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Eye Tracking

You'll learn: what eye trackers measure • how metrics are computed • how to interpret results

Session roadmap

1) Devices & setup

Remote vs wearable vs VR
What affects data quality

2) What we measure

Fixations, saccades, pupil, blinks
AOI metrics

3) From samples to metrics

Cleaning, segmentation
Event detection (I-VT / I-DT)

4) Visualize & interpret

Heatmaps, scanpaths
Common pitfalls + ethics

Quick warm-up (30 seconds)

Think of a time you “got stuck” reading a page, searching a website, or preparing your morning coffee — what might your eyes have been doing?

What is eye tracking?

Measuring where people look (point of gaze) and how their eyes move

What you get

- A stream of gaze samples (x, y) over time
- Derived events: fixations, saccades, blinks
- Optional: pupil size, head pose, scene video (wearables)

Why it’s useful

- Attention & visual search (What draws the eye?)
- Cognitive effort (Where do people struggle?)
- Usability / learning (How do people explore?)
- Safety & real-world behavior (driving, sports, work)

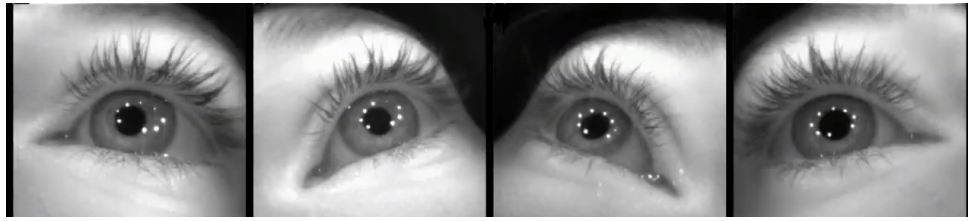
How do video-based eye trackers work?

Near-infrared light + camera(s) estimate gaze using pupil + corneal reflections

The basic idea (pupil-centre corneal reflection; PCCR)

- Infrared LEDs illuminate the eye (invisible to us)
- Cameras see the pupil + bright “glints” on the cornea
- Software estimates gaze direction and maps it onto a screen or scene
- Calibration links eye features to known targets

What the camera sees



Bright dots = corneal reflections (glints)
Dark circle = pupil

Fun fact

Corneal reflections help compensate for small head movements — improving robustness.

Eye tracking devices (the big families)

Remote trackers, wearable glasses, and eye tracking inside headsets

Remote (screen-based)

- Great for lab studies
- Often needs stable head position
- Best for 2D stimuli

Wearable (glasses)

- Real-world tasks
- Includes scene camera
- More post-processing

VR/AR (in headset)

- 3D interactions
- Need head + gaze together
- Often custom pipelines

Pick the device to match your question

Example: reading on a monitor → remote tracker; navigating a museum → wearable glasses.

Data quality: sampling rate, accuracy, precision

These determine what you can reliably measure

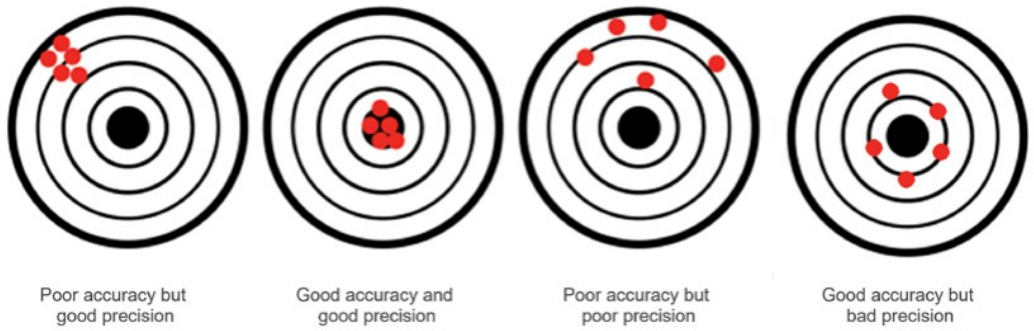
Key terms

Sampling rate (Hz): samples per second

Higher Hz captures faster movements (e.g., saccades) but produces more data.

