

EyeLink® 3 User Manual

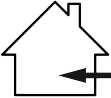
Version 1.0.3



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SAFETY MARKINGS

	Caution, refer to accompanying documents.
	Read instructions before use.
	For indoor use only.
	Intertek Safety Mark: Compliance of this product with applicable standards is certified by Intertek, an independent testing agency.
	At the end of the service life electric and electronic equipment should be disposed of using separate collection, treatment, recovery/recycling. If in doubt, contact your local authorities to determine the proper disposal method.
Product complies with IEC 62368-1:2018 safety standards. Refer to Chapter 6 of the User Manual.	

FCC Statement:

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment can radiate radio frequency energy and may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at the user's expense.

CISPR WARNING: This is a Class A product. In domestic environments this product may cause radio interference in which case the user may be required to take adequate measures.

WARNING: Opening up the EyeLink 3 wearable unit, modifying the unit or connectors will void the user's warranty and authority to operate the equipment, and may affect safety compliance of the system. There are no user-serviceable parts inside - contact SR Research for all repairs.

WARNING: If the USB cable outer jacket is damaged, a shock hazard to the participant may exist. Remove the unit from service immediately if such damage is found.



Caution – Using controls or adjustments or the performance of procedures other than those specified herein may result in product damage. Refer to Chapter 6 of the User Manual.

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1 Introduction

This section introduces the technical capabilities and supporting documentation for the EyeLink 3 eye tracker.

The EyeLink 3 is a completely new kind of head-mounted eye tracker for screen-based research, providing high-speed eye movement 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 core system components consist of a wearable unit and an external near-infrared (NIR) marker. The EyeLink 3 wearable unit is mounted on a headband and comes with three high-speed miniature cameras and integrated near-infrared illuminators - two of the cameras installed inside the front plastic enclosure are used for eye tracking and a third forward-looking camera views the external NIR marker and collects head tracking data.

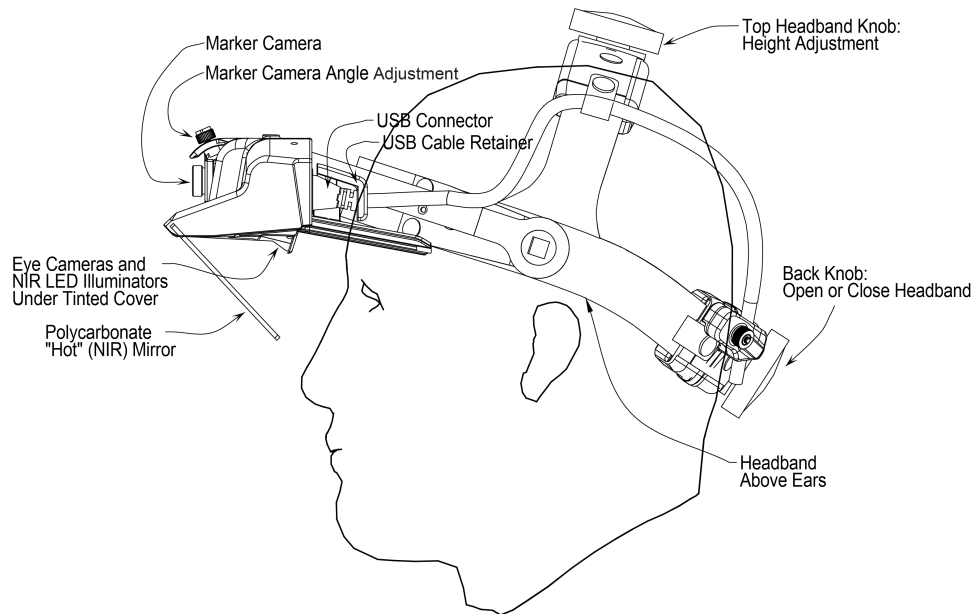


Figure 1-1: EyeLink 3 Wearable Unit

In a typical use configuration, the EyeLink 3 headband is worn on the participant's head. The eye tracker illuminates and views the user's eyes reflected from a hot mirror. The camera images are processed by a Host PC to identify landmarks on the eyes allowing measurement of the participant's eye movements. The EyeLink 3 employs Pupil-CR tracking technology and provides both eye position and pupil size data binocularly at 250, 500, and 1000 Hz. As with other EyeLink-family eye trackers, the EyeLink 3 operates with extremely low levels of noise, provides gaze recordings with high spatial accuracy, and

ensures low temporal variability and near-instant online access to eye tracking data. Unlike other EyeLink eye trackers, the EyeLink 3 also provides high-speed video recordings of the eyes at up to 500 fps, allowing researchers to explore new aspects of saccade and pupil dynamics and facilitating research into eye tracking methodologies.

The EyeLink 3 uses both an inertial measurement unit (IMU) installed on the wearable unit and an NIR marker to provide fused head-tracking data. The fusion between the IMU and marker tracking not only allows the system to record accurate gaze data with full head movement compensation, but also enables reporting of up to 1000 Hz, drift free 6DOF head tracking data that is perfectly synchronized with eye tracking data: head positions along the X, Y, Z axes and head rotations around the X, Y, Z axes (i.e., pitch, yaw, roll). In addition to the standard pixel-based gaze data, the EyeLink 3 also provides novel pixel-based head and eye data, allowing the relative contributions of head and eye rotations to gaze shifts to be visualized and interpreted in a very straightforward way. Finally, the EyeLink 3 also supports applications where head tracking is based on the IMU only. This marker-free tracking may reduce setup complexity and removes the marker trackable range restrictions.

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

IMPORTANT: Please examine the safety information for the EyeLink 3 system which can be found in Chapter 6.

1.1 EyeLink 3 System Configuration

A typical EyeLink 3 setup consists of the EyeLink 3 wearable unit, the NIR marker, and two computers (a Host PC and a Display PC) with their own monitors.

1.1.1 Eye Tracking Unit

The EyeLink 3 eye tracker consists of a headband-mounted tracking unit installed with high-speed miniature cameras and integrated illuminators, and a NIR marker (which is typically mounted on a computer display). A typical distance from the EyeLink 3 to the participant's face is about 20 mm from the lower edge of the mirror, and the effective optical distance from the eye camera and illuminators to the eyes is about 70 mm.

The EyeLink 3 is connected by a USB cable to a USB 3.0 port on the Host PC, usually a laptop computer. This connection is used for power and sending camera data which is then processed in real time by the Host PC to derive the position and rotational angle of the eyes and head. The near-infrared marker

(MRK3-120 supplied by default and an optional extended-range MRK3-240) are powered by a USB 2.0 connection, and are usually mounted on a computer monitor or other point (e.g., tripod), and used as a head-tracking reference. Distance from the marker to the participant can be from 30 cm to 300 cm depending on the marker model used.

1.1.2 Host PC

The Host PC connects to the eye tracker and is dedicated to data collection. It performs real-time eye and head tracking at up to 1000 samples per second while computing the gaze position of the participant on the Display PC's monitor. The Host PC also performs online detection and analysis of eye-motion events such as saccades, blinks, and fixations. In addition to the sample data, these events are stored in a data file on the Host PC. Both samples and events can be sent via the Ethernet link to the Display PC with minimal delay. From the Host PC, the operator performs participant setup and monitors the viewing position of the participant during the experiment.

The Host PC:

- Uses a timing-sensitive operating system which allows the eye tracker to safeguard data acquisition and minimize delays in online data access, and offers very low variability in the latency of this data access.
- Functions either as standalone eye tracker or as one controlled by a Display PC when connected to that Display PC via Ethernet.
- Communicates with the EyeLink camera through a USB 3.0 port.
- Integrates all the eye tracking functionality, including participant setup, calibration, sending real-time data through an Ethernet link, and data recording.
- Can be configured remotely via commands sent over the Ethernet link from the Display PC.
- Shows real-time feedback of eye data during calibration and data recording, allowing the Display PC to be devoted to accurate stimulus delivery.

1.1.3 Display PC

The Display PC is generally used for the presentation of stimuli to a participant. It is connected to the Host PC via an Ethernet link that allows the transfer of critical information between the two computers. The Display PC presents stimuli during experiments and can display camera images from the camera/Host PC to the Display PC during participant setup, and control key eye tracking functions such as calibration and data collection. The Display PC also marks critical experimental events, such as the onset of stimuli and the

occurrence of behavioral responses, in the eye tracking data file. Online eye and gaze position can be received from the EyeLink Host PC via the Ethernet link, making gaze-contingent paradigms possible. Licenses can be acquired from SR Research for Experiment Builder, a sophisticated program that assists researchers in creating EyeLink experiments on Windows and macOS computers via a graphical user interface that eliminates the need for complex scripting.

For users who wish to program their experiments in other programming environments, a wide range of options exist for accessing and controlling data acquisition on the Display PC. The EyeLink Developers Kit for Windows, macOS, and Linux provides a C/C++ programming API. Additionally, several programming environments (e.g., Psychtoolbox for MATLAB, PsychoPy, OpenSesame, Python/pygame, and anything with access to the Windows Common Object Model [COM] interface) have freely-available wrappers for this API, which allow you to interface with the EyeLink system from these programming environments. For full details and links to downloadable learning resources, including example experiments, visit and join the SR Research support forums at <https://www.sr-research.com/support/>.

The Display PC:

- Runs experiment presentation software to control presentation of the experimental materials to the participant while interfacing with the EyeLink eye tracker.
- Can configure and control the EyeLink tracker by communicating with the Host PC.
- Has access to real-time data including gaze position, eye movement events, and response box button presses with minimal delay and low variability in timing.
- Runs applications focused on stimulus generation and control of the experimental task. Relying on the Host PC for data acquisition makes millisecond-accurate timing possible, even when the Display PC is running under Windows.
- Supports data file viewing and conversion tools, such as EyeLink Data Viewer and EyeLink EDF2ASC converter, to assist researchers in analysis of the data obtained.

1.2 Supporting Documents

The EyeLink 3 User Manual (this document) contains information on using the eye tracker hardware, the Host PC application, tutorials on participant setup and calibration, and the basics of running an experiment. Information on system safety and maintenance can also be found in Chapters 5 and 6 of this document.

Additional documents are also available:

- EyeLink 3 Installation Guide – Describes a standard EyeLink 3 system layout as well as the steps required to install the EyeLink 3 hardware and software on both the Host and Display PCs.
- EyeLink Programmer's Guide – Provides suggestions on how to program EyeLink experiments in Windows, including a review of sample experiments and documentation of supported functions.
- SR Research Experiment Builder User Manual – Introduces an optional visual experiment creation tool for creating EyeLink experiments on Windows and macOS computers. This software allows for a wide range of sophisticated experimental paradigms to be created by someone with little or no programming or scripting experience. Version 2.6 or later of Experiment Builder is required for running an experiment with EyeLink 3.
- EyeLink Data Viewer User's Manual – Introduces an optional data analysis tool, EyeLink Data Viewer, which allows interactive display, filtering, extraction and summarizing of EyeLink EDF data. Viewing and analyzing EyeLink 3 recording files require Version 5.0 or later of the EyeLink Data Viewer software, which is Windows-only.

NOTE: Please be sure to check <https://www.sr-research.com/support/> for additional learning resources, including video tutorials and example experiments, as well as the latest software and documentation updates.

1.3 System Specifications

1.3.1 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 Accuracy¹	0.5°	
End-to-End Sample Delay²	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 Precision³	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 Resolution³	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.

1.3.2 EyeLink 3 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, or contact SR Research for a list of computers validated to work with EyeLink 3. • Computer must have 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/cm. • 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

1.3.3 MRK3-120 Specifications

Working Distance	300 to 1200 mm from EL3
Enclosure	Plastic
Dimensions (W×H×D)	160 mm × 25 mm × 44 mm, excluding cable and mount
Mounting Methods	¼"-20 tripod screw, monitor mount supplied
Weight	45 g excluding cable and mount
Power Requirements	4.5 - 5.5 V, 500 mA from USB 2 or 3 port or power adapter
Connection	3-meter USB cable, user replaceable
Marker Sources	• Wavelength: 940 nm, invisible NIR light • Eye exposure: less than 1 mW/cm • 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

1.3.4 MRK3-240 Specifications

Working Distance	400 to 3000 mm from EL3
Enclosure	Plastic
Dimensions (W×H×D)	280 mm × 52 mm × 100 mm, excluding cable and mount
Mounting Methods	¼"-20 tripod screw, monitor mount supplied
Weight	200 g excluding cable and mount
Power Requirements	4.2 - 5.5 V, 750 mA from USB 3 or charging port or power adapter
Connection	5-meter USB cable
Marker Sources	- Wavelength: 940 nm, invisible NIR light - Eye exposure: less than 1 mW/cm - 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

2 EyeLink 3 Host Software

This chapter covers the following topics:

- Web User Interface (Web UI)
- Starting the Host Application
- Modes of operation
- Basic tracker interface

The EyeLink 3 Host Application runs on QNX, a Unix-like real-time operating system, allowing the eye tracker to minimize delays in data acquisition and transmission and to provide very low data access variability.

2.1 Web User Interface (Web UI)

The Web User Interface (Web UI) is a tool supplied with the EyeLink 3 eye tracker that allows users to access files from the Host PC, configure eye tracker settings, and perform Host software updates. This tool can be run on both the Host PC and the Display PC. On the Host PC, you can access this interface by simply pressing Ctrl+Alt+Q to exit the current eye tracking session/Host PC Application or by clicking the “Exit” button on the Setup screen of the Host PC Application, and then clicking the “Exit EyeLink” button. On the Display PC, you can access this interface by typing <http://100.1.1.1> in the address bar of a browser (e.g., Chrome, Firefox; detailed instructions for running the Web UI on the Display PC are provided in Section 2.1.4).

The Web UI consists of a File Manager and a Configuration Tool.

2.1.1 File Manager

The File Manager allows the users to see how the Host PC’s files are organized and to copy, move, rename, download, upload, and edit files.

The File Manager consists of a title bar, a browser URL (if running from the Display PC side), a toolbar, a tree view panel, a folder view panel, and a preview/edit panel (see Figure 2-1).

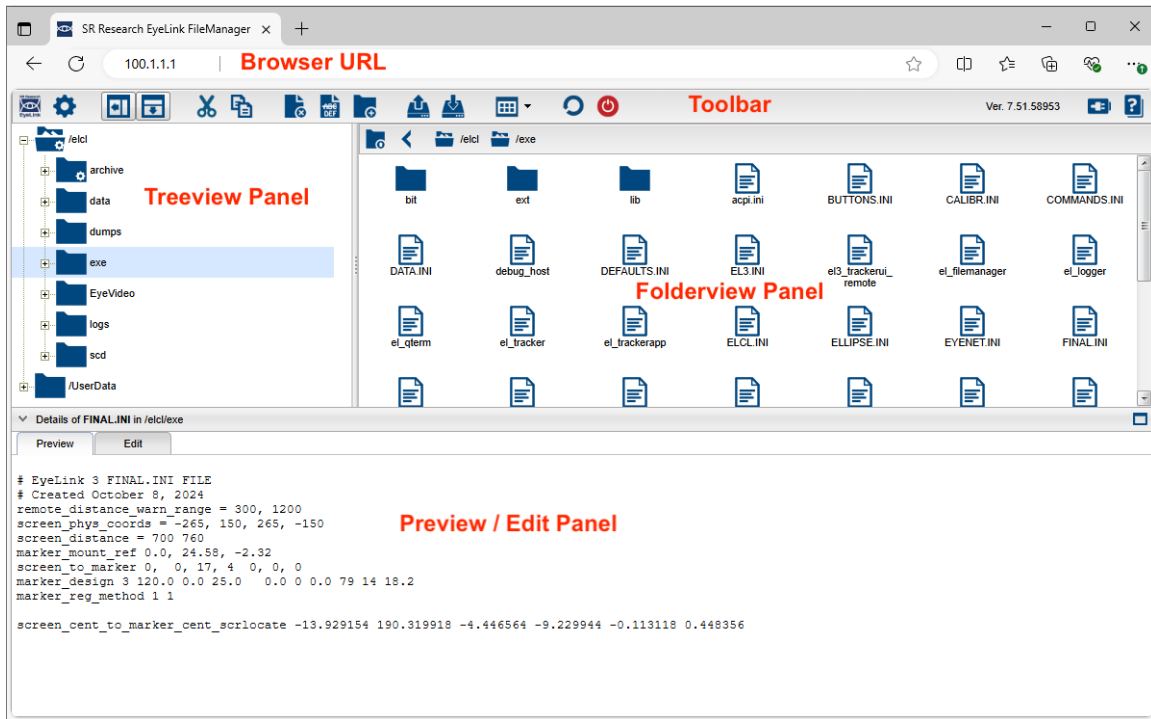


Figure 2-1: File Manager Screen

- 1) Titlebar – this displays “SR Research EyeLink File Manager”.
- 2) Browser URL – this is configured as <http://100.1.1.1/FileManager.html> by default. This URL depends on the IP address configuration of the Host PC (<http://100.1.1.1> is the default Host PC address).
- 3) Toolbar – this contains a list of buttons that perform actions on the currently selected files/folders. From left to right, the buttons on the toolbar are:

 Tracker	Clicking on this icon will start the EyeLink 3 Host application if the camera is attached to a USB 3.0 port on the Host PC.
 Configuration	Switches to the Configuration interface, allowing users to change some of the tracker settings.
 Show/Hide Treeview	Toggles on/off the visibility of the Tree View panel.
 Show/Hide Preview/Edit Panel	Toggles on/off the visibility of the Preview/Edit panel.
 Cut	Copies the selected file(s)/folder(s) to the clipboard. Once the file(s) are pasted into the intended folder, the original one(s) are removed. Therefore, the Cut and

	Paste combination can be used to move files from one folder to another.
 Copy	Copies the selected file(s)/folder(s) to the clipboard. Use the paste button to add the file(s)/folder(s) to a new location. The original file(s)/folder(s) are not removed from the old location.
 Paste	Inserts the previously cut/copied file(s) from the clipboard into the current location.
 Delete	Removes the selected file(s)/folder(s) after confirming the operation. Note: deleting will not copy the items to the clipboard. Therefore, if you want to move files/folders from one location to another, you may first cut the items and then paste the selection into the intended location.
 Rename	Brings up a dialog box for you to type in a new name for the selected file or folder.
 Create New Folder	When you create a new folder, the folder is created as a child of the folder selected in the Tree View and shown in the navigation bar of the Folder View. You may use the Rename button to change the folder name.
 Upload	This tool allows you to upload files to the current folder of the Host PC. Clicking on this button will bring up an Upload dialog box so that up to 10 files can be chosen to upload in one operation. This button is not available when running the File Manager on the Host PC.
 Download	This tool allows you to download the selected files and folders to the local computer (typically the Display PC). Usually the target location will be the “Downloads” folder of the user account. When multiple files are selected, you may choose to have the selection compressed (default setting) to speed up the download process. This button is not available when running the File Manager on the Host PC.
 View	This allows you to change the layout (Tiles vs. Details view) of the files/folders in the Folder View panel.
 Refresh	This forces an update of the entire File Manager screen.
 Eject	This removes a USB flash drive safely from the Host PC. The ejection operation is to ensure the operating system is not busy reading from or writing to the USB flash drive when you remove it, as this could result in corrupted data or a damaged drive.
 Shutdown	Clicking on this button performs an orderly system shutdown of the Host PC by closing all processes running and powering off the computer.
 Help	This brings up the help document.

4) Tree View –This panel contains the directory listing of the “ELCL” folder of the Host PC hard drive as well as any other drives attached to the Host PC (e.g., a USB flash drive). The following three folders are essential to the operation of the eye tracker: the “/elcl/exe” folder, which contains the Host application that runs the eye tracker as well as the configuration files, the “/elcl/data” folder, which is where all of the EDF files created during the experiments are stored, and “/elcl/logs”, which stores the log files for the recording sessions. The “/elcl/data” folder also stores screen grabs created by pressing ALT+F7 on the Host keyboard, which can be used for troubleshooting purposes. If eye videos are saved for a recording session, they are stored in the “/elcl/EyeVideo” folder.

The Tree View panel allows users to navigate around different folders of the Host PC. The currently-selected folder is highlighted in a blue background color. The subfolders and files within the current folder are displayed on the Folder View panel on the right. Navigating around the tree can be accomplished either by using the mouse, or by using the following keys.

- UP and DOWN arrows: move up or down along the tree.
- LEFT ARROW: if the current selection is an open folder, it closes it; otherwise it moves up the list to the parent folder.
- RIGHT ARROW: if the current selection is a closed folder, it opens it; otherwise, it moves down to the first child folder if there is one.

Clicking the right mouse button displays actions supported on the currently selected folder (cut, copy, paste, delete, rename, download, eject) on a popup menu. Not all operations are supported for all folders. Clicking on the download button allows you to download all of the files and subfolders in the currently selected folder to the Display PC (usually in the “Downloads” folder of the user account). Clicking on the Upload button allows you to upload files to the currently-selected folder of the Host PC. If a USB drive is connected to the Host PC, this drive can be ejected by choosing the “Eject” option from the right-click popup menu.

The disk space of the current drive will be displayed if the mouse cursor is placed on the uppermost parent folder of the tree.

The Tree View panel can be shown or hidden by clicking on the “Show/Hide Tree View” button in the toolbar. The size of the Tree View/Folder View windows can be adjusted by placing the mouse on top of the separation bar between the two panels. Once the resizing cursor shows up, drag the separation bar to the intended position.

5) Folder view – this shows a list of folders and files contained in the currently selected folder in the Tree View panel. The full path of the current folder is displayed in the navigation bar on the top of the panel; clicking on any of the parent nodes in this bar will update the content of the Folder View accordingly. The Folder view supports two viewing modes: Tiles view and Details view. Tiles view (default) displays the files and folders as icons with the file names printed underneath. All of the files and folders are arranged alphabetically. The Details view lists the contents of the current folder and provides detailed information about the files, including name, type, size, and date modified. The latter can be used to sort the files and folders listed in the current folder. To change the view, click on the "View" button in the toolbar and choose either Tiles or Details.

Selecting files/subfolders in the Folder View can be easily done with the computer mouse. A subfolder can be opened by first selecting the folder icon and then double clicking on it – the content of the Folder View, navigation bar, and Tree View will be updated accordingly. You can also use the UP, DOWN, LEFT, and RIGHT keys to change the selection in the Tiles view or the UP and DOWN keys to change the selection in the Details views. If the files in the current view fill the entire screen (with a vertical scrolling bar displayed on the right side), pressing the HOME key or END key displays the items at the beginning or end of the list, respectively. Pressing the PAGE UP or PAGE DOWN key scrolls up or down in the selection list.

Multiple items can be selected by holding down the CTRL key and then clicking the left mouse button once on top of the target item(s); a second click will remove the item from the current selection. To select items which are next to each other, click on the first item, hold down the SHIFT key, and then click on the last item in the desired selection. In the Tiles view, items which are next to each other can also be selected by holding down the CTRL key and then using LEFT, RIGHT, UP, and DOWN keys. To select all files in the folder, click on the right mouse button and select “Select All Items” from the popup menu. All of the currently-selected items can be deselected by clicking on the “Deselect all items” option from the popup menu.

For the files/folders that are currently selected, a right mouse click on the item(s) displays a list of supported actions (e.g., cut, copy, paste, delete, rename, download, and eject). Not all operations are supported for all files/folders. These actions can also be performed by clicking on the appropriate buttons in the application toolbar.

6) Preview/Edit panel - When a single plain text file (e.g., a tracker .INI configuration file or an eye tracker .LOG log file) or an image file is selected, its content will be displayed in the Preview panel at the bottom of the File Manager. The “Preview/Edit Panel” button on the toolbar toggles on/off the visibility of

this panel. The Preview/Edit panel can be expanded to full screen by clicking on the  button on the title bar of the panel or be restored to the original size by clicking on the  button. The size of the panel can also be adjusted by placing the mouse cursor on the title bar of the panel until a hand cursor shows up. Hold down the mouse button to drag the title bar to the intended position.

The Preview/Edit panel has two tabs. The Preview tab displays the content of an image or text file, or header of an EDF file. If the text file is too large, only the initial portion of it will be viewable. The edit tab can be used to edit the contents of plain text files. This can be handy for modifying the contents of tracker configuration files (i.e., the .INI files in the “/elcl/exe” folder). In the edit panel, some commonly-used text editing keyboard shortcuts are supported:

CTRL A	Selects the entire text in the file and highlights the selection.
CTRL C	Copies the current selection to the clipboard.
CTRL V	Pastes the content of the clipboard into the current location.
CTRL X	Cuts text that is highlighted.
CTRL Z	Performs an undo
CTRL Y	Performs a redo.
DELETE	Deletes the current selection without storing it to the clipboard (and thus, you cannot use CTRL V to paste it back).

2.1.2 Configuration Tool

The Configuration Manager provides a list of utilities that allows users to configure some of the commonly used tracker settings and to update the Host software. The Configuration Manager consists of the following components:

- 1) Titlebar – this displays “SR Research EyeLink Configuration”.
- 2) Browser URL –this is configured as <http://100.1.1.1/Configuration.html> by default. This URL depends on the IP address Host PC (<http://100.1.1.1> is the default tracker address).
- 3) Toolbar – this contains a list of configuration utilities or buttons (e.g., to start the tracker or to switch to the File Manager). From left to right, the buttons on the toolbar are:

 Tracker	Clicking on this icon will start the Host application if the EyeLink 3 camera is connected to a USB 3.0 port on the Host PC.
 File Manager	Switches to the File Manager interface for accessing files on the Host PC.
 Device Setting	Lists devices connected to the Host PC (e.g., button box, USB2TTL8) and allows users to configure the settings (e.g., disable or enable the device).

 Screen Setting	Allows configuration of settings that tell the eye tracker about physical characteristics of your setup such as screen size and EyeLink 3 Marker placement that are important for proper visual angle calculations and head tracking. Detailed instructions for updating the screen and Marker settings are provided in the EyeLink 3 Installation Guide.
 Network Setting	Reports the network card interfaces installed on the Host PC, with IP addresses and connection statuses displayed.
 System Time	Reports the current time of the Host PC and allows users to reset the computer time if necessary.
 System Update	Provides an interface to update or rollback the Host software. Detailed instructions are provided in Section 3.4 of the EyeLink 3 Installation Guide.
 Shutdown	Clicking on this button performs an orderly system shutdown of the Host PC by closing all processes running and powering off the computer.
 Help	This brings up an html version of the current document.

4) Configuring screen settings. To correctly compute visual angle, saccade amplitude, eye velocity, and to properly perform head tracking and head movement compensation, the EyeLink 3 eye tracker needs to know the physical characteristics of your setup, including the display dimensions and Marker configuration. Any time you change your physical configuration (for example, if a new monitor is used, or the Marker has been displaced since last configuration, etc.), you should use the Screen Settings configuration tool to ensure that the parameters accurately reflect your current setup. The first three parameters are important for all setups whereas the last parameter is important only for a Marker-free setup.

5) System Update - The EyeLink 3 Host software installed on the tracker can be updated through the “System Update” tool. First download the latest version of the Host software from our support website <https://www.sr-research.com/support/> (go to “Downloads -> Host PC Software -> Download: EyeLink 3”). Start the “System Update” utility, select the Update tab and click on the “Browse ...” button to locate the intended Host software update package (a file with the .el3 extension) and then click “Update” button. Wait until the Host software is updated – please be patient as this process may take a few minutes to complete.

2.1.3 Tracker Initialization Files

The Configuration tool described in the previous section covers some of the most important settings for operating the eye tracker. However, there are some

lower-level options that can be specified by editing the configuration files (*.INI files) or by sending commands from the Display PC via the Ethernet link. The configuration files are loaded by the EyeLink 3 eye tracker from the directory that contains the tracker program (/elcl/exe).

If you plan to make changes to the screen settings, please follow the instructions provided in the above “Configuration” tool (or Section 3.1 “Customizing Screen Settings” of the EyeLink 3 Installation Guide). If you plan to change the default settings for other non-screen related settings, please copy and paste the target commands from the relevant .INI file to the FINAL.INI file, and make the modification in that file for ease of future maintenance. The file FINAL.INI is the last configuration file to be processed by the tracker and thus overrides the settings listed in the other .INI files. This design makes it easy to edit a single file to keep track of any changes made, makes updating the software easy (updates retain the settings in the FINAL.INI), and assists in troubleshooting.

This is a selective list of EyeLink configuration files, and what they control:

BUTTONS.INI	-hardware definition of buttons, special button functions
CALIBR.INI	-commands used to control the calibration settings
COMMANDS.INI	-commands that are useful for drawing to host screen, performing online drift correction, etc.
DATA.INI	-controls data written to EDF files, and the Ethernet link
DEFAULTS.INI	-default settings for items in LASTRUN.INI
EL3.INI, ELCL.INI	-includes other .INI files to be loaded by the EyeLink 3 host software
ELLIPSE.INI	-enables and configures ellipse fitting parameters
EYENET.INI	-setup for Ethernet link: driver data
FX3USB.INI	-provides configurations for USB Transfers
HEADBAND.INI	-contains commands specific to the EyeLink 3 eye tracker
KEYS.INI	-special key function definitions, default user menus
LASTRUN.INI	-thresholds, menu choices etc. from the last session

PARSER.INI	-online parser data types, configuration, saccadic detection thresholds. SR RESEARCH STRONGLY RECOMMENDS THAT YOU DO NOT MODIFY THIS FILE.
PHYSICAL.INI	-monitor size, display resolution, and viewing distance settings
FINAL.INI	-commands to be executed last (will override or change the state of other settings)

2.1.4 Running the Web UI on the Display PC

The Host PC displays the Web UI interface when you close the Host application (by clicking on the “Exit” button in the Setup screen and choose the “Exit EyeLink” option or by pressing the CTRL+Alt+Q key combination), or when there is an issue in starting the eye tracker. For some applications (e.g., downloading EDF and log files to the Display PC, editing the .INI files on the “/elcl/exe” folder or updating the Host software), it might be easier and more convenient to run the Web UI on a different computer (i.e., the Display PC).

To run the Web UI interface on the Display PC, please make sure you have a network connection between the Display PC and the Host PC. On the Display PC side, you need to configure the settings of the network port that is used for the connection – the IP address should be set to 100.1.1.2, the subnet mask should be set to 255.255.255.0, and all other fields should be left blank. See Section 4.2.4 “Setting up the EyeLink Network Connection” of the EyeLink 3 Installation Guide. You can skip these steps if the Display PC is already able to communicate with the Host PC/eye tracker.

First make sure that the File Manager is running on the Host PC. Now you can start a browser (Firefox, Google Chrome, Safari, Windows Edge) on the Display PC, and type <http://100.1.1.1> in the address bar. Please note that it is “http://” and not “https://”.

