndrome**)	saccadometer (Ober Consulting)	Saccades – their latency	LATER model
[10]	24 + 20	**Huntington's disease**	saccadometer (Ober Consulting)	Saccades – their latency	LATER model
[11]	15 + 11	Parkinson's disease	saccadometer (Ober Consulting)	Saccades – their latency	LATER model

Application of eye tracker in Alzheimer's disease research

Other approaches (constantly improving):

....using deep learning [12]

...using VR for visual tasks with eye tracking [13]

...using deep learning and 3D Visual Stimuli [14]

https://dot.la/media-library/purple-and-blue-light-digital-wallpaper.jpg?id=33442101&width=2000&height=1500&quality=85&coordinates=0%2C0%2C1680%2C0

Literature

[1] „Impairment of Spatially Directed Attention in Patients with Probable Alzheimer's Disease as Measured by Eye Movements" Scinto, Daffner, Castro

[2] „Deep Brain Stimulation: Eye Movements Reveal Anomalous Effects of Electrode Placement and Stimulation" Antoniades, Buttery, Fitz Gerald, Barker, Carpenter

[3] „Saccadic latency distributions in Parkinson's disease and the effects of Ldopa" Michell,Xu, Fritz, Lewis, Carpenter et al.

[4] „Inhibitory Control of Saccadic Eye Movements and Cognitive Impairment in Alzheimer's Disease" Crawford, Higham, Renvoize, Patel, Dale, Suriya, Tetley

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[8] „Using saccades to diagnose convert hepatic encephalopathy" Cunniffe, Munby, Chan, Saatci, Edison, Carpenter, Massey

[9] „Different decision deficits impair response inhibition in progressive supranuclear palsy and Parkinson's disease" Zhang, Rittman, Nombela, Fois, Coyle-Gilchrist, Barker, Hughes, Rowe

[10] „The use of quantitative oculometry in the assessment of Huntington's disease" F. Ali, A. Michell, R. Barker, R. Carpenter

[11] „Antisaccade errors reveal cognitive control deficits in Parkinson's disease with freezing of gait" C.Walton, C.O'Callaghan et al.

[12] Sun Jinglin , Liu Yu , Wu Hao , Jing Peiguang , Ji Yong „ A novel deep learning approach for diagnosing Alzheimer's disease based on eye tracking data" , Frontiers in Human Neuroscience, 2022

[13] Davis Rebecca „The Feasibility of Using Virtual Reality and Eye Tracking in Research With Older Adults With and Without Alzheimer's Disease", Frontiers in Aging Neuroscience, 2021

[14] Fang, Zuo., Peiguang, Jing., Jinglin, Sun., Jizhong., Duan., Yong, Ji., Yu, Ping, Liu. „Deep Learning-based eye tracking Analysis for Diagnosis of Alzheimer's Disease Using 3D Comprehensive Visual Stimuli." EEE JOURNAL OF BIOMEDICAL AND HEALTH INFORMATICS, 2023

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On the use of eye tracking in man – machine interfaces

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