EyeLink® 3

A Complete Eye and Head Tracking Solution

FAST, ACCURATE, RELIABLE EYE TRACKING

SR Research
EyeLink®

THE EYELINK® 3

A Complete Eye and Head Tracking Solution

The EyeLink 3 is a completely new kind of eye tracker for screen-based research*, providing high-speed (up to 1000 Hz) gaze data and **perfectly synchronized six-degrees of freedom (6DOF) head tracking data** – both with the outstanding levels of accuracy and precision that EyeLink systems are renowned for. The EyeLink 3 has the fastest sampling rate and highest accuracy and resolution of any head-mounted video-based eye tracker, and, like all EyeLink systems, it is easy to use, with fast and simple participant setup and calibration. The exceptional data quality and combined gaze and head position data make the system ideal for a wide range of research scenarios. Furthermore, the EyeLink 3 introduces the ability to record high-speed video of the eyes at up to 500 Hz, allowing researchers to observe the behavioural phenomenon behind the data, in a way that has never been possible in the past.

Key Features

- » 1000 Hz Gaze data
- » 1000 Hz 6DOF Head data
- » High speed eye videos
- » Novel pixel-based head and eye data
- » Easy to use and lightweight

Simultaneously recording both eye movements and head movements has the potential to provide important insights into the study of human behavior and coordination. For example, common laboratory based eye tracking tasks such as reading or visual search are typically accompanied by head movements when performed in the real world, but the contribution of head movements to task performance is rarely considered by researchers. In addition, difficulties in our ability to coordinate eye and head movements could potentially provide insights into neurological and psychiatric disorders.

* Please note, the EyeLink 3 is intended for screen-based experiments. It is not suitable for research applications requiring a scene camera.

DATA

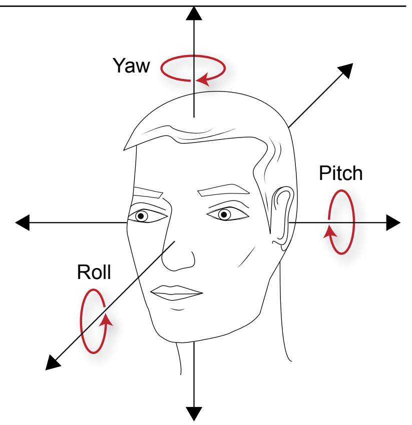
In addition to the gaze data typically recorded for screen-based applications, the EyeLink 3 system offers comprehensive positional data, including separate measurements for head-in-space and eye-in-head positions, both reported in screen pixel coordinates. Furthermore, the eye tracker provides 6DOF head tracking data, enabling precise tracking of the head's translational and rotational movements.

6DOF Head Data

Head tracking data is typically described in a three-dimensional Cartesian space with three axes, X, Y, and Z, that are perpendicular to each other. The X-axis is horizontal, the Y-axis is vertical, and the Z-axis is distance.

The head is free to change position through translation – movement along the three axes, as well as by rotation around the same three axes.

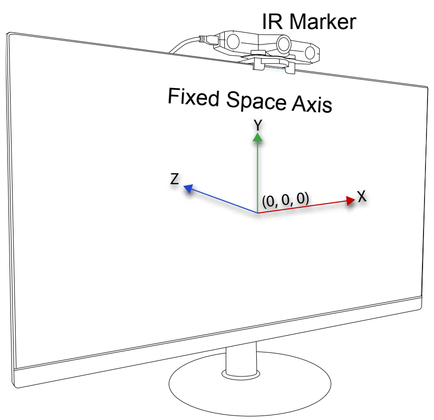
Thus, any head pose in three-dimensional space can be described with three translational values (X, Y, and Z coordinates) and three corresponding rotational angles (often referred to as pitch, yaw and roll).

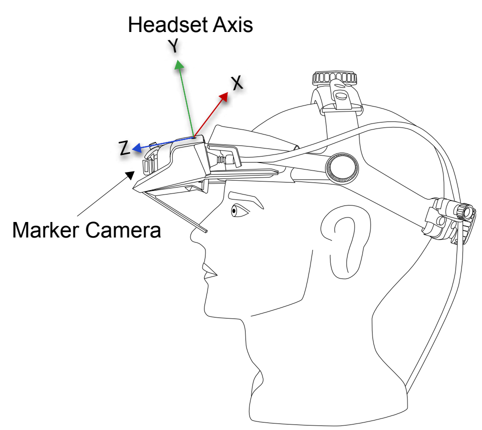


Drift-Free Head Data

The EyeLink 3 uses a novel infrared (IR) marker, placed above or below the calibrated plane. The IR marker is viewed by a forward facing camera on the head band. The marker defines the origin of the reference plane and is used to ground the head pose data from the inertial measurement unit (IMU) on the headset, thus avoiding any drift in the 6DOF data.

The standard IR marker (MRK3-120) is intended for use with monitors. A long range IR marker (MRK3-240) is available for research using larger projected surfaces.





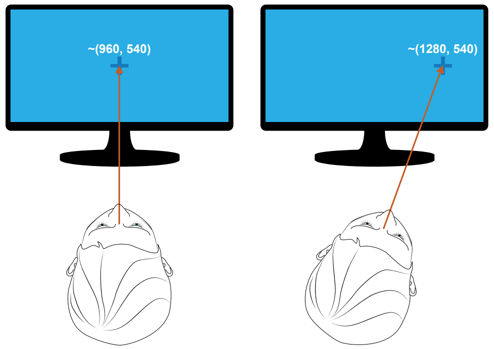
Novel Pixel-Based Head and Eye Data

Like all EyeLink systems, the EyeLink 3 delivers precise gaze data in screen pixel coordinates, where (0, 0) marks the top-left corner and the bottom-right reflects the full screen resolution (e.g., 1920×1080). In addition to standard gaze data, and 6DOF head pose data, the EyeLink 3 provides separate head-in-space and eye-in-head positions in screen pixel coordinates. This innovative feature allows for a simple and clear analysis of the relative contributions of both head and eye movements to shifts in gaze.

