

EyeLink® Portable Duo User Manual







Version 1.0.7



Copyright ©2016-2021, SR Research Ltd.

EyeLink is a registered trademark of SR Research Ltd.,
Oakville, Ontario, Canada

SAFETY MARKINGS

	Read instructions before use.
	For indoor use only.
	DC Power
	Class II Equipment, no protective earth required
	Separate electrical and electronic collection.
	Intertek Safety Mark: Compliance of this product with applicable standards is certified by Intertek, an independent testing agency.

SAFETY WARNINGS

WARNING: Do not open or modify the EyeLink Portable Duo eye tracker in any way. This may render the unit unsafe, resulting in shock or burn hazards, and will void the warranty and safety certifications. No user-serviceable parts inside - contact SR Research for all repairs.

WARNING: The EyeLink Portable Duo is not intended for use in an oxygen-rich environment, or in the presence of flammable anaesthetics.

WARNING: The Host PC, and all peripherals connected to it with cables, should be positioned out of reach of the participant (at least 120 cm away). Only devices included with the system and clearly identified as suitable for contact with the participant (such as a response device) should be within the participant's reach.

WARNING: The operator should avoid simultaneously contacting the participant and the computer, or any device connected with cables to the Host PC, such as a keyboard or mouse, that were not included with the system and clearly identified as suitable for contact with the participant.

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.

WARNING: Do not place any objects on top of the EyeLink Portable Duo that could block air circulation around the unit. If the unit has been inadvertently covered during operation, it could be hot! Uncover it immediately, turn off its power source and let it cool, before touching it or allowing participants near it.

WARNING: This unit is drip-proof and spill-resistant; it is not watertight or waterproof. 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 unit, and should be returned for inspection and repairs.

WARNING: The EyeLink Portable Duo is always powered while the Host PC is connected and powered on. Therefore observe these precautions for participant safety:

- Before performing any cleaning other than wiping the optical window, power off the Host PC or disconnect both plugs of the USB cable of the eye tracker (see Chapters 5 and 6).
- Do not cover or place any items on top of the EyeLink Portable Duo while the Host PC is powered on, unless the eye tracker cable is disconnected from both USB ports. Operating the unit while covered could cause it to overheat and possibly cause a burn hazard.
- If the EyeLink Portable Duo fails to operate properly, is running at a higher than normal temperature, or if the cable is damaged / the illuminator is not glowing, disconnect the USB cable or turn off the Host PC, until the operator can troubleshoot the system.

WARNING: Use of this equipment adjacent to or stacked with other equipment should be avoided because it could result in improper operation. If such an arrangement is unavoidable, please make sure to check the data from all equipment to ensure that it is operating normally.

WARNING: Changes or modifications not expressly approved by the manufacturer will void the warranty and authority to operate the equipment. This includes modification of cables or opening unit without express instructions from the manufacturer.

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.

WARNING: Portable RF communications equipment (including peripherals such as antenna cables and external antennas) should be used no closer than 30 cm (12 inches) to any part of the EyeLink Portable Duo, including cables specified by the manufacturer. Otherwise, degradation of the performance of this equipment could result.

WARNING: This equipment was not tested for degradation of performance during immunity testing. If degradation of performance is observed that is unacceptable, check for sources of interference that may be responsible.

CONTACT ADDRESS

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

Fax: (613) 482-4866
Phone: (613) 271-8686
Toll Free: 1-866-821-0731 (North America only)

Email: support@sr-research.com
Sales: <http://www.sr-research.com>
Support: <http://www.sr-support.com>

MANUFACTURER ADDRESS

SR Research Ltd.
8-1400 Cornwall Rd.
Oakville, Ontario, L6J 7W5
Canada

EU AUTHORISED REPRESENTATIVE

EyeSeeTec GmbH
Neumarkter Str. 84c
81673 München
Germany

Table of Contents

1	Introduction	1
1.1	EyeLink Portable Duo System Configuration	2
1.1.1	Eye Tracking Unit.....	2
1.1.2	Host PC	3
1.1.3	Display PC.....	4
1.2	Supporting Documents	5
1.3	System Specifications.....	7
1.3.1	Operational / Functional Specifications	7
1.3.2	Physical Specifications	8
2	EyeLink Portable Duo Host Software.....	9
2.1	Web User Interface (Web UI)	9
2.1.1	File Manager	9
2.1.2	Configuration Tool.....	14
2.1.3	Tracker Initialization Files.....	15
2.1.4	Running the Web UI on the Display PC	17
2.2	Starting the Host Application	17
2.3	Modes of Operation	18
2.4	EyeLink Portable Duo Host Application Navigation.....	19
2.4.1	Setup Screen.....	20
2.4.2	Calibration Screen.....	27
2.4.3	Validation Screen	30
2.4.4	Drift Check/Drift Correct Screen.....	32
2.4.5	Record Screen	34
3	An EyeLink Portable Duo Tutorial: Running an Experiment	39
3.1	The Setup Screen	40
3.2	Participant Setup	41
3.2.1	Participant Setup in Head-Stabilized Mode.....	41
3.2.2	Participant Setup in Remote Head-Free-to-Move Mode	45
3.3	Setting Pupil Thresholds	52
3.4	Setting the Corneal Reflection (CR) Threshold.....	54
3.5	Search Limits	55
3.6	Pupil Tracking Algorithm.....	55

3.7	Calibration	56
3.8	Validation	60
3.9	Improving Calibration Quality	61
3.10	Recording Gaze Position	63
3.11	Drift Checking and Drift Correction	63
3.11.1	<i>Enabling Drift Correction</i>	64
3.11.2	<i>Online Drift Correction</i>	64
3.12	Exiting the Host Application	66
3.13	EyeLink Portable Duo Setup Summary	66
3.14	Experiment Practice	67
3.15	Next Steps: Other Sample Experiments	67
4	Data Files	71
4.1	File Contents	71
4.2	Recording EDF Files	72
4.2.1	<i>Recording from the EyeLink Portable Duo Host PC</i>	72
4.2.2	<i>Recording from the EyeLink API or SR Research Experiment Builder</i>	72
4.3	The EyeLink On-Line Parser	72
4.3.1	<i>Parser Operation</i>	72
4.3.2	<i>Parser Limitations</i>	73
4.3.3	<i>EyeLink Parser Configuration</i>	73
4.3.4	<i>Parser Data Type</i>	74
4.3.5	<i>Saccadic Thresholds</i>	74
4.3.6	<i>Pursuit Thresholds</i>	75
4.3.7	<i>Fixation Updates</i>	75
4.3.8	<i>Other Parameters</i>	76
4.3.9	<i>Sample Configurations</i>	76
4.4	File Data Types	77
4.4.1	<i>Samples</i>	77
4.4.2	<i>Position Data</i>	78
4.4.3	<i>Pupil Size Data</i>	80
4.4.4	<i>Button Data</i>	81
4.5	Events	81
4.5.1	<i>Messages</i>	81
4.5.2	<i>Buttons</i>	82

4.5.3	<i>Eye Movement Events</i>	82
4.6	Setting File Contents	86
4.6.1	<i>Sample Data</i>	86
4.6.2	<i>Event Data</i>	87
4.6.3	<i>Event Types</i>	88
4.7	EDF File Utilities	88
4.8	Using ASC Files	89
4.9	The ASC File Format	90
4.9.1	<i>ASC File Structure</i>	90
4.9.2	<i>Sample Line Format</i>	91
4.9.3	<i>Event Line Formats</i>	93
4.9.4	<i>Data-Specification Lines</i>	96
4.10	Processing ASC Files	98
5	System Care	100
5.1	Periodic Inspection	100
5.2	Cleaning and Disinfection	101
6	Important Information	104
6.1	Electrical Safety	104
6.1.1	<i>Power Source and Isolation</i>	104
6.1.2	<i>Disconnection</i>	105
6.1.3	<i>Maintaining Participant Isolation</i>	105
6.1.4	<i>Exposure to Fluids and Spills</i>	106
6.2	Eye Illumination Safety	107
6.2.1	<i>Eye Safety and Comfort</i>	107
6.2.2	<i>Visibility of Illuminator</i>	107
6.2.3	<i>Illuminator Warm-Up Period</i>	107
6.3	SERVICING INFORMATION	107
6.4	Electromagnetic Compliance and Immunity	108
6.4.1	<i>Suitable Electromagnetic Environments</i>	108
6.4.2	<i>Sources of Interference and Degraded Performance</i>	109
6.4.3	<i>Preserving Electromagnetic Compatibility</i>	109
6.4.4	<i>Other Electromagnetic Compatibility Statements</i>	110
6.5	Limited Hardware Warranty	110
6.6	Limited Software Warranty	111