Accuracy: how close measured gaze is to true gaze

Precision: how consistent the samples are (scatter/variation)



Practical tip

If you need word-level reading measures or tiny AOIs, prioritize accuracy + head stabilization (e.g., chin rest).

Common causes of bad data

- Poor calibration / drift over time
- Glasses glare / heavy makeup / eyelashes
- Large head motion or device slippage
- Low sampling rate for fast dynamics

Calibration & validation

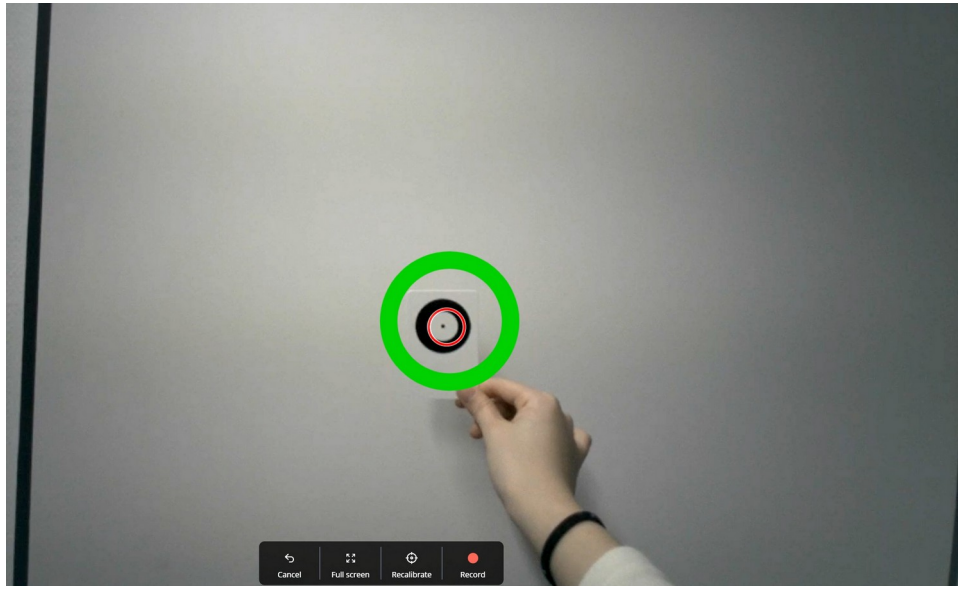
Teaching the tracker what your gaze looks like

Screen-based calibration

Typical: 5–9 points. Then validate to check error.

- Seat distance + screen position matter
- Recalibrate after breaks or if drift appears