Head-in-Space

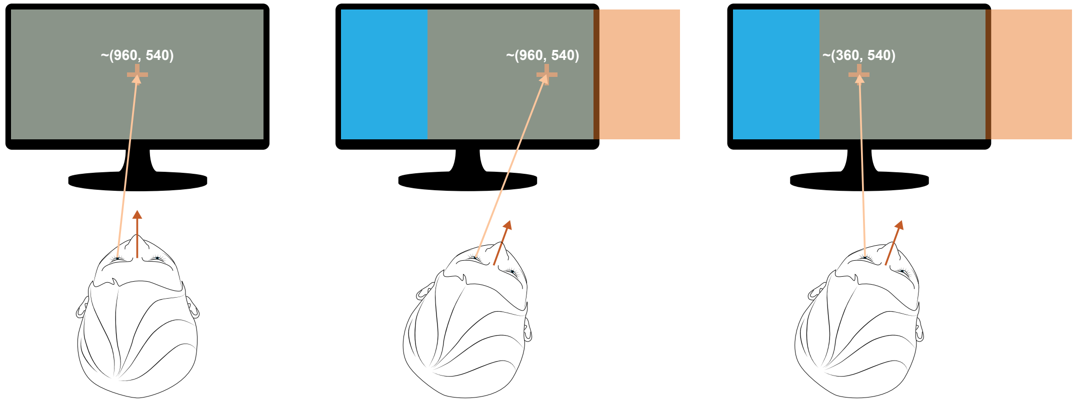
For the head-in-space pixel-based coordinate, picture a virtual rod extending forwards from between the participant's eyes towards the screen / calibrated plane. The point at which the rod intersects with the screen provides the head coordinate.

In the figure on the right, as the participant rotates her head to the right, the X value of the head-in-space coordinate increases.



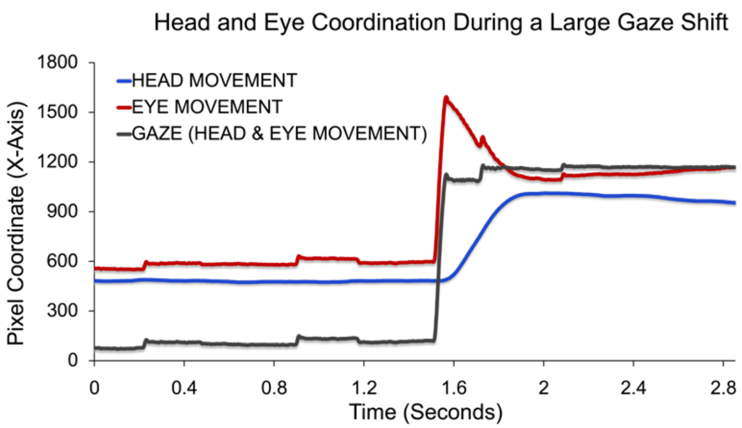
Eye-in-Head

The eye-in-head pixel-based coordinate metric represents the rotation of the eye within the head. Imagine a virtual screen that is the exact size of the physical screen, and which is yoked to a participant's head. See the orange screen moving with the head below. The eye pixel-based coordinate is the location of gaze on this virtual screen (which shares the same pixel resolution as the actual screen). Thus, if the head rotates, but the eyes stay still (see middle image below), the eye-in-head value does not change. If the head rotates and the eye counter-rotates (see right image below), the eye-in-head position changes. The eye-in-head position is now on the left side of the virtual screen at approximately (360, 540), while the gaze position remains at the center of the screen. This can also be thought of as the gaze without compensating for head-movement, i.e., if using a chin-rest, eye-in-head and standard gaze should be approximately identical.



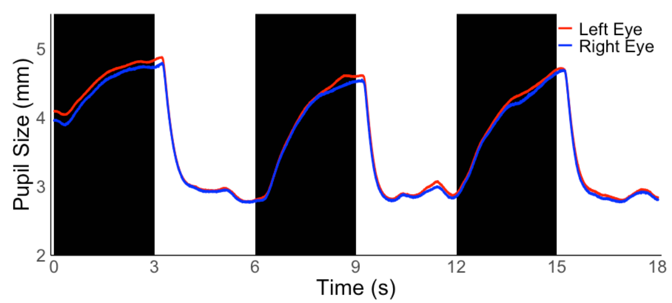
Pixel-Based Data

The novel pixel-based data allows for very straightforward comparisons of the relative role and timing of head and eye movements. The following data plot illustrates a gaze shift involving both head and eye movements, showing that the head movement follows the eye movement.



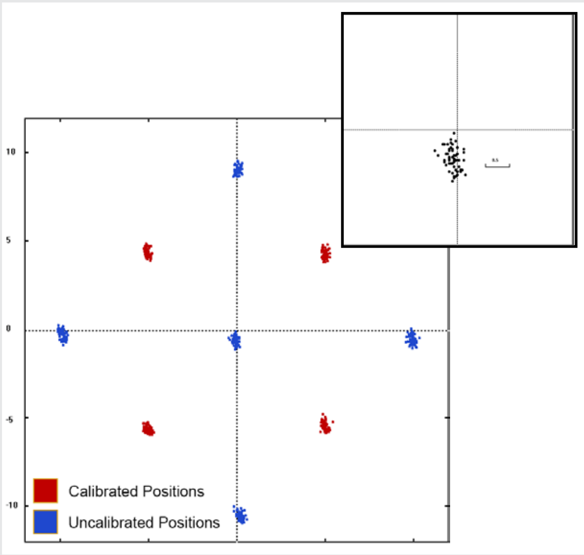
Pupil Size Data

The EyeLink 3 records pupil size (diameter or area) with each sample. The measurements are noise-limited, with noise levels at 0.1% of the diameter. This corresponds to a resolution within 0.01 mm for a 5 mm pupil. The image below plots the raw pupil size data for the left and right eye during cycles of black / white screen. Note the relatively fast constriction and slower dilation.