6.7	Copyrights / Trademarks	112
-----	-------------------------------	-----

List of Figures

Figure 1-1: EyeLink Portable Duo Eye Tracker, Showing Internal Camera Lens and Illuminator	2
Figure 1-2. Example Use Scenarios (Left: Eye Tracker Mounted on Top of a Tripod; Right: Eye Tracker Installed on a Laptop Mount).....	3
Figure 2-1: File Manager Screen	10
Figure 2-2: EyeLink Portable Duo Host PC Application Overview	19
Figure 2-3: Example Setup Screen.....	20
Figure 2-4: Example Calibration Screen	27
Figure 2-5: Example Validation Screen	30
Figure 2-6: Example Drift Check/Drift Correct Screen.....	33
Figure 2-7: Example Record Screen (Gaze Cursor View).....	35
Figure 2-8: Example Record Screen (Plot View)	36
Figure 3-1: Example Setup Screen.....	40
Figure 3-2: Camera Setup with Participants Wearing Glasses	44
Figure 3-3: Focusing the Camera Image	45
Figure 3-4: Setup Screen in the Remote Mode	46
Figure 3-5: EyeLink Remote Target Placement	49
Figure 3-6: Pupil and CR Thresholds and Bias Values	50
Figure 3-7: Symptoms of Poor Pupil Threshold	53
Figure 3-8: Potential Pupil Threshold Issues when Viewing Screen Corners	54
Figure 3-9: Corneal Reflection	54
Figure 3-10: Calibration Grid	58

List of Tables

Table 1: EyeLink Portable Duo Configuration Files 17

Table 2: Cleaning and Disinfecting Rules..... 102

Table 3: Approved Cleaning and Disinfecting Methods, Ordered by Risk 103

1 Introduction

This section introduces the technical capabilities and supporting documentation for the EyeLink Portable Duo eye tracker. The EyeLink Portable Duo eye tracker is intended for researchers who require high-quality eye tracking data both in and out of the laboratory. The eye tracker illuminates the participant's face and eyes with invisible near-infrared light; an internal USB camera acquires up to 2000 images per second. The camera images are processed by the attached Host PC to identify landmarks on the eyes and face, allowing measurement of the participant's gaze location.

The EyeLink Portable Duo, with IEC 60601-1 medical certification, meets the requirements for use in medical environments (e.g., more stringent electrical isolation, easier cleaning, etc.). These goals are met by adopting a unitary design with a simple enclosure, and with no exposed parts such as lenses or illuminator arrays. In addition to providing electrical isolation from internal parts and cable entry protection, this enclosure also provides low thermal resistance to keep the internal parts (especially the sensor) cool while radiating sufficient heat to keep its temperature within safety requirements. The compact design of the eye tracking unit makes the EyeLink Portable Duo easier to transport and simpler to set up compared to other models of EyeLink eye trackers.

Another unique design feature of the EyeLink Portable Duo is its built-in capability for dual use as either a high-accuracy head-stabilized eye tracker or as a head free-to-move remote eye tracker. By adopting a compact, yet highly sensitive lens and illumination module, the EyeLink Portable Duo can operate in two distinct modes with the same set of eye tracking hardware (i.e., no change of lens or illumination module is required). The head-stabilized and remote modes can be easily accessed through the Host Application, and share the same application programming interface (API) and EyeLink Data File (EDF) output. This allows experimenters to seamlessly switch between data collection and analysis modes that best suit their particular experimental paradigm or to accommodate different participant populations.

The EyeLink Portable Duo operates at an extremely low noise level, which is required for accurate gaze-contingent paradigms, and which offers researchers the high levels of data quality that careful research demands. EyeLink systems are the only modern commercial eye-tracking equipment to run on a real-time operating system; running on such an operating system ensures low temporal variability and near-instant access to eye data measures. Compared to other remote systems on the market, the EyeLink Portable Duo provides high-accuracy eye tracking data with extremely low noise.

A typical EyeLink Portable Duo setup consists of two computers – one, which is called the Host PC, connects to the eye tracker and is dedicated to data collection. The second computer is referred to as the Display PC, and is generally used for the presentation of stimuli to a participant. The two computers are connected via an Ethernet link that allows the transfer of critical information between the two computers. This transfer allows the Display PC access to the eye data, such as ongoing gaze position and saccade and fixation events (which are being processed and recorded on the Host PC). It also allows the transfer of camera images from the camera/Host PC to the Display PC during participant setup. Similarly, the Display PC can send information to the Host PC over that same Ethernet connection, allowing Display PC applications to direct the collection of data and mark critical experimental events, such as the onset of experimental stimuli, in the eye tracking data file. This message passing also allows events collected by I/O devices on the Display PC (e.g., button boxes, microphones, etc.) to be marked in the data file.

IMPORTANT: Please examine the safety information for the EyeLink Portable Duo system which can be found in Section 6.

1.1 EyeLink Portable Duo System Configuration

1.1.1 Eye Tracking Unit

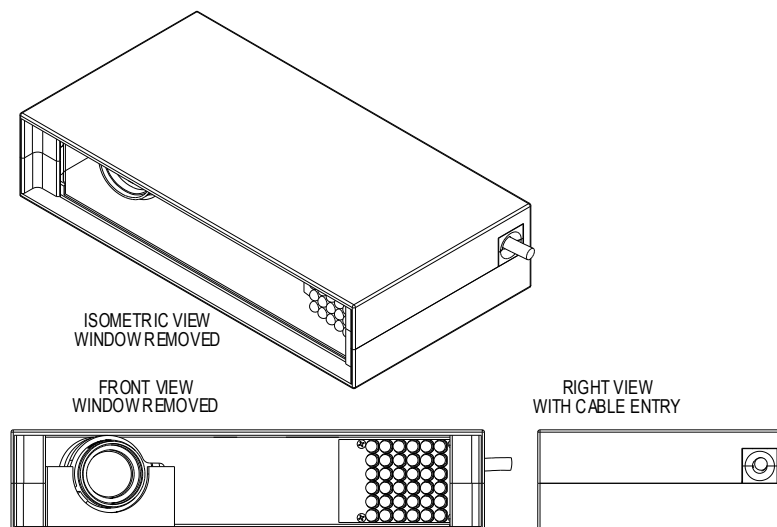


Figure 1-1: EyeLink Portable Duo Eye Tracker, Showing Internal Camera Lens and Illuminator

The EyeLink Portable Duo eye tracker comes with a high-speed USB camera (on the left side of the unit) and an infrared illuminator (on the right side of the

unit). The lens and illuminator components allow for a more compact enclosure, while supplying the high light output and sensitivity required for fast sampling rates and low noise levels. All image processing and data recording is handled by a laptop or desktop Host PC, which connects to the eye tracker with a high-speed USB 3.0 cable.

The eye tracking unit can be mounted on a tripod and sit below the display that the participant views during the experiment. If a laptop is used as a Display computer, a laptop mount option can be used so that eye tracking can be done on the laptop screen. Since the EyeLink Portable Duo's eye tracking unit is near the stimulus display, no electronics need to be near the participant's head. The eye tracker can operate in either a head-stabilized mode (any head support can be used) or in a head free-to-move Remote mode.