Wearable calibration



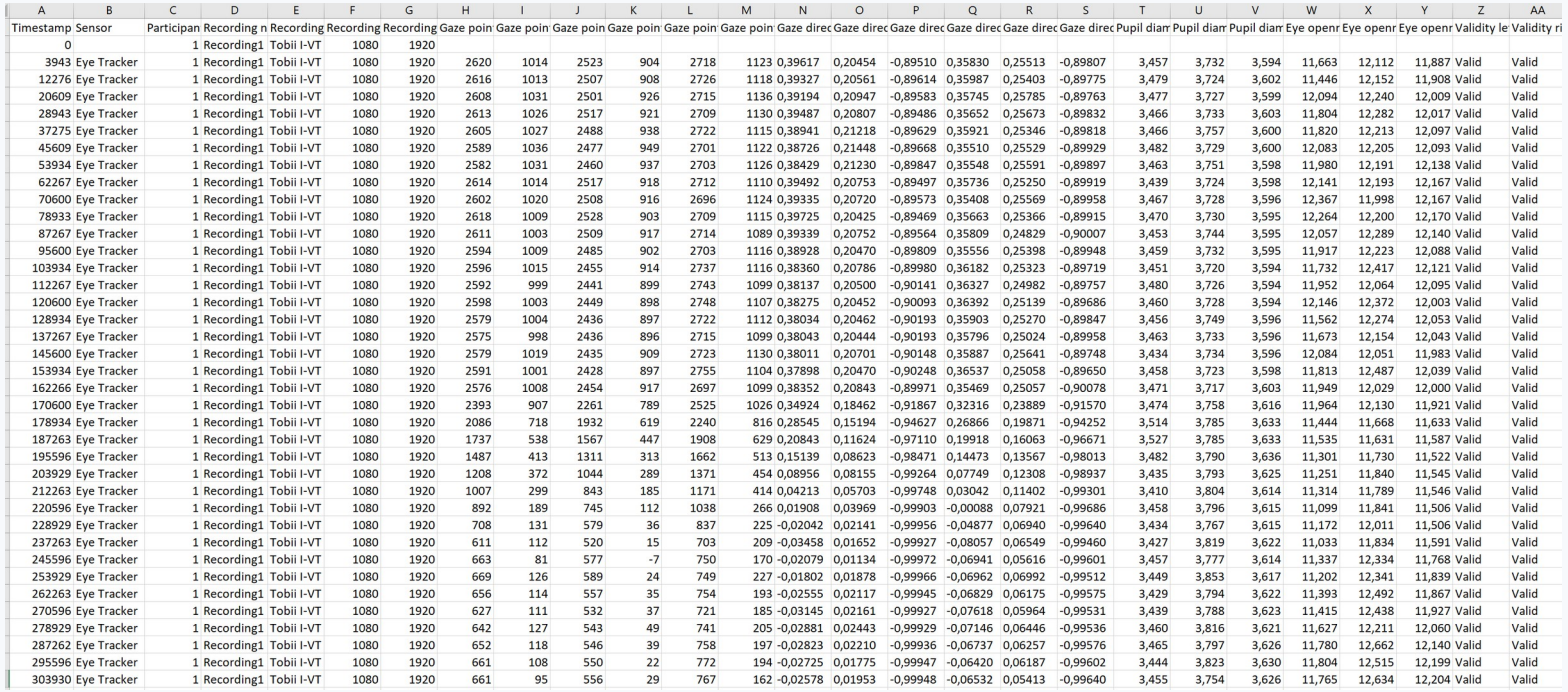
Often: look at a marker at a known distance (or multiple markers).

Troubleshooting

If calibration is poor (often with glasses), try repositioning and give a short break before retrying.

What does eye-tracking data look like?