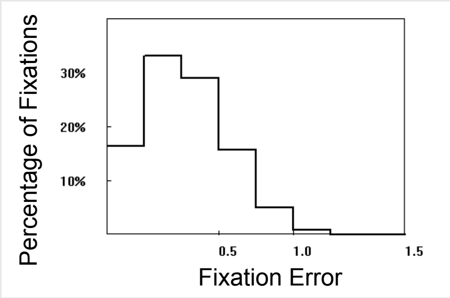


When tracking the pupil in Ellipse Mode, the EyeLink 3 can provide the X, Y position of the pupil ellipses for the tracked eyes in camera coordinates and the length of the major and minor axis (in camera pixels) of the pupil ellipses. The latter two can be used to derive pupil size in physical units (e.g., in millimeters) by applying a conversion factor. The EyeLink 3 also reports the angle (in degrees) between the major-axis and x-axis for the eyes. Pupil size is available online at 1000 Hz binocularly.

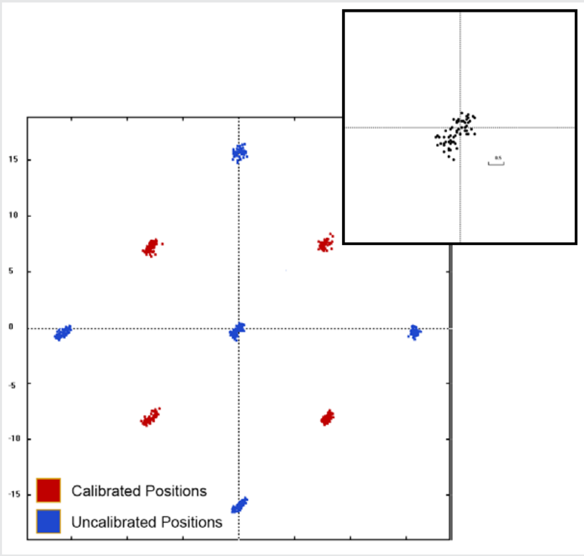
Fixation Accuracy (Standard Monitor)



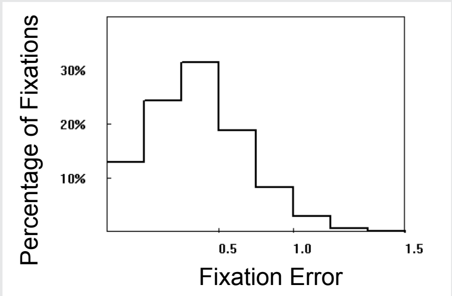
Repeated target fixations to nine screen locations on a standard 40 x 30 cm monitor viewed at a distance of ~80cm. Each dot represents a fixation at a target. The inset plot represents an enlarged view of the fixation distribution around the center target position. Below is a fixation error histogram demonstrating the tight fixation accuracy distribution (Mean= 0.42°, Median = 0.40°, and Standard Deviation = 0.21°).



Fixation Accuracy (Projected Screen)



Repeated fixations to 9 points on a projected screen, following a 13 point calibration. The projected area was approximately 140x100cm and viewed from a distance of ~150cm. Both head and eye movements were made to refixate the targets. The inset plot is an enlarged view of the fixation distribution around the center target position. The plot below shows the fixation error (Mean = 0.49°, Median = 0.48° and Standard Deviation = 0.25°).

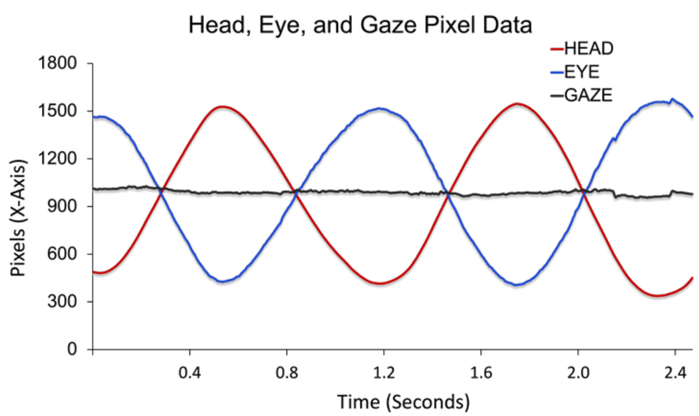


EXAMPLE RESEARCH APPLICATIONS

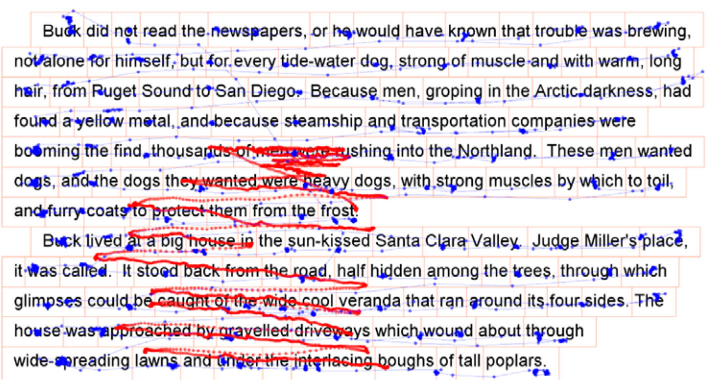
As with our other systems, which operate in head-fixed or remote mode, the EyeLink 3 provides fast, accurate and reliable gaze data for a wide variety of screen based research applications. The built-in head tracking and eye video recording capabilities considerably extend this range, opening up exciting new possibilities for cutting-edge research across a range of diverse topics. A few examples are outlined below.

Vestibular / VOR Research

The combined eye and head data provided by the EyeLink 3 make it the perfect tool for studying vestibular function and the vestibular ocular reflex (VOR). The plot to the right illustrates the three pixel-based data types (gaze, head-in-space, and eye-in-head) as a participant makes "yaw" head rotations (i.e., shakes head back and forth) whilst maintaining fixation on a central target. The gaze data remains unchanged, approximately fixed at the center of the screen along the X-axis, but the head and eye data change in opposite directions – as the eye counter-rotates within the head to maintain the fixation.