2.2 Starting the Host Application

Make sure that you have attached the USB cable of the EyeLink 3 to a USB 3.0 port on the Host PC, and the USB cable of the Marker is attached to a USB port of a computer. Place the EyeLink 3 wearable unit on a mannequin head in a stable, upright position. Now turn on the Host PC. The EyeLink Host application will start automatically. You will first see an EyeLink 3 splash screen, followed by the Setup view of the Host Application. Please make sure you are using the latest version of the Host Application. The version of the Host

Application that is being used will be displayed on the splash screen as well as on the right side of the toolbar of the File Manager (just to the left of the  button). The latest Host software can be downloaded from the SR Research support website <https://www.sr-research.com/support/> and can be installed using the System Update tool (see instructions in Section 3.4 “Host Software Update” of the EyeLink 3 Installation Guide).

From the Web UI, the Host Application can be started by clicking on the tracker icon  from either the File Manager or the Configuration tool. To close the Host Application, press the Ctrl+Alt+Q key combination on the Host PC keyboard, or go to the Setup screen, click on the “Exit” button, and choose the “Exit” option. To turn off the Host PC, click the “Shutdown” button on the Web UI.

If the eye tracker fails to start, please watch closely for the error message that is displayed. The complete error message is written to the eye.log file in the “/elcl/logs” folder and is retrievable through the File Manager. Consult Section “3.5 Troubleshooting Instructions” of the EyeLink 3 Installation Guide for common troubleshooting tips. Click on the tracker icon on the File Manager to restart the Host Application. If the problem persists, please contact support@sr-research.com.

2.3 Modes of Operation

The EyeLink Host Software is designed to be used in two different operating modes:

Link: In Link mode, the eye tracker can be controlled by the Display PC via commands sent over the Ethernet link. The degree of Display PC control is dependent only on the display application itself. With appropriate programming, it is possible to have full control of the tracker via the Display PC. SR Research Experiment Builder software and various other programming interfaces have been designed to facilitate interacting with the Host PC. A common scenario is to have the application on the Display PC send commands to the Host PC/eye tracker to start participant setup and calibration, while the operator/experimenter can use the EyeLink Host PC's keyboard to remotely monitor and control data collection, perform drift correction, and handle problems if they occur.

Standalone: In Standalone mode, the Host PC/eye tracker acts as an independent system, controlled by the operator via the Host Application tracker interface and keyboard. In such a setup the Host PC may still be connected to a display-generating computer for the purpose of displaying calibration targets only. In Standalone mode, Data is saved in the EyeLink EDF file format (see

Chapter 4 “Data Files”). This can be converted to an ASCII file using the EDF2ASC conversion utility, or analyzed with EyeLink Data Viewer software. EDF Files can be manually created and closed via the “Advanced Settings” in the Setup Screen.

2.4 EyeLink 3 Host Application Navigation

The EyeLink Host Application consists of a set of setup and monitoring screens, which may be navigated by means of the Host PC mouse, keyboard shortcuts, or from the Display PC application via link commands.

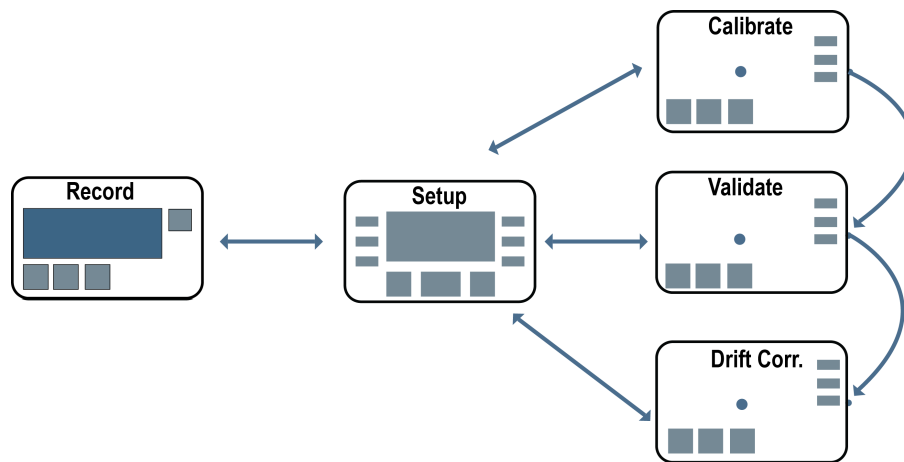


Figure 2-2: EyeLink 3 Host PC Application Overview

Each of the screens shown in Figure 2-2 has a special purpose. Where possible, each screen has a distinctive appearance. Navigation buttons to access other Tracker screens are on the left, while selection buttons for eye-tracking settings and other functions are on the right of the screen. The thumbnail images of the eyes are displayed at the bottom of each screen. Arrows represent the navigations possible by key presses on the Host PC keyboard or via button selection using the Host PC mouse. All screens are accessible from the Display PC by link control. Note the central role of the Setup screen.

From any screen, pressing the on-screen Help button  or hitting the F1 key will open a screen-sensitive Help menu listing all available key shortcuts for that screen. The key combination ‘CTRL+ALT+Q’ will exit the EyeLink Host Application.

The following sections explain the functions of each screen and the main access keys to other screens.

2.4.1 Setup Screen

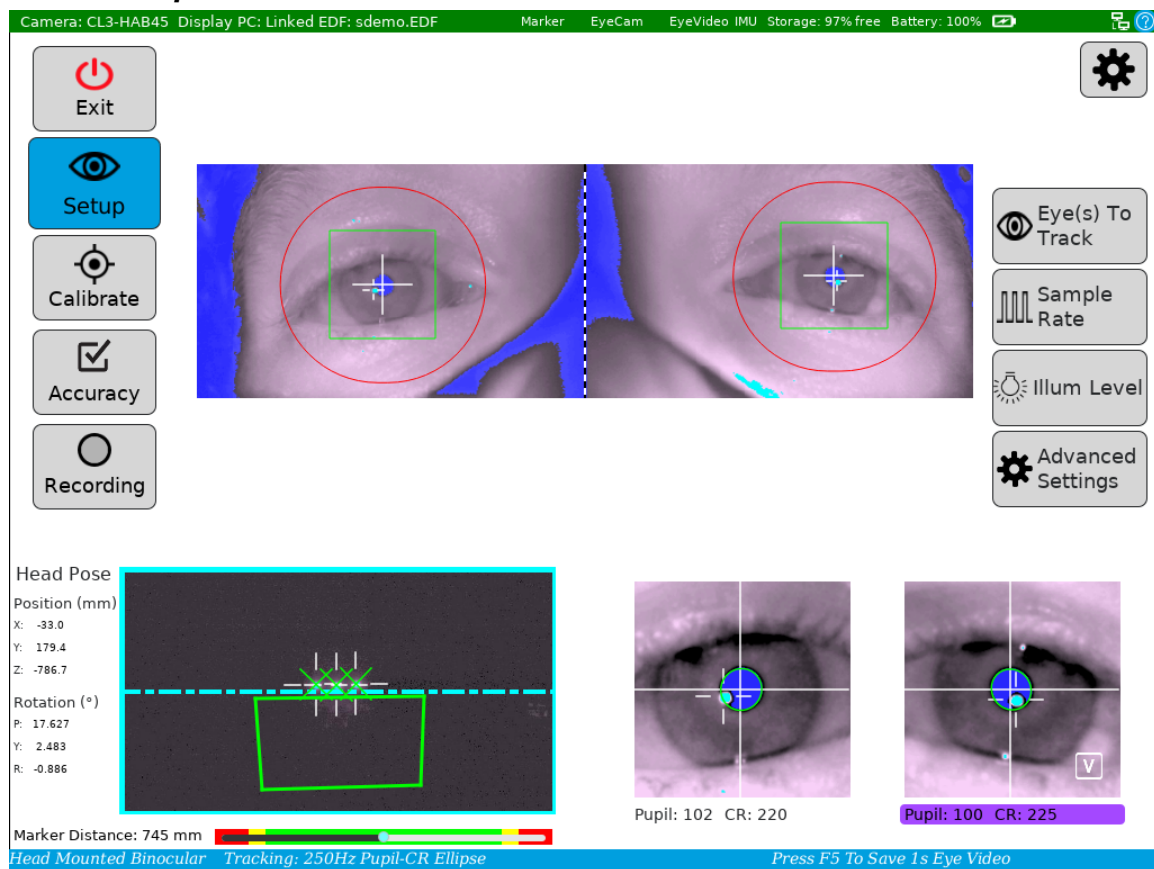
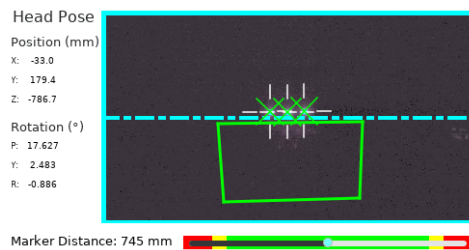


Figure 2-3: Example Setup Screen

2.4.1.1 Setup Screen Purpose

This is the central screen for most EyeLink setup functions. From this screen, a global view from the eye cameras and a Marker view can be used to optimize the participant setup and establish the pupil and corneal reflection (CR) detection thresholds. The eye to be tracked, tracking mode, illumination level, and some other tracker settings can be configured from the Setup screen. Calibration, Accuracy Check (Validation, Drift Correct), and Recording can be initiated from this screen.

2.4.1.2 Setup Screen Main Functions

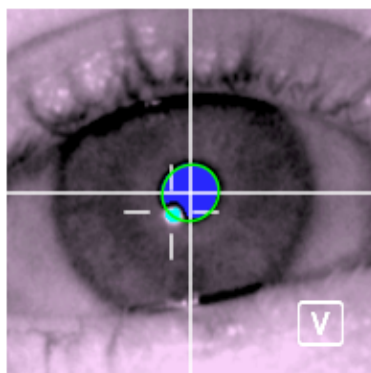


The marker view shows the marker tracking status and reports the camera-to-marker distance in millimeters. It will display a “MARKER MISSING” warning if the marker cannot be seen by the marker camera on the headband, or a “MARKER DISABLED” warning if the marker is

turned off through Advanced Settings. Clicking on this view will swap the locations of the marker view and the global view.

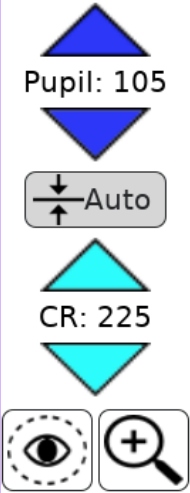
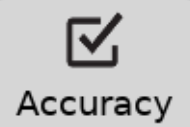
When the host software is running, six-degrees-of-freedom head-tracking data are displayed on the left side of the marker view. The top three rows report the head position data along the X-, Y-, and Z-axes (in millimeters, if the marker is tracked), and the bottom three values are the head rotation data around the X- (pitch), Y- (yaw), and Z- (roll) axes (in degrees). Please see this blog post <https://www.sr-research.com/eye-tracking-blog/background/head-tracking/> for an illustration and the origin of the coordinate systems.

The Marker Distance is displayed at the bottom of the marker view, with a distance scale indicating its current value (marked by a blue dot) relative to the working range. If the blue dot enters the red zone at either end, the marker is too close or too far. Note that the Marker Distance is measured from the Marker Camera to the center LED of the Marker, which differs from the Head Position Z, measured from the Marker Camera to the center of the screen.



Pupil: 100 CR: 224

The thumbnail windows show a zoomed-in view of the tracked eye(s). Pupil and CR thresholds and status are displayed beneath the camera image. A “PUPIL MISSING” error is displayed if the Pupil or CR is not present, a “Calib Limits” if the eye location is outside of the calibrated region, a “BOUNDS” error if pupil or CR is missing, or the fitted gaze data doesn’t appear to be valid, and a “SIZE” warning if the pupil size is larger or smaller than the maximum- or minimum- allowed pupil size. If only one eye is being tracked, the thumbnail image box of the other eye will be grayed out.

	When one of the thumbnail eye images is selected, a threshold adjustment context menu will be displayed. Clicking the UP / DOWN buttons manually increases or decreases the selected pupil threshold or CR threshold. If you click the “Auto” button the Host PC will attempt to automatically compute the optimal pupil and CR threshold levels. Fine-tuning may be necessary. Users can also adjust the size of the search limits from this menu. Keyboard Shortcuts: ↑ and ↓ increase and decrease pupil threshold respectively; + and - increase and decrease CR threshold respectively; A = Auto Threshold.
	Click to go to the ‘Setup’ (current) screen.
	Click to go to the ‘Calibration’ screen. After setting up the camera and adjusting thresholds, users need to calibrate the system for proper gaze recording. Keyboard Shortcut: C = Go to Calibration screen
	Click ‘Accuracy’ to go to the Accuracy check screen, which allows the experimenter to assess the gaze position accuracy achieved by the current calibration model. Users can perform a Validation, or a Drift Correction/Check, both of which should only be run <i>after</i> a calibration has been performed. Keyboard Shortcut: V = Go to Validation screen; D = Go to Drift Correction/Check screen.
	Click to start eye tracker recording. This is generally initiated by the application running on the Display PC, so this button is most useful when using the EyeLink eye tracker in standalone mode. Keyboard Shortcut: O = Go to ‘Record’ screen
	Click to exit the Host Application or to shut down the Host PC. Keyboard Shortcut: CTRL + ALT +Q = Exit the host application

	Click to bring up a configuration panel that can be used to set the Eyes to Track, Sampling Rate, Illumination Level, and some additional configurations through “Advanced Settings”.
 Eye(s) To Track	Select the eye(s) to track for recording. Keyboard Shortcuts: B = Track both eyes; R = Track right eye; L = Track left eye; E = Cycle through eyes to track.
 Sample Rate	Select the sampling rate for recording. Keyboard Shortcuts: F = Cycle through different sampling rates.
 Illum Level	Power level (50%, 75%, or 100%) of the eye camera illuminators. Keyboard Shortcut: I = Change illuminator power level.
 Advanced Settings	The Advanced tab allows many eye tracker options to be configured manually. This is useful when doing manual recording sessions in standalone mode that are not driven by a Display PC using the EyeLink API, or to override or manipulate options not set by the Display PC application. Ideally, all critical settings should be set by the Display PC application at runtime via a set of API calls. The Default Settings should be sufficient for many tracking applications. Details of the individual commands are listed in Section 2.4.1.3.

2.4.1.3 Advanced Settings

2.4.1.3.1 General Settings

General	Calibration	Data	Eye Video	Recording	PlotView	EDF	Version	
Eyes To Track				Left	Both	Right		
Sampling Rate				250	500	1000		
Pupil Tracking Algorithm				Centroid	Ellipse			
Use Search Limits				On				
Move Search Limits				Off				
Illumination Level				100%	75%	50%		
Pupil Only Mode				Pupil Only	Pupil/CR			
Enable Marker for Head Tracking				On				
☒ Auto-Center After Search Limit Resize						Search Limits Area		
						Restore Default		
Reset				Apply				Cancel

Figure 2-4: General Tab of the “Advanced Settings”

Command Setting	Function
Eyes to Track	Select the eye(s) to track during recording.
Sampling Rate	Select the sampling rate for recording. Note the 1000 Hz option is not available if eye video recording is enabled.
Pupil Tracking Algorithm	Select the method (centroid vs. ellipse fitting) used to fit pupil and determine pupil position.
Use Search Limits	Search Limits are used to restrict the area of the camera image to be searched for the pupil and CR. A red ellipse around the searched area appears in the Host PC’s global view if this option is enabled. If ‘Search Limits’ is enabled and the pupil position moves, search for the pupil is confined to the area within the red ellipse; otherwise, the entire image is searched.
Move Search Limits	If ‘Move Limits’ is checked, the search limit area moves along with the pupil.
Illumination Level	Power level (100%, 75%, 50%) of the illuminators for eye tracking.
Pupil Only Mode	Select the tracking mode (pupil-only vs. pupil-CR) for recording. Typically, Pupil-CR is recommended for better tracking accuracy.

Enable Marker for Head Tracking	EyeLink 3 uses the fused data from the NIR Marker and an inertial measurement unit (IMU) on the headband for drift-free head tracking and proper head movement compensation. In some applications, the Marker may be turned off/removed so that head tracking is only based on the IMU data. Please note the position data will be less accurate and tend to drift in the Marker-free mode.
Auto-Center After Search Limit Resize	Check this box to recenter the search limits after resizing them.
Search Limits Area Restore Default	Click this button to restore the default sizes for the search limits.

2.4.1.3.2 Calibration Settings

General
Calibration
Data
Eye Video
Recording
PlotView
EDF
Version

Calibration Type

...

•

••

•••

••••

Calibration Control

Manual
Auto

Calibration Pacing Interval

Off
500
1000
1500

Randomize Calibration Order

On

Repeat First Target

On

Apply Drift Correction

On

Remove Cached Calibration Data

Remove

Reset
Apply
Cancel

Figure 2-5: Calibration Tab of the “Advanced Settings”

Command Setting	Function
Calibration Type	Select the Calibration Type for calibration. Generally speaking, the more locations sampled, the greater the accuracy that can be expected.
Calibration Control	If set to “Manual”, the experimenter or participant needs to press the spacebar or ENTER key on Host or Display PC when the participant is looking at each calibration or validation target. If set to “Automatic”, the calibration and validation procedure automatically samples a target

	fixation once the eye settles and moves on to the next target.
Calibration Pacing Interval	Select the delay in milliseconds between successive calibration or validation targets if automatic target detection is active (i.e., “Calibration Control” is set to “Auto”).
Randomize Calibration Order	Randomize the calibration and validation target presentation order.
Repeat First Target	Redisplay the first calibration or validation target at the end of the calibration sequence. As this is typically amongst the poorest samples obtained, toggling this option on is recommended.
Apply Drift Correction	Whether a correction will be applied to the calibration mapping when checking the system drift. If “Apply Drift Correction” is toggled on, a true drift correction will be performed; otherwise, the tracker just reports the error without correcting for it.

2.4.1.3.3 Data Settings

General	Calibration	Data	Eye Video	Recording	PlotView	EDF	Version
File Data Contents		Samples	Events				
File Sample Contents		Raw	HREF	Gaze	Button	Input	
Eye Event Data		Gaze	HREF				
Saccade Parser Sensitivity		Normal	High				
File Sample Filter		Off	Stand...	Extra			
Link Sample Filter		Off	Stand...	Extra			
Pupil Size Data		Area	Diame...				
Reset		Apply			Cancel		

Figure 2-6: Data Tab of the “Advanced Settings”

File Data Content	Selecting ‘Samples’ will record data samples to the EDF file, and selecting Events will record online parsed events. These options are only useful for standalone
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	recordings. If you collect data by running a display program, these settings will likely be overwritten by display commands.
File Sample Contents	The data to be recorded for the sample data structure. • Raw - Record the raw (x, y) coordinate pairs from the camera to the EDF file. See Section 4.4.2.1 for description of raw data type. • HREF - Record head-referenced eye-rotation angle (HREF) to the EDF file. See Section 4.4.2.2 for description of HREF data type. • GAZE - Record gaze position data in the EDF file. See Section 4.4.2.3 for description of GAZE data type. • BUTTON - Record EyeLink button state and change flags, in the EDF file. • INPUT - Record external device data (from the supported device such as USB2TTL8) on each sample, in the EDF file.
Eye Event Data	Select whether to record eye events (fixations and saccades) in Gaze or HREF coordinate. GAZE is screen gaze x, y; HREF is head referenced-calibrated x, y. See Section 4.4.2 for description of the data types.
Saccade Parser Sensitivity	Define the sensitivity of the EyeLink parser for saccade event generation. Normal is intended for cognitive tasks like reading; while High is intended for psychophysical tasks where small saccades must be detected. See Section 4.3.5 Saccadic Thresholds for details of event parsing.
File Sample Filter	EyeLink eye trackers use a heuristic filtering algorithm for data smoothing. Data filtering can be applied independently for the data saved in the EDF file and for the data sent over the link. The current option selects filter level of data recorded to the EDF file. Each increase in filter level reduces noise by a factor of 2 to 3. Note: By changing the File Sample Filter from Extra to Standard or Off, this will affect EyeLink Data Viewer, EDF2ASC, and other analysis tool data calculations. SR Research Ltd. strongly recommends keeping the default file sample filter setting (“Extra”).
Link Sample Filter	Select the filter level for data available via the Ethernet link output.

	Each increase in filter level reduces noise by a factor of 2 to 3 but introduces a 1-sample delay to the link sample feed.
Pupil Size Data	Record the pupil area or diameter. The area is recorded in scaled camera image pixels. Diameter is calculated from the pupil area fit using a circle model.

2.4.1.3.4 Eye Video Settings

The “Eye Video” tab lists options for configuring eye video recordings. Eye video recording is not available if the eye tracker is sampling at 1000 Hz.

Figure 2-7: Eye Video Tab of the “Advanced Settings”

Enable Eye Video Streaming	Check this box to enable the eye video stream. This option is only available if the sampling rate is 250 or 500 Hz. Checking this option will not save eye video automatically. Users need to either manually save eye video for a few seconds by pressing F5 key, or programmatically by sending commands to the tracker to control the start and stop of the eye video recording, or by enabling the “Auto-Record Eye Video Stream when recording” option. See “COMMANDS.INI” for a list of commands related to eye video recording.
Auto-Record Eye Video Stream when recording	Check this option to automatically record eye video when the eye tracker starts eye data recording. Note, users should avoid this option and control eye video

	recordings by sending commands instead because of the large amount of disk space required by eye video recordings.
Eye Video Recording Dowsample Rate	The EyeLink 3 is able to record eye videos at up to 500 frame per second. High video recording frame rates mean large recorded files, which can take up a lot of disk space and result in potentially unusable files. As a result, high-speed eye video recordings should really be only performed for short-recording durations (e.g., a few seconds). If users want to record eye videos for a long time, they should choose a low recording frame rate from the dropdown list.
Duration For Manual (F5) Eye Video Saving (1-20 s):	Eye videos can be recorded by either sending start and stop commands programmatically to the host software from the connected display applications, or manually by pressing F5 on the Host PC keyboard (if the “Enable Eye Video Streaming” option is checked). With this option, users can set the duration (1 to 20 seconds) of the manually triggered eye video recordings.

2.4.1.3.5 Recording Settings

Default View	This controls what to show on the Record screen during data output. If Record View is set to “Gaze”, the Host PC Record screen will display the participant’s current eye position (gaze, head-in-space, or eye-in-head) as a cursor overlaid on a simulated display screen. If Record View is set to “Plot”, x, y data traces will be graphed as a function of time. If Record View is set to “Eye Video”, the host screen shows the view of the eyes as you typically see in the Setup screen.
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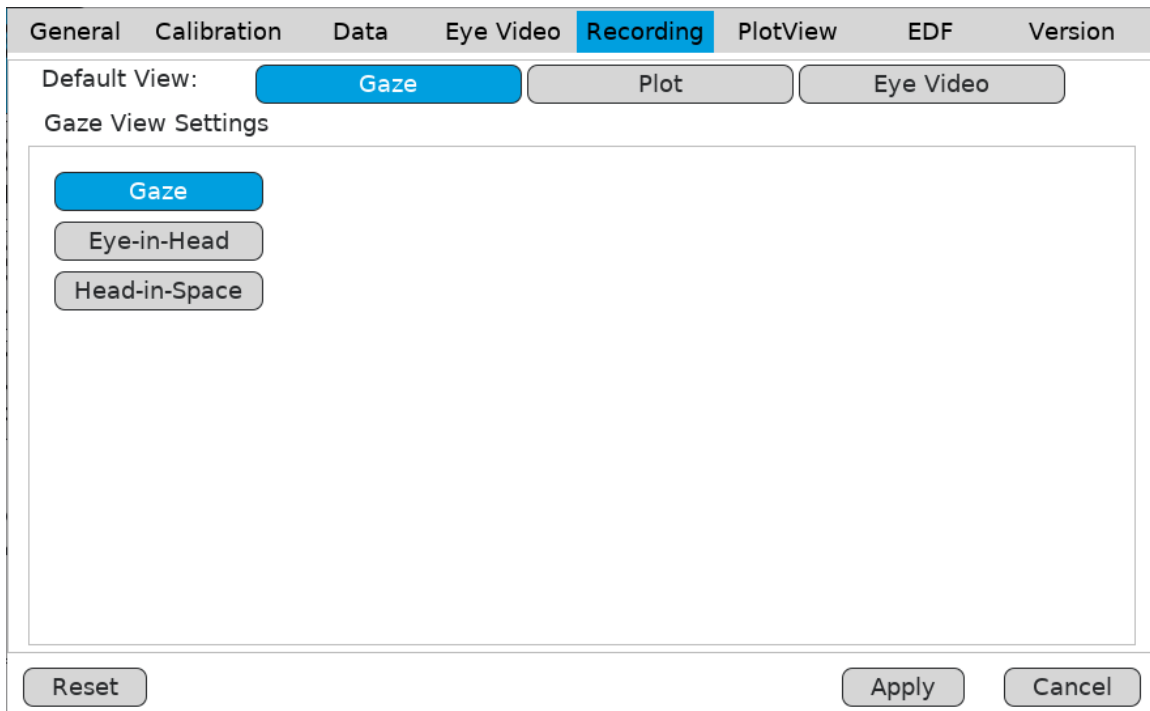


Figure 2-8: Recording/Gaze Tab of the “Advanced Settings”

If “Gaze” View is selected, users can configure the type of data to be drawn on the host screen: Gaze, Eye-in-head, and Head-in-Space. Gaze refers the point of regard (screen pixel coordinates) on a screen. It reflects both the head pose (its position and orientation) and the eye rotation within the head. Eye-in-head data reports the participant's eye pose in relation to the head, without head-movement contribution, represented as a gaze point on the screen (X, Y in screen pixel coordinates). Head-in-space reports the participant's head pose in relation to the screen represented as a point on the screen (X, Y in screen pixel coordinates). Please see this page (<https://www.sr-research.com/eye-tracking-blog/background/eyelink-3-screen-pixel-data/>) for a discussion of the three pixel-based coordinate systems.

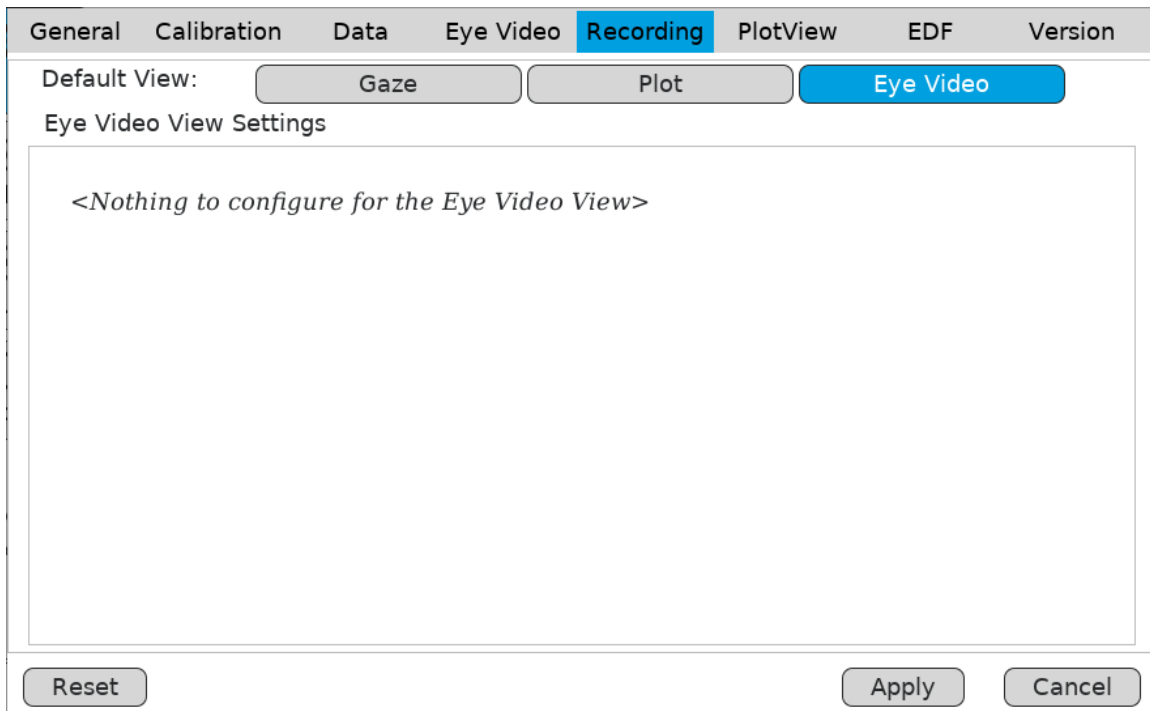


Figure 2-9: Recording/Eye Video Tab of the “Advanced Settings”

No configuration option is available if the “Eye Video” View is selected.

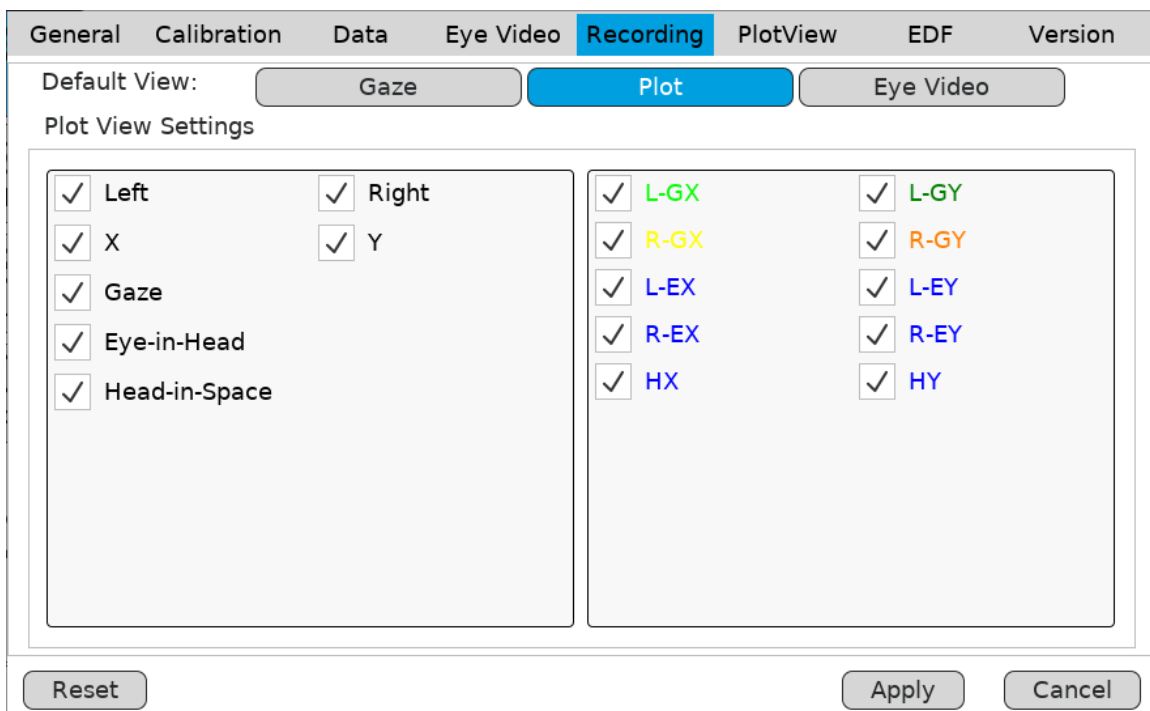


Figure 2-10: Recording/Plot Tab of the “Advanced Settings”

If “Plot” is selected, users can configure the traces to be drawn in the recording screen. The left and right panels represent two different trace configuration methods. The panel on the left allows users to batch select/unselect traces. For example, checking/unchecking the “Left” option will select or unselect all of the “Left” traces on the right-side panel. Checking/unchecking the “X” option will select or unselect all of the “X” traces on the right-side panel. Checking / unchecking the “Eye-in-Head” option will select or unselect all of the “E” traces on the right side. Users can additionally select/unselect the traces individually on the right side - the final configuration of the traces to be drawn during recording is reflected there.