Raw data is usually a table (CSV/TSV) with timestamped samples



A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
Timestamp	Sensor	Participan	Recording n	Recording	Recording	Recording	Gaze poin	Gaze poin	Gaze poin	Gaze poin	Gaze poin	Gaze poin	Gaze direc	Gaze direc	Gaze direc	Gaze direc	Gaze direc	Gaze direc	Pupil diam	Pupil diam	Pupil diam	Eye openr	Eye openr	Eye openr	Validity le	Validity ri
0		1	Recording1	Tobii I-VT	1080	1920																				
3943	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2620	1014	2523	904	2718	1123	0,39617	0,20454	-0,89510	0,35830	0,25513	-0,89807	3,457	3,732	3,594	11,663	12,112	11,887	Valid	Valid
12276	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2616	1013	2507	908	2726	1118	0,39327	0,20561	-0,89614	0,35987	0,25403	-0,89775	3,479	3,724	3,602	11,446	12,152	11,908	Valid	Valid
20609	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2608	1031	2501	926	2715	1136	0,39194	0,20947	-0,89583	0,35745	0,25785	-0,89763	3,477	3,727	3,599	12,094	12,240	12,009	Valid	Valid
28943	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2613	1026	2517	921	2709	1130	0,39487	0,20807	-0,89486	0,35652	0,25673	-0,89832	3,466	3,733	3,603	11,804	12,282	12,017	Valid	Valid
37275	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2605	1027	2488	938	2722	1115	0,38941	0,21218	-0,89629	0,35921	0,25346	-0,89818	3,466	3,757	3,600	11,820	12,213	12,097	Valid	Valid
45609	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2589	1036	2477	949	2701	1122	0,38726	0,21448	-0,89668	0,35510	0,25529	-0,89929	3,482	3,729	3,600	12,083	12,205	12,093	Valid	Valid
53934	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2582	1031	2460	937	2703	1126	0,38429	0,21230	-0,89847	0,35548	0,25591	-0,89897	3,463	3,751	3,598	11,980	12,191	12,138	Valid	Valid
62267	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2614	1014	2517	918	2712	1110	0,39492	0,20753	-0,89497	0,35736	0,25250	-0,89919	3,439	3,724	3,598	12,141	12,193	12,167	Valid	Valid
70600	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2602	1020	2508	916	2696	1124	0,39335	0,20720	-0,89573	0,35408	0,25569	-0,89958	3,467	3,728	3,596	12,367	11,998	12,167	Valid	Valid
78933	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2618	1009	2528	903	2709	1115	0,39725	0,20425	-0,89469	0,35663	0,25366	-0,89915	3,470	3,730	3,595	12,264	12,200	12,170	Valid	Valid
87267	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2611	1003	2509	917	2714	1089	0,39339	0,20752	-0,89564	0,35809	0,24829	-0,90007	3,453	3,744	3,595	12,057	12,289	12,140	Valid	Valid
95600	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2594	1009	2485	902	2703	1116	0,38928	0,20470	-0,89809	0,35556	0,25398	-0,89948	3,459	3,732	3,595	11,917	12,223	12,088	Valid	Valid
103934	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2596	1015	2455	914	2737	1116	0,38360	0,20786	-0,89980	0,36182	0,25323	-0,89719	3,451	3,720	3,594	11,732	12,417	12,121	Valid	Valid
112267	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2592	999	2441	899	2743	1099	0,38137	0,20500	-0,90141	0,36327	0,24982	-0,89757	3,480	3,726	3,594	11,952	12,064	12,095	Valid	Valid
120600	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2598	1003	2449	898	2748	1107	0,38275	0,20452	-0,90093	0,36392	0,25139	-0,89686	3,460	3,728	3,594	12,146	12,372	12,003	Valid	Valid
128934	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2579	1004	2436	897	2722	1112	0,38034	0,20462	-0,90193	0,35903	0,25270	-0,89847	3,456	3,749	3,596	11,562	12,274	12,053	Valid	Valid
137267	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2575	998	2436	896	2715	1099	0,38043	0,20444	-0,90193	0,35796	0,25024	-0,89958	3,463	3,733	3,596	11,673	12,154	12,043	Valid	Valid