Reading With Head Movements



The EyeLink 3 can be used to explore the role of head movements in gaze shifts during reading. In the left image the red trace shows the "head" (x,y) pixel location, and the blue data shows the gaze (x,y) pixel location.

Even when reading naturally on a typically-sized screen, eye movements may be complemented by head movements, reducing the need for making large-amplitude eye movements.

Treadmill with Projection Screen and Long Range IR Marker

When combined with a treadmill, the EyeLink 3 is a convenient tool for research into combined eye and head movements during gait. It can also be combined with a balance / force place for research into the role of head and eye movements in balance.

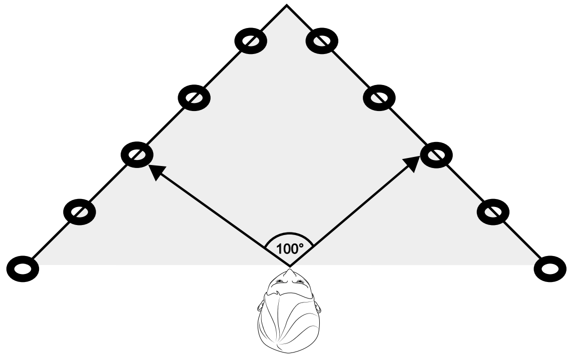
The long range IR marker (MRK3-240) operates at distances of up to 300 cm and is perfect for research in which participants are viewing stimuli via a projector.

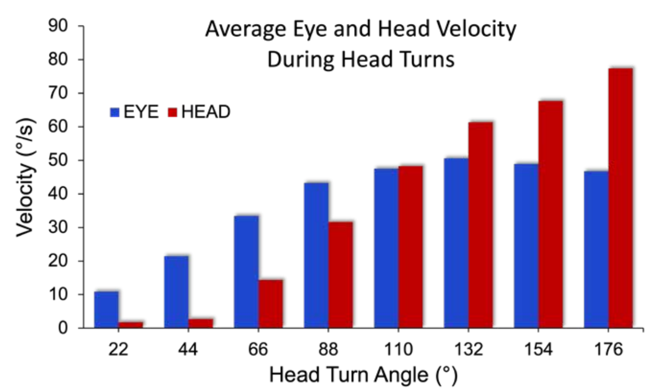
When participants make combined head and eye movements, the EyeLink 3 can accurately track gaze to projected areas that subtend up to 70x50 degrees of visual angle.

Marker Free Tracking Mode

The 6DOF head data and gaze-compensation are drift free while the IR marker remains in view of the camera. However, in a few exceptional cases, users may want to operate the system with the marker disabled or even removed (e.g., tracking in complete darkness, tracking that requires large head movements out of the marker range, or tracking with an extended period of marker loss).

The EyeLink 3 also supports applications where head tracking is based on the IMU only. This "marker free" tracking reduces setup complexity and removes the marker trackable range restrictions.





However, in Marker Free mode, the EyeLink 3 delivers only the head rotation data from the IMU. There is no position data. As such, Marker Free mode is intended for research scenarios in which eye and head rotation / rotational velocity are the key metrics of interest.

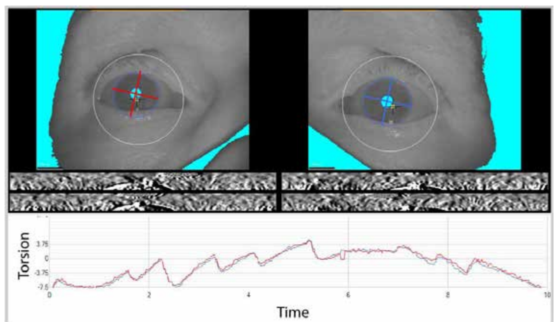
For example, the data on the left shows the average eye and head velocities during large gaze shifts that involved both head and eye movements.

Eye Video Recordings

The EyeLink 3 provides high-speed (up to 500 fps) recordings of the eyes – allowing researchers to explore new aspects of blink, saccade and pupil dynamics. For example the eye video could be used to provide onset / offset times for blinks / partial blinks or to explore the role of pupil size changes in post-saccadic oscillations.

The high quality eye recordings facilitate research into eye tracking methodologies, for example allowing the performance of various parsing algorithms to be tested against a ground truth, testing blink detection algorithms, and allowing researchers to develop and test their own image processing algorithms.

Torsion



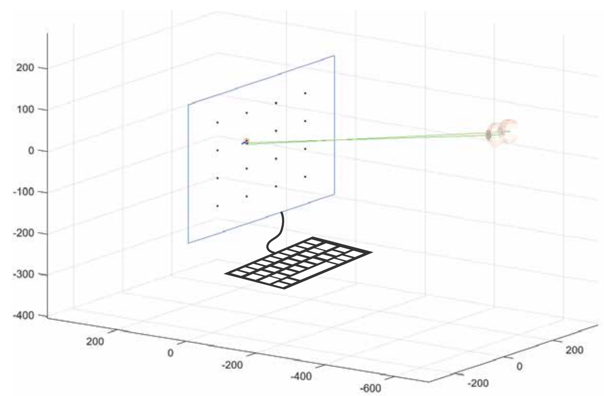
Torsional eye movements are important components of our ability to maintain stable gaze during head movements and can provide insights into vestibular and neurological disorders.

The eye video recordings could potentially be used to study torsional eye movements using open source software, as illustrated on the left (using OpenIris).

The data shows torsional eye movements made during ear-to-shoulder head rotations.

3D Gaze

The combined eye and head tracking data provided by the EyeLink 3 enables the creation of 3D gaze vectors. This allows researchers to study gaze behavior across various planes or objects positioned at different depths. In the image on the right, the green lines extending from the eyes indicate the 3D gaze point, which is close to the currently visible target (highlighted with a red circle). The blue dots indicate individual 3D fixations.