2.4.1.3.6 Plot View Settings

Users can configure the color of the plot view screen background and the colors of the individual traces in the “PlotView” tab. First select the color to be modified, then adjust the R, G, B values at the lower left corner using the slider bars.

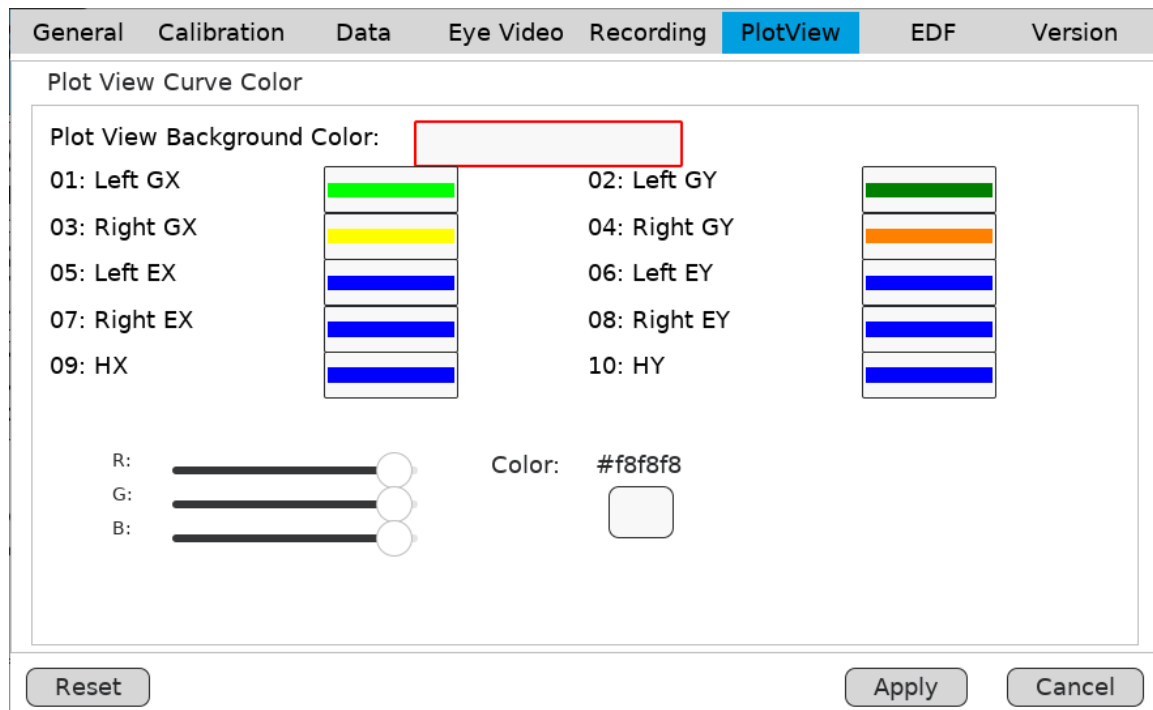


Figure 2-11: PlotView Tab of the “Advanced Settings”

2.4.1.3.7 EDF Settings

This is only useful when operating the EyeLink 3 in standalone mode. Users can manually open an EDF file to track and record eye movement data, and add messages to the recording. Be sure to close the data file before closing the tracker application.

Figure 2-12: EDF Tab of the “Advanced Settings”

EDF File	Enter an intended EDF file name if it is not already supplied.
Open File	Click to open an EDF file for data recording and closes any currently open EDF file.
Close File	Close the currently open EDF file
Add Message	Add a message to the EDF file

2.4.1.3.8 Version Settings

The Version tab provides information about the eye tracker hardware (camera serial number and camera configuration files) and the Host PC software version.

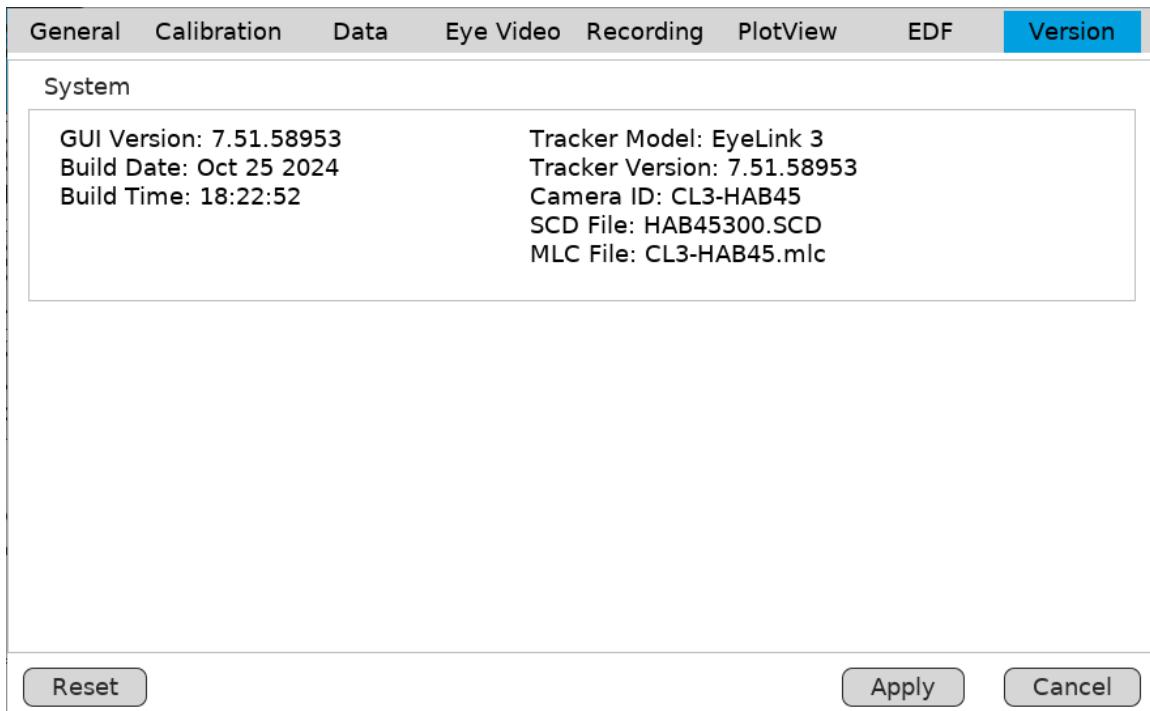


Figure 2-13: Version Tab of the “Advanced Settings”

2.4.1.4 Setup Screen Key Shortcuts

Key	Function
CTRL+ALT+Q	Exit the EyeLink Host Application.
F1	Open the Help dialog, which contains a brief overview of the role of the current screen and the key functions for it.
ALT + F7	Take a screenshot.
Page Up and ↑	Increase pupil threshold.
Page Down and ↓	Decrease pupil threshold.
+ and -	Set corneal reflection threshold.
⇐ and ⇒	Select eye, and cycle through the global or zoomed view for link.
A	Auto threshold selected image.
ENTER	Toggles sending camera images over link to the Display PC.
C	Go to the Calibration screen.
V	Go to the Validation screen.
D	Go to the Drift Check/Correction screen.
O	Go to the Record screen.
E	Cycle through eye(s) to track.
F	Select sampling rate of EyeLink recording.
L	Select left eye for recording.
R	Select right eye for recording.
B	Select both eyes for recording.
Q	Select Centroid or Ellipse pupil tracking methods
U	Toggle search limits on or off.

SHIFT and cursor keys (←, →, ↑, or ↓)	If search limits are enabled, these keys can be used to move the position of the search limits.
ALT and cursor keys (←, →, ↑, or ↓)	If search limits are enabled, use these keys on the Host PC keyboard to adjust the size and shape of the search limits.
M	Toggles mouse-click autothreshold on and off.
X	Toggle crosshair display.
T	Toggle threshold coloring display.
I	Change illuminator power.

2.4.2 Calibration Screen

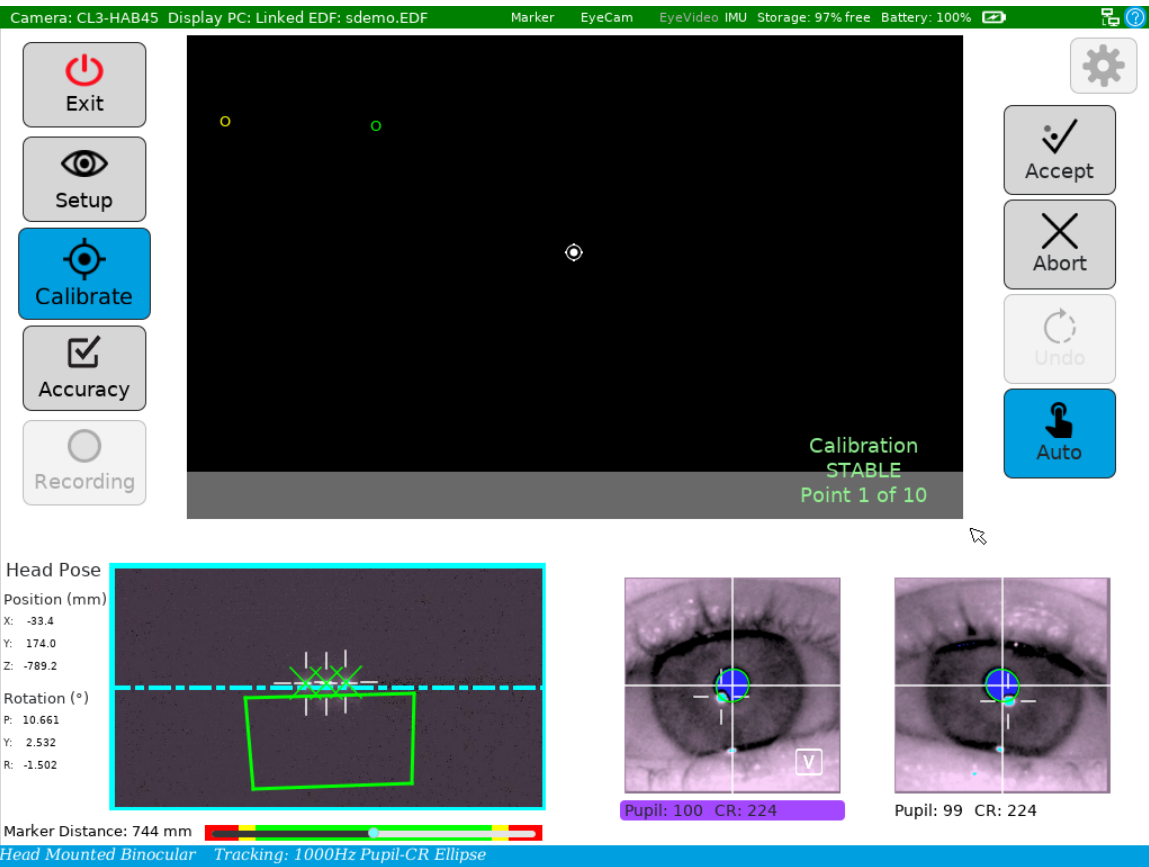


Figure 2-14: Example Calibration Screen

2.4.2.1 Calibration Screen Purpose

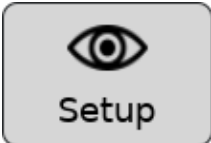
Calibration is used to collect gaze position samples when targets are being presented at known points in order to map raw eye data to either gaze position or HREF data. Targets are serially presented by the Display PC during calibration. The participant should fixate each target while samples are collected by the Host PC. During the calibration process, feedback graphics are presented on the Host PC display to aid the experimenter/operator. The

calibration is automatically checked when finished, and feedback about the quality of the calibration is provided. Calibration should be performed after camera setup and before an accuracy check (Validation or Drift Correction). Validation provides the experimenter with information about calibration accuracy/the quality of the calibration model.

As in the Setup screen, the bottom of the Calibration/Validation/Drift Correct screens displays the thumbnail camera images and the Marker view. For the thumbnail eye images, the pupil and CR status as well as the threshold values are displayed. The calibration status and calibration target currently being presented are indicated at the bottom right of the screen.

To perform a calibration, have the participant look at the first fixation point and select the 'Accept' button, or press the ENTER key or the Spacebar, to start the calibration. For subsequent targets, fixations can be accepted either automatically by the Host Application, or manually by the experimenter. If the 'Auto' button is disabled (which will be the case if the 'Calibration Control' in the Advanced Settings -> Calibration is set to "Manual"), you will need to manually accept fixation for each of the calibration targets. Pressing the ENTER key or the Spacebar after accepting the first target will switch from an automatic calibration to a manual calibration, in which case all of the remaining target fixations will need to be manually accepted. This can be useful for participants who have difficulty fixating targets or who inappropriately anticipate new target positions. The 'Undo' button, or the 'Backspace' key can be used to undo the most recently accepted fixation target (e.g., if a participant fixates the wrong target position or anticipates the new target position). Pressing the backspace key repeatedly will successively remove acquired fixation data and present the calibration targets again. This gives the experimenter a chance to intervene when the acquired samples may be erroneous.

2.4.2.2 Calibration Screen Main Functions

	Click to exit the Host Application or to shut down the Host PC. Keyboard Shortcut: CTRL + ALT +Q = Exit the host application
	Click to go to the 'Setup' screen. Keyboard Shortcut: ESC = 'Setup'

 Accuracy	Click to go to the Accuracy Check screen, which allows the experimenter to assess the gaze position accuracy achieved by the current calibration model. Users can perform a Validation, or a Drift Correction/Check, both should be run <i>after</i> a calibration has been performed. Keyboard Shortcut: V = Go to Validation screen; D = Go to Drift Correction/Check screen.
 Accept	Click to accept fixation value, after the participant's gaze is stable on the target. Keyboard Shortcuts: ENTER, Spacebar = 'Accept Fixation'
 Abort	Terminate Calibration sequence. Keyboard Shortcut: ESC = Abort
 Undo	Click to repeat the last calibration target or last few targets. Keyboard Shortcut: Backspace = Undo last targets
 Auto	Click to automate the calibration sequencing. Keyboard Shortcut: A = Auto Trigger
 Restart	Restart the calibration. Keyboard Shortcut: Delete = Restart
 Accept	Click to accept the calibration and switch to the Setup screen. Keyboard Shortcut: ENTER = Accept the calibration
 Validate	Click to validate calibration values. Keyboard Shortcut: V = Validate calibration values
 Discard	Click to discard the calibration values and switch the tracker to the Setup screen. Keyboard Shortcut: ESC = Discard calibration values

2.4.2.3 Calibration Screen Key Shortcuts

Key	Function
CTRL+ALT+Q	Exit the EyeLink Host Application.
F1	Open the Help dialog, which contains a brief overview of the role of the current screen and the key functions for it.
ALT + F7	Take a screenshot.
Page Up and ↑	Increase pupil threshold.
Page Down and ↓	Decrease pupil threshold.
+ and -	Set corneal reflection threshold.
⇐ and ⇒	Select Eye, and cycle through the Global or zoomed view for link.
ESC	Exit to the Setup screen.
A	Automatic calibration set to a configurable pacing interval (one second by default). (Auto trigger ON). EyeLink accepts current fixation if it is stable.
During Calibration	
ENTER or Spacebar	Starts calibration sequence. After the first point, it can be used to select manual calibration mode.
ESC	Terminate calibration sequence and exit to the Setup screen.
M	Manual calibration (Auto trigger turned off)
A	Automatic calibration set to the pacing interval (one second by default). (Auto trigger ON). EyeLink accepts current fixation if it is stable.
Backspace	Undo last calibration target
After Calibration	
ENTER	Accept calibration values.
V	Validate calibration values.
ESC	Discard calibration values.
Backspace	Repeat last calibration target.

2.4.3 Accuracy Check (Validation) Screen

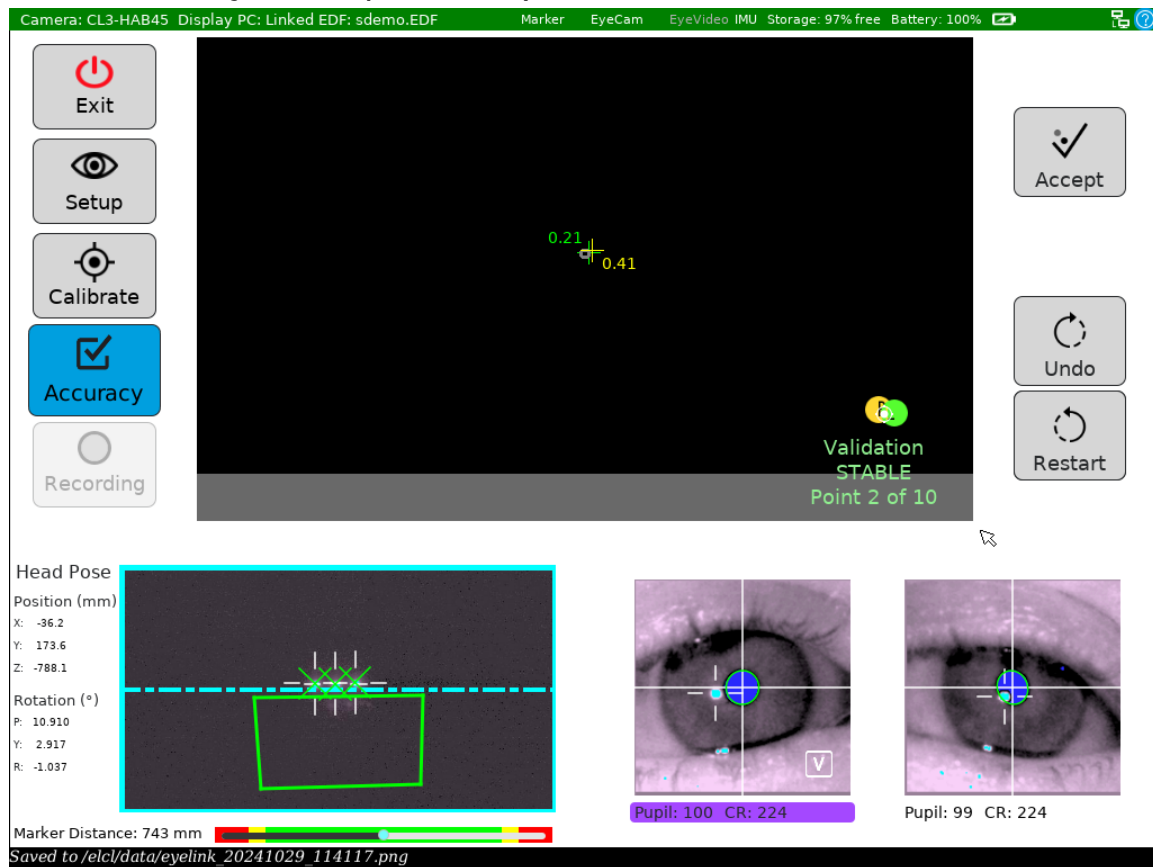


Figure 2-15: Example Validation Screen

2.4.3.1 Accuracy Check (Validation) Screen Purpose

Accuracy Checks allow users to assess how good the current calibration model is. Users can perform a single-point accuracy check (i.e., Drift Correction/Drift Check), or a multi-point Validation test. Ideally a Validation should be performed after a calibration, and a Drift Correction/Drift Check should be performed immediately before each trial. If Validation is selected, the tracker displays a sequence of target positions to the participant and measures the difference between the target position and the computed fixation position for the target based on the calibration model. Spatial error is reported in degrees of visual angle, and can reflect both the adequacy of the initial calibration model, and the participant's ability to refixate the targets during validation. The functionality available in the Validation screen is very similar to that of the Calibration screen.

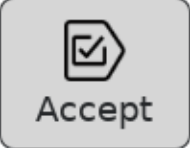
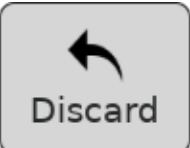
Validation should only be performed after Calibration.

To perform a validation, have the participant look at the first fixation target and press the 'Accept Fixation' button, or the ENTER or Spacebar key, to start the validation. If 'Auto Trigger' is not enabled, you'll need to accept the target fixation manually for subsequent validation targets.

If the accuracy at a fixated position is not acceptable, you can press the backspace key to go back and repeat a point. If you continue to press backspace you will go further back in the calibration routine to repeat even older points. The host software also resamples the worst two points. If you are not satisfied with the calibration results you may choose to perform a calibration again and then recheck fixation accuracy by revalidating.

2.4.3.2 Accuracy Check (Validation) Screen Main Functions

 Exit	Click to exit the Host Application or to shut down the Host PC. Keyboard Shortcut: CTRL + ALT + Q = Exit the host application
 Setup	Click to go to the 'Setup' screen. Keyboard Shortcut: ESC = 'Setup'
 Calibrate	Click to go to the 'Calibration' screen. After setting up the camera and adjusting thresholds, users need to calibrate the system for proper gaze recording. Keyboard Shortcut: C = Go to Calibration screen
 Accept	Click to accept fixation value, after the participant's gaze is stable on the target. Keyboard Shortcuts: ENTER, Spacebar = 'Accept Fixation'
 Abort	Click to terminate the validation process and revert to the Setup screen. Keyboard Shortcut: ESC = Abort the validation process
 Undo	Click to repeat the last validation target or last few targets. Keyboard Shortcut: Backspace = Undo last few targets
 Auto	Click to automate the validation sequence according to a configurable Pacing Interval (one second by default value).
 Restart	Click to restart the validation process Keyboard Shortcut: DELETE = Restart validation

	Click to accept the validation and switch to the Setup screen. Keyboard Shortcut: ENTER = Accept the validation
	Click to discard the current validation and switch the tracker to the Setup screen. Keyboard Shortcut: ESC = Discard the validation

2.4.3.3 Accuracy Check (Validation) Screen Key Shortcuts

Key	Function
CTRL+ALT+Q	Exit the EyeLink Host Application.
F1	Open the Help dialog, which contains a brief overview of the role of the current screen and the key functions that are available for it.
ALT + F7	Take a screenshot.
Page Up and ↑	Increase pupil threshold.
Page Down and ↓	Decrease pupil threshold.
+ and -	Set corneal reflection threshold.
⇐ and ⇒	Select Eye, and cycle through the Global or zoomed view for link.
ESC	Terminate validation and go back to Setup.
A	Automatic validation set to a configurable pacing interval (one second by default). (Auto trigger ON). EyeLink accepts current fixation if it is stable.
<u>During Validation</u>	
ESC	Terminate validation and go back to Setup.
ENTER or Spacebar	Begins validation sequence or accepts fixation on the target if in manual mode. After first point, also selects manual validation mode.
M	Manual validation (Auto trigger turned off).
A	Auto validation (Auto trigger ON). EyeLink accepts current fixation if it is stable.
Backspace	Repeat previous validation target(s).
<u>After Validation</u>	
ENTER	Accept validation values.
ESC	Discard the current validation and switch to setup screen.
DELETE	Restart validation.

2.4.4 Accuracy Check (Drift Correction) Screen

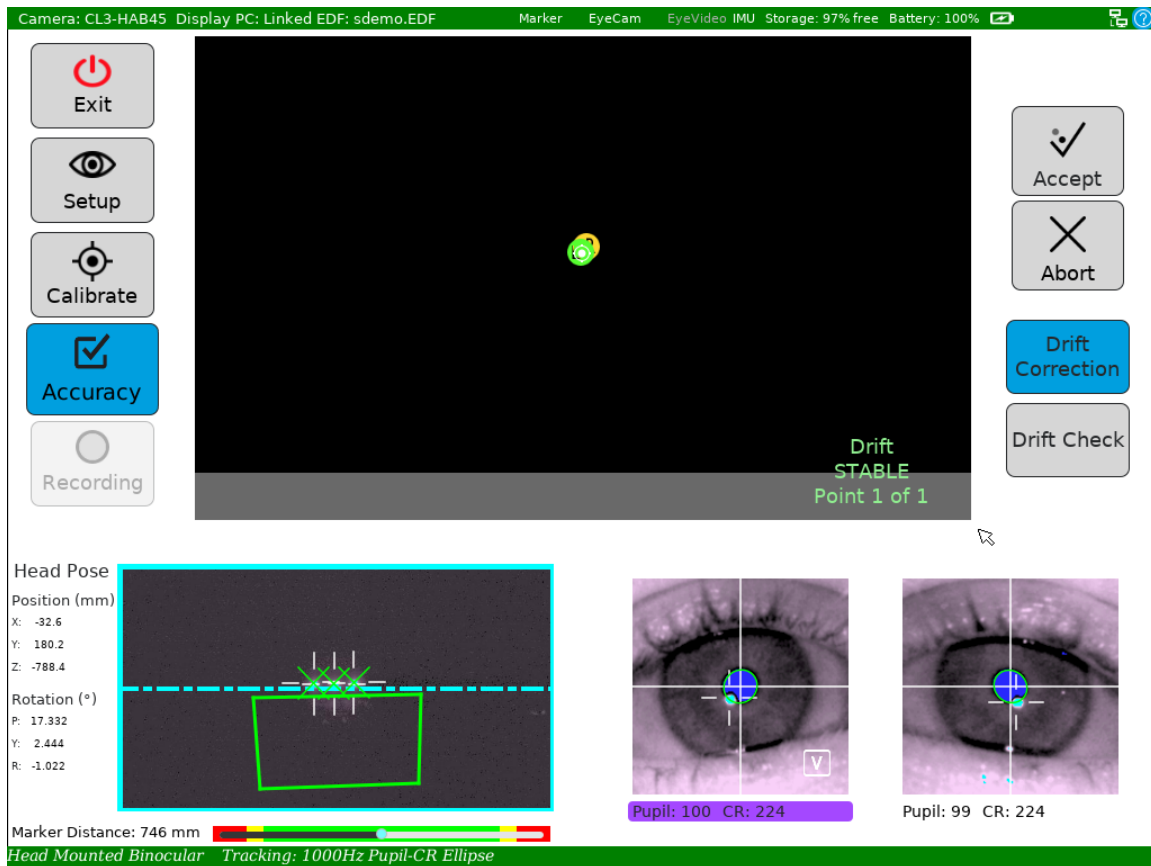


Figure 2-16: Example Drift Correction Screen

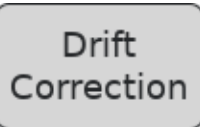
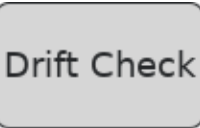
2.4.4.1 Accuracy Check (Drift Correction) Screen Purpose

Users can also perform a single-point accuracy check, commonly called Drift Correction, when the “Accuracy” button is pressed. The Drift Correction screen displays a single target to the participant and then measures the difference between the computed fixation position and the current target. It is important to note that unlike our head-stabilized or remote eye trackers such as the EyeLink 1000, 1000 Plus, and Portable Duo, the default “drift correction” configuration of EyeLink 3 measures the fixation error and uses it to shift/correct the calibration map. If the error between the measured location of the fixation and the drift correction target is large, the drift correction will fail and another calibration will be required (see Section 3.12 for more details).

To perform a drift check/correction, have the participant look at the fixation point and click the ‘Accept Fixation’ button, or press ENTER or the Spacebar, to evaluate the adequacy of the calibration parameters.

Note: Users can easily switch to the Drift Check mode as in EyeLink 1000, 1000 Plus, or Portable Duo by clicking the “Drift Check” button. Drift Check reports the calculated fixation error without altering the calibration map in any way.

2.4.4.2 Drift Correction Screen Main Functions

 Exit	Click to exit the Host Application or to shut down the Host PC. Keyboard Shortcut: CTRL + ALT + Q = Exit the host application
 Setup	Click to go to the 'Setup' screen. Keyboard Shortcut: ESC = 'Setup'
 Calibrate	Click to go to the 'Calibration' screen. After setting up the camera and adjusting thresholds, users need to calibrate the system for proper gaze recording. Keyboard Shortcut: C = Go to Calibration screen
 Accept	Click to accept fixation value, after the participant's gaze is stable on the target. Keyboard Shortcuts: ENTER, Spacebar = 'Accept Fixation'
 Abort	Click to terminate the drift correction/drift check and exit to the Setup screen. Keyboard Shortcut: ESC = 'Setup'
 Drift Correction	Click to toggle on the drift correction mode (i.e., a correction will be applied to the calibration mapping). Keyboard Shortcut: D = Toggles between the "Drift Correction" and "Drift Check" modes
 Drift Check	Click to toggle on the drift check mode (i.e., the tracker just reports the error without correcting for it). Keyboard Shortcut: D = Toggles between the "Drift Correction" and "Drift Check" modes

2.4.4.3 Drift Correction Screen Key Shortcuts

Key	Function
CTRL+ALT+Q	Exit the EyeLink Host Application.
F1	Open the Help dialog, which contains a brief overview of the role of the current screen and the key functions for it.
ALT + F7	Take a screenshot.
Page Up and ↑	Increase pupil threshold.
Page Down and ↓	Decrease pupil threshold.
+ and -	Set corneal reflection threshold.
← and →	Select Eye, and cycle through the Global or zoomed view for link.

ENTER or Spacebar	Accept the fixation on the target.
ESC	Terminate the drift correction/drift check process and exits to setup screen.
D	Toggle between the Drift Correction and Drift Check modes.

2.4.5 Record Screen

2.4.5.1 Record Screen Purpose

The Record screen allows users to initiate and observe data collection. Users can choose a Gaze View (see Figure 2-17), a Plot View (see Figure 2-18), or an Eye View (see Figure 2-19) by clicking the modes buttons at the upper right corner of the screen, or toggle between views by pressing the G key.