145600	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2579	1019	2435	909	2723	1130	0,38011	0,20701	-0,90148	0,35887	0,25641	-0,89748	3,434	3,734	3,596	12,084	12,051	11,983	Valid	Valid
153934	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2591	1001	2428	897	2755	1104	0,37898	0,20470	-0,90248	0,36537	0,25058	-0,89650	3,458	3,723	3,598	11,813	12,487	12,039	Valid	Valid
162266	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2576	1008	2454	917	2697	1099	0,38352	0,20843	-0,89971	0,35469	0,25057	-0,90078	3,471	3,717	3,603	11,949	12,029	12,000	Valid	Valid
170600	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2393	907	2261	789	2525	1026	0,34924	0,18462	-0,91867	0,32316	0,23889	-0,91570	3,474	3,758	3,616	11,964	12,130	11,921	Valid	Valid
178934	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	2086	718	1932	619	2240	816	0,28545	0,15194	-0,94627	0,26866	0,19871	-0,94252	3,514	3,785	3,633	11,444	11,668	11,633	Valid	Valid
187263	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	1737	538	1567	447	1908	629	0,20843	0,11624	-0,97110	0,19918	0,16063	-0,96671	3,527	3,785	3,633	11,535	11,631	11,587	Valid	Valid
195596	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	1487	413	1311	313	1662	513	0,15139	0,08623	-0,98471	0,14473	0,13567	-0,98013	3,482	3,790	3,636	11,301	11,730	11,522	Valid	Valid
203929	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	1208	372	1044	289	1371	454	0,08956	0,08155	-0,99264	0,07749	0,12308	-0,98937	3,435	3,793	3,625	11,251	11,840	11,545	Valid	Valid
212263	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	1007	299	843	185	1171	414	0,04213	0,05703	-0,99748	0,03042	0,11402	-0,99301	3,410	3,804	3,614	11,314	11,789	11,546	Valid	Valid
220596	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	892	189	745	112	1038	266	0,01908	0,03969	-0,99903	-0,00088	0,07921	-0,99686	3,458	3,796	3,615	11,099	11,841	11,506	Valid	Valid
228929	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	708	131	579	36	837	225	-0,02042	0,02141	-0,99956	-0,04877	0,06940	-0,99640	3,434	3,767	3,615	11,172	12,011	11,506	Valid	Valid
237263	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	611	112	520	15	703	209	-0,03458	0,01652	-0,99927	-0,08057	0,06549	-0,99460	3,427	3,819	3,622	11,033	11,834	11,591	Valid	Valid
245596	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	663	81	577	-7	750	170	-0,02079	0,01134	-0,99972	-0,06941	0,05616	-0,99601	3,457	3,777	3,614	11,337	12,334	11,768	Valid	Valid
253929	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	669	126	589	24	749	227	-0,01802	0,01878	-0,99966	-0,06962	0,06992	-0,99512	3,449	3,853	3,617	11,202	12,341	11,839	Valid	Valid
262263	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	656	114	557	35	754	193	-0,02555	0,02117	-0,99945	-0,06829	0,06175	-0,99575	3,429	3,794	3,622	11,393	12,492	11,867	Valid	Valid
270596	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	627	111	532	37	721	185	-0,03145	0,02161	-0,99927	-0,07618	0,05964	-0,99531	3,439	3,788	3,623	11,415	12,438	11,927	Valid	Valid
278929	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	642	127	543	49	741	205	-0,02881	0,02443	-0,99929	-0,07146	0,06446	-0,99536	3,460	3,816	3,621	11,627	12,211	12,060	Valid	Valid
287262	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	652	118	546	39	758	197	-0,02823	0,02210	-0,99936	-0,06737	0,06257	-0,99576	3,465	3,797	3,626	11,780	12,662	12,140	Valid	Valid
295596	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	661	108	550	22	772	194	-0,02725	0,01775	-0,99947	-0,06420	0,06187	-0,99602	3,444	3,823	3,630	11,804	12,515	12,199	Valid	Valid
303930	Eye Tracker	1	Recording1	Tobii I-VT	1080	1920	661	95	556	29	767	162	-0,02578	0,01953	-0,99948	-0,06532	0,05413	-0,99640	3,455	3,754	3,626	11,765	12,634	12,204	Valid	Valid