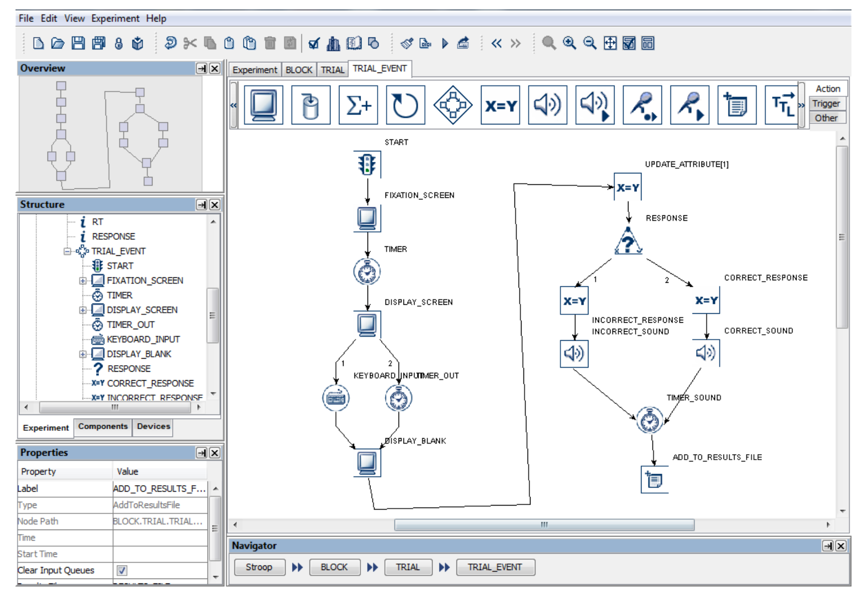


EXPERIMENT BUILDER

The EyeLink 3 is fully compatible with our stimulus presentation software, Experiment Builder. Experiment Builder is a graphical programming environment for creating computer-based psychology and neuroscience experiments. The software is capable of delivering complex visual and auditory stimuli and dealing with hardware devices with extremely high levels of temporal precision.

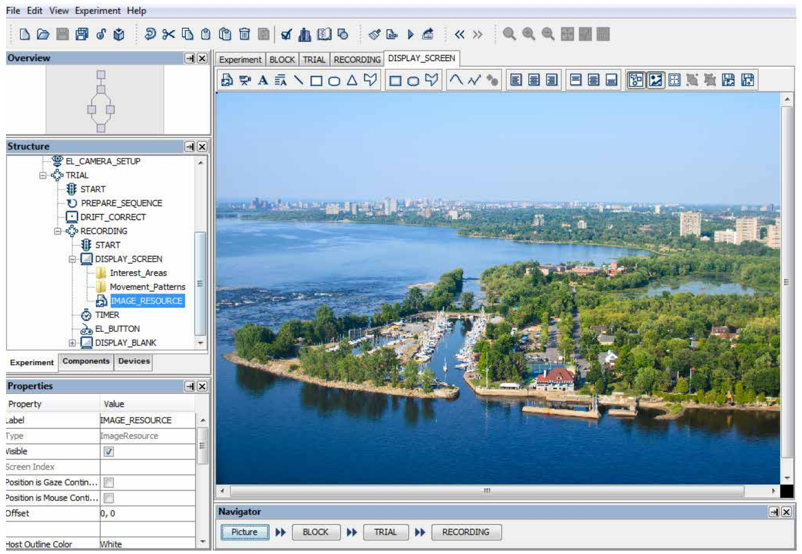
Key Features

- Cross-platform compatible for Windows (32-bit and 64-bit) and macOS
- Graphical User Interface supports drag and drop experiment programming
- Easy-to-use hierarchical experiment creation interface
- Conditional branching and looping for flexible experiment flow control
- Millisecond precise timing of video, audio, TTL, and response devices
- Gaze-contingent stimulus control (e.g., for moving window and boundary crossing paradigms)
- Built-in screen editor for manipulating text, image, and video resources
- Built-in data source (stimulus list) editor to specify the parameters of individual trials
- Automatic generation of interest areas for text
- Multi-language / Unicode support throughout the application
- Direct integration with a range of EEG / fNIRS and other biometric recording devices
- Advanced support for EyeLink eye trackers and seamless integration with Data Viewer software
- Add custom Python code to extend experiments as desired



Powerful and Intuitive Experiment Creation Tools

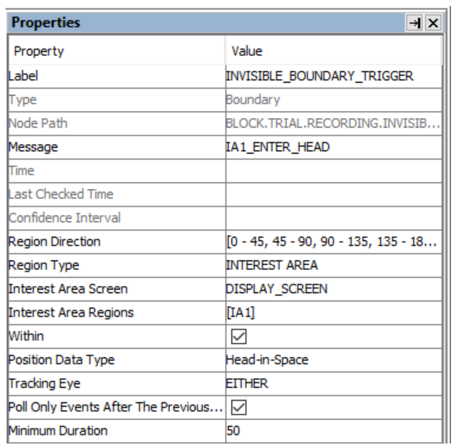
With a built-in data source (stimulus list), powerful randomization options, conditional branching and looping capabilities, Experiment Builder is simple enough for a novice user but rich enough to handle the most advanced experimental paradigms.

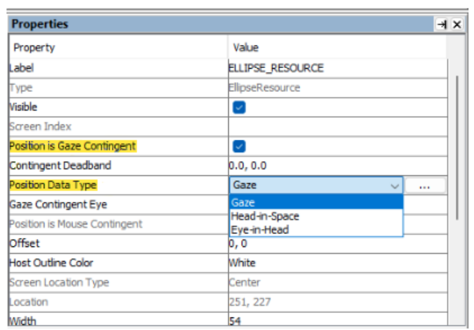


Python data structures and commands can be incorporated into the GUI interface to allow for increased flexibility. Advanced users can even program entire experimental procedures using custom Python scripts.