When the “Gaze” View () is selected, the host software plots the current eye or head position of the participant in the calibrated screen pixel coordinates. In this view, users can choose to plot either gaze, eye-in-head, or head-in-space position data. Gaze refers the point of regard on a screen that reflects both the head pose (its position and orientation) and the eye rotation within the head. Eye-in-head data reports the participant's eye pose in relation to the head, without head-movement contribution, represented as a gaze point on the screen (X, Y in screen pixel coordinates). Head-in-space reports the participant's head pose in relation to the screen represented as a cursor on the screen (X, Y in screen pixel coordinates). See <https://www.sr-research.com/eye-tracking-blog/background/eyelink-3-screen-pixel-data/> for detailed discussions on the three pixel-based coordinates. The Gaze View is only useful when the EyeLink system's built-in calibration routines have been used for position calculation. Any graphics drawn on the screen can be used as a reference for the real-time position cursor.

If the “Plot” View () is clicked, the host software displays the x and y data traces as a function of time. If the “Eye” View () is selected, the host software shows an view of the eyes (the one the experimenters typically see in the Setup screen). However, the host software isn't actually recording the eye view into a file; users will need to initiate the recording themselves if they need to save the eye video – please see discussions in Section 2.4.1.3.4 “Eye Video Settings”.

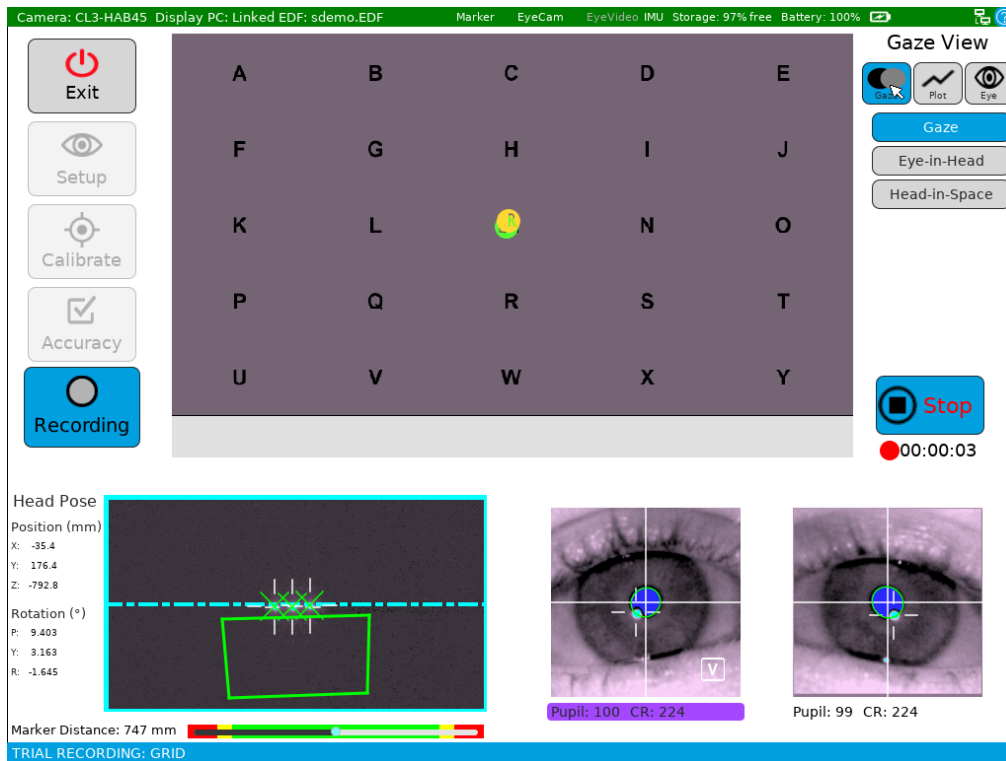


Figure 2-17: Example Record Screen (Gaze View)

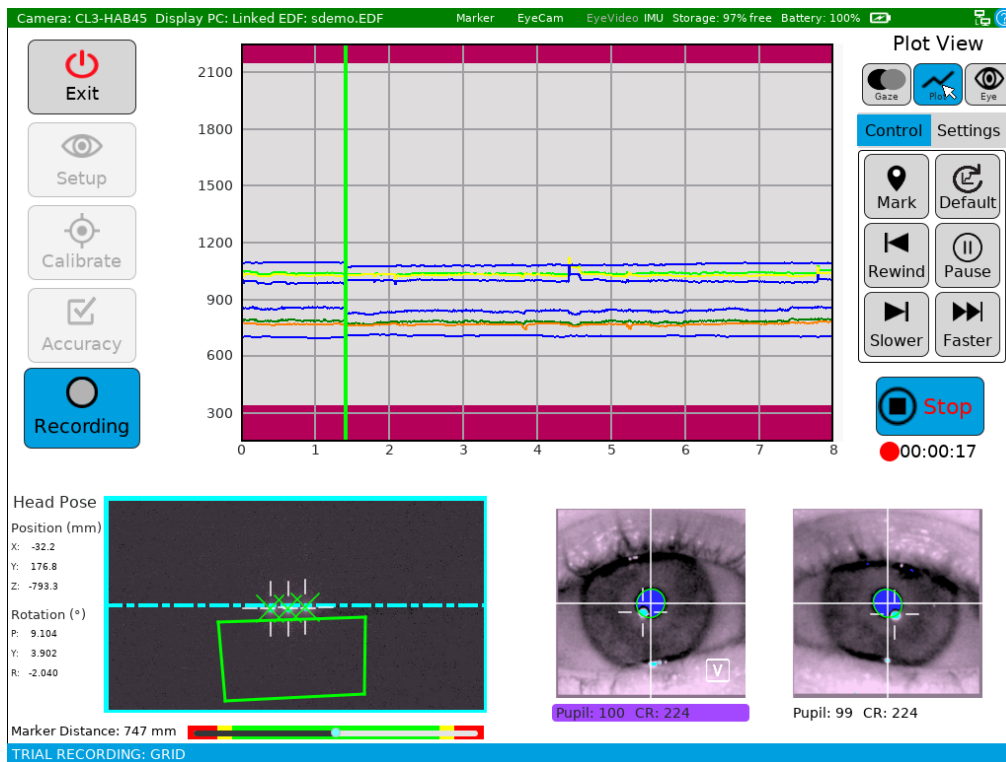


Figure 2-18: Example Record Screen (Plot View)

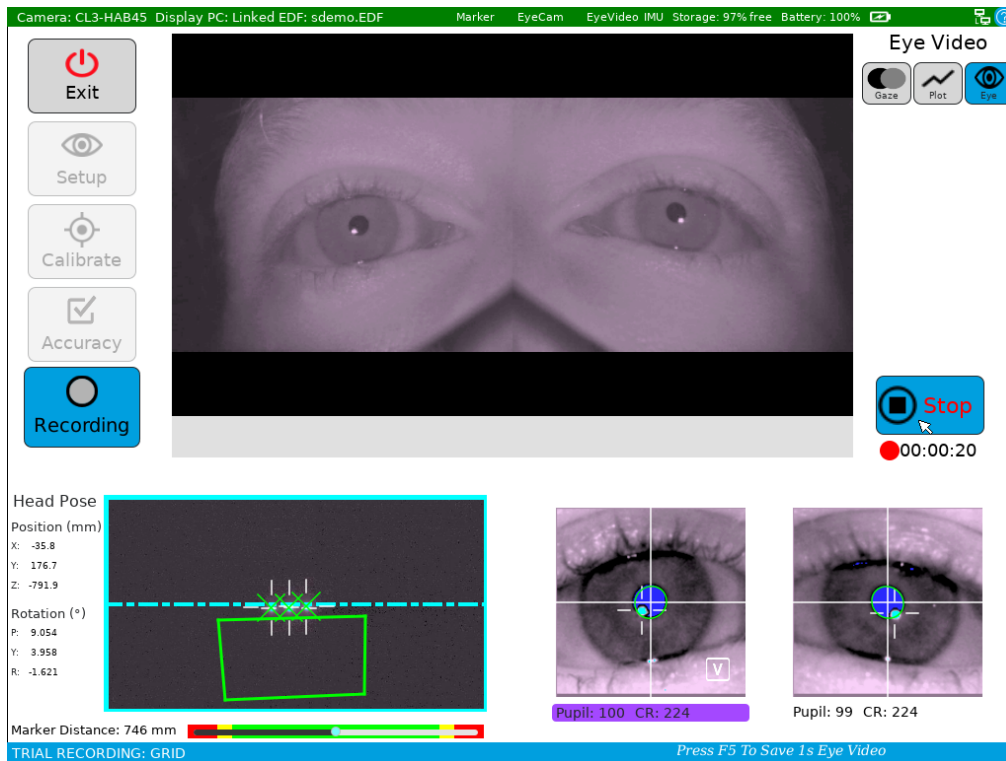
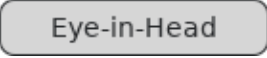
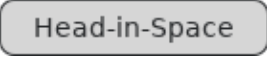


Figure 2-19: Example Record Screen (Eye View)

2.4.5.2 Record Screen Main Functions (All Views)

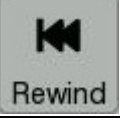
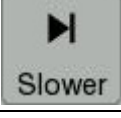
	Click to switch to the Plot View which plots the x, y eye data being acquired as a function of time. Keyboard Shortcut: G = Toggle between Gaze View/Eye View/ Plot View
	The Host PC Record screen will display the participant's current eye position (gaze, head-in-space, or eye-in-head) as a cursor overlaid on a simulated display screen. Keyboard Shortcut: G = Toggle between Gaze View/Eye View/ Plot View
	The Host PC Record screen shows a view of the eyes as you typically see in the Setup screen. Keyboard Shortcut: G = Toggle between Gaze View/Eye View/ Plot View
	Click to exit the Host Application or to shut down the Host PC. Keyboard Shortcut: CTRL + ALT +Q = Exit the host application
	Stop the recording of data to the EDF file. Keyboard Shortcut: ESC = Stop Recording

2.4.5.3 Buttons Used in the Gaze View

	Gaze plots the point of regard on a screen that reflects both the head pose (its position and orientation) and the eye rotation within the head.
	Eye-in-head plots the participant's eye pose in relation to the head, without head-movement contribution, represented as a point on the screen (X, Y in screen pixel coordinates).
	Head-in-space plots the participant's head pose in relation to the screen represented as a point on the screen (X, Y in screen pixel coordinates).

2.4.5.4 Buttons Used in the Plot View

The Plot View plots the participant's gaze position in pixel (x, y) display coordinates. The vertical scale is displayed on the left side of the plot view. The two purple bands at the top and bottom portions of the display represent data that is out of normal range. The user can change the scale of the plotting by using SHIFT ⇐ or SHIFT ⇒ so that fine details or global patterns of the x, y traces can be viewed. The position where the traces are displayed can be changed by dragging your finger on the touch pad of the Host PC, or by pressing SHIFT ↑ or ↓. The plotting speed of the view can be changed by clicking on the “Faster” and “Slower” buttons, or by pressing < or > keys.

	The “Mark” button marks the time this button pressed on the screen with a thin white line. Keyboard Shortcut: INS = Add rewind marker
	Change to the default viewing settings. Keyboard Shortcut: C = Revert to default view
	The “Rewind” button clears data plotting since last marked point. If no marker is set, clears data from the left end of the screen. Keyboard Shortcut: DEL = Rewind to marker or start
	Stop data plotting (the eye tracker continues recording despite that the plot view stops screen updating). Keyboard Shortcut: P = Freeze data plotting
 	Set the amount of data to be plotted on screen per sweep. Keyboard Shortcuts: < and > = Change plot speed

The choice of eye traces can be controlled by clicking the “Settings” tab of the control panel. The left and right panels represent two different trace configuration methods. The panel on the left allows users to batch select/unselect traces. For example, checking/unchecking the “Left” option will

select or unselect all of the “Left” traces on the right-side panel. Checking / unchecking the “X” option will select or unselect all of the “X” traces on the right-side panel. Checking/unchecking the “Eye-in-Head” option will select or unselect all of the “E” traces on the right side. The panel on the right allows users to select/unselect individual traces directly – this configuration determines what the host software will use for trace drawing.

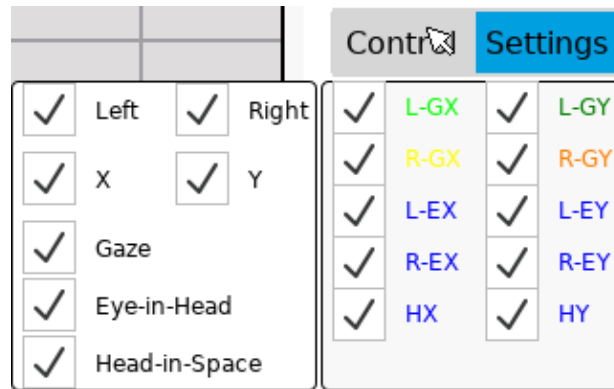


Figure 2-20: Configuring Plot View Traces

2.4.5.5 Record Screen Key Shortcuts

Key	Function
CTRL+ALT+Q	Exit the EyeLink Host Application.
F1	Open the Help dialog, which contains a brief overview of the role of the current screen and the key functions for it.
ALT + F7	Take a screenshot.
Page Up and ↑	Increase pupil threshold.
Page Down and ↓	Decrease pupil threshold.
+ and -	Set corneal reflection threshold.
← and →	Select Eye, and cycle through the Global or zoomed view for link.
ESC	Exit to the Setup screen.
G	Toggle between Gaze View, Eye View, and Plot View.
Plot View Only (Recording Screen)	
< or >	Change plot speed.
P / F	Pause or resume plotting (also marks).
C	Change to default view and speed.
INS	Add a rewinding marker.
DEL	Rewind to marker or start.
HOME	Clear all data.
SHIFT ← and →	Zoom out/in.
SHIFT ↑ or ↓	Scroll up/down.

3 An EyeLink 3 Tutorial: Running an Experiment

The following tutorial will allow you to test the EyeLink 3 system, assuming that you have already arranged a proper layout of the eye tracker equipment and configured display and Marker settings for your setup (see Section 1.1 “Suggested Equipment Layout” and Section 3.1 “Customizing Screen Settings” of the “EyeLink 3 Installation Guide” document). A summary of the setup procedure can be found at the end of Section 3.14 EyeLink 3 Setup Summary. This section leads you through the key steps involved in setting up a participant and running a basic eye-tracking task. For the most straightforward setup, you should select a participant for the test that can sit still when required, and does not wear eyeglasses. Once comfortable with these participants, you can tackle more complex setup scenarios.

IMPORTANT: Please note that extraneous infrared and visible light sources can potentially interfere with the Marker tracking. Please remove any infrared and visible light sources that are in the view of (or cause reflections that are in the view of) the Marker Camera. Avoid setting up the system facing a window. During recording, the lens filter of the Marker Camera should remain on at all times to block visible light sources.

During the description of the tutorial session, we will take the opportunity to discuss many important aspects of system use. These may make the setup process appear long, but a practiced experimenter can set up a participant in much less than two to three minutes, including calibration and validation.

If the EyeLink Host Application is not yet running on the Host PC, start it by clicking on the EyeLink logo at the top-left corner of the File Manager (see Section 2.2 “Starting the Host Application” of this document).

The current chapter illustrates how to run through a typical eye tracker session using the TRACK.EXE example from the latest version 2.2 of the EyeLink Developers Kit for Windows. This software can be downloaded from the SR Research Support Forum <https://www.sr-research.com/support/thread-13.html> and should be installed on the Display PC. If you prefer to use other examples or operating systems, please see Section 3.16 of the current chapter. To start the TRACK example on a Windows Display PC, click:

Start -> All Programs -> SR Research -> TRACK

When TRACK starts, a dialog will appear on the Display PC asking you to enter an EDF file name. Enter “TEST” (without the quotes “ ”; the default session name is "sdemo"). If your Display PC has two monitors attached, the dialog also allows you to select which monitor to use.

Once TRACK is running, control of the task and eye tracker is possible both from the Host PC and Display PC keyboards, and the application will reflect the

state of the EyeLink Host software by drawing appropriate graphics on the Display PC. The advantages of the Display PC-based control are 1) that it allows the experimenter to work near the participant and 2) that it allows you to perform self-setup.

3.1 The Setup Screen

The first step in an eye-tracking session is to set up the participant and eye tracker. When the Host Application starts up, you will see four camera-image windows - a global view of both eyes at the top, zoomed view(s) of the eye(s) being tracked beneath, and Marker view at the bottom left. Navigation buttons to access other Tracker screens are on the left, while selection buttons for eye-tracking settings and other functions are on the right of the screen (click the cogwheel icon to reveal).

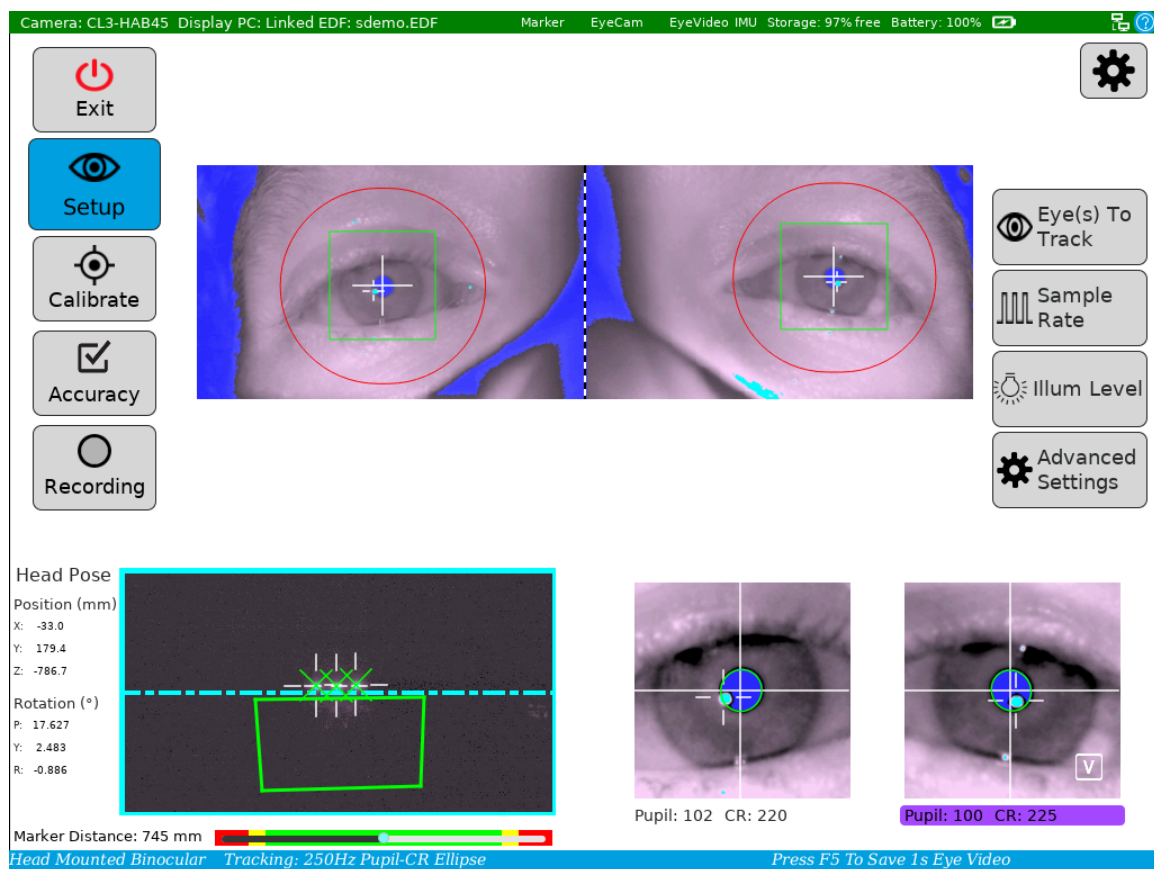


Figure 3-1: Example Setup Screen

Throughout the EyeLink Host software, you can use the Host PC mouse to select options and navigate throughout the tracker screen. Most navigation buttons have an equivalent keyboard shortcut. The key shortcut mappings

available for the currently-displayed screen can be accessed via the Help button, or by pressing F1.

If an experiment is open on the Display PC (like TRACK.EXE) then pressing the ENTER key from the Setup screen will start displaying an image of the selected camera or Marker view on the Display PC's monitor. In the Setup screen, you can select which of the views is active and transferred to the Display PC, (if an image is currently being transferred) by pressing the $\Leftarrow$ and $\Rightarrow$ cursor keys.

3.2 Participant Setup

NOTE: It is recommended that the Host PC be switched on, and software started, at least 10 minutes before recording data, as the illuminator brightness and camera image quality may change slightly during the warm-up period.

IMPORTANT: EyeLink 3 uses an inertial measurement unit (IMU) on the wearable unit and the NIR Marker for head tracking. When starting the EyeLink 3 host software, please place the headband on a mannequin head in a stable, upright position to let the IMU perform a self-calibration upon startup. This process just takes a few seconds to complete, after which an "Initialization Complete!" message is displayed above the Marker view.

WARNING: When not in use, the EyeLink 3 wearable unit should always be stored on the mannequin head to prevent scratching of the mirror.

WARNING: Be careful when putting the headband on or taking it off, as the bottom of the mirror can come close to the face or eyewear.

WARNING: Any internal metal parts that are exposed by enclosure damage might be hot. Do not touch any internal parts that are exposed if the cover is removed or damaged. Contact SR Research for repairs.

To practice setting up the EyeLink 3 system you will need a participant to wear the headband. If none is available, you can practice this part of the procedure on yourself. It is actually easier to practice on yourself first, but be sure to repeat with several participants later. Because all keys on the Display PC keyboard are sent to the EyeLink software by TRACK, you can practice calibration and observe your tracked eye-position too. Since no menus appear on the Display PC, you will need to be able to see the Host PC display as well.

Please make sure you use a height-adjustable chair so that you can raise/lower the participant to the appropriate height. The Display PC monitor should be set such that when the participants are seated and looking straight ahead, their eyes are level with the top 25% of the monitor.

Some care should be used in applying the headband and removing it from the participant to prevent the mirror from coming into contact with the participant's eyes, nose, or eyeglasses. The following shows a simple yet safe sequence.

- 1) ALWAYS hold the headband by both the top knob and the rear knob when fitting it to the head.
- 2) Begin by opening the headband as wide as possible using the clamp knob at the back.
- 3) Place the headband on top of the head so that the sides are just above the ears and the top section is close to vertical. Watch the mirror carefully to prevent contact with the face or glasses!
- 4) Adjust the headband angle so that the front pad is just above the eyebrows. Also check that no hair is between the front pad of the headband and the forehead, as this may cause the headband to slip.
- 5) A good fitting of the headband shouldn't block the participant's view, especially to the top of the monitor. If the headband sits too high or too low, turn the top knob to change the height.
- 6) Looking from the front, rotate the headband left or right so that the cutout of the mirror is centered on the nose. Check the global view, either on the Host PC or the Display PC. A dotted vertical line is drawn in the camera image to represent the hemifields in which the left and right eyes will appear; make sure both eyes are in the horizontal center of their respective hemifields.
- 7) Turn the rear knob to tighten the headband, until it is firmly in place on the head.
- 8) If the pupils are not appearing in the vertical center of the camera view, adjust the position of the front enclosure of the wearable unit by holding just in front of the USB cable. **DO NOT TOUCH THE MIRROR**, as this will leave fingerprints. Please also pay attention to the nose cutout, which should be comfortable over the nose.

To remove the headband, reverse the procedure:

- 1) Open the headband to its maximum size while holding the knob on the top of the headband.
- 2) Carefully raise the front of the headband above the head while keeping the back of the headband in contact with the skull, then lift the headband up. Again, watch the mirror carefully to prevent contact with the face or glasses!

Between uses, it is recommended that the EyeLink 3 headband always be stored on a mannequin stand. If the system is not going to be used for an extended period, you may wish to disconnect the cables from the computer and pack the unit in the shipping case. Please be careful to not damage the mirror.

Important: Make sure the mannequin head is firmly secured and can withstand accidental pulling of the headband or cabling, or accidental bumps/impacts without becoming detached from the table.

After fitting the headband and checking the camera image in the global view, move the Host PC mouse cursor on top of each eye and click on the left mouse button. The camera image for the eye should now be displayed in the zoomed thumbnail view. If the pupil is detected, a crosshair will now be drawn on the eye image.

For participants wearing glasses, reflections may block the image of the pupil and CR. There are two types of glass reflections: one is from the built-in camera illumination of the eye tracker, which usually appears as a large blob of cyan color (see the middle panel of Figure 3-2), and the other is the (possibly multiple) reflections of the Marker LEDs, which typically manifest as an array of white dots (see the right panel of Figure 3-2). Depending on the shape and angle of the glasses, you may need to make adjustments to the headband fitting so that neither type of reflections from the glass interferes with pupil or CR acquisition. For example, you may try placing the headband higher on the forehead and pushing the front enclosure down so that the camera illumination is not hitting the glasses from a straight-on angle. The left panel of the following figure illustrates a good camera setup whereas the reflections in the center and right panel may potentially block the pupil image. Please be advised that not every participant with glasses will be trackable. If the eyeglasses have an anti-reflective coating, image contrast may be poor and pupil tracking may be noisy.

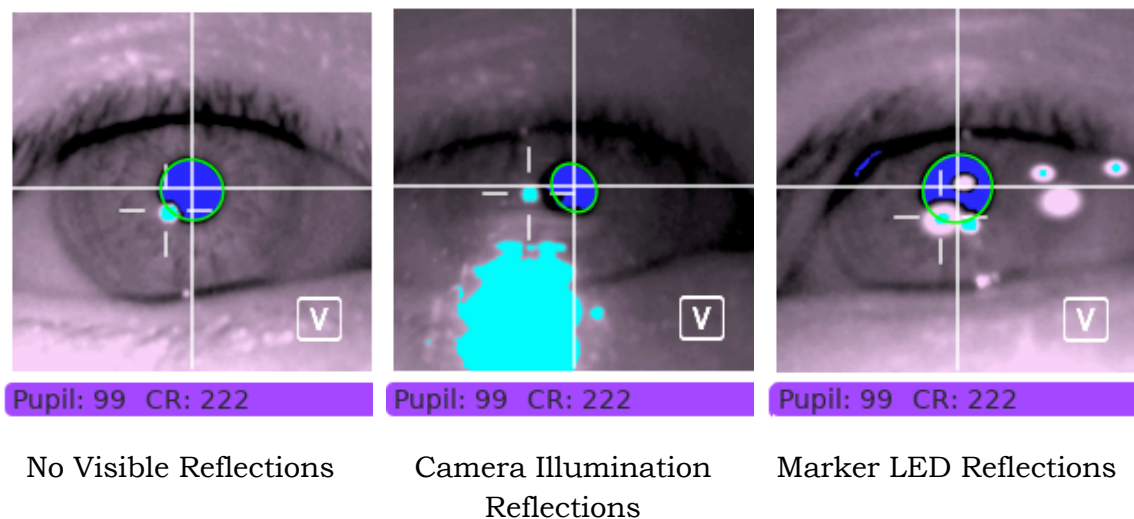


Figure 3-2: Camera Setup with Participants Wearing Glasses

Since the eye tracker illuminates and views the user's eyes reflected from a hot mirror, it is essential to keep the mirror clean to prevent tracking issues. Small dust particles, fingerprints, and smudges on the mirror may interfere with

proper thresholding of the eyes. To clean the mirror, follow the cleaning and disinfection instructions provided in Section 5.1 of this User Manual.

3.3 Setting Pupil Thresholds

The zoomed camera image(s) of the eye(s) should now be clear, with the pupil centered when the participant looks at the eye image on the Display PC. The pupil threshold may now be automatically set by pressing the 'Auto' button or the 'A' key when the camera image is selected. The pupil of the eye should be solid blue when the threshold is properly set. If large areas other than the pupil are colored blue, the participant may have blinked during the 'Auto Threshold' procedure: press A to do Auto Threshold again. Sometimes, the autothreshold procedure may not be able to find optimal thresholds. When this happens, you will see ??? by the threshold values, and will need to manually adjust the thresholds.

The pupil threshold should be checked by closely examining the blue area in the zoomed camera image. Figure 3-3 shows the symptoms to look for. If the threshold is too low, the blue area will be smaller than the pupil, and the eye tracker data will be excessively noisy. If the threshold is too high, there will be shadows at the edges and corners of the eye, especially when the eye is rotated. Adjust the pupil threshold by using the pupil threshold adjustment buttons or with the ↑ and ↓ keyboard shortcuts: a mnemonic is to think of the ↑ key as increasing the blue area, and the ↓ key as decreasing the blue area.

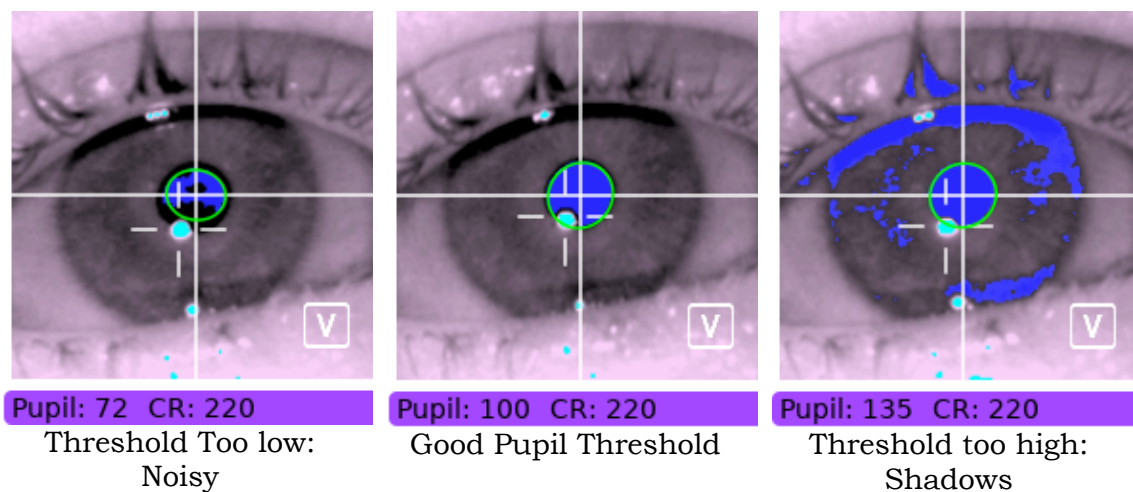


Figure 3-3: Symptoms of Poor Pupil Threshold

The Setup display is updated very rapidly, so the impact of threshold adjustments on noise, shadows, etc. will be easily detected. Ask the participant to look at each of the corners of the monitor in turn, and watch the pupil image

for problems. One common problem is for shadows at the corners of the eye, which can capture the pupil (see the right panel of Figure 3-4). These may be eliminated by decreasing the threshold with the ↓ key. Be careful not to drop the threshold too much, as the pupil thresholding may be poor at extreme eye positions. The pupil on the Host screen should have a crosshair drawn around its center, indicating that it has been detected. If a shadow captures the pupil, or the pupil is severely under-thresholded (as in the left panel of Figure 3-4), the crosshair will disappear and the pupil will be lost. On the Host PC, a “Pupil Missing” error will appear in the zoomed eye image.