Common columns

- Timestamp
- Gaze point (x, y)
- Eye validity / trackloss
- Pupil diameter
- Event markers (stimulus, response)

Big idea

We turn these samples into meaningful events (fixations / saccades), then compute summary metrics.

Basic eye movements (events)

Most analyses start by identifying these from gaze samples

Fixation

Eyes stay relatively still
Information intake happens here

Saccade

Fast jump between fixations
(very brief, high velocity)

Smooth pursuit

Eyes follow a moving target
Continuous tracking

Blink

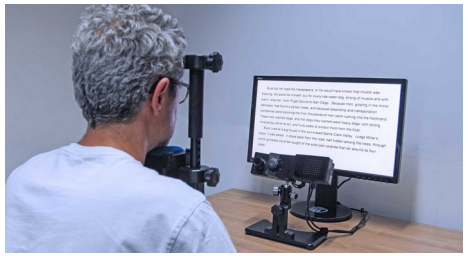
Eyelids close briefly
Creates missing samples

Pupil dynamics

Pupil size changes
(light + cognition)

Rule of thumb

Most “attention” metrics are derived from fixations and how they move between areas.



Example lab setup

Fixation measures (most common)

Duration and count are widely used for attention and task difficulty

Core metrics

- Fixation duration (ms): how long the gaze stays in one place
- Number of fixations: how many fixations occur during a task or on an AOI
- Total fixation duration: sum of all fixations (per stimulus/AOI)
- Fixation rate: fixations per second (sometimes used for workload)

Typical durations

Often ~100–350 ms
(depends on task & stimulus)

Interpreting fixations

- Longer fixations can reflect more cognitive effort or difficulty
- Experts may show different patterns (e.g., focus on relevant regions)
- Always interpret in context (task, stimulus, expertise)

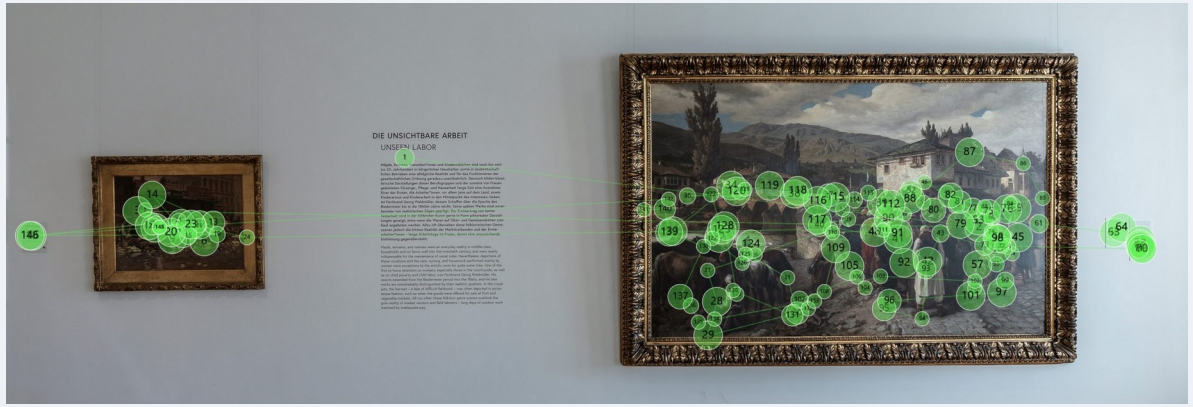
Saccade & scanpath measures

How the gaze moves between fixations

Saccade metrics

- Amplitude: how far the eye jumps (degrees or pixels)
- Velocity: speed of the jump (deg/s)
- Direction: where the gaze moves next
- Saccade rate: saccades per second

Scanpath (sequence of fixations + saccades)



What can saccades tell us?

- Search strategy (local vs global scanning)
- Attention shifts (what attracts from a distance)
- Comparing novices vs experts

Common summary stats

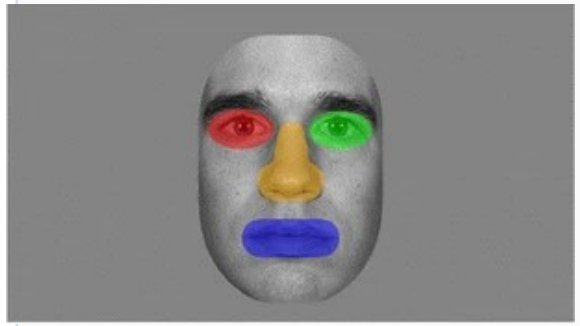
Mean / median amplitude
Velocity distributions
Scanpath length
Transitions between AOIs