Gaze, Head and Eye Contingent Resources and Triggers

The EyeLink 3 6DOF head data and novel pixel data can both be accessed by Experiment Builder over the link, allowing users to easily create head and eye-in-head contingent tasks, as well as gaze-contingent tasks.



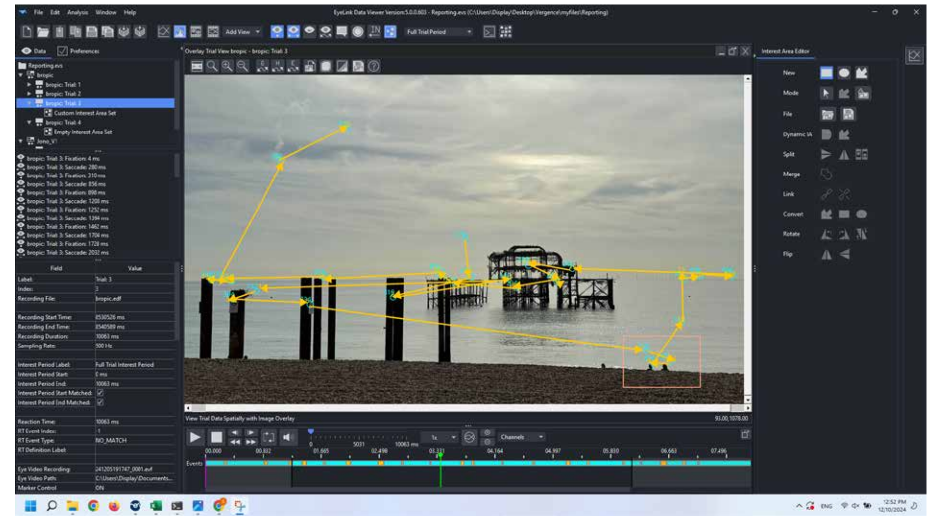


All Display Screen resources (e.g., shapes, images, text) can have their positions contingent on the novel pixel head-in-space and eye-in-head data. Sample Velocity and Invisible Boundary trigger nodes can be configured to fire based on this novel pixel data.

DATA VIEWER

A new-look version of Data Viewer, our analysis software, allows the rich data provided by the EyeLink 3 to be visualized and analyzed efficiently. Several different viewing options provide convenient ways to visualize and inspect both temporal and spatial aspects of the head and eye movement data.

The software provides a range of analysis tools that can be used to generate tab-delimited summary reports based on interest areas, fixations, saccades, time bins, or samples.



Key Features

» Multiple data visualization modes:

» Animation Playback View shows a movie of the trial with pixel coordinate data (gaze / eye-in-head / head-in-space) overlaid (including bee-swarm for multiple trials)

» Spatial Overlay View superimposes saccade and fixation scanpath information over an image. Again, all pixel based data can be plotted

» Temporal Graph View supports visualization of eye, head and eye-in-head data over time

» Supports both static and dynamic interest areas (rectangular, elliptical, or freeform polygons)

» Generate static or dynamic heat maps for selected trials or groups of trials

» Output sample, fixation, saccade, interest area, or trial-based reports for statistical analysis

» Output Time Series (binning) reports for Visual World / Dynamic tasks

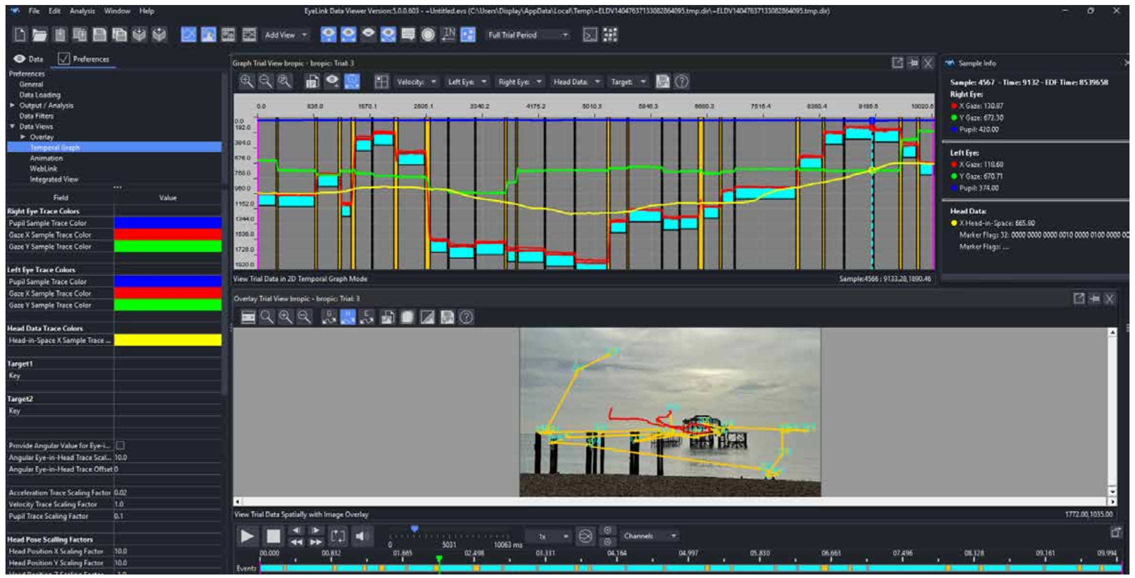
» Calculate hundreds of dependent measures including most common reading measures

» Create interest periods for temporal data filtering

» Highly integrated with SR Research Experiment Builder, WebLink, E-Prime, PsychoPy, Psychtoolbox and other stimulus presentation solutions

Advanced Visualizations

Version 5 and above of EyeLink Data Viewer have advanced visualization and export capabilities for gaze, eye-in-head, head-in-space, and 6DOF data recorded with EyeLink 3 eye tracker. These data can be visualized in the Spatial Overlay, Temporal Graph, and Animation Playback views, and exported in various output reports. The Timeline provides a full-featured player for trial recording playback that is available in all viewing modes. It allows users to synchronize playback positions across different viewing modes and easily seek specific positions within the recording data. In addition to displaying experimental stimuli, Data Viewer 5 and above support the playback of Eye Video recordings for EyeLink 3 sessions, as well as accessory live audio and video recordings of the participant collected via the WebLink or Participant Camera plugin.