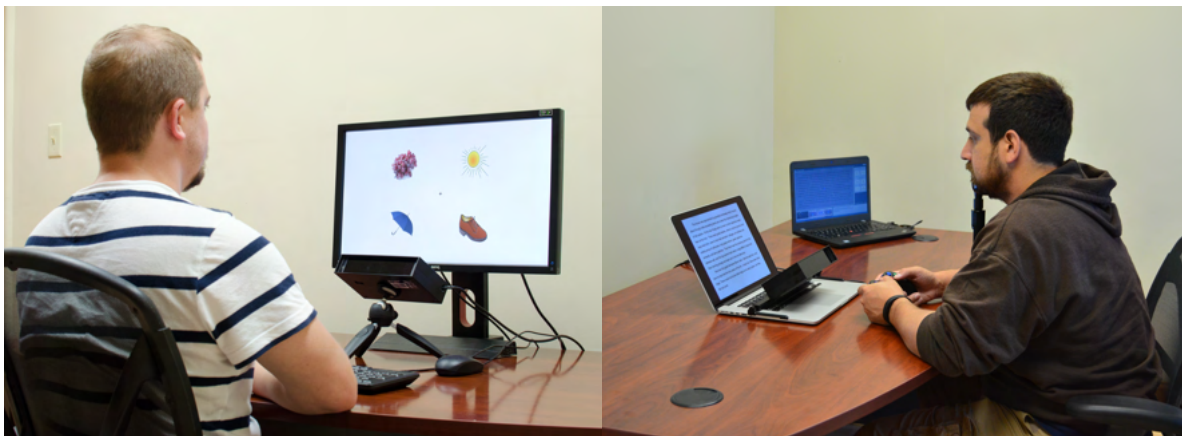


Figure 1-2. Example Use Scenarios (Left: Eye Tracker Mounted on Top of a Tripod; Right: Eye Tracker Installed on a Laptop Mount)

1.1.2 Host PC

The EyeLink Portable Duo Host PC performs real-time eye tracking at either up to 2000 samples per second while computing the gaze position of the participant on the Display PC's monitor. The Host PC also performs on-line 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. They can be sent via the Ethernet link to the Display PC with minimal delay, or output as analog signals (if the optional analog/digital I/O card is installed in a workstation Host PC). 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 offer 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 USB 3.0 ports. A workstation Host PC can also house an optional analog output/digital I/O card.
- Integrates all the eye tracking functionality, including participant setup, calibration, sending real-time data through an Ethernet link or optional analog output card, 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 presents stimuli during experiments and, via the Ethernet Link, can control key eye tracking functions such as calibration and data collection. 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 via a graphical user interface that eliminates the need for complex scripting.

For users who wish to program their own experiments in other programming environments, a wide range of options exist for accessing and controlling data acquisition on the Display PC. A C/C++ programming API with example code exists for Windows, macOS, and Linux. Additionally, several programming environments (e.g., Psychtoolbox for MATLAB, E-Prime, Presentation, Python, LabView, 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 resources, visit and join the SR Research support forums at <http://www.sr-support.com>.

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, and have 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 experiment sequence. Relying on the Host PC for data acquisition and registering responses 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 Portable Duo 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 Portable Duo Installation Guide – Describes a standard EyeLink Portable Duo system layout as well as the steps required to install the EyeLink Portable Duo hardware and software on both the Host and Display PCs.
- EyeLink Programmer's Guide – Provides suggestions on how to program experiments with EyeLink Portable Duo 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 32-/64-bit Windows and macOS. This software allows for a wide range of sophisticated experimental paradigms to be created by someone with little or no programming or scripting experience.
- 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.

NOTE: Please be sure to check <http://www.sr-support.com> for the latest product and documentation updates.

1.3 System Specifications

1.3.1 Operational / Functional Specifications

	Head-stabilized Mode	Remote Mode (Head free-to-move)
Average Accuracy ¹	Down to 0.15° (0.25° to 0.5° typical)	0.25-0.5° typical
Sampling rate	Monocular: 250,500,1000,2000 Hz Binocular: 250,500,1000,2000 Hz	Monocular: 250,500,1000 Hz Binocular: 250,500,1000 Hz
End-to-End Sample Delay ²	1000 Hz: M=1.88 ms SD=0.36 ms 2000 Hz: M=1.34 ms SD=0.18 ms	500 Hz: M=3.21 ms SD=0.61 ms 1000 Hz: M=2.10 ms SD=0.37 ms
Blink/Occlusion Recovery	1.0 ms @ 1000 Hz 0.5 ms @ 2000 Hz	2.0 ms @ 500 Hz 1.0 ms @ 1000 Hz
Spatial Resolution ³	0.01°	
Noise with Participants ⁴	Filter (Off/Normal/High): 1000 Hz: 0.03°/0.02°/0.01° 2000 Hz: 0.05°/0.03°/0.02°	Filter (Off/Normal/High): 500 Hz: 0.03°/0.02°/0.01° 1000 Hz: 0.05°/0.03°/0.01°
Eye Tracking Principle	Dark Pupil - Corneal Reflection	
Pupil Detection Models	Centroid or Ellipse Fitting	Ellipse Fitting
Pupil Size Resolution ⁴	0.1% of diameter	
Gaze Tracking Range	Customizable – Default is 32 ° horizontally × 25 ° vertically	
Allowed Head Movements Without Accuracy Reduction	±25 mm horizontal or vertical	20 cm × 20 cm at 52 cm
Optimal Camera-Eye Distance	42 - 62 cm	
Glasses Compatibility	Excellent	
On-line Event Parsing	Fixation / Saccade / Blink / Fixation Update	
EDF File and Link Data Types	Gaze, Raw, and HREF eye position data/ Pupil size / Online events / 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 or Analog output. Optional data filter algorithm adds one sample delay for each filtering level.

³ Measured with an artificial eye.

⁴ Measured with real subject fixations.

1.3.2 Physical Specifications

Physical	Anodized aluminum enclosure, acrylic optical window
Device Model	USB1000 series (e.g., USB1000-850-WA, USB1000-880-WA, EyeLink Portable Duo)
Focus Option	Focus adjustment wheel (installed)
Lens Option	25 mm lens
Water and Ingress Rating	<ul style="list-style-type: none"> • IP21 • Drip-proof and spill-resistant
Dimensions	206.0mm W × 44.4mm H × 109.5mm D
Weight	930g w/o cable, 1050g including cable
Power Requirements	<ul style="list-style-type: none"> • 5.0V, 1800 mA from USB 3.0 ports on Host PC • Continuous Operation
Connection	2 meter USB 3.0 cable (data and power plugs), integrated with unit
Grounding	Class II (insulated, no protective earth required)
Computer Requirements:	<ul style="list-style-type: none"> • Host computer supplied with the system
Internal Illuminator	<ul style="list-style-type: none"> • Eye exposure: less than 1 mW/cm² at > 300 mm from illuminator • IEC 62471 compliant (Exempt device)
Operating conditions	<ul style="list-style-type: none"> • 15°C to 25°C, 30%-75% humidity (non-condensing). • 0-2000 m (0-6500 ft) altitude (70-106 kPa) • For indoor use only • Not for use in oxygen-rich environments or in the presence of flammable anesthetics
Storage and Transportation conditions	<ul style="list-style-type: none"> • -10°C to 60°C, 10%-90% humidity (non-condensing) • 0-2000 m (0-6500 ft) altitude. (70-106 kPa) • Allow to warm to room temperature before use after storage at temperatures below 10°C to prevent condensation
Isolation	Cable and enclosure insulated from USB power
Electromagnetic compatibility	<ul style="list-style-type: none"> • FCC Part 15, Subpart B: Class B • CISPR 11:-- Class B • 60601-1-2 Medical Device EMC Compatibility, Ed.3 (2007-03)
Certifications	IEC 60601-1 ed. 3., AAMI ES60601-1, CSA C22.2#60601-1 ed. 3.1, IEC 62366 ed. 1, ISO 15004-1, ed. 1, ISO 15004-2, IEC 62471 ed. 1, ISO 14971. ed. 2, IEC 60601-1-6 ed. 3.0, IEC 60601-1-2, ed. 4

2 EyeLink Portable Duo Host Software

This chapter covers the following topics:

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

2.1 Web User Interface (Web UI)

The Web User Interface (Web UI) is a tool supplied with the EyeLink Portable Duo 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 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 EyeLink Portable Duo 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. 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).