AOI metrics (Area of Interest)

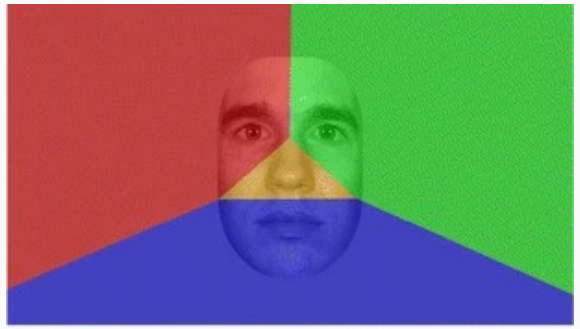
Summarize attention to meaningful regions (buttons, words, faces…)

AOI examples (face processing)

Site header



Manual/figure drawing



Voronoi

Common AOI measures

- Dwell time (time spent) on AOI
- Time to first fixation (TTFF)
- Fixation count on AOI
- Revisits / returns to AOI
- Sequence of AOI transitions

Interpret with care

Long dwell time can mean interest… or confusion. Pair eye metrics with task performance and think-aloud when possible.

Pupil & blink measures

Useful, but require careful preprocessing

What we can extract

- Pupil diameter / pupil dilation (changes over time)
- Blink rate and blink duration
- Trackloss periods (often align with blinks)

Why preprocessing matters

Blinks create missing values and sharp spikes. A common pipeline is:
1) remove invalid samples
2) smooth noisy segments
3) interpolate short gaps
4) baseline-correct pupil size

Interpreting pupil & blinks

- Pupil size is strongly affected by lighting — control luminance!
- After control/baseline, pupil dilation can reflect cognitive effort
- Blink rate is sometimes studied as workload / fatigue signal

From samples → fixations & saccades

Simple event detection: I-VT (velocity) and I-DT (dispersion)

I-VT (Identification by Velocity-Threshold)

- Compute point-to-point gaze velocity
- If velocity < threshold → fixation sample
- Group consecutive fixation samples into fixations
- Enforce minimum fixation duration (e.g., 60–100 ms)

Typical threshold (example)

Many studies use ~30–50 deg/s for I-VT (then tune for your task & tracker).

I-DT (Identification by Dispersion-Threshold)

- Slide a time window over samples
- Compute spatial spread (“dispersion”)
- If dispersion < threshold → fixation
- Else → saccade / transition

Why thresholds matter

Too strict → split real fixations into many small ones.
Too loose → merge separate fixations.
Always report your algorithm + parameters.

Data processing pipeline (end-to-end)

A practical workflow for reliable metrics

1) Clean

Remove invalid trials & samples

2) Filter

Smooth noise
Interpolate gaps

3) Segment

Split by condition/events

4) Detect

Fixations
Saccades
Blinks

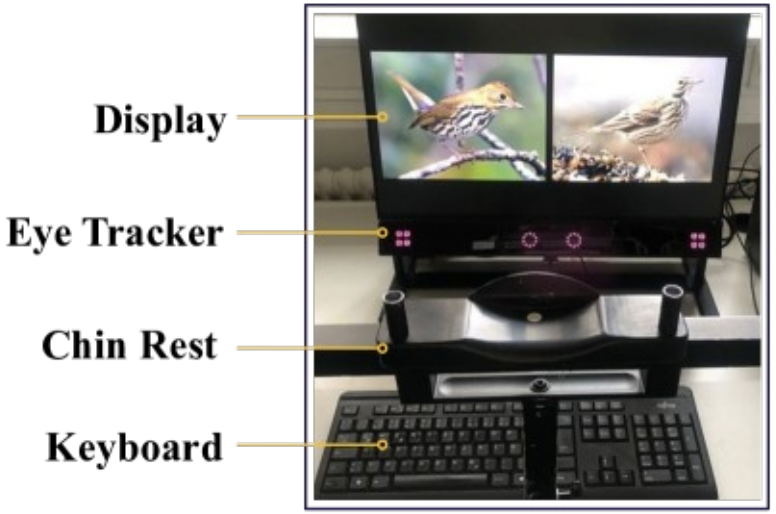
5) Extract

Metrics (AOI, scanpath, pupil)