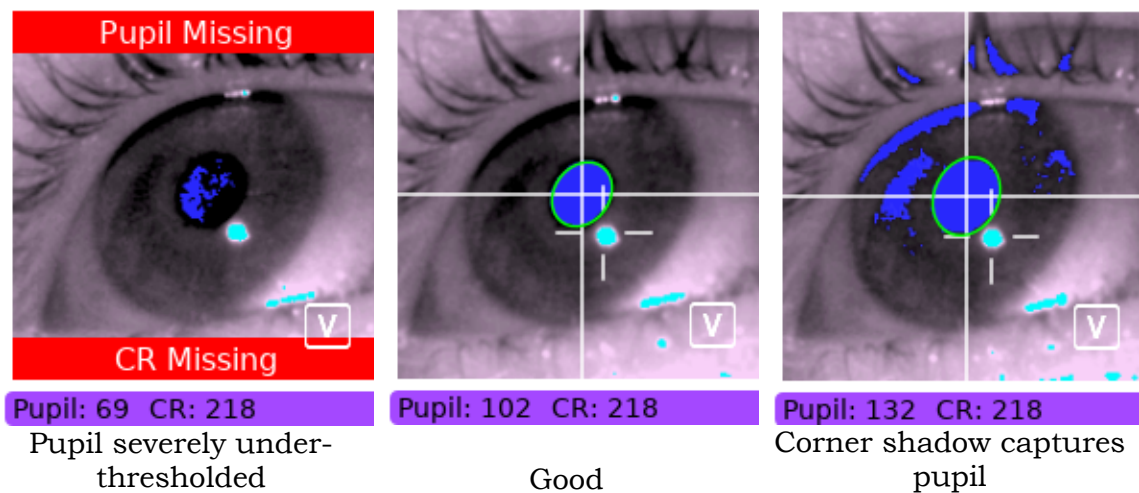


Figure 3-4: Potential Pupil Threshold Issues when Viewing Screen Corners

In general, after threshold adjustment, pupil thresholds should be between 70 and 120. If the pupil threshold is too low, try increasing the camera illumination level through the Settings option on the upper right corner of the screen. If the pupil threshold or corneal thresholds are too high, try reducing the illumination level.

3.4 Setting the Corneal Reflection (CR) Threshold

By default, EyeLink 3 uses the pupil-CR tracking mode, which provides more accurate and drift free eye position data compared to the pupil-only mode. The corneal reflection, if present, is identified by a circular shape in cyan.

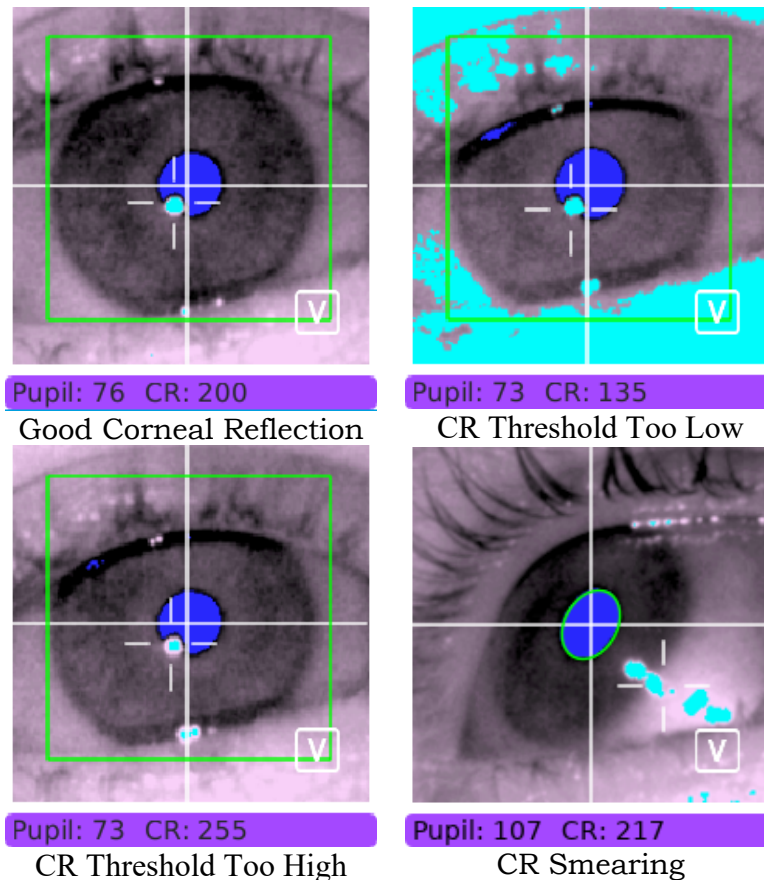


Figure 3-5: Corneal Reflection

Follow the steps below to acquire the best CR:

- 1) Press the Auto button to set the CR threshold (if this wasn't already done to set the Pupil threshold). You should see a colored circle appear near the pupil on each eye. Auto threshold should almost always set the correct CR threshold (see the top-left panel of Figure 3-5).
- 2) If the auto thresholding sets the threshold too low or high, use the CR threshold buttons, or the + and - keys, to manually adjust the CR threshold. If the CR threshold value is set too low, large areas may be painted in cyan, and the host software could potentially lock onto CR artifacts instead of the proper target (see the top-right panel of Figure 3-5). If the threshold value is set too high, the CR may not be sufficiently thresholded and you may lose tracking of the CR (and the eye!) at some point (see the bottom-left panel of Figure 3-5).
- 3) Ask the participant to look at each of the corners of the monitor in turn, and ensure that the corneal reflection does not get lost. If the CR does get lost, a "PUPIL MISSING" or "CR MISSING" error message will be displayed in the zoomed eye image.

- 4) Another potential problem to look for is CR smearing, which is typically seen when the participant looks at the top-left or top-right corner of the display (see the bottom-right panel in Figure 3-5). This is an indication that the viewing angle is too large for the setup. If this occurs, try increasing the distance between the participant and the monitor or lowering the monitor slightly.

NOTE: The corneal reflection may not be stable with all participants, particularly those wearing glasses with a heavy anti-reflection coating. If reflections from glasses cause difficulties in the proper acquisition of the pupil image, try adjusting the angle/height of the headband. If you are unable to acquire a stable corneal reflection after the above adjustments, it is suggested that you do not use the participant for the experiment.

3.5 Search Limits

The EyeLink 3 provides a “Use Search Limits” option. If enabled, it draws a red ellipse in the global view of the camera image to reduce the area of the camera image that is searched to locate the pupil and CR. If the “Use Search Limits” option is turned off, the eye tracker will attempt to search for pupil and CR across the entire camera image in case the pupil is lost. While the “Use Search Limits” feature is optional for participants who don’t wear glasses, it should be enabled for those participants wearing glasses. The search limits can be used to exclude regions of the camera image (e.g., the frame of the glasses) that may otherwise be detected as a pupil/CR. The disadvantage of using the search limits, however, is that if the participant completely removes the headband and then puts it back, the search limits may not be in the correct location. In this case, you will need to click on the pupil image to re-center the search limit area.

The size of the search limit area for the selected eye can be adjusted by first selecting the thumbnail eye image on the Host and then clicking on the search limits button () in the context menu displayed (see Figure 3-6). Users can also adjust the search limit size by pressing ALT and cursor keys on the Host keyboard together (ALT + ↑ or ↓ to adjust the height; ALT + ⇐ and ⇒ to adjust the width). The position of the search limits can be adjusted by double clicking on the eye image in the global view, or by using the SHIFT and cursor keys. In a binocular setup, size/position of the search limits need to be adjusted for each eye separately.

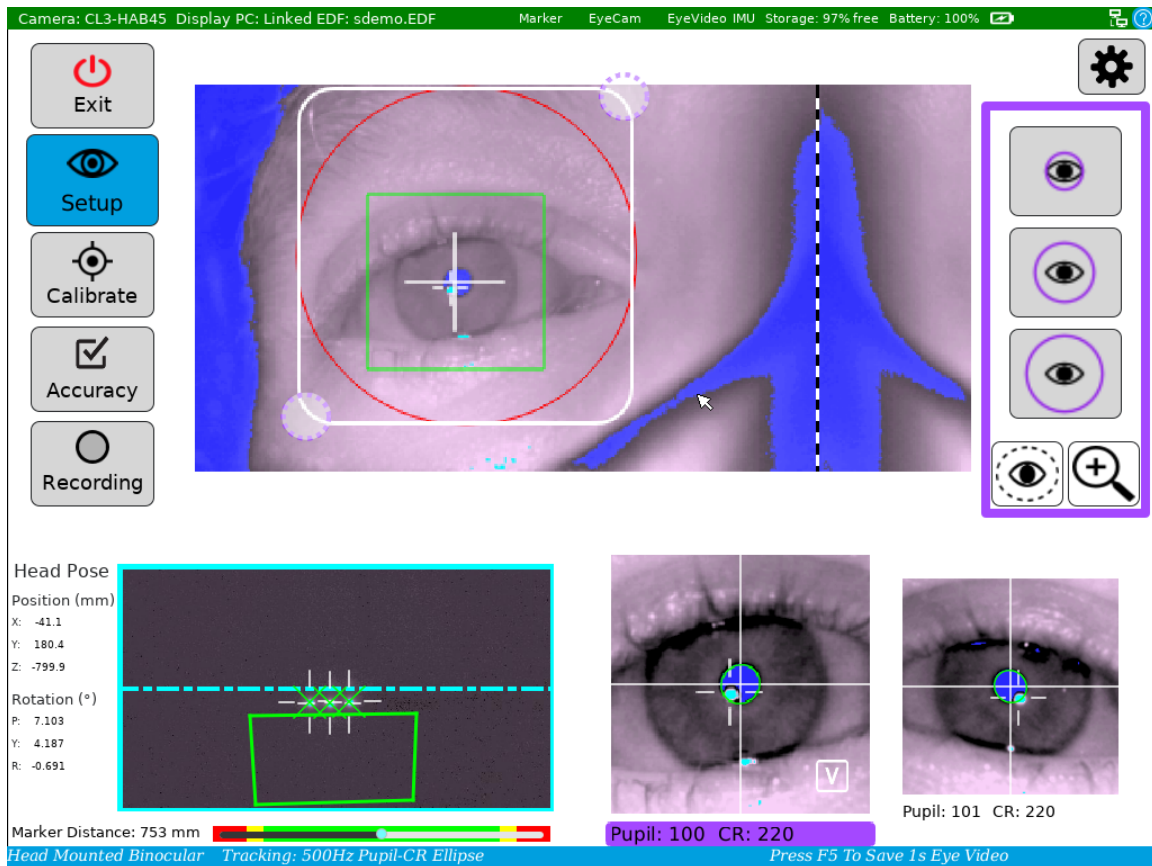


Figure 3-6: Adjusting Search Limits through the Context Menu

3.6 Pupil Tracking Algorithm

The EyeLink 3 implements two pupil tracking algorithms: Centroid and Ellipse Fitting. The Centroid mode tracks the center of the thresholded pupil using a center-of-mass algorithm, whereas the Ellipse mode determines the center of the pupil by fitting an ellipse based on the thresholded pupil mass. When pupil occlusion is present, the Ellipse mode interpolates points that may drop behind the eyelid or eyelashes in an attempt to better approximate the pupil position. The Host software represents the ellipse-fitting solution with a green ellipse drawn around the pupil area.

The Centroid algorithm is advantageous in some application scenarios as it has very low noise. However, if the pupil is significantly occluded the Ellipse Fitting algorithm may give a more accurate estimate of the eye position. The Ellipse-Fitting mode decreases drift potential and copes well with pupil occlusion at the cost of a slightly higher noise level.

Note: EyeLink 3 provides pupil ellipse data for the tracked eyes (X, Y position, the major and minor axis, and angle of the pupil ellipses; see Section 4.4.2.1

“Pupil Ellipse Data” for details). This data output is only available when tracking the pupils using the Ellipse Fitting algorithm.

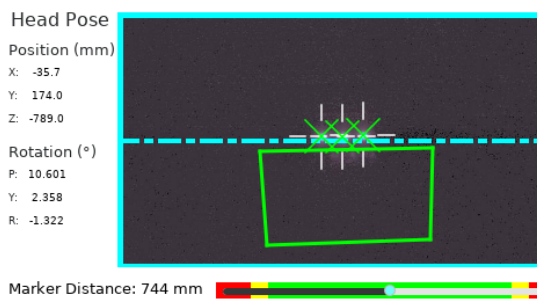
3.7 Head Tracking with/without the Marker

The EyeLink 3 provides head tracking using an inertial measurement unit (IMU) installed on the wearable tracking unit. If the NIR Marker is used, the head tracking data from the IMU is fused with the pose (heading and position) data from the Marker so that the system produces positional and rotational head tracking data with no or little drift and, in turn, records precise gaze data with excellent head-movement compensation. This is ideal for screen-based applications where accurate gaze data is desirable and the participant’s head movements tend to be within the trackable range of the Marker (short periods of Marker loss is compensated). However, when the Marker becomes unavailable for an extended period of time, the recorded gaze data may show obvious drift and the head tracking data may exhibit discontinuities due to attempted corrections when the Marker reappears.

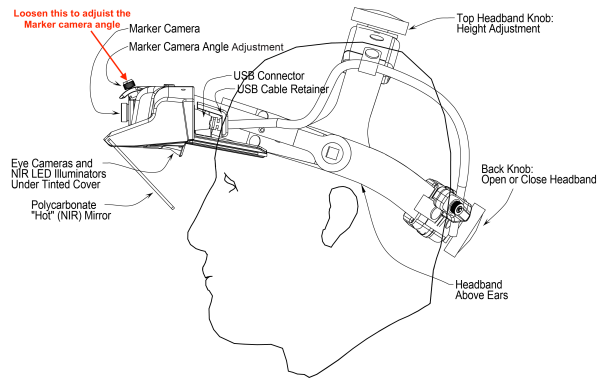
For the Marker to function properly, users need to perform screen setup and Marker configuration using the Guided or Manual Marker setup method (see Sections 3.1 and 3.2 of the EyeLink 3 Installation Guide)¹. Please take a moment to verify the accuracy of the Marker setup. Remove the filter cap of the Marker Camera and point the EyeLink 3 wearable unit at the monitor of the Display PC (ideally running the TRACK.EXE). In the Marker view of either the Display or Host PC, check whether a green box is properly overlaid on top of the video image of the viewable portion of the monitor and the three green crosses (fusion crosshairs) are drawn on top of the Marker LEDs. Once you have confirmed the accuracy of the marker setup, replace the filter cap on the Marker Camera, ensure it is pressed on flat/flush to prevent image distortion. During data collection, the lens filter of the Marker Camera should remain on at all times to block visible light sources.

For the best Marker tracking accuracy and largest trackable range, the Marker fusion crosshairs should ideally appear near the vertical center of the Marker view (see the left panel of Figure 3-7). Users can adjust the angle of the Marker Camera by loosening the angle adjustment screw of the Marker Camera (see the right panel of Figure 3-7), tilting the camera up and down until the Marker appears in the vertical center of the view and then tightening the screw. Once you enter the participant calibration mode or the record mode, do not readjust the Marker Camera angle—it should be securely fastened with the screw.

¹ Please note, a flashing yellow Marker icon () at the top of the setup screen when the host software is running means that the Marker hasn’t been configured yet. Please click on the icon to proceed with the guided Marker setup procedure.



Marker Appearing in the Vertical Center of the View



Adjusting Marker Camera Angle

Figure 3-7: Adjusting Marker Camera Angle

Head tracking with the Marker is recommended in most applications to ensure better data quality. 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 movement out of the Marker range, or tracking with an extended period of Marker loss). In this case, head tracking is done through the IMU only. Please note that with a Marker-free setup, the gaze data will be not as accurate and the absolute head position data will not be available. The rotational head tracking data is always available but is susceptible to drift over time. However, in Marker-free mode the head tracking data is not restricted by the Marker trackable range or contaminated by discontinuities caused by Marker loss / reappearance.

To turn off Marker tracking, start the Host software. Click the Settings button on the top-right corner and then select “Advanced Settings”. In the General tab, click the value field of the “Enable Marker for Head Tracking” option to toggle it Off. If the Marker is not used for head tracking, a “Marker Disabled” text will be displayed right under the Marker view.

3.8 Calibration

The preceding steps set up the EyeLink 3 to track the position of the selected eye(s). Almost all eye-movement research requires information on the participant's point of gaze on a display of visual information, such as a screen of text. To compute this, we need to determine the correspondence between the pupil - CR position in the camera image and gaze position on the Display screen. We do this by performing a system calibration, displaying several targets at fixed locations for the participant to fixate. The pupil - CR position for each target is recorded, and the set of target and pupil - CR positions is used to compute gaze positions during recording.

There are several possible calibration types available, each of which serves a different purpose. By default, a nine-point calibration type (“HV9”) is used. This is good for most eye tracking applications. However, if a large tracking area is used, the “HV13” calibration type should be used for the best calibration accuracy. If you record eye movements from a special population that is particularly difficult to calibrate (i.e. young children, or any other population that has difficulty stably fixating over many points), you might consider using fewer calibration points.

Begin calibration by pressing the ‘Calibrate’ button from the Setup menu, or by pressing the C key. A calibration target will appear on both the Host PC display and the Display PC monitor. The participant display is drawn by the experimental application (in this tutorial, the TRACK application), in response to commands from the EyeLink tracker. The Host PC screen will also display the raw pupil position as a moving letter O (in yellow for the right eye and in green for the left eye). The thumbnail images of the eyes and target as well as the relative positions of the eye(s) in the global camera view are displayed in the windows at the bottom of the screen. A status bar at the bottom-right of the display reports the progress of the calibration.

The eye-position cursor will move from location to location during the calibration as stable fixations are accepted for each calibration target. Instructing the participant to carefully look at the center of the calibration target will help improve fixation stability and calibration accuracy. While head movements during calibration will be corrected, for best calibration accuracy, please instruct the participant to keep their head still.

If the cursor jumps continuously and rapidly, or disappears intermittently, the setup for the eye needs to be corrected – the experimenter should go back to the setup screen and recheck the camera image as well as the thresholds. The bottom-right side of the status bar on the Host PC’s display reports the current eye movement status (e.g., whether the eye is stably fixating or in motion). Eye position will only be accepted when a stable fixation is detected.

When the eye appears stable, press the “Accept Fixation” button or the ENTER key or spacebar key to accept the first fixation. The eye tends to come to rest gradually and to make small vergence movements at the start of the fixation, or even make a small corrective saccade so as to foveate the center of the target precisely, so do not respond too quickly. However, do not wait too long before accepting the fixation, as participants tend to make involuntary saccades that move the eye away from the target over time. The proper timing is best learned by watching the gaze cursor during validation (discussed later).

The EyeLink system helps prevent improper triggering by locking out the ENTER key and spacebar if the eye is moving. Sometimes the ENTER key will

be locked out because of poor camera setup, with the pupil noisy or undetected in some positions. You can use the ↑ and ↓ keys to change the threshold if required. If this fails, press the 'ESC' key to exit back to the Setup screen.

After the first fixation has been accepted, the remaining calibration targets are displayed in sequence and fixations collected for each. The EyeLink calibration system presents these targets in a random order, which discourages participants from anticipating the location of the next target, and saccading away from the current target before it disappears. However, it is important to remind the participant to look at each calibration target until the next target appears.

If automatic sequencing has been enabled, targets will be presented and fixations collected without further intervention. Each time a new target is displayed, the participant should quickly make a saccade to it. The EyeLink system detects these saccades and the fixation following, producing an automated sequencing system.

NOTE: Sequencing may halt if the improper setup of the eye causes pupil loss or noise at the target position. If this happens, press the 'ESC' key twice to exit the calibration, adjust the threshold and/or the participant setup, and then restart the calibration. Pressing the 'ESC' key once will restart the calibration whereas pressing it twice will exit calibration and return to the Setup menu.

Even though the calibration is automatic, watch the Host PC's display carefully. Note the position of the cross-shaped pupil position markers: these should form a grid shape for the 9-point calibration. Lapses of participant attention will be clearly visible in the movements of this cursor. Also visible will be any difficulties the participant has in fixating targets, and most camera setup problems. The following figure illustrates a good calibration (left panel) and a poor calibration or calibration done with lots of head movements (right panel). For best accuracy, please instruct the participant to keep their head still during calibration.

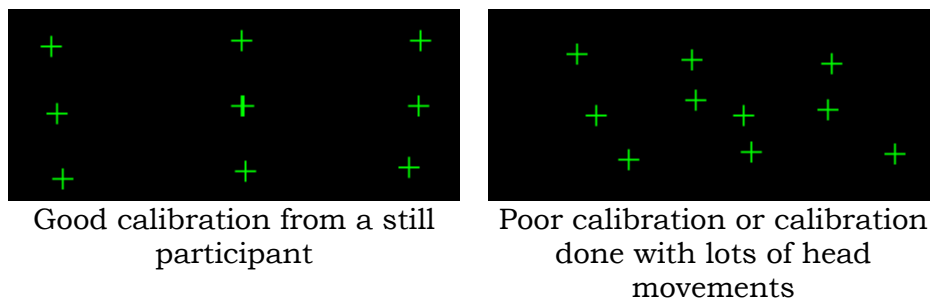


Figure 3-8: Calibration Grid

For some participants (especially those with neurological conditions) short fixations or lapses of attention can make the automated procedure unusable. A manual calibration mode can be used for these participants, where the ENTER key or spacebar must be pressed to collect each fixation. Pressing the 'M' key switches automatic calibration off. It may be switched back on by pressing the 'A' key.

One useful key in the middle of a calibration sequence is the Backspace key (or the "Undo" button), which can undo recent calibration targets. With each press of this key, data collected for the last point in the calibration sequence is erased and new calibration data can then be collected. This can be used to improve calibration accuracy for one or a few selected points without having to restart the calibration procedure. This is especially helpful for those participants whose calibration data is hard to get.

When the last calibration target has been presented, the calibration will be evaluated. At the bottom of the Calibrate screen, each eye's calibration is graded and displayed as follows:

GOOD: No obvious problems found with the data

FAILED: Could not use data, calibration must be repeated

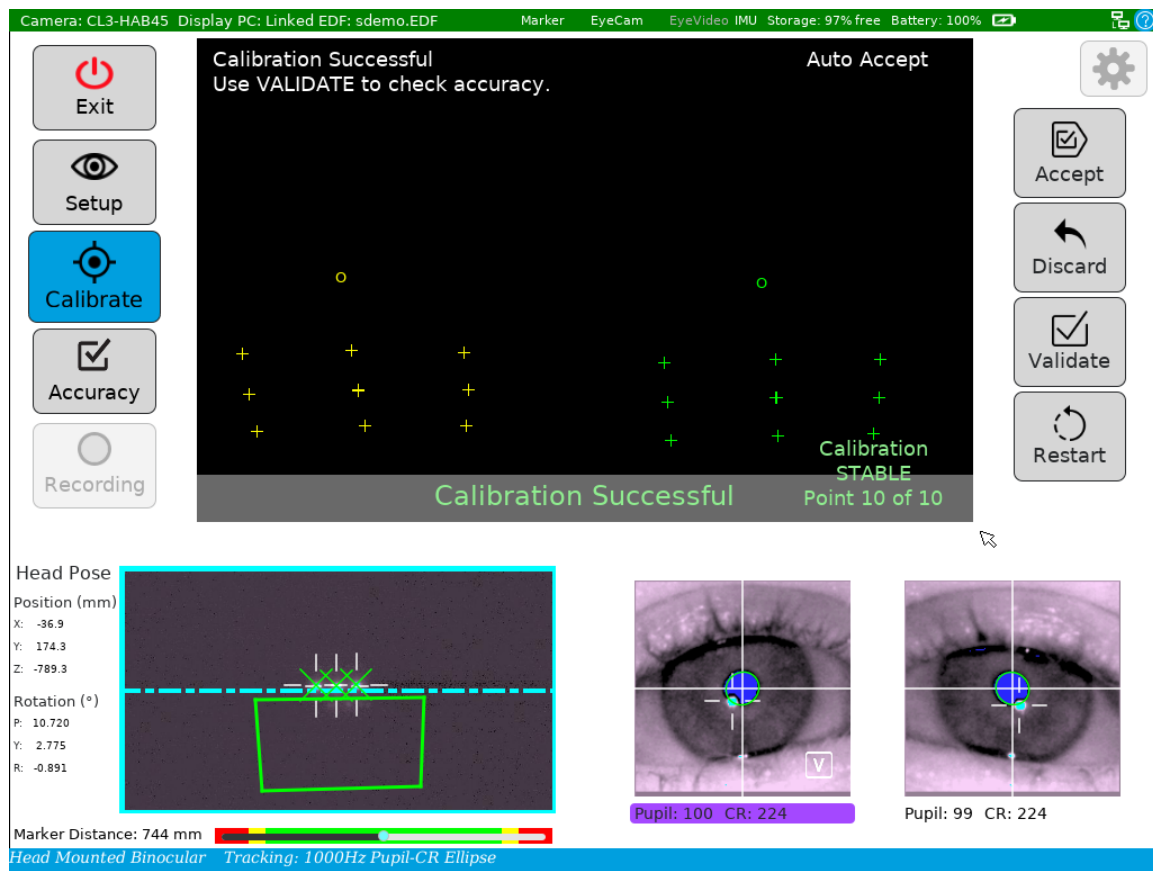


Figure 3-9: Calibration Results Reporting

The user must still check the accuracy of the calibration: only serious problems can be detected automatically. In particular, please examine the pattern formed by the eye-position cursors (arrays of crosses) for misplaced or missing fixations. If the participant sits still, a good calibration is indicated by a regular pattern of parallel horizontal and vertical lines formed by the calibration fixation crosses. If the calibration was successful, you may press the “Accept” button or the ENTER key to accept the calibration results. Pressing the “Restart” button or the ‘ESC’ key will restart the calibration. Pressing ‘ESC’ twice exits to the Setup screen. So if you want to keep the current calibration, never press the ESC key at the end of the calibration where the calibration grid is displayed. Doing so will discard the current calibration and thus revert to the existing cached calibration.

In all screens, the Host Application reports any unusual status for the pupil or corneal-reflection signals near the thumbnail eye and target images if there are any lapses in data collection. Should any of the indicators be displayed and the participant is looking at the screen and not blinking, there is a problem with the setup that must be addressed to prevent data loss.

Indicator	Status of Pupil
SIZE	Pupil is too large or too small
PUPIL MISSING	Pupil is missing
Calib Limits	The eye location is outside of the calibrated region.
BOUNDS	Pupil is missing or the gaze data is not valid

The pupil status error message “SIZE”, highlighted in yellow, indicates that the size of the pupil is too large or too small. The pupil status error message “MISSING” highlighted in red, indicates that the pupil is missing from the camera view. This could be that the participant is blinking. It could also be that there is a problem with camera setup. Please adjust as needed.

Indicator	Status of Corneal Reflection
MISSING	Corneal Reflection is missing
BOUNDS	Corneal Reflection is missing or the gaze data is not valid

The corneal reflection status error message “MISSING”, highlighted in red, indicates that the corneal reflection is not visible to the camera. See Section 3.4 for details on how to set up corneal reflection properly.

All status flags remain on for a minimum of 200 milliseconds, even if the condition that caused the warning or error to be raised lasts for less than 200 milliseconds.

3.9 Validation

It is important that any problems with the calibration be identified and corrected in order to avoid collecting eye-movement recordings containing inaccurate and poor-quality data. By running a validation immediately after each calibration, the accuracy of the system in predicting gaze position from pupil-CR position can be established. If the validation result is poor, the calibration/validation cycle should be repeated before data collection begins.

During validation, targets are again presented to the participant in a random order, similar to the calibration procedure. When the participant fixates these targets, the calibration model is used to estimate the gaze position of the participant, and the error (difference between actual target position and computed gaze position) is calculated. Note: a scaling factor is built in for automatically-generated validation points to pull in the corner positions (see the *'validation_corner_scaling'* command setting in the CALIBR.INI file). This is used to limit validation to the useful part of the display and test the calibration accuracy on uncalibrated points.

The gaze-position error comes largely from errors in fixation data gathered during the calibration/validation, which come from two sources: the eye-tracking system and physiological eye-movement control. The EyeLink system has extremely low eye-position noise and very high resolution, and corrects for head motion during calibration and recording. These common sources of error in the eye-tracking system are virtually eliminated. One physiological source of calibration inaccuracy is the natural variability of participant's ability to accurately fixate the targets. Vergence eye movements also contribute – this can be seen clearly during validation with binocular gaze position displayed.

For calibrations, it is possible that one or more targets may be fixated with an error of 1° or greater. Poor eye/camera setup can cause a highly distorted calibration pattern thus magnifying small errors. Some participants may show substantial drifts in gaze position during fixations or may not fixate carefully, adding to the errors.

To begin the validation procedure, press the 'V' key in the Setup screen, or click "Accuracy" button on the host and then select the "Validation" option. The Host PC display will show the gaze position as a round, colored cursor. Note the movements of the cursors, and the change in relative horizontal position (vergence) following saccades. Once the cursor appears stable, and close to the target, press the ENTER key or the spacebar to accept the first fixation. The remaining points are collected automatically or manually, as in the calibration process.

As each fixation is collected, a cross is used to mark its computed position relative to the target. The error (in degrees) is printed next to the cross. As with the calibration procedure, the user can use the Backspace key in the middle of a validation sequence to redo data collection for the last or last few validation points collected. After the final fixation is collected, the average and maximum errors are displayed at the bottom of the screen, and the accuracy is scored. Each eye is graded separately, using color coded messages similar to the calibration results:

GOOD (green background): Errors are generally acceptable.

FAIR (grey background): Errors are moderate, calibration should be improved.

POOR: (red background): Errors are too high for useful eye tracking.