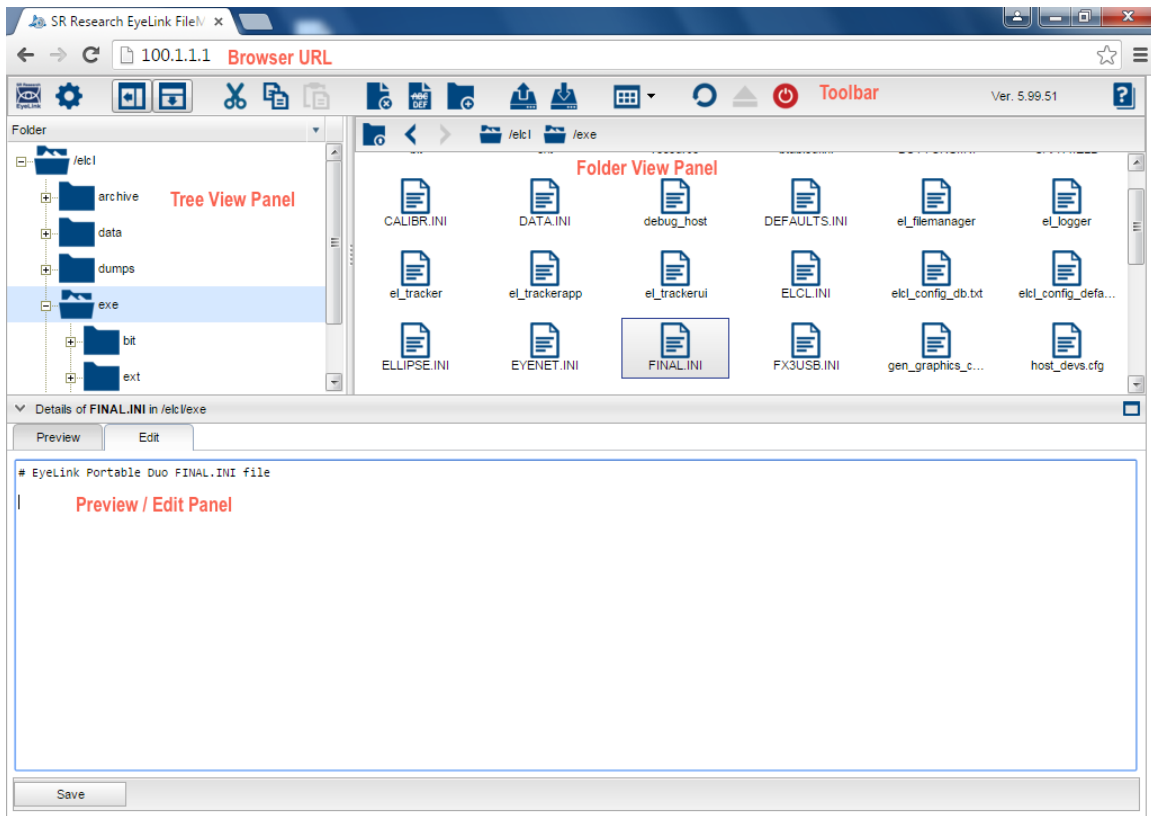



















Figure 2-1: File Manager Screen

- 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 (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 Portable Duo Host application if the camera is attached to the USB 3.0 ports on the Host PC.
	Configuration	Switches to the Configuration interface, allowing users to change some of the tracker settings.
	Show/Hide Tree	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 device safely from the Host PC. The ejection operation is to ensure the operating system is not busy reading from or writing to the USB 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 two 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, and the “elcl\data” folder, which is where all of the EDF files created during the experiments are stored. The “elcl\data” folder also stores the log files for the recording sessions and screen grabs created by pressing ALT+F7 on the Host keyboard, which can be used for troubleshooting purposes.

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 local computer (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. Neither the download nor upload operation is supported on the Host PC when the Web UI is running. 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 on 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 presently 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 the icons. 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; a second click will remove the item from the current selection. To select items which are next to each other, you may 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 (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 and another 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 Portable Duo camera connected to the USB 3.0 ports 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 (analog card, parallel port, button box) 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 that are

	important for proper visual angle and eye velocity calculations. Detailed instructions for updating the screen settings are provided in the EyeLink Portable Duo 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 5.4 of the EyeLink Portable Duo 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 the current document.

4) Configuring screen settings. To correctly compute visual angle, saccade amplitude, and eye velocity, the EyeLink eye tracker needs to know the physical characteristics of your setup. Any time you change your physical configuration (for example, if a new monitor is used, if the eye-to-screen viewing distance is changed, 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 Remote Mode use.

5) System Update - The EyeLink Portable Duo 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 <http://www.sr-support.com> (go to “Downloads -> Host PC Software -> Download: EyeLink Portable Duo”). Start the “System Update” utility, select the Update tab and click on the “Browse ...” button to locate the intended Host software installer 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 Portable Duo 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 5.4

“Customizing Screen Settings” of the EyeLink Portable Duo 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 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 other .INI files. This design makes it easy to edit a single file to keep track of changes made, makes updating the software easy (just 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
DATA.INI	-controls data written to EDF files, and the Ethernet link
DEFAULTS.INI	-default settings for all items in LASTRUN.INI: can be loaded from Setup menu
ELCL.INI	-contains commands specific to the EyeLink Portable Duo series; includes other .INI files for specific mounts
PDUOBTABLEU.INI, PDUOMTABLEU.INI, PDUORTABLEU.INI, and PDUORBTABLEU.INI	-list of mount-specific configuration files
EYENET.INI	-setup for Ethernet link: driver data, TCP/IP address
KEYS.INI	-special key function definitions, default user menus
LASTRUN.INI	-thresholds, menu choices etc. from the last session
PARSER.INI, REMPARSE.INI	-on-line parser data types, configuration, saccadic detection thresholds for the Remote (REMPARSER.INI) and the non-Remote mode (PARSER.INI). SR RESEARCH STRONGLY RECOMMENDS THAT YOU DO NOT MODIFY THESE FILES.

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)

Table 1: EyeLink Portable Duo Configuration Files

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. You can skip these steps if the Display PC is already able to communicate with the Host PC/eye tracker.


Now you can start a browser and type 100.1.1.1 in the address bar. The following browsers are supported:

- Firefox (version 20.0 or later)
- Google Chrome
- Internet Explorer (version 9.0 or later)
- Safari (version 5.0 or later).

2.2 Starting the Host Application

Make sure you have attached both plugs of the camera cable to the USB 3.0 ports on the Host PC. Now turn on the Host PC. The EyeLink Host application will start automatically. You will first see an EyeLink Portable Duo 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 lower-left corner of the Setup screen. The latest Host software can be downloaded from the SR Research support website <http://www.sr-support.com>

and can be installed using the System Update tool (see instructions in Section 5.1 “Host Software Update” of the EyeLink Portable Duo 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\data” folder and is retrievable through the File Manager. Consult section “5.2 Troubleshooting Instructions” of the EyeLink Portable Duo 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. There are two possible data output modes when running the EyeLink Portable Duo as a standalone system. These output modes are not mutually exclusive:

- a) Analog Output. Using the optional analog output card installed on a Desktop Host PC, data are available in analog format. Analog output

options are configurable in the ANALOG.INI file in the “elcl\exe” folder of the Host PC.

b) File Output. Eye data are available 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 the EyeLink Data Viewer software. Files can be manually created and closed via the “Advanced Settings” in the Setup Screen.

2.4 EyeLink Portable Duo 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.

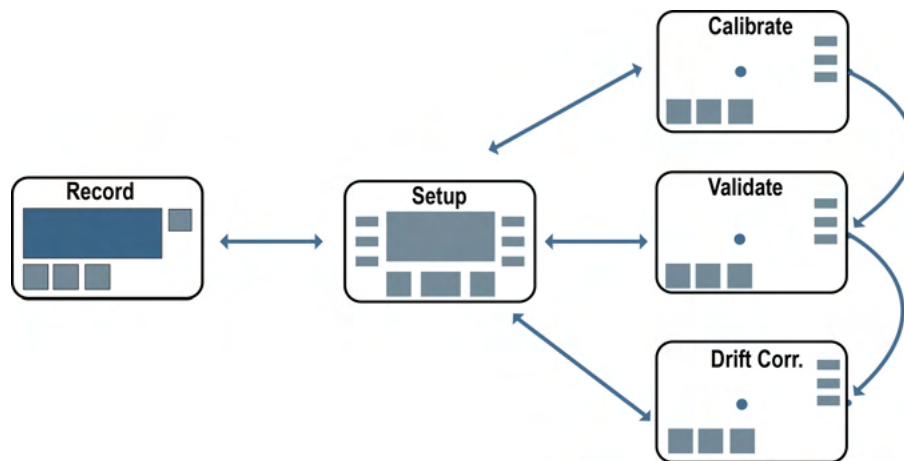



Figure 2-2: EyeLink Portable Duo Host PC Application Overview

Each of the modes shown in Figure 2-2 has a special purpose. Where possible, each screen has a distinctive appearance. Buttons for navigation and setup are provided on the right side of the screens. 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 modes 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.

Across all modes, the top of the screen displays the current eye tracker configuration, pupil tracking algorithm, as well as the camera and network connection status. The status area at the bottom of the screen displays the currently active recording data file as well as any warning or status messages.

The following sections explain the functions of each mode and the main access keys to other modes.