6) Analyze

Stats + visualizations

Example: what “cleaning” can remove



Good practice checklist

- Define exclusion rules before you look at results
- Log task events (stimulus onsets, responses)
- Report algorithms + thresholds (I-VT/I-DT etc.)
- Visualize data (heatmaps/scanpaths) as sanity checks

Visualization 1: heatmaps (saliency maps)

Aggregate fixations into a “hot–cold” attention map

How they’re built

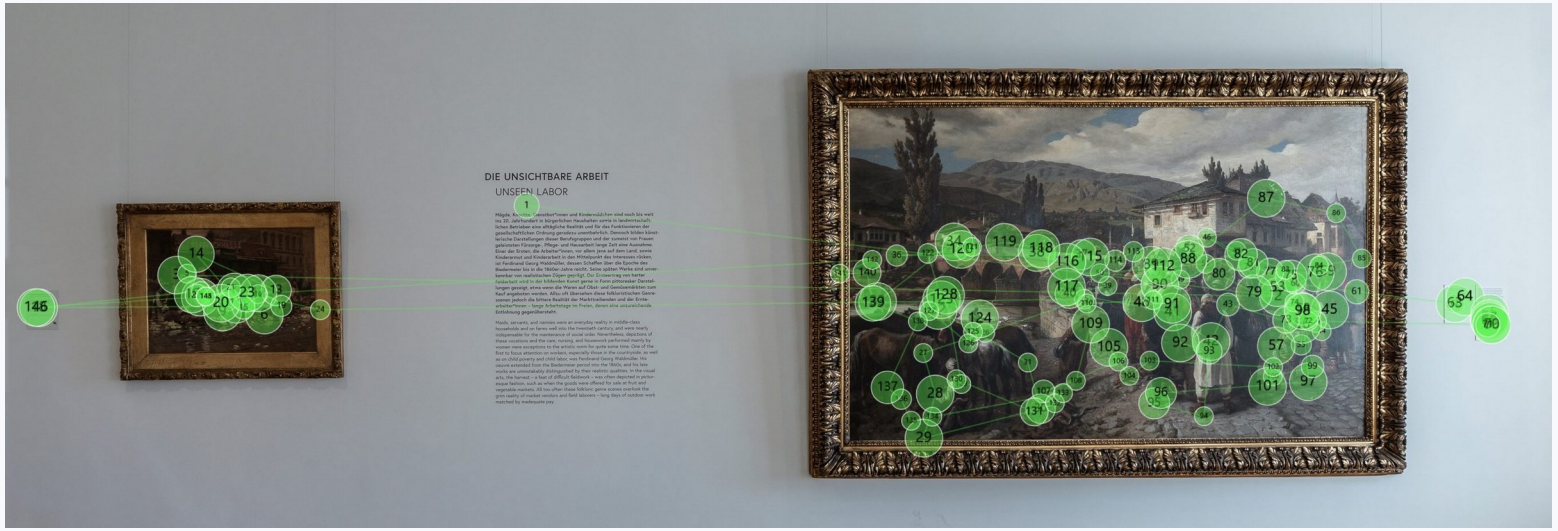
- Start with fixation locations (x, y)
- Weight by duration (optional)
- Apply a Gaussian blur around each fixation
- Sum across time or participants

What to say out loud

Heatmaps are great for “where” questions, but they hide the order of looking. Use scanpaths for sequence.

Visualization 2: scanpaths & gaze plots

Show the order of attention (sequence + movement)



How to read it

- Dots = fixations
- Bigger dots = longer duration
- Lines = saccades
- Numbers = order