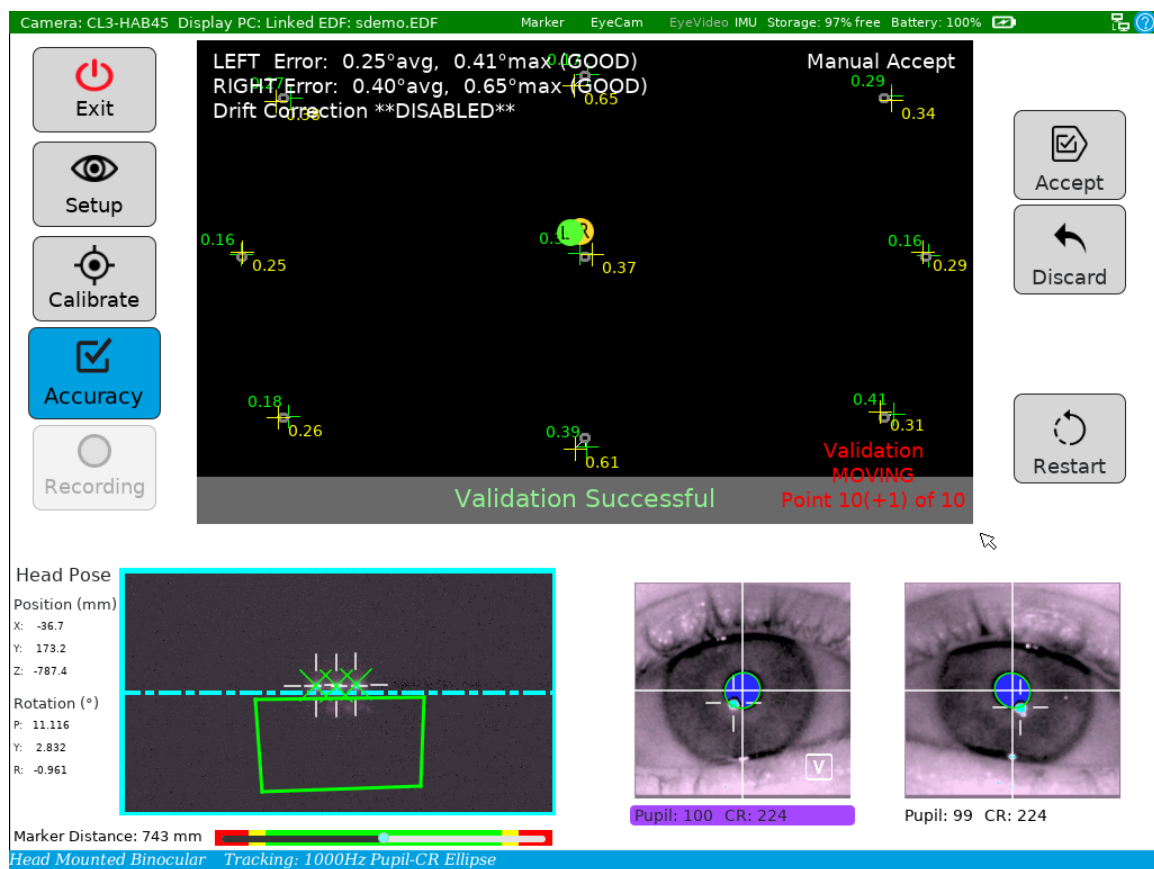


Figure 3-10: Validation Results Reporting

Note, this categorical scoring of calibration accuracy is a general guideline and different fields of research may choose to use different cut-offs to those reported above. Always adhere to the convention in your field of research rather than accepting the categorical scoring of calibration accuracy.

Observe the pattern of errors for each target position. If only one target has a large error, the participant may simply have mis-fixated that point during the validation, and the validation may be repeated to check this: press 'ESC' to return to the Setup screen, and 'V' to repeat the validation. If that target still has a large error, it is likely that the target was mis-fixated during the calibration. If a systematic pattern of error is seen (i.e. all fixations on the left side are too low) there is probably a calibration or camera setup problem. In either case, press 'ESC' to return to the Setup screen, adjust the setup as needed and re-calibrate, then repeat the validation process. Press the ENTER key to accept the validation. Pressing the ESC key when the validation results are displayed will discard the results and doesn't apply any drift corrections if applicable.

3.10 Improving Calibration Quality

The quality of the calibration determines how useful the recorded data and how accurate the gaze calculation will be. Below are some simple procedures to improve data quality and gaze accuracy:

- Always ask the participant to look at the four corners of the display after performing the camera setup. Be sure to instruct the participant to fixate within the bounds of the display or loss of tracking may occur because they have looked too far outside of the trackable range of the eye tracker (not because of a poor set-up). Watch for the warning signals on the tracker screen to make sure that the pupil and CR signals are not lost when the participant is looking at each corner, and check the CR is not becoming distorted or "smeared" when the participant looks at the top corners. Try moving the monitor away to increase the viewing distance when the CR smearing is seen (typically at the upper portion of the display).
- Participants who have never been calibrated before may require some practice in stably and accurately fixating the calibration targets. If the result of the first calibration is not optimal, try to perform at least two calibrations per participant before beginning to collect data.
- Encourage participants to sit still! A participant that doesn't sit still probably is not paying proper attention to the experimental task. Try to give the participant a short break in the middle of the experiment and recalibrate before resuming the experiment.
- Always check the pattern of the calibration grid. For a 9-point calibration, the fixation crosses should form three parallel horizontal (or close-to-horizontal) lines and three parallel vertical (or close-to-vertical) lines if the

participants sit still. Redo the calibration or camera setup if you do not see this.

- If the current calibration looks good, press either the ENTER key to accept the calibration or press V to go to the validation screen. Never press the ESC key – doing so will discard the current calibration and thus revert to the cached calibration results.
- When writing your own applications, make sure you match the background color of the calibration and validation screen to that of the experimental displays. Changes in pupil size caused by large changes in brightness between the calibration and the experimental displays can degrade the system accuracy. At the beginning of the experiment, let the participant adapt to the environment and the ambient light levels before performing calibration and data collection. If the brightness levels are altered (i.e. the lights are dimmed) shortly before the experiment begins, the calibration accuracy will be reduced as the participant adapts to the new brightness level and the pupil dilates or constricts.

3.11 Recording Gaze Position

After the system is set up and calibrated, we can monitor gaze position in real time, and record it for later analysis or viewing. This can be done by pressing the “Record” button or the ‘O’ key from the Setup screen.

In this session, we assume the TRACK application is running on the Display PC. When TRACK senses that the Host PC has entered Record mode, it sets up a recording session under its own control.

On the Display PC, it displays a page of text or a grid of letters on its own screen for the participant to read, alternating between recording sessions. The Host PC screen will display a background image of what the participant sees. This serves as a reference for the gaze-position cursor displayed by the eye tracker during recording, allowing the experimenter to see where the participant is looking and detect problems in eye tracking or participant’s inattention.

TRACK displays the gaze position as a blue cursor on the participant’s display. To implement this feedback, TRACK requests the host application to send it up to 1000 samples per second of gaze-position via the EyeLink API. This data is used to move the gaze cursor. Pressing the ‘G’ key on the Display PC keyboard will cycle through several different eye data options (e.g., left-only, right-only, cyclopean gaze data, no cursor, head-in-space, eye-in-head data).

TRACK also sends commands to the Host PC to create a data file (SDEMO.EDF) on the Host PC’s hard disk, which contains samples, fixations, and saccade data. When the TRACK exits, this file will be automatically transferred from the

Host PC to the Display PC. `SDEMO.EDF` may be viewed with EyeLink Data Viewer or processed with other EDF utilities. Information on the EDF file format can also be found in Chapter 4 of the current document.

3.12 Drift Correction

We provide templates for a wide range of stimulus presentation software (see Section 3.16). In the vast majority of the examples, a drift correction is performed at the beginning of each trial. This ensures that the recorded data is always spatially accurate, and any issues with spatial accuracy can be resolved by recalibrating if necessary. Drift correction works by computing and applying a corrective offset to the raw eye-position data. It is important that before performing a drift correction the participant is instructed to sit still and fixate the center of the drift correction target carefully. If you are consistently seeing observable drift between the target and the gaze cursor, it may be worth reviewing how participants are set up (how well the headband is balanced and fit, the instructions to the participant for calibration, etc.) and may repeat a calibration after a certain number of trials.

Note, the EyeLink 3 provides both “Drift Correction” and “Drift Check” options. In both cases, a single target is displayed to the participant and the difference between the computed fixation position and position of the current target is computed. By default, similar to the earlier EyeLink I and II head-mounted eye trackers, the EyeLink 3 will correct the calibration map based on the drift correction result. This is especially important if the participant moves a lot or if you suspect there is a headband slippage during the experiment. If the “Drift Check” option is selected, the eye tracker will only report the calculated fixation error from the drift correction procedure and not actually adjust the calibration map in any way. Therefore, this procedure is better viewed as a “Drift Checking” procedure.

Drift correction is typically performed at the beginning of each trial, before actual recording starts. To enable the drift correction procedure to adjust the calibration rather than simply checking that the error level is within a certain range, you may go into the Accuracy screen, and choose the “Drift Correction” button. Alternatively, the following EyeLink command should be placed in the `FINAL.INI` or sent across the link.

```
driftcorrect_cr_disable = OFF
```

Another useful parameter to be aware of is the threshold value that is used to determine acceptable error levels in the target fixation that is used to assess drift. The parameter is the ‘`drift_correction_rpt_error`’ variable (default is 2.0 degrees). If the fixation is not within this level of error, other fixation samples can automatically be taken to ensure that the fixation sample wasn’t itself in

error (e.g., attempted during a blink or when the participant was not complying with instructions to fixate the target) or the experimenter can enter into the Camera Setup mode (ESC on the keyboard) and undertake a new camera setup or calibration procedure.

3.13 Exiting the Host Application

IMPORTANT: Remember to exit the EyeLink software by pressing the key combination CTRL+ALT+Q and then clicking on the shutdown button on the File Manager toolbar, or by clicking the “Exit” button from the Setup Screen, and choose “Shutdown” in the following dialog box. Avoid switching off the computer while the EyeLink Host software is still running, as data may be lost or get corrupted.

You can now close the EyeLink Host Application. Press the key combination ‘CTRL+ALT+Q’ from any point in the Host PC tracker program or click on the “Exit” button in the Setup screen and choose the “Exit” option to go to the File Manager. To perform an orderly shutdown of the Host PC by closing all processes running, click on the “Exit” button from the Setup screen and then choose “Shut Down” option if the Host Application is still running. From the File Manager, you may click on the red Shutdown button on the toolbar.

3.14 EyeLink 3 Setup Summary

It is suggested that you practice the procedures in this section until you feel comfortable with the EyeLink 3 setup, and can reliably get good calibration/validation results.

This is a summary of the steps detailed in the practice session. It assumes no setup problems are encountered.

- Place the EyeLink 3 wearable unit upright and stable on the mannequin head
- Start the EyeLink Host Application.
- Start TRACK.EXE on the Display PC.
- Have the participant seated in the chair comfortably. Adjust the height of the chair so that the participant’s eye line is at the upper part of the monitor.
- From the Setup screen, press ENTER to transfer the camera image to the Display PC.
- Fit the headband on the participant’s head. Make sure the participant has a clear view of the display, and the eyes appear vertically centered on the global view of host.

- Click on the eye image(s) in the global view to properly acquire the pupil to track.
- Set the threshold with the ‘A’ key, and fine-tune with ↑ and ↓ keys. Have the participant look at the four corners of the screen to check pupil/CR image and thresholding. Repeat this for each eye if recording binocular data.
- Press ‘C’ to start calibration, press ENTER to collect the first fixation, let the sequence run by itself. Press ENTER to accept result, ESC to discard.
- Press ‘V’ to start validation, press ENTER to collect the first fixation, let sequence run by itself. Press ENTER when finished.
- Repeat calibration if validation is poor.
- Press ‘O’ to record eye movement data. ‘G’ on Display PC keyboard toggles between different eye position data or turn off the cursor.
- Press ‘CTRL+ALT+Q’ or click on the “Exit” button from the Setup screen to exit the EyeLink Host PC Application.
- Click on the Shutdown button from the File Manager tool bar to turn off the Host PC at the end of the day.

3.15 Experiment Practice

The TRACK.EXE program is the most flexible way to practice the EyeLink tracker setup, allowing almost any sequence of actions to be performed. In real experiments, the sequence of actions is much more defined. Usually the experiment begins with participant setup and calibration from the Setup menu, perhaps followed by practice trials. Then a series of experimental trials are performed, often with a drift correct before each trial.

This flow allows little room for practice, and makes it important that initial setup and calibration be performed correctly and carefully validated. If tracking issue develops in the middle of the experiment, users should consider going back to the Setup screen (e.g., pressing ESC at the pre-trial drift correction screen) to fix eye setup or calibration, and then continue the data collection.

3.16 Next Steps: Other Sample Experiments

For both Windows and macOS, the EyeLink Developers Kit contains several sample experiments that are valuable demonstrations of how the EyeLink system can be used and programmed. On Windows, sample experiments written in C (using GDI or SDL graphics) can be accessed from “Start -> All Programs -> SR Research -> EyeLink Sample Experiments”. On macOS, the

examples can be run from “Applications -> EyeLink -> SampleExperiments -> SDL”.

All sample experiments have the following key shortcuts that can be used from the Display PC keyboard. These keys are available after the experiment has started and a Data File name has been entered.

ENTER	View camera or accept Calibration / Validation if Calibration / Validation has just been performed
<- or ->	Select the zoomed or global camera view.
C	Perform Calibration
V	Perform Validation
O	Start experiment

The following table describes the purpose and use of each sample experiment. For detailed information on the programming / API aspect of these samples, please refer to the EyeLink Programmer’s guide.

Experiment	Purpose
Simple	This experiment is the most basic EyeLink sample experiment that draws directly to the display.
Text	Template for an experiment that uses bitmaps to display formatted pages of text.
Picture	Template for an experiment that uses image files to display pictures.
eyedata	Template for an experiment that uses real-time link data to display a gaze-position cursor, and plays back data after the trial.
gcwindow	Template for an experiment that displays text and pictures, using a large gaze-contingent window.
control	Template for an experiment that uses the participant’s gaze position to select items from a grid of letters.
dynamic	Template experiment that includes several types of dynamic displays (sinusoidal smooth pursuit, and saccadic task).
broadcast	Template for an application that listens in on any application, reproducing calibration targets and displaying a gaze cursor (if real-time sample data is enabled).

comm_listener comm_simple	Templates that illustrate a dual-computer experiment. The comm_simple template is a modified version of the simple template, which works with the comm_listener template. This illustrates how real-time data analysis might be performed, by reproducing the display (based on the TRIALID messages) and displaying a gaze cursor.
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In addition to the C examples, other programming languages and tools can be used to display experiment stimuli and talk to the eye tracker. For example, Experiment Builder supplies some template experiments (installed at "C:\Users\{User Name}\Documents\ExperimentBuilder Examples" for Windows, or "Documents\ExperimentBuilder Examples" on macOS). Each of these experiment templates illustrates a typical experimental paradigm. The following table provides a brief description of the experiments. See the SR Research Experiment Builder User Manual for a detailed description of each template's operations.

Experiment	Purpose
Simple	The basic experiment template, displaying a single word in the center of the screen in each trial. This example is used to introduce how to create an experiment with SR Research Experiment Builder step by step.
Stroop	The basic template for creating non-EyeLink experiments. This template illustrates the use of a results file, RT calculation, and audio feedback, etc.
Picture	Illustrates various parameter settings for showing an image on the screen (in original size versus stretched, centered versus not centered).
TextLine	Experiment to show a single line of text, illustrating the use of runtime interest area segmentation.
TextPage	Experiment to show a full screen of text using a multi-line text resource.
GCWindow	Demonstrates how to use real-time gaze position to display a gaze-contingent window.
Track	Displays the user's current gaze position during recording and illustrates how to set the resource position contingent on the current gaze position.
Change	Displays several almost-identical screens rapidly. It also illustrates the use of the fixation trigger.

Saccade	Illustrates the creation of a simple experiment for saccade/anti-saccade research.
Pursuit	Illustrates several kinds of sinusoidal movement in a pursuit task.
PosnerTask	Implements the classic Posner cueing task, in which either a neutral, valid or invalid cue is presented centrally prior to a target appearing in either a left or right placeholder. Participant is asked to indicate as rapidly as possible which side the target appeared on via a keypress response.
Video	Illustrates creating an experiment displaying video clips.
InfantVideo	Performs calibration and drift correction/check using animated calibration targets.
VisualWorld	Illustrates the implementation of the popular Visual World Paradigm. Audio is played through ASIO driver on Windows or OSX driver on Mac. Positions of the screen resources are set through an UPDATE_ATTRIBUTE action.
EEG Integration	This folder contains examples and instruction docs to illustrate integration with EEG systems from Biosemi, Brain Products, Neuroscan, and Philips-EGI. All of the examples are based on the “Simple” and “Stroop” templates.

For users who wish to program their experiments in other programming environments, a wide range of options exist for accessing and controlling data acquisition on the Display PC. Refer to the *Getting Started with Experimental Programming* section of our support forums (<https://www.sr-research.com/support/forum-81.html>) for information on various programming environments, including Psychtoolbox for MATLAB, PsychoPy, OpenSesame, Python/pygame, etc.

4 Data Files

The EDF file format is used by the EyeLink tracker and supporting applications to record eye-movements, head tracking data, and other data. It is designed to be space-efficient and flexible, allowing for complete records of experimental sessions and data. It adapts to monocular and binocular recording, with compatibility support for future enhancements.

The EDF file format is a platform-portable binary record of eye-position, head tracking data, and synchronization events. This format is used directly by the EyeLink Data Viewer application, and may be translated by the EDF2ASC utility into a text-format ASC file (see Section 4.7 “EDF File Utilities” for detailed discussions). The ASC lists most of the important data in the EDF file in a more easily-accessible format, but at the expense of a much larger file size.

Note: Changing the File Sample Filter from Extra to Standard or Off will affect EyeLink Data Viewer, EDF2ASC, and other analysis tools’ data calculations. SR Research Ltd. strongly recommends keeping the default file sample filter setting (“Extra”).

4.1 File Contents

For an EyeLink 3 recording, the EDF files contain two streams of data: eye-position and head tracking samples (up to 1000 samples per second) and events (eye-movement events such as saccades and fixations, participant responses, and synchronizing events/messages from the experimental application). Both streams (samples and events) are time-synchronized for easy analysis. The file is organized into blocks of data, one for each recording segment. Each block may have samples, events, or both. Also, the data items recorded in each sample or event may be configured at recording, and are available at the block start to aid in analysis.

Samples are time-stamped in milliseconds and contain monocular or binocular eye-position data in eye-rotation angle (HREF) or display-gaze coordinates (GAZE), as well as the head-in-space and eye-in-head data in screen pixel coordinates. EyeLink 3 also records 6DOF head tracking data (head position and head rotation). Pupil size, as area or diameter, are also recorded. Samples may also contain eye-movement resolution (pixels per degree of visual angle, used to compute true velocity or saccadic amplitudes), as well as button presses and the status of digital inputs.

Eye-movement events record eye position changes identified by the EyeLink tracker's online parser. These events include fixations, blinks, and saccades. Both the onset and end of these events are marked, allowing samples to be assigned to eye-movement events without complex algorithms. Important data for analysis such as average position for fixations and peak velocity for saccades is also recorded in the end events. Other events record participant

responses (such as button presses) and synchronization and data messages sent from applications running on the Display PC. These can be used to record the time of a change in the display, or an experimental condition.

4.2 Recording EDF Files

EDF files are created by the EyeLink 3 eye tracker, recording eye-position and head tracking data, events from the online parser, and button and input events. These are recorded only when the tracker is in recording mode. Messages sent from applications on the Display PC through the Ethernet link may be recorded at any time. Recording EDF files involves opening a data file, recording data from one or more trials in record mode, and closing the file. These operations can be performed manually using the EyeLink Host application on the Host PC, or (more typically) remotely from the Display PC through the Ethernet link. In both cases, it is important that the screen and Marker settings are set up properly for accurate head movement compensation for gaze data recording, and accurate recording of data resolution and velocity calculation.

4.2.1 Recording from the EyeLink 3 Host PC Manually

In some eye-tracking situations, it may be convenient to initiate the recording of eye movement data directly. For example, displays may be generated by manually-operated equipment, or by non-EyeLink applications. Special provisions must be made to display the calibration pattern in these situations. By using the EyeLink 3 tracker's "Advanced Settings" tool, files may be opened and closed, and recording sessions may be started and stopped. Refer to Chapter 2 of this manual "*EyeLink 3 Host Software*" for information.

4.2.2 Recording from the EyeLink API or SR Research Experiment Builder

Most eye-movement research involves running many participants through a sequence of experimental trials, with tens or hundreds of recording blocks per file. This is best done by remote control over the link from an experimental application. The connection from the Display PC to the EyeLink eye tracker is implemented by an Ethernet link. Refer to the *Getting Started with Experimental Programming* section of our support forums (<https://www.sr-research.com/support/forum-81.html>) for details on how to use the Display PC software to set up and record EDF files.

4.3 The EyeLink Online Parser

As with all EyeLink systems, the EyeLink 3 Host Software incorporates a unique online parsing system which analyzes eye position data into meaningful events and states (saccades, fixations, and blinks).

4.3.1 Parser Operation

The parser uses velocity and acceleration-based saccade detection methods. Because of the EyeLink tracker's exceptionally low noise levels and high spatial resolution, very little data filtering is needed and thus delay is kept at a minimum. For each data sample, the parser computes instantaneous velocity and acceleration and compares these to velocity and acceleration thresholds. If either is above threshold, a saccade signal is generated. The parser will check that the saccade signal is on or off for a critical time before deciding definitively that a saccade has begun or ended. This check does not affect the recorded time of the saccade start or end, but adds some delay to the real-time events sent through the link.

During each saccade or fixation, data is collected related to the velocity, position, and pupil size. At the end of the saccade or fixation, this data is used to compute the starting, ending, and average position, pupil size and velocity, as well as the peak velocity. This data is then used to create events which are sent over the link and/or recorded in an EDF file. See the Section 4.5.3 "*Eye Movement Events*" for more information on events.

4.3.2 Parser Limitations

The EyeLink parser is designed for rapid, online identification of saccades and blinks. Detection of very small saccades (microsaccades) may require off-line processing, as the special filtering and computation of global velocity cannot be performed online. In smooth pursuit research, the parser is less sensitive to small back-up saccades (opposite to the direction of pursuit) than forward saccades, due to the low peak velocity of back-up saccades.

The parser only looks "ahead" in the data a short time to compute velocity and acceleration. This limits the data checking the parser can do. Post-processing or data cleanup may be needed in some analysis scenarios. For example, short fixations may need to be discarded or merged with adjacent fixations, or artifacts around blinks may have to be eliminated.

Nonetheless, the EyeLink parser does an excellent job in most recording situations. Adjusting the configuration of the parser may help bias its performance for some specific applications. Its performance is easily checked: record eye movements using the display of interest, with both sample and event data. Then view the EDF file with EyeLink Data Viewer or convert the EDF file to an ASC file to see the correspondence between the sample data and the events identified by the parser.

4.3.3 EyeLink Parser Configuration

Note: For the vast majority of eye movement research, the default parser configuration should be used. While the saccade detection parameters can be

configured (see below), it should be noted that any such alterations may need to be justified to reviewers when publishing the research.

The saccadic detection parameters for the EyeLink online parser can be optimized for the type of experimental investigation being performed. For example, neuropsychophysical researchers may want to detect small saccades that occur during pursuit or nystagmus, while reading researchers may want to detect only large saccades and will want fixation durations maximized. This section explains the function of, and suggests values for, the most useful parser parameters.

Some experimentation may be required to select the best parameters. Users can try different parser settings and perform recordings with full sample data recorded. The eye-movement data can then be viewed with EyeLink Data Viewer with saccades and blinks overlaid, to confirm the parsing accuracy. Once correct parameters are determined, they can be set by the EyeLink commands over the link as part of the experimental setup, or the EyeLink configuration file `PARSER.INI` or `FINAL.INI` can be edited to change the default parameters.

4.3.4 Parser Data Type

Three eye-position data types are available from the EyeLink tracker for each sample: raw eye position, head-referenced angle (HREF), and gaze position (GAZE, see the Section 4.4 “File Data Types” for more information). The parser can use GAZE or HREF data for detecting saccades and generating data for events.

The parser data type is set by the EyeLink command “*recording_parse_type*”. It can be changed by editing the configuration file `DEFAULTS.INI`, or by sending a command over the link. The text of the command is one of:

```
recording_parse_type = GAZE  
recording_parse_type = HREF
```

Please note, for event parsing in an EyeLink 3 recording, GAZE reflects the combined position data from both the eyes and head, and the velocity refers to the combined velocity of the eye and head. In contrast, HREF represents the eye rotation angle relative to the head, excluding any contributions from head data. By default, EyeLink 3 uses GAZE for event parsing; however, using HREF may be more appropriate if GAZE data is unavailable (e.g., in Marker-free head tracking with off-screen stimuli).

4.3.5 Saccadic Thresholds

Three thresholds are used for saccade detection: motion, velocity, and acceleration. The values of these are in degrees, degrees/sec, and degrees/sec² respectively.

The velocity threshold is the eye-movement velocity that must be exceeded for a saccade to be detected. A velocity threshold of 22 degrees per second allows detection of saccades as small as 0.3°, ideal for smooth pursuit and psychophysical research. A conservative threshold of 30°/sec is better for reading and cognitive research, shortening saccades and lengthening fixation durations. The higher threshold also reduces the number of microsaccades detected, decreasing the number of short fixations (less than 100 ms in duration) in the data. Some short fixations (2% to 3% of total fixations) can be expected, and many researchers simply discard these.

Use of eye-movement acceleration is important for detection of small saccades, especially in smooth pursuit. Acceleration data has much more noise than velocity data, and thresholds of 3800°/sec² for small saccade detection and 8000°/sec² for reading and cognitive research are recommended. Lower acceleration thresholds will produce false saccade reports. Acceleration data and thresholds for the EyeLink eye tracker system may be larger than those reported for analog eye trackers. These systems use multi-pole filters for noise reduction that add delay and smooth the data, significantly reducing the measured acceleration.

The saccadic motion threshold is used to delay signaling the onset of a saccade until the eye has moved significantly. A threshold of 0.1° to 0.2° is optimal for most research scenarios. Larger values may be used with caution to eliminate short saccades: for example, a threshold of 0.4° will always merge fixations separated by saccades of 0.5° or less, but may eliminate some 1° saccades as well.

Examples of the commands to set these thresholds are:

```
saccade_velocity_threshold = 30  
saccade_acceleration_threshold = 8000  
saccade_motion_threshold = 0.15
```

4.3.6 Pursuit Adjustment Threshold

During smooth pursuit and nystagmus, saccades must be detected against a background of smooth eye motion as fast as 70°/sec. While acceleration can be used to detect these saccades, velocity data must also be used for reliable detection of all saccades. The EyeLink parser raises the saccadic velocity threshold by the average velocity over the last 40 milliseconds. This is reliable, and does not degrade parser performance during non-pursuit eye movements.

The pursuit adjustment threshold limits the amount that the saccadic threshold can be raised. A limit of 60°/sec works well for most pursuit and other research, but may have to be raised if very rapid pursuit or nystagmus is being recorded.

The limit is set in degrees per second. An example of this command is:

saccade_pursuit_fixup = 60

4.3.7 Fixation Updates

Monitoring eye position or pupil size during fixations usually requires processing all samples produced by the tracker. This is acceptable for file data, but is computationally expensive for real-time systems using data sent via the link. Fixation updates solve this problem by sending updates on eye position, pupil size, velocity etc. at regular intervals during a fixation. The first update is sent one update interval after the start of the fixation, and the last is sent at the end of the fixation. Data is aggregated over a preset period, which lowers data noise. The interval between updates and the data accumulation period can both be set.

Fixation updates are most useful for real-time display paradigms. In some studies, the participant is required to fixate a target while stimuli are presented. Fixation updates can be used to check gaze position every 100 ms or so. Computer interfaces operated via eye movements is a paradigm dramatically simplified by fixation updates. Actions are triggered by gaze on an active area of the screen for a critical duration. This is implemented simply by counting sequential fixation updates that fall within the area.

Two commands set the fixation update interval and data accumulation period in milliseconds. Usually these are set to the same value. An interval of zero disables fixation update. An update interval of 50 or 100 ms is a good choice:

fixation_update_interval = 50

fixation_update_accumulate = 50

4.3.8 Other Parameters

The EyeLink PARSE.INI configuration file contains other commands that configure the parser. These are of several types:

- Verification delays. These set the time in milliseconds that the parser requires a detector output (saccadic velocity or acceleration thresholds, or missing pupil for blink) to be stable before the parser changes its state and sends events to the data file or link. These values have been determined empirically, and there is little advantage to changing them.
- Parser filter types. Two velocity filters are available: fast and slow. The fast filter works better in most cases. The slow filter is less noise-sensitive, but increases saccade duration and decreases sensitivity slightly.
- Saccade extension. This is intended to allow the saccade period to include the lower-velocity start and end of the saccadic period. This is usually disabled, as its effect is minor.
- Internal constants. These MUST NOT be changed.

4.3.9 Sample Configurations

The complete set of commands for the most useful tracker configurations is given below. The cognitive configuration is conservative, is less sensitive to noise and ignores most saccades smaller than 0.6° . The psychophysical configuration is useful for neurological and smooth-pursuit research, and reports very small saccades. It also provides better estimates of true saccade durations and average velocities.

Cognitive Configuration:

```
recording_parse_type = GAZE
saccade_velocity_threshold = 30
saccade_acceleration_threshold = 8000
saccade_motion_threshold = 0.1
saccade_pursuit_fixup = 60
fixation_update_interval = 50
```

Psychophysical configuration:

```
recording_parse_type = GAZE
saccade_velocity_threshold = 22
saccade_acceleration_threshold = 3800
saccade_motion_threshold = 0.0
saccade_pursuit_fixup = 60
fixation_update_interval = 50
```

4.4 File Data Types

The data contents of an EDF file are organized in two streams: samples and events. Samples are used to record instantaneous eye position and head tracking data, while events are used to record important occurrences, either from the experimental application or from changes in the eye data.

Both samples and events can report eye data in several forms. These are discussed in the description of sample data. Eye movement data is parsed by the EyeLink tracker online and used to generate eye-movement events, which are discussed with application messages and button events.

4.4.1 Samples

Samples are records of eye-position, head tracking data (head position and rotation), pupil size, and button or input states. EyeLink 3 eye tracker can record up to 1000 samples per second. Each sample is stored as a binary record in the EDF file, with simple compression used to minimize disk space.

Even with compression, recording 1000 samples per second binocularly will create very large EDF files: about 100 KB of data per second.

Each sample may contain several data fields, including:

- Time of the sample (timestamp) in milliseconds
- Eye position data in gaze, HREF, or RAW data, monocular or binocular
- Eye-in-head and head-in-space data in screen pixel coordinates
- Head tracking data (head position and head rotation)
- Pupil size, monocular or binocular
- Pupil ellipse data when using the ellipse fitting tracking algorithm
- Button or input port state bits

All samples contain a timestamp, recorded in milliseconds. The time is measured from the time the tracker software was first started, and is temporally precise and uninterrupted. This constant and consistent timestamp makes detection of missing samples possible, as well as simplifying processing of data. Usually all samples produced by the EyeLink eye tracker are recorded. Other types of sample data are discussed in greater detail below.