2.4.1 Setup Screen

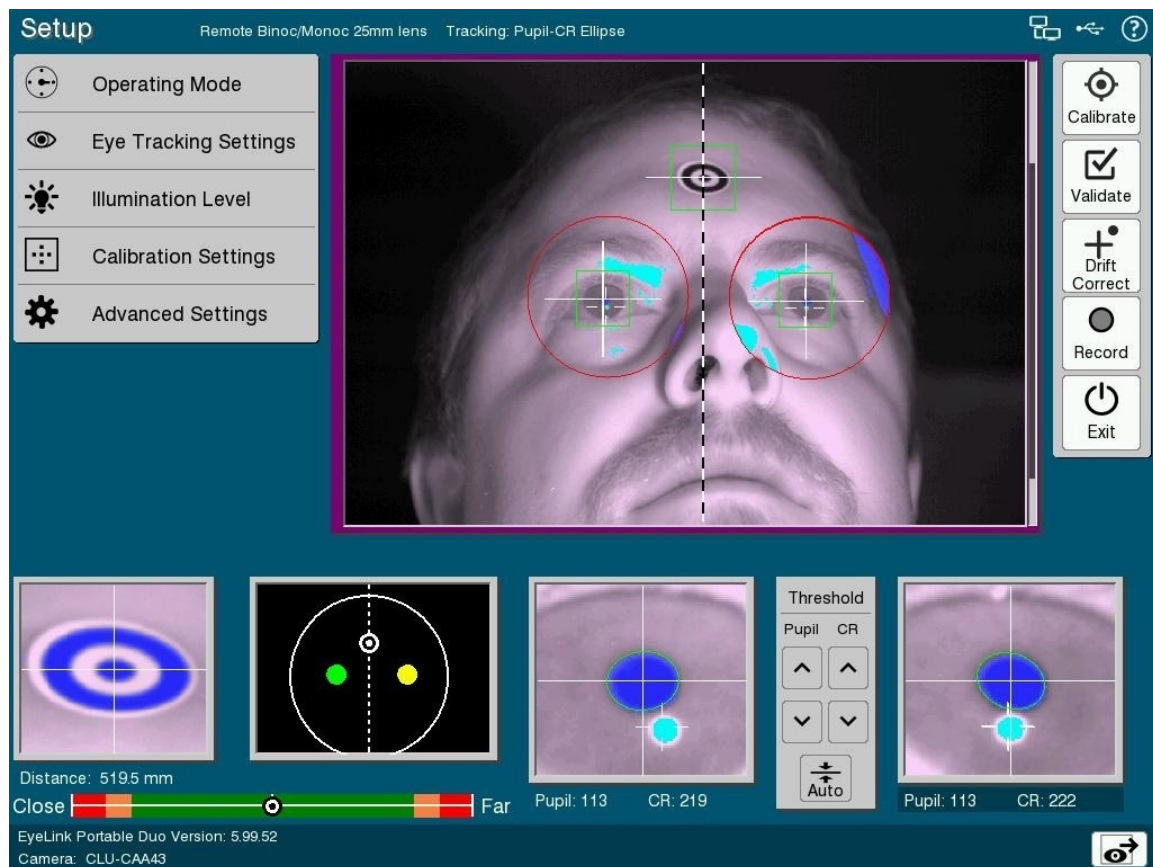



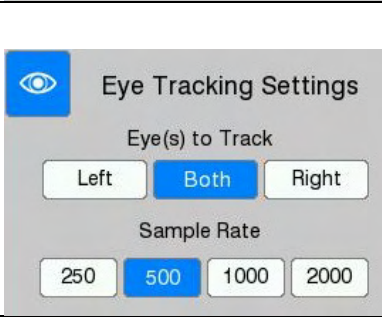

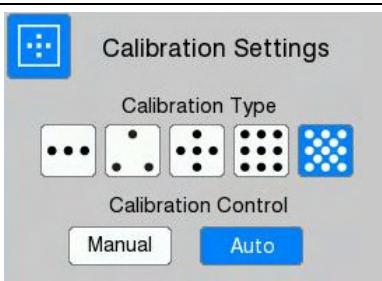
Figure 2-3: Example Setup Screen

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 camera 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, calibration settings, illumination level, and some other advanced tracker settings can be configured from the Setup screen.

Calibration, Validation, Drift Check/Drift Correct, and Recording can be initiated from this screen.

2.4.1.2 Setup Screen Main Functions

	<p>Select the tracker configuration (remote, head free-to-move mode, or head-stabilized mode). Here the head-stabilized mode is selected.</p>
	<p>Select the eye(s) to track and sampling rate during recording. Here both eyes are selected.</p> <p>Keyboard Shortcuts: B = Track both eyes; R = Track right eye; L = Track left eye; E = Cycle through eyes to track.</p>
	<p>Power level (100%, 75%) of the illuminators for the head-stabilized mode. The Remote Mode always uses 100% illumination level.</p> <p>Keyboard Shortcut: I = Change illuminator power level.</p>
	<p>This tab allows users to adjust two important calibration-related settings, namely, the calibration type and calibration mode.</p> <p>Calibration Type: Select the Calibration Type for calibration. Generally speaking, the more locations sampled, the greater the accuracy that can be expected. While the 9-point calibration type is good</p>

for the head-stabilized tracking mode, we recommend using 13-point calibration type for the Remote Mode to get the best recording accuracy.

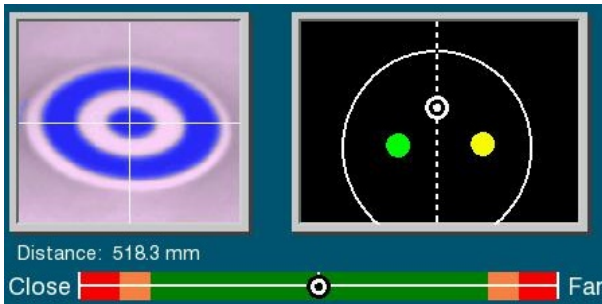
Calibration Mode: If set to “Manual”, the experimenter or participant needs to press the spacebar or ENTER key on Host or Display PC when the participant is looking at each calibration or validation target. If set to “Automatic”, the calibration and validation procedure automatically samples a target fixation once the eye settles and moves on to the next target.



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 settings to be crucially controlled are set by the Display PC application at runtime via a set of API calls. The Default Settings should be sufficient for many tracking applications.

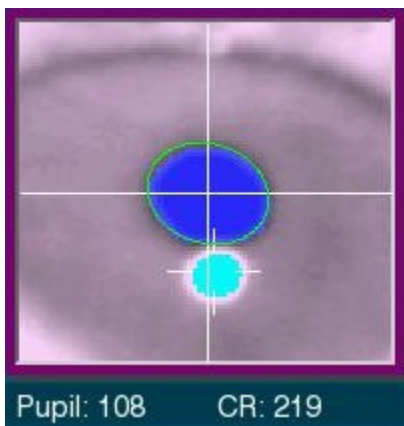
Details of the individual commands are listed in section 2.4.1.3.










The target thumbnail image shows the target sticker tracking status and reports the target-to-camera distance in millimeters (in the Remote mode only). It will display a “MISSING” error if the target is not present, or a “BIG ANGLE” error if the target has too large an angle to be tracked properly.

A target-to-camera distance scale is displayed at the bottom in the Remote mode to provide feedback whether the current distance is too close or too far.

The map view on the right shows the participant’s head position in the global camera image – the two colored dots represent each of the eyes; the target sticker image is also displayed in the Remote mode. Adjustments to the camera and/or participant’s position are required if the target and/or eyes are missing or very off-center in the map.



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. It will display a “PUPIL MISSING” error if the Pupil or CR is not present, a “BOUNDS” error if pupil or CR is missing, or the fitted gaze data doesn’t appear to be valid, and “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.