DISPLAY SOFTWARE

As with all EyeLink systems, the EyeLink 3 comes with a free Software Development Kit (SDK), which enables integration with third-party hardware and stimulus presentation software.

- SDKs are available for Windows, macOS, and Linux
- SDKs include easy-to-follow example eye tracking tasks written in C, C# and Python as well as example templates for Psychopy, E-Prime, OpenSesame, and MATLAB / Psychtoolbox

E-Prime · powered by Psychtoolbox · PsychoPy · LabVIEW · Open Sesame · Presentation · python · C · C++ · C#

WEBLINK

SR Research WebLink is a powerful software solution that allows EyeLink users to track eye movements while participants view and interact with dynamic media such as websites, PDF files, scene camera, online games, and computer software. It is ideal for performing usability testing and also perfect for running simple “slideshow” experiments with image and video stimuli.

Key Features

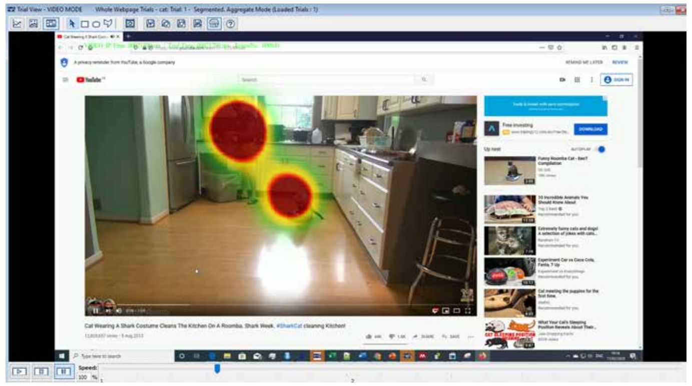
- » A simple and intuitive drag and drop interface for the rapid creation of tasks
- » Powerful screen recording that captures dynamic screen events and changes as an mp4 video file
- » Synchronization between the screen capture video recording and eye-tracking data for easy analysis in Data Viewer
- » The ability to record all key presses and mouse clicks
- » The ability to record video and audio of the participant via a webcam
- » Hotkeys which can be used to send messages into the eye tracking recording or send TTLs to synchronize with other recording equipment and experimental devices
- » Dual monitor capabilities that provide live gaze feedback and facilitate task control during the recording session
- » Stimulus randomization in the Timeline or Repetition Sequence
- » Advanced features such as listening to external messages or streaming online samples through socket connection
- » Compatible with all EyeLink eye trackers

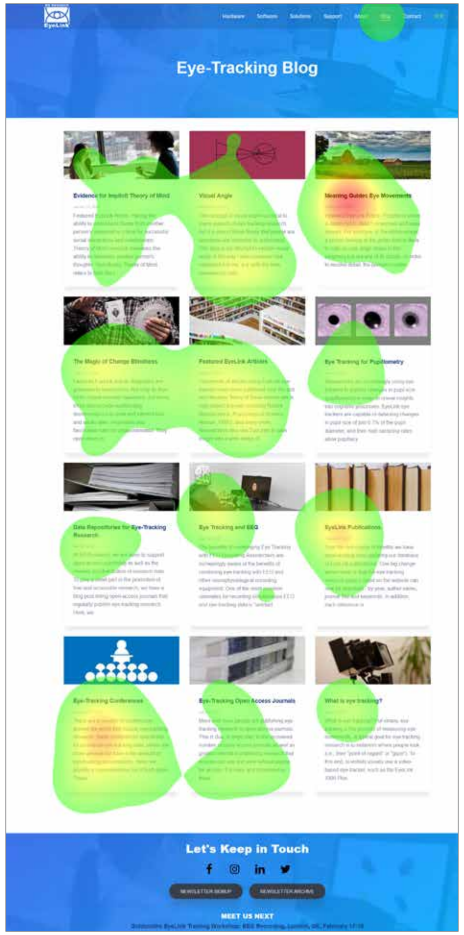
The EyeLink 3 allows users to interact with software in a naturalistic way, for example, allowing researchers to study translators working with dual monitor setups (see below).

WebLink for Website Research

WebLink has a number of features that make it particularly suitable for studies in which users browse websites. In combination with our analysis software Data Viewer (see pages 11-12), WebLink allows users to:

- Capture websites using Firefox or Chrome browsers
- Capture an entire webpage content as a single image for offline analysis and creation of interest areas and heat maps
- Capture dynamic website content (e.g., video and audio) with .mp4 screen recording
- Simultaneously record live video / audio from participant to capture reactions / verbal responses
- Capture browser navigation and history (URL or local address for offline webpages) – allowing data to be automatically grouped by webpage in Data Viewer
- Perform automatic scroll compensation of samples and events during analysis in Data Viewer

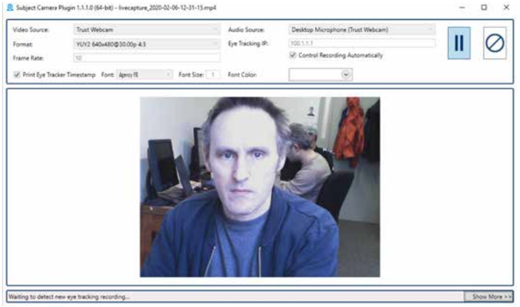




Participant Camera Plugin

The Participant Camera Plugin allows users to capture data from a webcam or other video input. The video feed is recorded as an .mp4, and the timestamp from the EyeLink Host PC is overlaid on each frame of the video, allowing it to be synchronized with the eye tracking data at the analysis stage.

The Participant Camera Plugin can operate in standalone mode or be controlled by Experiment Builder. It does not require a license to run.