4.4.2 Eye Position Data

Eye position data is produced by the EyeLink 3 eye tracker every 1, 2 or 4 milliseconds. It is then processed to compute eye rotation angles and to compensate for participant head motions. The processed data in one or all of the forms outlined below may be recorded in the samples. Data is written as (x, y) coordinate pairs, or two pairs for binocular data. The types of position data available are explained below.

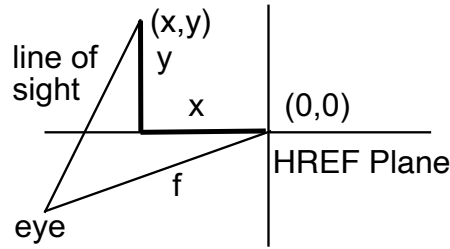
4.4.2.1 PUPIL / RAW

Pupil position data are raw (x, y) coordinate pairs from the camera. They have not been converted to eye angles or to gaze position. There may be a non-linear relationship between these data and true gaze position. Pupil position is reported in integer values, with 200 to 400 units per degree of visual angle.

When a calibration has not been performed, the EyeLink system cannot convert pupil data to the more useful data types. Raw pupil position is useful when auto-sequencing calibrations, or when the user wishes to perform their own post-hoc calibration, such as for patients with nystagmus. Most users will not need this type of data.

4.4.2.2 HREF

The HREF (head-referenced) position data reflects the line of sight in the geometric model illustrated below:



The HREF coordinates are reported in integer values, with 260 or more units per visual degree. The (x, y) positions define a point in the HREF plane at distance f (15000 units) from the eye.

The HREF units are independent of system setup, display distance, and display resolution. As such, HREF coordinates can be convenient when determining angles relative to a known eye position, or when measuring eye movement velocities, as described below.

The eye rotation angles may be directly computed from the HREF (x, y) pairs. There are several methods of specifying eye-rotation angles. The formula below gives the angular distance (eye rotation magnitude) between any two HREF points. Multiply the result by 57.296 to get the angle in degrees.

$$angle = a \cos\left(\frac{f^2 + x_1 \times x_2 + y_1 \times y_2}{\sqrt{(f^2 + x_1^2 + y_1^2) \times (f^2 + x_2^2 + y_2^2)}}\right)$$

The HREF angular resolution (X and Y) may be computed as the first derivative of the rate of change of HREF position using the formulas below. These formulas give the x and y resolution in units of change in HREF position per degree of visual angle:

$$xres = 0.01745 \times \frac{f^2 + x^2 + y^2}{\sqrt{f^2 + y^2}}$$

$$yres = 0.01745 \times \frac{f^2 + x^2 + y^2}{\sqrt{f^2 + x^2}}$$

Velocity can be calculated as the rate of change in HREF units. It is generally sufficient to compute velocity separately for the x and y coordinate directions. Velocity can be calculated with various algorithms. For example, the following velocity formula (a fast velocity filter) for a given sample **n** is equivalent to averaging the instantaneous velocity of two samples. SR is the sampling rate of the recording.

$$VFx_{[n]} = \frac{SR \times (x_{[n+1]} - x_{[n-1]})}{2 \times xres_{[n]}}$$

The following is another less noisy version of velocity calculation (a slow velocity filter) which is a weighted sum of four samples.

$$VSx_{[n]} = \frac{SR \times (x_{[n+2]} + x_{[n+1]} - x_{[n-1]} - x_{[n-2]})}{6 \times xres_{[n]}}$$

4.4.2.3 GAZE

Gaze position data reports the actual (x, y) coordinates of the participant's gaze on the display, compensating for any head movements. The units are in actual display coordinates (usually pixels) which can be set in the EyeLink configuration file PHYSICAL.INI. The default EyeLink coordinates are those of a 1024 by 768 VGA display, with (0, 0) at the top left.

The resolution data for gaze position data changes constantly depending on participant head position and point of gaze, and therefore is reported as a separate data type (see below). A typical resolution is about 36 pixels per degree for an EyeLink setup in which the distance between the participant's eyes and the display is twice the display's width, and the screen resolution is set to 1024 by 768.

The high resolution of the EyeLink tracker data is preserved by multiplying the position by a prescaler, recording the value as an integer in the EDF file, then dividing by the prescaler when the file is read. The usual prescaler value is 10, allowing gaze position to be recorded with 0.1 pixel of resolution. Actual EyeLink tracker resolution is limited only by measurement noise.

4.4.2.4 Gaze Resolution Data

For gaze position, unlike the HREF data, the relationship between visual angle and gaze position is not constant. The EyeLink eye tracker computes and can record the instantaneous angular resolution at the current point of gaze. This is measured as the units (usually pixels) per degree of visual angle, computed for a change in x and y position separately.

This resolution data may be used to estimate distances between gaze positions, and to compute velocities of eye movements. To compute the angular distance of two points, compute the x and y angular distances of the points separately by dividing the distance in pixels by the average of the resolutions at the two points, then compute the Euclidean distance from the x and y distances. For instantaneous velocity in degrees per second, compute the x and y velocities, then divide each by the x or y resolution, square and add the x and y velocities, and take the square root.

Resolution is computed at the point of gaze on the display, and can vary up to 15% over the display. The resolution data in an EDF file is recorded using a prescaler for extra precision, as noted in the gaze-position section.

4.4.2.5 Eye-in-Head Data

During an EyeLink 3 recording session, the participant's head is typically not restrained and therefore, both head and eye movements contribute to gaze. In addition to GAZE, EyeLink 3 provides another novel pixel-based coordinate, Eye-in-Head data, to report the contribution of the eye's rotation to gaze.

The eye-in-head 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. The eye-in-head pixel coordinate is the gaze location on this virtual screen. Please see this blog (<https://www.sr-research.com/eye-tracking-blog/background/eyelink-3-screen-pixel-data/>) for further illustration of the eye-in-head coordinate.

The eye-in-head data is recorded to the EDF file on a sample-by-sample basis. The eye-in-head data of the starting and ending samples are also available to each parsed eye event, along with the averaged data across all samples within the event.

4.4.1 Head Tracking Data

Unless Marker tracking is disabled, the EyeLink 3 provides high-speed (up to 1000 Hz) drift-free six degrees of freedom (6DOF) head-tracking data that is synchronized with the eye movement data. The head tracking data is produced by the eye tracker every 1, 2 or 4 milliseconds and reported in the same eye movement sample. The types of head tracking data available are explained below.

4.4.1.1 6DOF Head Tracking

The EyeLink 3 provides 6DOF Head Tracking data. With an unrestrained head, it is free to change position through translation – movement along the three axes of the Cartesian coordinate system, 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, providing 6 data points in total. The rotation angles are typically referred to as pitch (the rotation around the X-axis), yaw (the rotation around the Y-axis), and roll (the rotation around the Z-axis). Please see this blog post (<https://www.sr-research.com/eye-tracking-blog/background/head-tracking/>) for an illustration and the origin of the coordinate systems.

The EyeLink 3 uses an IMU installed on the front enclosure to track head movements. If the IR Marker is used, the head tracking data provided by the IMU is fused with the position data provided by the Marker to provide 6DOF positional and rotational head data with no or little drift. When operating the EyeLink 3 with the Marker removed or disabled, the head tracking data is provided by the IMU only. As a result, absolute head position data is not available and the rotational data is susceptible to drift over time. Therefore, when using the head tracking data users should pay attention to the Marker tracking status message reported in the sample line (see Section 4.9.2.2).

Head tracking data is reported in the sample data together with eye tracking data. For parsed eye events, head tracking data of the starting and ending samples and average values across all samples within an event, are also provided.

4.4.1.2 Head-in-Space

For the EyeLink 3, reporting of the participant's head pose can also be done in screen pixel coordinates. For the pixel-based head coordinate (Head-in-Space), 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. Please see this blog (<https://www.sr-research.com/eye-tracking-blog/background/eyelink-3-screen-pixel-data/>) for further illustration of the head-in-space coordinate.

The head-in-space data is recorded to the EDF file for each sample. Each parsed eye event in the EDF file also reports the head-in-space data of the starting and ending samples and the averaged data across all samples within that event.

Together, the novel head-in-space and eye-in-head pixel-based coordinates provide a simple and convenient solution for determining the relative contributions of head and eye movements to gaze shifts made in traditional eye tracking tasks such as visual search, scene perception, reading, prosaccades and smooth pursuit.

4.4.2 Pupil Size Data

Pupil size is also measured by the EyeLink 3. It may be reported as pupil area, or pupil diameter. The pupil size data are not calibrated, and the units of pupil measurement will vary with participant setup. Pupil size is an integer number, in arbitrary units. Typical pupil area is 100 to 10000 units, with a precision of 1 unit, while pupil diameter is in the range of 400-16000 units. Both measurements are noise-limited, with noise levels of 0.2% of the diameter. This corresponds to a resolution of 0.01 mm for a 5 mm pupil.

Pupil size measurements are affected by up to 10% by pupil position, due to the optical distortion of the cornea that accompanies rotations of the eye to view the

peripheral parts of the display, and camera-related factors. If you intend to measure pupil size, the participant should ideally not move their eyes during the trials. They can be presented with a fixation point with aural stimulus presentation, or a single stimulus position at display center may be used. It is also possible to counterbalance stimulus position during the experiment. Since pupil size is also affected by luminance, cognitive load, and emotional responses, those factors not being explicitly manipulated should also be equated across conditions to achieve a valid measure of pupil size. Lastly, since pupil size is recorded in arbitrary units that are not calibrated across participants, measures of pupil size are best recorded as percent change relative to a baseline period.

4.4.2.1 Pupil Ellipse Data

Pupil ellipse data is also available when using ellipse-fitting pupil tracking algorithm. For both monocular and binocular recordings, EyeLink 3 can provide the X, Y position of the pupil ellipses for the tracked eyes in camera coordinates and 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. EyeLink 3 also reports the angle (in degrees) between the major-axis and x-axis for the eyes; however, please note that the angle data can be unreliable when the fitted ellipse is very close to a circle.

4.4.3 Button Data

The state of up to 8 buttons or input port bits may be recorded in each sample. Button ports, bits, and polarity may be set in the EyeLink tracker configuration file `BUTTONS.INI`.

The button data consists of two 8-bit fields, recorded as a 16-bit number. The lower 8 bits contain the current status of the 8 buttons (bit = 0 if off, 1 if pressed). Each of the upper 8 bits will be set to 1 if its button has changed since the last sample. The least-significant bit in each byte corresponds to button 1, and the most-significant to button 8.

4.5 Events

One of the most significant aspects of the EyeLink tracking system and the EDF file format is its online parsing of eye-movement data to identify and record events such as fixations and saccades. Event data can also include application data such as the time of a display change and experimental conditions, or real-time events such as button presses. Events also define the start and end of blocks of data in the EDF file, allowing applications to process data recorded with different data types.

Each event contains one or two timestamps (in milliseconds) and several data fields. Data for each event are compressed, and an extendable data format allows compatibility with future expanded file formats.

Note that not all the event data listed here are available through the EDF2ASC translator program.

4.5.1 Messages

The most flexible event type is the message event. A message is most often text, but can contain any type of binary data as well. Messages are created by the application software, and sent over the link to the EyeLink tracker, which timestamps the message and writes it to the EDF file. The application does not need precise time keeping, since link delays are usually very low (on the order of 1 or 2 milliseconds).

Message events are used for two main purposes. They serve to precisely record the time of important events, such as display changes, participant responses, etc. They also record experiment-specific data, such as trial conditions.

Message events consist of a millisecond timestamp, and the message data. Current EyeLink applications only support text messages with zero-terminated strings. If sending lots of messages at a time, users are recommended to combine multiple messages into a single one to avoid message loss. Recent versions of the EyeLink host software removes the restrictions on the length of messages that can be accepted by the eye tracker.

4.5.2 Buttons

Each button event records a change in state (pressed or released, 1 or 0) of up to 8 buttons or input port bits, monitored by the EyeLink tracker. Button ports, bits, and polarity may be set in the EyeLink tracker configuration file `BUTTONS.INI`.

Each button event contains a timestamp (in milliseconds) of the time the button was pressed, and a word of button data. This consists of two 8-bit fields, recorded as a 16-bit number. The lower 8 bits contain the current status of the 8 buttons (bit = 0 if off, 1 if pressed). Each of the upper 8 bits will be set to 1 if its button has changed since the last sample. The least-significant bit in each byte corresponds to button 1, and the most-significant is button 8.

Button events are usually recorded at the start of each recording block, with all upper 8 bits (change flags) set to 0. This allows applications to track the current button state at all times.

4.5.3 Eye Movement Events

Events are generated by the EyeLink tracker in real-time from the eye-movement data stream. These provide an efficient record of the data in a form ready to use for most types of eye-movement research. The use of events

simplifies the analysis of sample data as well. For example, analysis of pursuit gain requires rejection of saccades, which are clearly marked in the events. Eye-movement events are generated in pairs: one event at the start of an eye-movement condition, and another at the end of the condition. When used in real-time processing with data sent via the link, the event pairs allow an application to monitor eye movement state in real time. These pairs accurately label the samples in a file between the events, as the file is read from beginning to end.

Eye-movement events are always labeled by which eye generated the event. If binocular data is recorded, a separate start and end event is generated for each eye. The time differences between eyes are very important for neurological analysis, for example. The main classes of data events are summarized below.

Start events contain the time of the start of the eye-movement condition. They may also contain the state of the eye at the onset of the condition: for example, the position and pupil size at the start of a fixation.

End events contain both the start and end time of the event. The end time is actually the time of the last sample in the event, so length of an event must be computed as the difference between the end and start times plus the time between samples (1, 2 or 4 milliseconds). End events also contain summary data on the condition as well: average gaze position of a fixation, for example.

Please note that when reading real-time data through the link, the event data will be delayed from the corresponding sample. This is caused by the velocity detector and event validation processing in the Host software. The time stamps in the event reflect the true (sample) times.

4.5.3.1 Record Blocks

Each block of recorded data in an EDF file begins with one or both of a STARTSAMPLES or STARTEVENTS event. These contain the time of the recording start, and specify what data can be expected to follow. This allows for flexible adaptation to almost any file-data configuration. Information included in the start events include:

- Which eye recorded from
- Sample data rate
- Sample data contents
- Event data contents
- Event types included
- Gaze-position and velocity prescalers

Each block of recorded data ends with one or both of an ENDSAMPLES or ENDEVENTS event. This simply terminates the data block, and specifies the time that recording ended.

The text files generated from EDF files by the EDF2ASC translator utility create a simplified form of START and END events. A single START or END line is produced for both sample and event blocks, which specifies which eye was

recorded from, and whether samples, events, or both, are present in the following data block. Other data is given on following SAMPLES, EVENTS, PRESCALER, etc. lines.

4.5.3.2 Fixations

The online EyeLink tracker parser processes eye-position data, identifying saccades and fixations and compiling data on these conditions. For fixations (which are defined as starting when the end of a saccade is detected by the parser, and ending when the onset of a saccade is detected), these data include:

- The time of the first and last sample in the fixation
- The eye that generated the event
- Average gaze or HREF position data during the fixation
- Average pupil size during the fixation
- Average gaze data angular resolution during the fixation
- Head-in-space data at the beginning and end of the fixation as well as the averaged data during the fixation
- Eye-in-head data at the beginning and end of the fixation as well as the averaged data during the fixation
- Head rotation (pitch, yaw, roll) and head position (x, y, z) data at the beginning and end of the fixation as well as the averaged data during the fixation

All of these data may appear in the ENDFIX event that terminates the fixation. Only the starting data can appear in the STARTFIX event that initiates the fixation.

In a sorted EDF file or a text ASC file (produced by EDF2ASC) that contains both samples and events, the STARTFIX event will precede the first sample in the file that is part of the fixation, and the ENDFIX event will follow the last sample in the fixation. This allows the sample data in the files to be processed by saccade or fixation in a single pass.

The data contained in STARTFIX and ENDFIX events may be configured by modifying the DATA.INI file for the EyeLink tracker. For most research, only simple fixation statistics are required, such as average position and pupil size. By default, STARTFIX events are configured to contain only the start time of the fixation.

Other data in the ENDFIX event may be useful for some types of analysis. The resolution may be used to estimate angular distance between fixations. Angular (Euclidean) distance can be calculated by subtracting the x and y position for the fixations, and dividing by the average corresponding resolution data.

$$dx = (x1 - x2) / ((rx1 + rx2)/2.0);$$

```
dy = (y1 - y2) / ((ry1 + ry2)/2.0);  
dist = sqrt(dx*dx + dy*dy);
```

4.5.3.3 Fixation Updates

Data within a fixation can be broken into smaller time segments, useful for real-time analysis and control via eye movements. FIXUPDATE events may be produced at regular intervals within a fixation, and contain data for a specified length of time within the fixation. The data recorded in the FIXUPDATE event is similar to that in the ENDFIX event.

FIXUPDATE events are most useful in real-time applications using the link. Recording samples in the EDF file is more useful for most psychophysical research.

4.5.3.4 Saccades

The EyeLink tracker's parser detects saccades by the velocity and acceleration of the eye movements. Because of variations in acceleration profiles, the onset and offset point of saccades can vary by one or two samples from "ideal" segmentation done by hand. Nonetheless, the saccadic data compiled by the parser is sufficient for most neuro-psychophysical research, including smooth pursuit. Some cognitive research may ignore the saccadic data and only use the fixation data produced by the EyeLink parser. The data produced for saccades includes:

- The time of the first and last sample in the saccade
- The eye that generated the event
- Start and end HREF or gaze position data
- Saccade amplitude (the angular distance between the start and end gaze points)
- Peak eye-movement velocity
- Gaze-data angular resolution
- Head-in-space data at the beginning and end of the saccade as well as the averaged data during the saccade
- Eye-in-head data at the beginning and end of the saccade as well as the averaged data during the saccade
- Head rotation (pitch, yaw, roll) and head position (x, y, z) data at the beginning and end of the saccade as well as the averaged data during the saccade

All of these data may appear in the ENDSACC event that terminates the saccade. Only the starting data can appear in the STARTSACC event that initiates the saccade.

In a sorted EDF file or a text ASC file (produced by EDF2ASC) that contains both samples and events, the STARTSACC event will precede the first sample in the file that is part of the saccade, and the ENDSACC event will follow the last sample in the saccade. This allows the sample data in the files to be processed

as saccade or fixation in a single pass. The data contained in STARTSACC and ENDSACC events may be configured by modifying the DATA.INI file for the EyeLink tracker. Saccadic events may be eliminated entirely, if only fixation data is required. By default, STARTSACC events are configured to contain only the start time of the saccade.

The peak and average velocity data for saccades is especially valuable for neuro-psychophysical work. These are the absolute velocities measured as the Euclidean sum of x and y components. The EyeLink parser computes velocity by use of a multiple-sample moving filter adjusted for different sampling rates. This is optimal for detection of small saccades, minimizes the extension of saccade durations, and preserves saccadic peak velocities.

Other data in the ENDSACC event may be useful for some types of analysis. The start and end position, and start and end resolution, may be used to compute saccadic amplitude using the same calculation method discussed in Section 4.5.3.2.

In general, the saccadic amplitude will be slightly less than the distance between average position of the preceding and following fixations, as saccades do not include sub-threshold velocity parts of the eye movement that precede and follow the rapid phase.

4.5.3.5 Blinks

The STARTBLINK and ENDBLINK events bracket parts of the eye-position data where the pupil size is very small, or the pupil in the camera image is missing or severely distorted by eyelid occlusion. Only the time of the start and end of the blink are recorded.

Blinks are always preceded and followed by partial occlusion of the pupil, causing artificial changes in pupil position. These are sensed by the EyeLink parser, and marked as saccades. The sequence of events produced is always:

- STARTSACC
- STARTBLINK
- ENDBLINK
- ENDSACC

Note that the position and velocity data recorded in the ENDSACC event following a blink are not valid. All data between the STARTSACC and ENDSACC events in a blink-containing saccade should be discarded. The duration of the blink may be computed by either the duration of the missing pupil between the STARTBLINK and ENDBLINK events, or the difference between the ENDSACC and STARTSACC events in the sequence.

Fixations immediately preceding and following blinks should be examined carefully, as they may have been truncated or produced by the blink process.

Discarding fixations shorter than 100 ms proceeding or following blinks will eliminate most artifacts.

4.6 Setting File Contents

The data recorded in samples and events may be set in the EyeLink configuration file DATA.INI, and maybe overwritten by the settings in LASTRUN.INI and FINAL.INI. As a result, it is preferred to send those commands to the tracker across the link, via the API `eyecmd_printf()`. Similar commands exist for samples and events sent over the link for real-time applications.

4.6.1 Sample Data

The sample data written to the EDF file are controlled by the "*file_sample_data*" command, which is followed by a list of data types to include. A single keyword is included for each type:

Keyword	Data Type
LEFT, RIGHT	Sets the intended tracking eye (usually include both LEFT and... RIGHT)
GAZE	includes screen gaze position data
GAZERES	includes units-per-degree screen resolution at point of gaze
HREF	head-referenced eye position data
HMARKER	Head tracking (position and rotation) data
PUPIL	raw pupil coordinates
AREA	pupil size data (diameter or area)
BUTTON	buttons 1-8 state and change flags
STATUS	warning and error flags
INPUT	input port data lines

The default data are:

```
file_sample_data =  
LEFT,RIGHT,GAZE,GAZERES,PUPIL,HREF,HMARKER,AREA,STATUS,INPUT
```

Usually, data for both eyes are enabled, and the options in the EyeLink tracker Host software are used to set which eye is actually tracked. Recording of gaze and pupil area is essential for most work, and resolution is important if velocity is to be computed later. Recording of HREF data is optional.

4.6.2 Event Data

Eye-movement events are generated by processing one of the types of eye movement data (GAZE or HREF) as specified by the "*recording_parse_type*" command (the default setting is GAZE). This command may be edited in the DEFAULTS.INI file of the EyeLink tracker, or may be sent over the link.

recording_parse_type = <data type: one of GAZE or HREF>

The data type used for parsing will always be included in the event data. Other data reported for eye-movement events are controlled with the "*file_event_data*" command. This is followed by a list of data types and options, selected from the list below:

Keyword	Effect
GAZE	includes display (gaze) position data
GAZERES	includes units-per-degree screen resolution (for start, end of event)
HREF	includes head-referenced eye position
AREA	includes pupil area or diameter
VELOCITY	includes velocity of parsed position-type (average, peak, start and end)
STATUS	includes warning and error flags, aggregated across event (not yet supported)
FIXAVG	include ONLY averages in fixation end events, to reduce file size
NOSTART	start events have no data other than timestamp

The "*file_event_data*" command may be edited in the DATA.INI file of the EyeLink tracker, or may be sent over the link. Some example settings are given below:

GAZE,GAZERES,AREA,HREF,VELOCITY	- default: all useful data
GAZE,GAZERES,AREA,FIXAVG,NOSTART	- reduced data for fixations
GAZE,AREA,FIXAVG,NOSTART	- minimal data

4.6.3 Event Types

The "*file_event_filter*" command specifies what type of events will be written to the EDF file. It may be changed in the DATA.INI file of the EyeLink tracker, or may be sent over the link. The command is followed by a list of data types and options, selected from the list below:

Keyword	Effect
LEFT, RIGHT	Sets the intended tracking eye (usually include both LEFT and RIGHT)
FIXATION	includes fixation start and end events
FIXUPDATE	includes fixation (pursuit) state update events
SACCADE	includes saccade start and end events
BLINK	includes blink start and end events
MESSAGE	includes messages (ALWAYS use)
BUTTON	includes button 1-8 press or release events
INPUT	includes changes in input port lines

The following is an example command illustrating the default event configuration:

```
file_event_filter= LEFT,RIGHT,FIXATION,SACCADE,BLINK,MESSAGE,BUTTON
```

4.7 EDF File Utilities

A number of utility programs are included in the EyeLink software package, to process and view EDF files. The utility EDF2ASC translates EDF files into text ASC files for processing with user applications.

On Windows, a Visual EDF2ASC converter is bundled with the EyeLink Data Viewer software (<https://www.sr-research.com/support/thread-7.html>). After installation, the converter can be found at “Start -> Programs -> SR Research -> EyeLink -> VisualEDF2ASC”. A command line version of the converter is bundled with the EyeLink Developers Kit for Windows (<https://www.sr-research.com/support/thread-13.html>). On macOS, there is a GUI version of the converter called EDFConverter, which can be found at <https://www.sr-research.com/support/thread-23.html>. A command line version of the converter is bundled with the EyeLink Developers Kit for macOS (<https://www.sr-research.com/support/thread-13.html>)

EyeLink Data Viewer (<https://www.sr-research.com/support/thread-7.html>) is an optional tool that allows displaying, filtering, and reporting the output of EyeLink Data Files. Please check EyeLink Data Viewer User’s Manual for details. Please note that viewing and analyzing EyeLink 3 recording files require Version 5.0 or later of the EyeLink Data Viewer software, which is Windows-only.

4.8 Using ASC Files

The EDF file format is an efficient storage format for eye movement data; however, the file cannot be viewed directly in text editors because it is a binary file. The EDF files can be processed directly by some EDF file reading packages (e.g., some written in MATLAB, R) or be converted through an EDF2ASC conversion tool into a text version that is easily accessible from almost any programming language. The converted ASC files contain lines of text, with each line containing data for a single sample, event or data parameter.

The EDF2ASC utility reads one or more EDF files, creating text files with the same name but with the ASC extension. It scans the input file, reordering data as required, and converting samples and events into lines of text. It can also compute resolutions and instantaneous velocity for sample data. An ASC file will generally be about twice as large as the original EDF file.

The EDF2ASC converter utility can be run from the GUI interface (called EDF Converter) assuming that you have installed the EyeLink Data Viewer software (<https://www.sr-research.com/support/thread-7.html>). Users can also run the EDF2ASC converter from the command line prompt, assuming that Windows Display Software (<https://www.sr-research.com/support/thread-13.html>) has been installed. To translate an EDF file from the command line prompt, type "edf2asc" followed by the name of the file to be translated and any conversion options. Wildcards (* and ?) may be used in the input file name, allowing conversion of multiple EDF files to ASC files with the same name. Optionally, a second file name can be specified for the output ASC file. Many options exist for the file conversion. One set of options will be best for your work, and creation of a single-line batch file (called, for example, E2A.BAT) will make the use of the translator easier. The following table lists commonly-used options.

-l or -nr	outputs left-eye data only if binocular data file
-r or -nl	outputs right-eye data only if binocular data file
-sp	outputs sample raw pupil position if present
-sh	outputs sample HREF angle data if present
-sg	outputs sample GAZE data if present (default)
-res	outputs resolution data if present
-vel	outputs velocity data in samples if possible
-s or -ne	outputs sample data only
-e or -ns	outputs event data only
-nse	blocks output of start events
-nmsg	blocks message event output
-neye	outputs only non-eye events (for sample-only files)
-miss <string>	replaces missing data in ASC file with <string>
-setres <xr> <yr>	uses a fixed <xr>,<yr> resolution always
-defres <xr> <yr>	uses a default <xr>,<yr> resolution if none in file

The following conversion options are specifically for an EyeLink 3 recording:

-hr	outputs head resolution
-pe	outputs pupil ellipse data
-geom	outputs messages with !GEOM, !IMU, and !MIPI

4.9 The ASC File Format

The ASC file format is defined by the type of data lines that appear in it, the format of these lines, and the order in which these lines occur. Data lines consist of several types:

- Blank or comment lines, which are ignored. The first non-blank character on a comment line is one of "#", "/" or ";".
- File preamble or file-description lines. These begin with "***". Usually these lines are ignored when processing the ASC file.

- Sample data lines. Each line begins with a number, representing the time of the sample.
- Event and data-description lines. Each line begins with a keyword, identifying the type of data in the rest of the line.

4.9.1 ASC File Structure

For sample-only ASC files, file structure is very simple. These files are produced using the "-s" or "-ne" options of EDF2ASC, and only sample data lines are present. There is no data on what type of eye-position data or which eye produced the data. Recording blocks are separated by sample lines consisting of missing-value data (dots or the string specified with the "-miss" option). Gaps in the sequence of sample timestamps may also be used to determine sample block divisions.

For ASC files containing events (and optionally samples), the order of lines is carefully structured. The file begins with a copy of the EDF file's preamble, with each line preceded by "***". The preamble reports the file version, date created, and any description from the application.

The sequence of events and samples in the ASC file follows strict rules. These are:

- START events mark the beginning of each recording block, and END events mark the end of each block. The START events also specifies which eye's data is present, and if samples, events, or both are present.
- Data-specification lines follow each START event. These specify the type of data in samples and events in the block, and allow flexible data processing without prescanning the file.
- All eye-movement samples and events occur between the START event and the matching END event.
- All events and samples appear in temporal order. That is, the timestamps of samples, end-time timestamps of eye-movement end events, and start-time timestamps of all other events will be the same or greater than any preceding data.
- Eye-data samples are nested between eye-movement start and end events. For example, the first sample in a fixation will follow the SFIX event for that fixation, and the EFIX event for a fixation will follow the last sample in the fixation. This allows on-the-fly classification of samples as the data file is read.

Before writing an analysis program to process an ASC file, it is helpful to convert a small EDF file containing the data of interest, and examine it with a text editor or print it out.

4.9.2 Sample Line Format

Sample lines contain time, eye position (raw, HREF, or GAZE), pupil size, head position and rotation data, and head-in-space and eye-in-head data. Optionally, velocity, resolution, and pupil ellipse data may be included. Each sample line begins with a timestamp. The time stamp field is followed by X and Y position pairs and pupil size data for the tracked eye, and optionally by X and Y velocity pairs for the eye, resolution X and Y values, and the extended head tracking and eye position data. Missing data values are represented by a dot ("."), or the text specified by the "-miss" option to EDF2ASC.

Several possible sample line formats are possible. These are listed below.

SAMPLE LINE FORMATS

- Monocular recording

<time> <xp> <yp> <ps> [<xv> <yv> <xr> <yr>] <xhr> <yhr> <zhr> <xhp> <yhp> <zhp> <hisx> <hisy> <eihx> <eihy> [<hisxr> <hisyr> <eihxr> <eihyr>] [<pex> <pey> <pema> <pemi> <pea>]

Note:

- <xv> <yv> are the optional gaze velocity data (enabled by -vel switch);
- <xr> <yr> are the optional gaze resolution data (enabled by -res switch);
- <hisxr> <hisyr> <eihxr> <eihyr> are the optional head-in-space and eye-in-head resolution data (enabled by -hr switch);
- <pex> <pey> <pema> <pemi> <pea> are the optional pupil ellipse data if using the ellipse-fitting pupil tracking algorithm (enabled by -pe switch).
- head tracking data (<xhr> <yhr> <zhr> <xhp> <yhp> <zhp>) can be disabled with the "-nht" switch.
- extended eye/head position data (<hisx> <hisy> <eihx> <eihy>) can be disabled with the "-ned" switch.