<p>Threshold</p> <p>Pupil CR</p> 	<p>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 automatically compute the pupil and CR threshold levels. Fine-tuning may be necessary.</p> <p>Keyboard Shortcuts: ↑ and ↓ increase and decrease pupil threshold respectively; + and - increase and decrease CR threshold respectively; A = Auto Threshold. For the Head-Stabilized Mode, pressing the key automatically computes the pupil and CR thresholds for the selected eye image; for the Remote Mode, it centers the search limit area on top of the current eye position, and resets the pupil/CR threshold bias.</p>
 <p>Calibrate</p>	<p>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.</p> <p>Keyboard Shortcut: C = Go to Calibration screen</p>
 <p>Validate</p>	<p>Click ‘Validate’ to go to the Validation screen. Validation shows the experimenter the gaze position accuracy achieved by the current calibration model. Validation should be run <i>after</i> a calibration has been performed.</p> <p>Keyboard Shortcut: V = Go to Validation screen</p>
 <p>Drift Correct</p>	<p>Click to go to the ‘Drift Check’ or ‘Drift Correct’ screen. A Drift Check/Correction is recommended before each trial to ensure that accuracy of the calibration parameters is maintained. Generally this is initiated via the application running on the Display PC.</p> <p>Keyboard Shortcut: D = Go to Drift Check/Drift Correct screen</p>
 <p>Record</p>	<p>Click to start eye tracker recording. This is generally initiated by the application running on the Display PC, so is most useful when using the EyeLink eye tracker in the standalone mode.</p> <p>Keyboard Shortcut: O = Go to ‘Record’ screen</p>
 <p>Exit</p>	<p>Click to exit the Host Application or to shut down the Host PC.</p>
	<p>Select to present the camera image on the Display PC monitor. This button will only be available when a display program is running on Display PC to control the eye tracker.</p> <p>Keyboard Shortcut: ENTER = toggle sending images over link</p>

2.4.1.3 Advanced Settings

Command Setting	Function
Randomize Calibration Order	Randomize the calibration and validation target presentation order.
Calibration Pacing Interval	Select the delay in milliseconds, between successive calibration or validation targets if automatic target detection is active (i.e., “Calibration Mode” is set to “Auto”).
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. The EyeLink Portable Duo eye tracker is generally drift-free so we recommend users keep the default setting (with the option turned off).
Use Search Limits Move Search Limits	<p>Search Limits are used to narrow down the area of the camera image to be searched for the pupil or CR. A red ellipse around the searched area appears in the Host PC’s global view if this option is enabled.</p> <p>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.</p> <p>If ‘Move Limits’ is checked, the search limit area moves along with the pupil.</p> <p>Search Limits are automatically active with the Remote Mode.</p>
Pupil Tracking Algorithm	Select the method (Centroid or Ellipse Fitting) used to fit the pupil and determine pupil position. The Ellipse model is the only method available with the Remote Mode option.
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.
File Data Content	Selecting ‘Samples’ will record data samples to the EDF file, and selecting Events will record on-line parsed events. These options are only useful for standalone recordings. If you collect data by running a display program, these settings will likely be overwritten by display commands.

Pupil Size Data	Record the pupil area or diameter. The area is recorded in scaled camera image pixels. Diameter is calculated from pupil area fit using a circle model.
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 Content	<p>The data to be recorded for the sample data structure.</p> <ul style="list-style-type: none"> • 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 parallel port or EyeLink Analog Card) on each sample, in the EDF file.
File Sample Filter	<p>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 to link/analog output. The current option selects filter level of data recorded to the EDF file.</p> <p>Each increase in filter level reduces noise by a factor of 2 to 3.</p>
Link/Analog Filter	<p>Select the filter level for data available via the Ethernet link and analog card output.</p> <p>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.</p>
Open File	Click to open a data file for data recording and closes any open file.
Close File	Close the currently open EDF file
Add Message	Add a message to the EDF file

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.
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.
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 for the Head-Stabilized Mode. For the Remote Mode, center the search limit area on top of the current eye position, and reset the pupil/CR threshold bias.
E	Cycle through eye(s) to track.
L	Select left eye for recording.
R	Select right eye for recording.
B	Select both eyes for recording.
F	Select sampling rate of EyeLink recording.
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. On the Display PC, use a combination of Ctrl and cursor keys instead.
X	Toggle crosshair display.
T	Toggle threshold coloring display.
I	Change illuminator power.
CTRL + E	Toggle Auto Exposure on or off.
CTRL and ↑, or ↓	Adjust bias value of Auto Exposure.

2.4.2 Calibration Screen

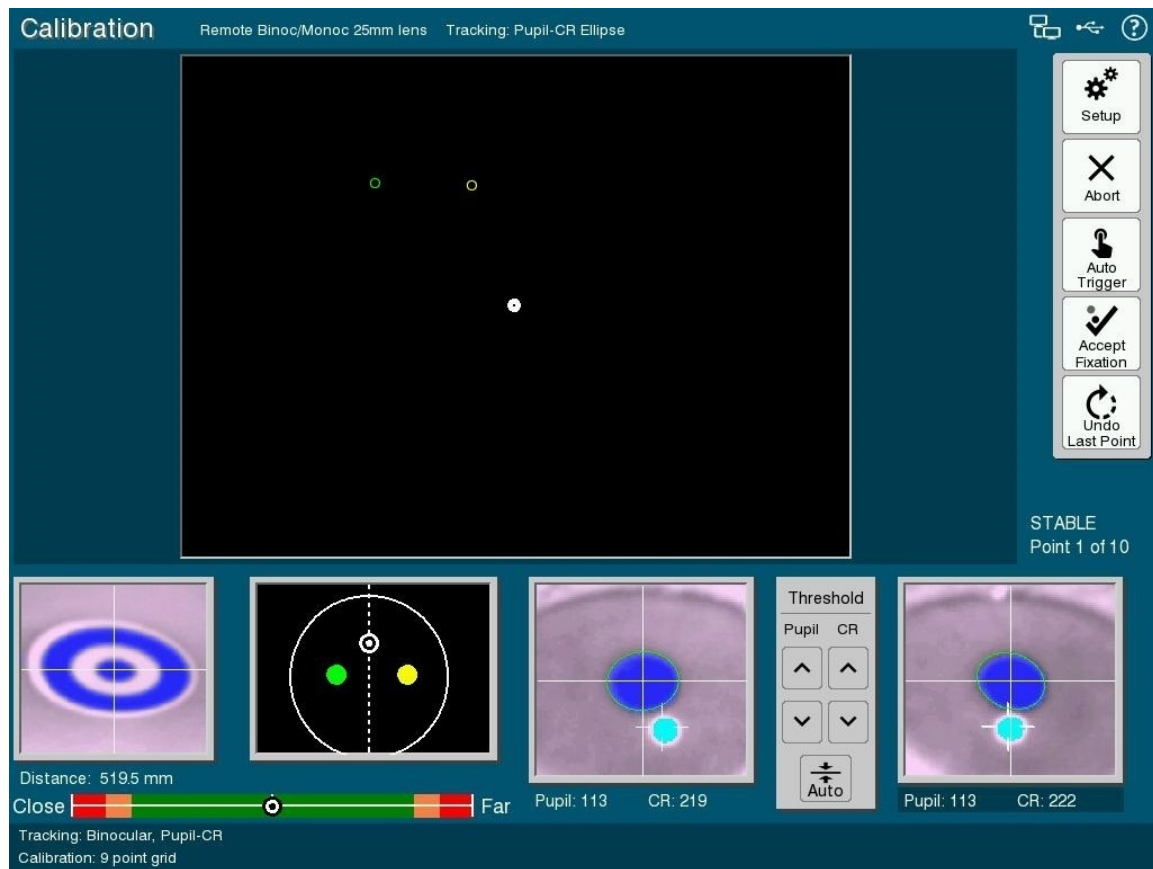


Figure 2-4: Example Calibration Screen

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 for that target. During this time, feedback graphics are presented on the Host PC display to aid the experimenter/operator in the process. 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 validation. 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. The panels on the left show the view of the target sticker (in the Remote mode only), and the map view of the eyes and target sticker in the global camera image. Camera adjustment is

required if the target and/or eyes are missing or very off-center in the map. 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 Fixation' 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 Trigger' button is disabled (which will be the case if the 'Calibration Control' in the Calibration Settings 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 '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

 Setup	Click to go back to the 'Setup' screen. Keyboard Shortcut: ESC = 'Setup'
 Abort	Terminate Calibration sequence. Keyboard Shortcut: ESC = Abort
 Restart	Restart the calibration. Keyboard Shortcut: Delete = Restart
 Auto Trigger	Click to automate the calibration sequencing. Keyboard Shortcut: A = Auto Trigger
 Undo Last Point	Click to repeat the last calibration target or last few targets. Keyboard Shortcut: Backspace = Undo last few targets

	Click to accept fixation value, after the participant's gaze is stable on the target. Keyboard Shortcuts: ENTER, Spacebar = 'Accept Fixation'
	Click to accept the calibration and switch to the Setup screen. Keyboard Shortcut: ENTER = Accept the calibration
	Click to validate calibration values. Keyboard Shortcut: V = Validate calibration values
	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	Repeat previous calibration targets
After Calibration	
ENTER	Accept calibration values
V	Validate calibration values
ESC	Discard calibration values
Backspace	Repeat last calibration target