SPECIFICATIONS

EyeLink 3

Functional Specifications		
Sampling Rate	250/500/1000 Hz Monocular or Binocular	
Eye Tracking Principle	Dark Pupil - Corneal Reflection	
Pupil Detection Models	Centroid or Ellipse Fitting	
Gaze Accuracy[1]	0.5°	
End-to-End Sample Delay[2]	M = 2.37 ms (SD < 0.5 ms) @ 1000 Hz; M = 3.38 ms (SD < 1.1 ms) @ 500 Hz	
Blink/Occlusion Recovery	1.0 ms @ 1000 Hz	
Gaze Precision[3]	1000 Hz: 0.06°/0.03°/0.02° (Filter Off/Normal/High) 500 Hz: 0.05°/0.02°/0.01° (Filter Off/Normal/High)	
Trackable Eye Rotation Range (Decoupled X/Y Rotations)	± 26° Horizontal, ± 17° Vertical in Pupil-CR Mode ± 30° Horizontal, ± 25° Vertical in Pupil-Only Mode	
Gaze Tracking Range (Rectangular Area	40° × 25° (Without Head Movements) 70° × 50° (With Head Movements)	
Eye-to-Camera Distance	65 mm – 85 mm Effective Eye Distance > 20 mm Mirror Clearance to Eyes Fixed Focus	
Eye Video Frame Rate	Configurable (1 to 500 fps)	
Glasses Compatibility	Good (Glasses Dependent)	
Pupil Size Resolution[3]	0.1% of Diameter	
Head Tracking	NIR Marker and IMU Data Fused	IMU only (Marker Free)
Head Tracking Data	Full 6DOF (Head Position: X, Y, Z; Head Rotation: Pitch, Yaw, Roll)	Head Rotation: Pitch, Yaw, Roll
Trackable Head Rotation	Pitch: ± 15°, Yaw: ± 38°, Roll: ± 50°	Unlimited
Trackable Head Position	X: ± 55 cm; Y: 76 cm from -28 to 48 cm (@ 80 cm distance) Z: 30 to 120 cm for MRK3-120; 40 to 300 cm for MRK3-240	N/A
Online Eye Event Parsing	Fixation / Saccade / Blink / Fixation Update	
EDF File and Link Data Types	Pixel Data: Gaze, Eye-in-Head, Head-in-Space; Head Tracking Data: X, Y, Z (mm), Pitch, Yaw, Roll (angles); Additional Data Types: Raw, HREF Eye Data, Pupil Size and Pupil Ellipse data, Buttons, Messages, Digital Inputs	
Real-Time Operator Feedback	Eye position gaze cursor superimposed on static image or position traces with camera images and tracking status.	

Specifications are preliminary and subject to change without notice.
[1] Measured with real eye fixations at multiple screen positions on a per subject basis.
[2] Time from physical event until first registered sample is available via Ethernet output. Optional data filter algorithm adds one sample delay for each filtering level.
[3] Measured with an artificial eye.

Wearable Unit

Physical Specifications	
Enclosure	Plastic and silicone
Dimensions (W×H×D)	240 mm × 95 mm × 260 mm
Mounting Methods	Headband
Weight	480 g including headband (620 g with USB cable)
Power Requirements	4.5 - 5.5 V, 0.9 A from USB 3.x port on host computer
Connection	3-meter USB 3.0 cable
Computer Requirements	• Use only supplied computer with certification under EN/CSA/UL 60601-1. 60950-1, or 62368-1 or equivalent
Internal Illuminator	• Wavelength: 940 nm, invisible NIR light • Eye exposure: less than 1 mW/cm² • IEC 62471 compliant (Exempt device)
Operating conditions	• 15°C to 25°C, 10% - 90% humidity (non-condensing) • 0 - 2000 m (0 - 6500 ft) altitude. For indoor use only
Storage conditions	• -10°C to 60°C, 10% - 90% humidity (non- condensing) • Allow to warm to room temperature before use after storage at temperatures below 10°C to prevent condensation
Isolation	• USB powered • Full plastic enclosure
EMC	• FCC Part 15, Subpart B: Class A • CISPR 11:-- Class A
Certifications	EN 62368-1, CSA C22.2 No. 62368 -1:19, UL 62368-1, EN 62471 ed. 1, RoHS

Marker 120 and 240

Physical Specifications		
	MRK3-120	**MRK3-240**
Working Distance	300 to 1200 mm from EyeLink 3	400 to 3000 mm from EyeLink 3
Enclosure	Plastic	Plastic
Dimensions (W×H×D)	160 mm × 25 mm × 44 mm, excluding cable and mount	280 mm × 52 mm × 100 mm, excluding cable and mount
Mounting Methods	1⁄4”-20 tripod screw, monitor mount supplied	
Weight	45 g excluding cable and mount	200 g excluding cable
Power Requirements	4.5 - 5.5 V, 500 mA from USB 2 or 3 port or power adapter	4.2 - 5.5 V, 750 mA from USB 3 or charging port or power adapter
Connection	3 meter USB cable, user replaceable	Integrated 5 meter USB cable
Marker Sources	• Wavelength: 940 nm, invisible NIR light • Eye exposure: less than 1 mW/cm² • IEC 62471 compliant (Exempt device)	
Operating Conditions	• 15°C to 25°C, 10% - 90% humidity (non-condensing) • 0 - 2000 m (0 - 6500 ft) altitude • For indoor use only	
Storage Conditions	• -10°C to 60°C, 10% - 90% humidity (non-condensing) • Allow to warm to room temperature before use after storage at temperatures below 10°C to prevent condensation	
Isolation	• USB powered • Full plastic enclosure	
Isolation	• FCC Part 15, Subpart B: Class A • CISPR 11:-- Class A	
Certifications	EN 62368-1, CSA C22.2 No. 62368 -1:19, UL 62368-1, EN 62471 ed. 1, RoHS	

Specifications are preliminary and subject to change without notice.

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Fast, Accurate, Reliable Eye Tracking

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