- Binocular recording

<time> <xpl> <ypl> <psl> <xpr> <ypr> <psr> [<xvl> <yvl> <xvr> <yvr>] [<xr> <yr>] <xhr> <yhr> <zhr> <xhp> <yhp> <zhp> <hisx> <hisy> <eihlx> <eihrx> <eihcx> <eihly> <eihry> <eihcy> [<hisxr> <hisyr> <eihxr> <eihyr>] [<pelx> <pely> <pelma> <pelmi> <pela> <perx> <pery> <perma> <permi> <pera>]

Note:

- <xvl> <yvl> <xvr> <yvr> are the optional gaze velocity data (enabled by vel switch);
- <xr> <yr> are the optional gaze resolution data (enabled by -res switch);
- <hisxr> <hisyr> <eihxr> <eihyr> are the optional head-in-space and eye-in-head resolution data (enabled by -hr switch);
- <pelx> <pely> <pelma> <pelmi> <pela> <perx> <pery> <perma> <permi> <pera> are the optional pupil ellipse data if using the ellipse-fitting pupil tracking algorithm (enabled by -pe switch).
- head tracking data (<xhr> <yhr> <zhr> <xhp> <yhp> <zhp>) can be disabled with the "-nht" switch.

- extended eye/head position data (<hisx> <hisy> <eihlx> <eihrx> <eihcx> <eihly> <eihry> <eihcy>) can be disabled with the “-ned” switch.

DATA NOTATIONS

<time>	timestamp in milliseconds
<xp>, <yp>	monocular X and Y position data
<xpl>, <ypl>	left-eye X and Y position data
<xpr>, <ypr>	right-eye X and Y position data
<ps>	monocular pupil size (area or diameter)
<psl>	left pupil size (area or diameter)
<psr>	right pupil size (area or diameter)
<xv>, <yv>	instantaneous velocity (degrees/sec)
<xvl>, <yvl>	left-eye instantaneous velocity (degrees/sec)
<xvr>, <yvr>	right-eye instantaneous velocity (degrees/sec)
<xr>, <yr>	X and Y resolution (position units/degree)
<xhr> <yhr> <zhr>	Rotation angle (in degrees) of the head around the X-axis (pitch), the Y-axis (yaw), and the Z-axis (roll)
<xhp> <yhp> <zhp>	Translational movements along the X, Y, and Z axes
<hisx> <hisy>	Head position X, Y in screen pixel coordinates
<eihx> <eihy>	X, Y rotation of the monocular eye within the head projected onto a virtual screen (in screen pixel coordinates)
<eihlx> <eihly>	X, Y rotation of the left eye within the head projected onto a virtual screen (in screen pixel coordinates)
<eihrx> <eihry>	X, Y rotation of the right eye within the head projected onto a virtual screen (in screen pixel coordinates)
<eihcx> <eihcy>	X, Y rotation of the “cyclopean” eye within the head projected onto a virtual screen (in screen pixel coordinates)
<hisxr><hisyr>	Angular resolution (in screen pixels per visual degree) along the X-, or X-axis at the current head-in-space position.

<eihxr> <eihyr>	Angular resolution (in screen pixels per visual degree) along the X-, or Y-axis at the current eye-in-head position.
<pex> <pey>	X, Y position of the pupil ellipse for the monocular eye in camera coordinate
<pelx> <pely>	X, Y position of the pupil ellipse for the left eye in camera coordinate
<perx> <pery>	X, Y position of the pupil ellipse for the right eye in camera coordinate
<pema>	Major axis (in camera pixels) of the monocular pupil ellipse.
<pelma>	Major axis (in camera pixels) of the left pupil ellipse.
<perma>	Major axis (in camera pixels) of the right pupil ellipse.
<pemi>	Minor axis (in camera pixels) of the monocular pupil ellipse.
<pelmi>	Minor axis (in camera pixels) of the left pupil ellipse.
<permi>	Minor axis (in camera pixels) of the right pupil ellipse.
<pea>	Angle (in degrees) between the major-axis and x-axis for the monocular eye.
<pela>	Angle (in degrees) between the major-axis and x-axis for the left eye.
<pera>	Angle (in degrees) between the major-axis and x-axis for the right eye.

4.9.2.1 Samples Recorded in Corneal Reflection Mode

If the data file being processed was recorded using Pupil-CR mode, each sample line has an added 4 (monocular) or 6 (binocular) character fields before the head tracking data. These fields encode any warning messages relating to the corneal reflection processing that were present for that sample.

- MONOCULAR Corneal Reflection (CR) Samples

"..." if no warning for sample
first character is "I" if sample was interpolated
second character is "W" if eye exceeded the calibrated angle
third character is "C" if CR missing
fourth character is "R" if CR recovery in progress

- BINOCULAR Corneal Reflection (CR) Samples

"...." if no warning for sample
first character is "I" if sample was interpolated
second character is "W" if any of the eyes exceeded the calibrated angle
third character is "C" if LEFT CR missing
fourth character is "R" if LEFT CR recovery in progress
fifth character is "C" if RIGHT CR missing
six character is "R" if RIGHT CR recovery in progress

4.9.2.2 Status of Marker Tracking

EyeLink 3 sample lines also provide a string that encodes the status of the Marker tracking for the head tracking data. They are useful for the interpretation of the head tracking data.

- "...." if no warning for Marker tracking
- an X at the first character position indicates the Marker is turned off for IMU-only pose data tracking.
- an X at the second character position indicates that no Marker has been detected for longer than a certain time (settable through the 'fusion_horizon_us' command, the default is 10 seconds -above this would suggest that the drift of the IMU alone will be too high to rely on the data).
- an X at the third character position indicates Marker missing (currently > 30 ms) or not yet present
- an X at the fourth character position is designed as a general warning to the user of low pose data confidence.

4.9.3 Event Line Formats

Each type of event has its own line format. These use some of the data items listed below. Each line begins with a keyword (always in uppercase) and items are separated by one or more tabs or spaces.

DATA NOTATIONS

<eye>	which eye caused event ("L" or "R")
<time>	timestamp in milliseconds
<stime>	timestamp of first sample in milliseconds
<etime>	timestamp of last sample in milliseconds
<dur>	duration in milliseconds
<axp>, <ayp>	average X and Y position
<sxp>, <syp>	start X and Y position data
<exp>, <eyp>	end X and Y position data
<aps>	average pupil size (area or diameter)
<av>, <pv>	average, peak velocity (degrees/sec)
<ampl>	saccadic amplitude (degrees)
<xr>, <yr>	X and Y resolution (position units/degree)
<hissx>, <hissy>	X, Y head position in screen pixel coordinates when the event starts
<hisex>, <hisey>	X, Y head position in screen pixel coordinates when the event ends
<hisax>, <hisay>	Average X, Y head position in screen pixel coordinates
<eihsx>, <eihsy>	Participant's eye pose in relation to the head, without head-movement contribution, represented as a gaze point on the screen (X, Y in screen pixel coordinates) when the event starts
<eihex>, <eihey>	Participant's eye pose in relation to the head, without head-movement contribution, represented as a gaze point on the screen (X, Y in screen pixel coordinates) when the event ends
<eihax>, <eihay>	Average rotation of the eye within the head along the X- and Y-axis (in screen pixel coordinates)
<hrsx>, <hrsy>, <hrsx>	Rotation angle (in degrees) of the head around the X-axis (pitch), the Y-axis (yaw), and the Z-axis (roll) when the event starts.
<hrex>, <hrey>, <hrez>	Rotation angle (in degrees) of the head around the X-axis (pitch), the Y-axis (yaw), and the Z-axis (roll) when the event ends.
<hrax>, <hray>, <hrax>	Average rotation angle (in degrees) of the head around the X-axis (pitch), the Y-axis (yaw), and the Z-axis (roll).
<hpsx>, <hpsy>, <hpsz>	Translational movements along the X, Y, and Z axes when the event starts.
<hpex>, <hpey>, <hpez>	Translational movements along the X, Y, and Z axes when the event ends.
<hpax>, <hpay>, <hpaz>	Average translational movements along the X, Y, and Z axes.

4.9.3.1 Messages

- MSG <time> <message>

A message line contains the text of a time stamped message. A message is typically sent to the EyeLink tracker by an application. It contains data for analysis or timestamps important events such as display changes or participant responses. The <message> text fills the entire line after the timestamp and any blank space following it.

4.9.3.2 Buttons

- BUTTON <time> <button #> <state>

Button lines report a change in state of tracker buttons 1 through 8. The <button #> reports which button has changed state. The <state> value will be 1 if the button has been pressed, 0 if it has been released. Tracker buttons may be created to monitor any digital input port bit, and may be created by link commands or in the tracker configuration file BUTTONS.INI or FINAL.INI.

4.9.3.3 Block Start & End

- START <time> <eye> <types>
- END <time> <types> RES <xres> <yres>

START lines mark the beginning of a block of recorded samples, events, or both. The start time is followed by a list of keywords which specify the eye recorded from, and the types of data lines in the block. The eye recorded from is specified by "LEFT" for left-eye, "RIGHT" for right-eye, and both "LEFT" and "RIGHT" for binocular. The types of data lines included are specified by "SAMPLES" for samples only, "EVENTS" for events only, and both "SAMPLES" and "EVENTS" for both.

END lines mark the end of a block of data. The <types> are specified, as it is possible to turn recording of samples and events on and off independently. However, this is not suggested, and for most applications the <types> in the END line can be ignored. The two values following the "RES" keyword are the average resolution for the block: if samples are present, it is computed from samples; otherwise it summarizes any resolution data in the events. Note that resolution data may be missing: this is represented by a dot (".") instead of a number for the resolution.

4.9.3.4 Fixations

- SFIX <eye> <stime> <hissx> <hissy> <hisex> <hisey> <hisax> <hisay> <eihsx> <eihsy> <eihex> <eihey> <eihax> <eihay> <hrsx> <hrsy> <hrsyz>

<hrex> <hrey> <hrez> <hrax> <hray> <hraz> <hpsx> <hpsy> <hpsz> <hpex>
<hpey> <hpez> <hpax> <hpay> <hpaz>

- EFIX <eye> <stime> <etime> <dur> <axp> <ayp> <aps> [<xr> <yr>] <hissx>
<hissy> <hisex> <hisey> <hisax> <hisay> <eihsx> <eihsy> <eihex> <eihey>
<eihax> <eihay> <hrsx> <hrszy> <hrszy> <hrex> <hrey> <hrez> <hrax> <hray>
<hraz> <hpsx> <hpsy> <hpsz> <hpex> <hpey> <hpez> <hpax> <hpay>
<hpaz>

Note that [<xr> <yr>] are optional output enabled by passing in the -res switch. For both the start and end events, head tracking data (<hrsx> <hrszy> <hrszy> <hrex> <hrey> <hrez> <hrax> <hray> <hraz> <hpsx> <hpsy> <hpsz> <hpex> <hpey> <hpez> <hpax> <hpay> <hpaz>) can be disabled with the “-nht” switch. Additionally, extended eye/head position data (<hissx> <hissy> <hisex> <hisey> <hisax> <hisay> <eihsx> <eihsy> <eihex> <eihey> <eihax> <eihay>) can be disabled with the “-ned” switch.

The start of fixations are reported with a SFIX line, which can be eliminated with the EDF2ASC “-nse” option. The <eye> is “L” or “R”, indicating the eye's data that produced the event.

The end of and summary data on the fixation is reported with the EFIX line. This reports the time of the first and last sample in the fixation, and computes the duration of the fixation in milliseconds. The average X and Y eye position (the type of position data is determined when the event was generated) and the average pupil size (area or diameter) are reported. Optionally, the eye-position angular resolution (in units per visual degree) is given as well.

All samples that are within the fixation will be listed between the SFIX and EFIX event for each eye, simplifying data analysis.

4.9.3.5 Saccades

- SSACC <eye> <stime> <hissx> <hissy> <hisex> <hisey> <hisax> <hisay>
<eihsx> <eihsy> <eihex> <eihey> <eihax> <eihay> <hrsx> <hrszy> <hrszy>
<hrex> <hrey> <hrez> <hrax> <hray> <hraz> <hpsx> <hpsy> <hpsz> <hpex>
<hpey> <hpez> <hpax> <hpay> <hpaz>
- ESACC <eye> <stime> <etime> <dur> <sxp> <syp> <exp> <eyp> <ampl> <pv>
[<xr> <yr>] <hissx> <hissy> <hisex> <hisey> <hisax> <hisay> <eihsx> <eihsy>
<eihex> <eihey> <eihax> <eihay> <hrsx> <hrszy> <hrszy> <hrex> <hrey>
<hrez> <hrax> <hray> <hraz> <hpsx> <hpsy> <hpsz> <hpex> <hpey> <hpez>
<hpax> <hpay> <hpaz>

Note that [<xr> <yr>] are optional output enabled by passing in the -res switch. For both the start and end events, head tracking data (<hrsx> <hrszy> <hrszy> <hrex> <hrey> <hrez> <hrax> <hray> <hraz> <hpsx> <hpsy> <hpsz> <hpex> <hpey> <hpez> <hpax> <hpay> <hpaz>) can be disabled with the “-nht” switch. Additionally, extended eye/head position data (<hissx> <hissy> <hisex> <hisey>

<hisax> <hisay> <eihsx> <eihsy> <eihex> <eihey> <eihax> <eihay>) can be disabled with the “-ned” switch.

The start of saccades are reported with a SSACC line, which can be eliminated with the EDF2ASC “-nse” option from the command line prompt or by enabling “Block Start Event Output” from the EDF2ASC converter GUI preference settings. The <eye> is “L” or “R”, indicating the eye's data that produced the event.

The end of and summary data of the saccade are reported with the ESACC line. This reports the time of the first and last sample in the saccade, and computes its duration in milliseconds. The X and Y eye position at the start and end of the saccade (<sxp>, <syp>, <exp>, <eyp>) are listed. The total visual angle covered in the saccade is reported by <ampl>, which can be divided by (<dur>/1000) to obtain the average velocity. Peak velocity is given by <pv>.

All samples that are within the saccade will be listed between the SSACC and ESACC events for each eye, simplifying data analysis.

4.9.3.6 Blinks

- SBLINK <eye> <stime> <hissx> <hissy> <hisex> <hisey> <hisax> <hisay> <eihsx> <eihsy> <eihex> <eihey> <eihax> <eihay> <hrsx> <hrsy> <hrsz> <hrex> <hrey> <hrez> <hrax> <hray> <hraz> <hpsx> <hpsy> <hpsz> <hpex> <hpey> <hpez> <hpax> <hpay> <hpaz>
- EBLINK <eye> <stime> <etime> <dur> <hissx> <hissy> <hisex> <hisey> <hisax> <hisay> <eihsx> <eihsy> <eihex> <eihey> <eihax> <eihay> <hrsx> <hrsy> <hrsz> <hrex> <hrey> <hrez> <hrax> <hray> <hraz> <hpsx> <hpsy> <hpsz> <hpex> <hpey> <hpez> <hpax> <hpay> <hpaz>

For both the start and end events, head tracking data (<hrsx> <hrsy> <hrsz> <hrex> <hrey> <hrez> <hrax> <hray> <hraz> <hpsx> <hpsy> <hpsz> <hpex> <hpey> <hpez> <hpax> <hpay> <hpaz>) can be disabled with the “-nht” switch. Additionally, extended eye/head position data (<hissx> <hissy> <hisex> <hisey> <hisax> <hisay> <eihsx> <eihsy> <eihex> <eihey> <eihax> <eihay>) can be disabled with the “-ned” switch.

Blinks (periods of data where the pupil is missing) are reported by the SBLINK and EBLINK lines. The time of the start of the blink is indicated by the SBLINK line, which can be eliminated with the EDF2ASC “-nse” option. The <eye> is “L” or “R”, indicating the eye's data that produced the event. The end and duration are given in the EBLINK event.

Blinks are always embedded in saccades, caused by artificial motion as the eyelids progressively occlude the pupil of the eye. Such artifacts are best eliminated by labeling an SSACC...ESACC pair with one or more SBLINK events between them as a blink, not a saccade. The data contained in the ESACC event

will be inaccurate in this case, but the <stime>, <etime>, and <dur> data will be accurate.

It is also useful to eliminate any short (less than 100 millisecond duration) fixations that precede or follow a blink. These may be artificial or be corrupted by the blink.

4.9.4 Data-Specification Lines

Right before each block of recorded data, a few specification lines are written to the EDF file to report the recording information of the trial such as mount type, sampling rate, filtering level, pupil threshold, and pupil tracking algorithm.

- RECCFG <tracking mode> <sampling rate> <file sample filter> <link sample filter> <eye(s) recorded>

This specifies the tracking mode used (pupil-only vs. pupil-CR mode), sampling rate (250, 500, or 1000 Hz), file sample filter (0 – filter off; 1 – standard filter; 2 – extra filter), link sample filter (0 – filter off; 1 – standard filter; 2 – extra filter), and the eyes (L, R, or LR) recorded in the trial.

- ELCLCFG <mount configuration>

This reports the mount configuration used to do data collection.

Configuration	Typical Setup
HBAND	Head-mounted eye tracking

- GAZE_COORDS <left> <top> <right> <bottom>

This reports the pixel resolution of the tracker recording. Left, top, right, and bottom refer to the x-y coordinates of the top-left and bottom-right corners of display.

- THRESHOLDS <eye> <pupil> <CR>

This reports the pupil and CR thresholds of the tracked eye(s).

- ELCL_PROC <pupil tracking algorithm>

This reports the pupil fitting processing type (i.e., ELLIPSE or CENTROID).

- MARKER_CONTROL <on or off>

This reports whether the Marker is used for head tracking.

Immediately following a START line, several lines of data specifications may be present. These lines contain more extensive data than the START line about what data can be expected in the START...END block. These are most easily processed by creating a set of flags for each possible data option (left-eye events, right-eye samples, sample velocity, etc.), clearing these when the START line is encountered, and setting the appropriate flags when keywords ("LEFT", "VEL", etc.) are encountered in a data specification line.

- PRESCALER <prescaler>

If gaze-position data or gaze-position resolution is used for saccades and events are used, they must be divided by this value. For EDF2ASC, the prescaler is always 1. Programs that write integer data may use a larger prescaler (usually 10) to add precision to the data.

- VPRESALER <prescaler>

If velocity data is present, it must be divided by this value. For EDF2ASC, the prescaler is always 1. Programs that write integer data may use a larger prescaler (usually 10) to add precision to the data.

- PUPIL <data type>

This specifies the type of pupil size data (AREA or DIAMETER) recorded in the trial.

- EVENTS <data type> <eye> <data options>

This specifies what types of data are present in event lines, as a sequence of keywords. The <data type> is either "GAZE" or "HREF". The eye recorded will be "LEFT", "RIGHT", or both "LEFT" and "RIGHT" for binocular recordings. The <data option> keywords currently supported are:

"RES" for resolution data (both may be present)

"RATE" for the sample rate (250.00, 500.00, or 1000.0)

"TRACKING" for the tracking mode (P = Pupil, CR = Corneal Reflection)

"FILTER" for the filter level used (0=off, 1=standard, 2=extra)

- SAMPLES <data type> <eye> <data options>

This specifies what types of data are present in sample lines, as a sequence of keywords. The <data type> is one of "GAZE", "HREF" or "PUPIL". The eye recorded will be "LEFT", "RIGHT", or both "LEFT" and "RIGHT" for binocular recordings. The <data option> keywords currently supported are:

"VEL" for instantaneous velocity data

"RES" for resolution data (both may be present)

"RATE" for the sample rate (250.00, 500.00, or 1000.0)

"TRACKING" for the tracking mode (P = Pupil, CR = Corneal Reflection)

"FILTER" for the filter level used (0=off, 1=standard, 2=extra)

4.10 Processing ASC Files

An ASC file is a simple text file, and thus can be accessed by almost any programming language. The usual way to process the file is to read each line into a text buffer (at least 250 characters in size), and to scan the line as a series of tokens (non-space character groups).

The first token in each line identifies what the line is:

First character in first token	Line type
<no token>	Blank line--skip
# or ; or /	Comment line--skip
*	Preamble line--skip
Digit (0..9)	Sample line
Letter (A..Z)	Event or Specification line

Once the line is identified, it may be processed. Some lines may simply be skipped, and the next line read immediately. For sample lines, the tokens in the line can be read and converted into numerical values. The token "." represents a missing value, and may require special processing. For lines where the first token begins with a letter, processing depends on what the first token is. The tokens after the first are read and desired data from the line are extracted from them. Lines with unrecognized first tokens or with unwanted information can simply be skipped.

Processing of events and samples will depend on what type of analysis is to be performed. For many cognitive eye movement analyses, MSG line text specifying experimental conditions, EFIX event data, and BUTTON event times from each block are used to create data files for statistical analysis. For neurological research, samples between SFIX and EFIX events can be processed to determine smooth-pursuit accuracy and gain. In some cases, an entire block of samples may need to be read and stored in data arrays for more complex processing. For all of these, the organization and contents of the ASC files have been designed to simplify the programmer's task.

5 System Care

5.1 Cleaning and Disinfection

WARNING: Cleaning with a wet cloth, sprays applied directly to the EyeLink 3 wearable unit, or pouring fluids onto the unit could cause a shock hazard to participants by forcing liquids into the unit. Units returned with signs of such misuse will not be covered under warranty.

WARNING: After cleaning or disinfecting with any liquid, or if the unit is exposed to any liquid, let the unit dry thoroughly before allowing participants near it with the USB cable connected. Inspect unit and cable where accessible before reconnecting.

WARNING: When cleaning fingerprints or smudges on the mirror, please use the supplied non-alcoholic lens cleaning solution. An alcohol-based cleaner should be avoided as this may damage the coating on the mirror and degrade tracking performance.

The EyeLink 3 wearable unit and the near-infrared Marker are intended for use in indoor environments with controlled temperature and no risk of exposure to liquids. No consumables are used, and the system requires only occasional cleaning as maintenance. Use only the approved products and methods in this section for cleaning and disinfecting the system. Any other cleaning or disinfection products may damage the unit, and such damage will not be covered under warranty.

- The plastic parts of the headband and the leather padding, and silicone shade may be wiped with a damp cloth if cleaning is required.
- The front enclosure may be wiped with a damp cloth if cleaning is required.
- The filter and the lens of the Marker Camera may be wiped gently with a clean, dry, soft cloth, or glasses cleaning wipe.

Special care needs to be exercised when handling the hot mirror on the EyeLink 3 wearable unit.

- For dust on the mirror, use an anti-dust cleaning cloth, shake cloth out, and then wipe the mirror gently. You may also use a compressed air duster from at least 15 cm away.
- Please remove dust first before wet cleaning to make sure no abrasive particles are on mirror.
- To remove fingerprints or smudges on the mirror, use the supplied alcohol-free lens cleaning solution. Please don't use any alcohol-based cleaner as this will damage the coating on the mirror.
- Spray a couple times to cover the affected area, and then lightly wipe with the supplied cleaning cloth. Please shake cloth out before each contact.

- When cleaning the EyeLink 3 wearable unit, be careful not to get excessive fluid on the enclosure or camera windows. Users are advised to wipe windows after cleaning inside of mirror so moisture on cloth can be used without spraying directly on windows.

5.2 Storage and Transportation

Between uses, it is recommended that the EyeLink 3 headband should always be stored on the mannequin head, to prevent scratching of the mirror. If the system is not going to be used for an extended period, you may wish to disconnect the cables from the computer and pack the EyeLink 3 wearable unit in the shipping case.

For long-term storage, shipping, or transportation, it is recommended that the EyeLink 3 headband and Marker be stored in the shipping case that you originally received the system in. Be careful the mirror is not damaged or scratched.

Store the shipping case above freezing and below 40°C, and avoid high-humidity conditions which might cause water to condense within the device and damage the optics. Be sure to follow the unpacking and installation instructions when returning the packaged unit to operation.

6 Important Information

6.1 *Electrical and Thermal Safety*

WARNING: Do not use the EyeLink 3 wearable unit or Markers with enclosures removed or if enclosure is broken or damaged, as internal components may be hot or sharp. Do not touch any parts exposed if the cover is removed or damaged.

WARNING: If the USB cable outer jacket is damaged, a shock hazard to the participant may exist. Remove the unit from service immediately if such damage is found.

6.1.1 *Power Source*

WARNING: Do not use any power source except the computer or other device supplied with the EyeLink 3 or the system that it is bundled with, unless explicitly permitted in writing by SR Research Ltd. Connecting more than one power source to the USB cable could damage the Host PC or the USB cable.

WARNING: If exposed sections of the USB cable are damaged, a shock hazard to the participant may exist. Remove the unit from service immediately if such damage is found.

The EyeLink 3 is intended to be powered by the USB 3.0 port on the Host PC. The eye tracker safely isolates the participant from all connections to the Host PC through its enclosure (and its USB cable jacket), so IEC 60950 certified computers may be used to power it. Desktop and laptop computers are typically certified to IEC 60950 or equivalent, which provides electrical protection for the operator.

6.1.2 *Exposure to Fluids and Spills*

WARNING: Any exposure to substantial quantities of fluids carries risk of danger to participants. Unit should be taken out of service IMMEDIATELY after immersion or substantial spill onto the EyeLink wearable unit and the unit should be returned to the manufacturer for inspection and repairs.

To minimize risk to participants, it is recommended that any equipment involved in a spill or exposed to substantial quantities of dripping water, or any unit experiencing any degree of immersion, be dried carefully and returned to the manufacturer for inspection and repair.

6.2 Eye Illumination Safety

The EyeLink 3 complies with the IEC-62471 lamp safety standards, and meets requirements as an “exempt” device, which is safe under any conditions. The internal illuminator emits near-infrared (NIR) radiation. As these illuminators may be used in situations where they may be viewed for long periods of time, some precautions should be observed. Our experience has been that even safe levels of IR illumination can eventually cause some discomfort due to the slight drying effect of even this low level of illumination. This is especially true for wearers of contact lenses. Therefore, users should minimize time participants spend using the eye tracker, to reduce any discomfort to sensitive or irritated eyes.

6.2.1 Visibility of Illuminator

Though nominally invisible, the human eye has some residual sensitivity to NIR light. The illuminators may be visible in moderately lit rooms, though this is not expected to compromise most tasks.

6.2.2 Illuminator Warm-Up Period

The light output of the illuminators may change slightly for a period after the eye tracker is started up after extended shutdown. For applications where illumination level is critical, it is recommended that at least 10-15 minutes be allowed for the illuminators to reach a stable temperature before use. This warm-up period will also allow the camera circuitry to reach its operating temperature, resulting in best image quality and most stable eye tracking performance.

6.3 Servicing Information

WARNING: Changes or modifications to the EyeLink 3 enclosure, camera, illuminator, markers, or cables not expressly approved by SR Research Ltd. will void the warranty and authority to operate the equipment. This includes modification of cables or opening the unit without express instructions from the manufacturer.

WARNING: Opening or modifying the wearable unit or marker, will void the warranty and may affect safety compliance of the system. No user-serviceable parts inside — contact the service provider at the address listed below for all repairs or modifications.

6.3.1 Non-Serviceable Components

In the event of failure, cable damage, or immersion in fluids, the EyeLink 3 (cameras or illuminators) should be replaced as a unit, as there are no user serviceable parts inside and no internal adjustments or jumpers. Please contact

SR Research for repair or replacement if you suspect these are at fault. There are no user-serviceable parts within any of these components.

6.3.2 USB Cable Replacement

WARNING: Use of cables other than those specified or provided by the manufacturer of this equipment could result in increased electromagnetic emissions or decreased electromagnetic immunity of this equipment and result in improper operation. Contact SR Research Ltd if you need to replace or service the USB cables.

WARNING: The replacement USB cable to the wearable unit or marker should bear 60101-1, 62368-1, or 60950-1 certification.

A USB cable for the EyeLink 3 wearable unit and the MRK3 unit is supplied with the system, but users may replace this with any cable that provides adequate performance. The power source or device with the USB port must also bear another certification, such as 60101-1, 62368-1, or 60950-1 and it may be any USB cable that meets applicable USB standards and bears the USB symbol, either on the cable jacket, or embossed on the connector overmold.

Note: Not all USB cables will perform properly with EyeLink 3. The EyeLink 3 camera unit requires high data throughput and power close to the limit available through USB 3.0, thus voltage drop in the cable may affect performance (especially if the cable is more than 3.0 meters; the camera cable cannot be extended with any USB extension cable). There is no safety hazard from using a cable that does not meet the requirements, the EyeLink 3 camera unit will simply see too much voltage drop in the cable and either fail to start up or show poor performance. It is expected that users will select a cable recommended by SR Research Ltd or a distributor. When plugging in the EyeLink 3 cable, users should use a USB port with "SS" embossed next to the USB logo.

6.4 Limited Hardware Warranty

SR Research Ltd.
35 Beaufort Drive,
Ottawa, Ontario, K2L 2B9, Canada

EyeLink 3 – Limited Warranty

SR Research Ltd. warrants this product to be free from defects in material and workmanship and agrees to remedy any such defect for a period as stated below from the date of original installation.

EyeLink 3 Wearable Unit – Two (2) year parts and labor.
EyeLink 3 Marker – Two (2) year parts and labor.

Host PC – Two (2) year parts and labor.

LIMITATIONS AND EXCLUSIONS

This warranty does not apply to any product which has been improperly installed, subjected to usage for which the product was not designed, misused or abused, damaged during shipping, or which has been altered or repaired in any way that affects the reliability or detracts from the performance. Any replaced parts become the property of SR Research Ltd.

This warranty is extended to the original end purchaser only. Proof of original date of installation is required for warranty service to be performed.

This warranty does not apply to the software component of the product.

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In certain instances, some jurisdictions do not allow the exclusion or limitation of incidental or consequential damages, or the exclusion of implied warranties, so the above limitations and exclusions may not be applicable.

WARRANTY SERVICE

For product operation and information assistance, please contact SR Research Ltd. Support representative (support@sr-research.com). **For product repairs**, please contact your sales representative for appropriate instructions.

6.5 Limited Software Warranty

SR Research Ltd. warrants that the software disks and USB flash drives are free from defects in materials and workmanship under normal use for one (1) year from the date you receive them. This warranty is limited to the original owner and is not transferable.

The entire liability of SR Research Ltd. and its suppliers, and your exclusive remedy, shall be (a) replacement of any disk that does not meet this warranty which is sent with a return authorization number from SR Research Ltd. This limited warranty is void if any disk is damaged has resulted from accident, abuse, misapplication, or service or modification by someone other than SR Research Ltd. Any replacement disk is warranted for the remaining original warranty period or 30 days, whichever is longer.

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