2.4.3 Validation Screen

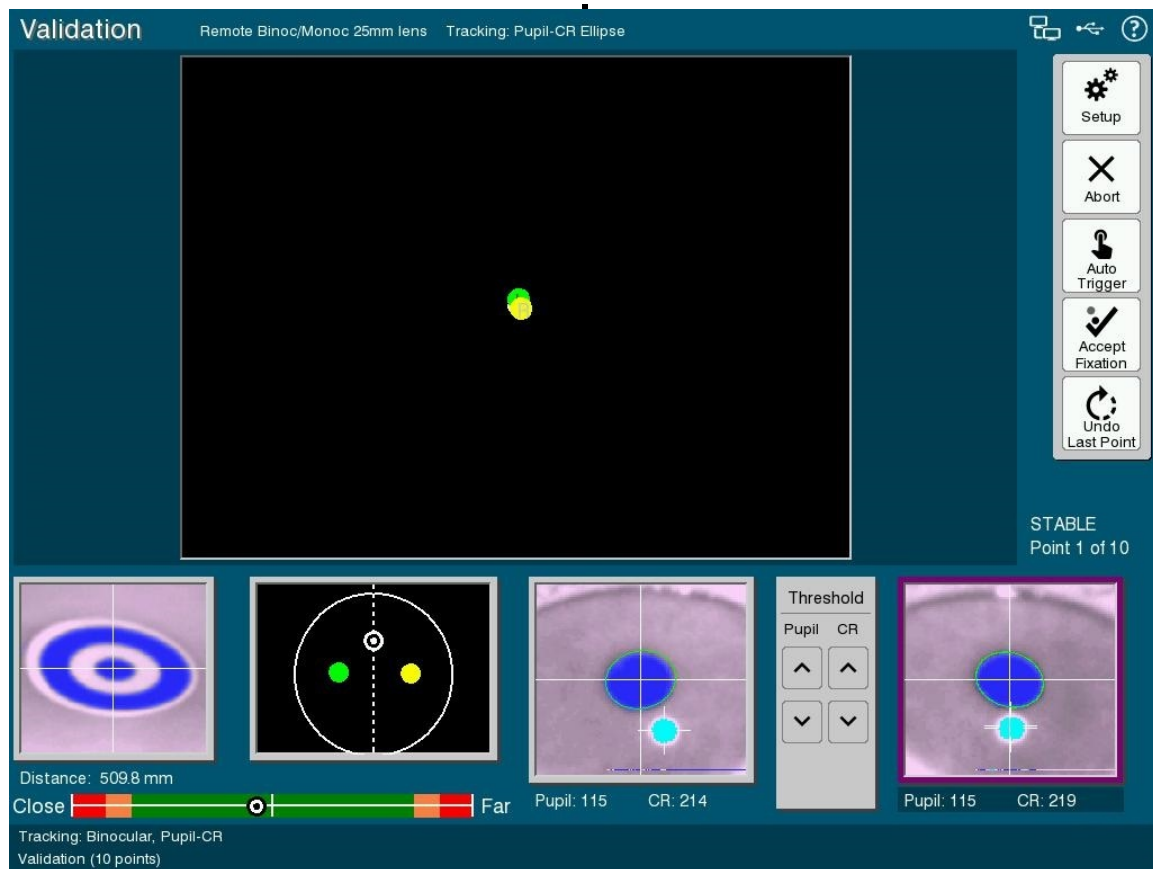


Figure 2-5: Example Validation Screen

2.4.3.1 Validation Screen Purpose

The Validation screen displays 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 point 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.

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. 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 Validation Screen Main Functions

 Setup	Click to go to the 'Setup' screen. Keyboard Shortcut: ESC = 'Setup'
 Abort	Click to terminate the validation process and revert to the Setup screen. Keyboard Shortcut: ESC = Abort the validation process
 Restart	Click to restart the validation process Keyboard Shortcut: DELETE = Restart validation
 Auto Trigger	Click to automate the validation sequence according to a configurable Pacing Interval (one second by default value).
 Accept Fixation	Click to accept fixation value, after the participant's gaze is stable on the target. Keyboard Shortcuts: ENTER, Spacebar = 'Accept Fixation'
 Undo Last Point	Click to repeat the last validation target or last few targets. Keyboard Shortcut: Backspace = Undo last few targets
 Accept	Click to accept the validation and switch to the Setup screen. Keyboard Shortcut: ENTER = Accept the validation
 Discard	Click to discard the current validation and switch the tracker to the Setup screen. Keyboard Shortcut: ESC = Discard the validation

2.4.3.3 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 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
During Validation	
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)
After Validation	
ENTER	Accept validation values
ESC	Discard the current validation and switch to setup screen
DELETE	Restart validation

2.4.4 Drift Check/Drift Correct Screen

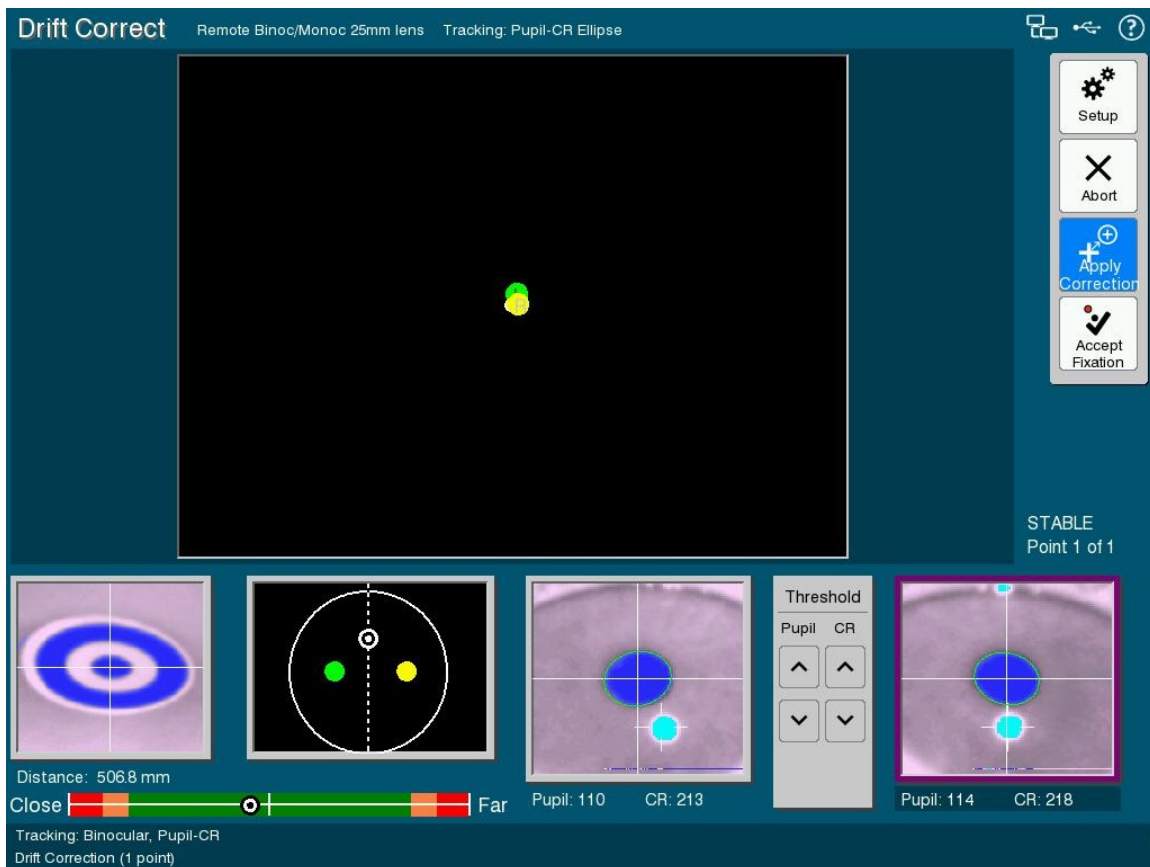


Figure 2-6: Example Drift Check/Drift Correct Screen





2.4.4.1 Drift Check/Drift Correct Screen Purpose

The Drift Check/Drift Correct screen displays a single target to the participant and then measures the difference between the computed fixation position and the current target. As with the EyeLink 1000 and 1000 Plus, the default “drift check” configuration of EyeLink Portable Duo leaves the calibration model unmodified. The purpose therefore, is to check whether the calibration model is still accurate. If the error between the measured location of the fixation and the drift check target is large, the experimenter is prompted to acquire another sample. If the error remains large (i.e., the prior sampling error was reproduced), the drift check will fail and another calibration will be required (see Section 3.11 for more details).

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

Important: In EyeLink I and II systems, the fixation error calculated during drift correction was used to shift/correct the calibration map. This linear adjustment often greatly improved the overall accuracy for the upcoming recording. However, with the EyeLink Portable Duo eye tracker, the default behavior in the pupil-CR mode is to report the calculated fixation error without altering the calibration map in any way. Therefore the procedure is better viewed as a “Drift Checking” procedure in the EyeLink Portable Duo, though a true drift correction can be easily enabled (by toggling on the “Apply Correction” button after entering in the Drift Check screen; see also section 3.11).

2.4.4.2 Drift Check/Drift Correct Screen Main Functions

 Setup	Click to go to the ‘Setup’ screen. Keyboard Shortcut: ESC = exit to Setup screen
 Apply Correction	Whether a correction will be applied to the calibration mapping. If “Apply Correction” is toggled on, a true drift correction will be performed; otherwise, the tracker just reports the error without correcting for it. Keyboard Shortcut: D = Toggles on/off the “Apply Correction” button
 Abort	Click to terminate the drift correction/drift check and exit to the Setup screen
 Accept Fixation	Press to accept fixation value, after the participant’s gaze is stable on the target. Keyboard Shortcuts: ENTER, Spacebar = ‘Accept Fixation’

2.4.4.3 Drift Check/Drift Correct 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 on/off the “Apply Correction” button.

2.4.5 Record Screen

2.4.5.1 Record Screen Purpose

The Record screen allows users to initiate and observe data collection. The user can choose either a Gaze Cursor View (see Figure 2-7) or Plot View (see Figure 2-8) by toggling the “Plot View” button, or by pressing the G key.

The Gaze Cursor View plots the current gaze position of the participant in the calibrated screen pixel coordinates. Any graphics drawn on the screen can be used as a reference for the real-time gaze-position cursor. The Gaze Cursor View is only useful when the EyeLink system’s built-in calibration routines have been used for gaze position calculation. The Plot View displays the x and y data traces as a function of time.

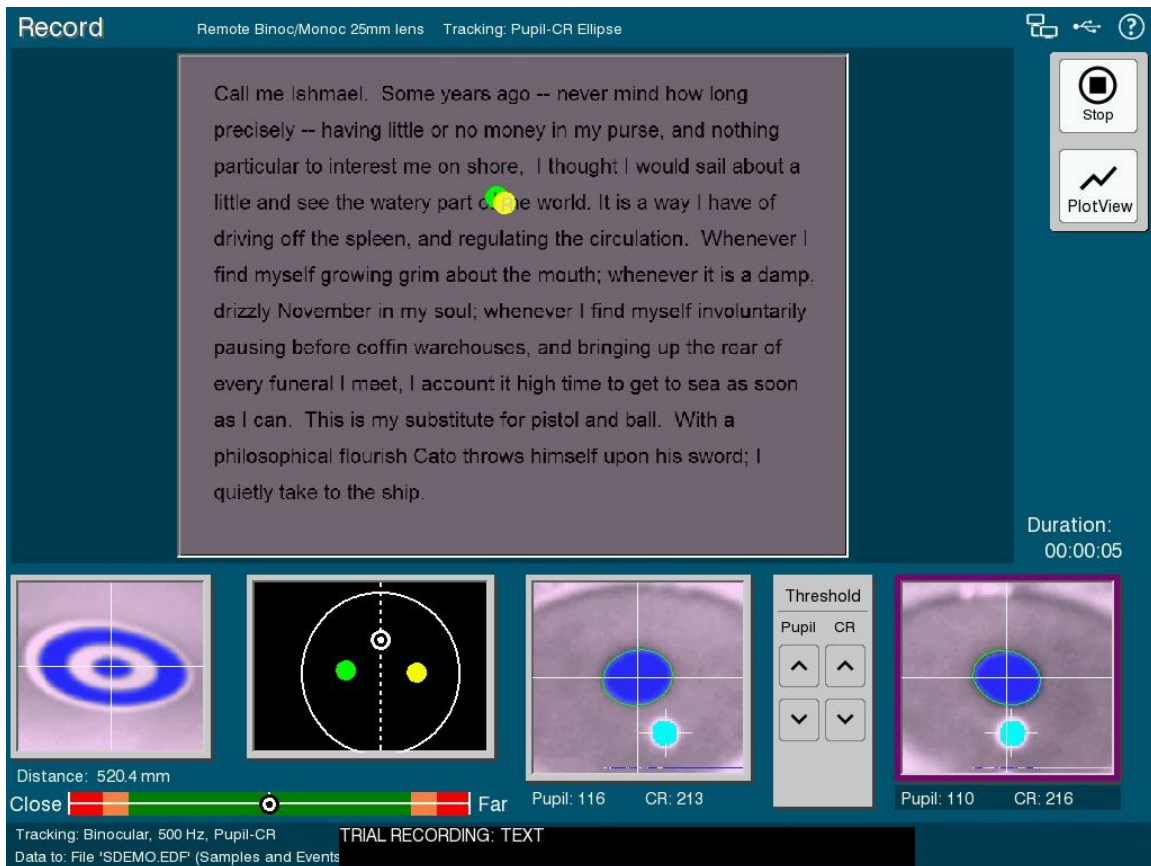





Figure 2-7: Example Record Screen (Gaze Cursor View)



Figure 2-8: Example Record Screen (Plot View)













2.4.5.2 Record Screen Main Functions (Gaze View and Plot View)

 Stop	Stop the recording of data to the EDF file. Keyboard Shortcut: ESC = Stop Recording
 PlotView	If enabled, plot the x, y eye data being acquired as a function of time. Keyboard Shortcut: G = Toggle between Gaze Cursor and Plot Views
 GazeView	If enabled, plot the x, y eye data in the calibrated screen pixel coordinates (on top of a reference image if available). Keyboard Shortcut: G = Toggle between Gaze Cursor and Plot Views

2.4.5.3 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 clicking on the “Zoom In” or “Zoom Out” button 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. The plotting speed of the view can be changed by clicking on the “Faster” and “Slower” buttons. The visibility of the x and y eye traces can be controlled by the “Left X”, “Left Y”, “Right X”, and “Right Y” buttons at the bottom of the plot control panel.

 Mark	The “Mark” button marks the time this button pressed on the screen with a thin white line. Keyboard Shortcut: INS = Add rewind marker	
 Default	Change to the default viewing settings. Keyboard Shortcut: C = Revert to default view	
 Rewind	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	
 Freeze	Stop data plotting (the eye tracker continues recording despite that the plot view stops screen updating). Keyboard Shortcut: P = Freeze data plotting	
 Zoom	 Zoom	Select zooming level (or use ALT + ↑ and ALT + ↓ keys). Keyboard Shortcuts: ALT + ↑/↓ = Adjust zooming levels
 Faster	 Slower	Set the amount of data to be plotted on screen per sweep. Keyboard Shortcuts: < and > = Change plot speed
 Left X	 Right X	Select which eye traces to be displayed.
 Left Y	 Right Y	

2.4.5.4 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.
G	Toggle between Gaze Cursor View and Plot View
Plot View Only (Recording Screen)	
< or >	Change plot speed
P	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 Portable Duo Tutorial: Running an Experiment

The following tutorial will allow you to test the EyeLink Portable Duo system, assuming that you have already arranged a proper layout of the eye tracker equipment and configured Screen Settings for your setup (see Section 1.1 “Suggested Equipment Layout” and Section 5.4 “Customizing Screen Settings” of the “EyeLink Portable Duo Installation Guide” document). A summary of the setup procedure can be found at the end of the discussion (“3.13 EyeLink Portable Duo Setup Summary”). This section leads you through a straightforward participant setup and eye-tracking demonstration. For the easiest 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.

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 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).

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 “Exit” 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.

The current chapter illustrates how to run through a typical eye tracker session using the TRACK.EXE example from the Windows Display Software. If you prefer to use other examples or operating systems, please see section 3.15 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 copyright message will appear on the Display PC, and a network icon will be displayed on the upper right corner of the Host screen.

A dialog will appear on the Display PC asking you to enter a Track EDF file name. Enter “TEST” (without the quotes “ ”).

Once TRACK is running, control is possible both from the Host PC and Display PC keyboard, 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. We will perform most of the EyeLink Portable Duo setup by using the Host PC keyboard.

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 camera-image windows in the middle of the display, a global view of the face on the top and zoomed view(s) of the eye(s) being tracked at the bottom. Navigation buttons to access other Tracker screens are on the right, while selection buttons for tracking mode and other functions are on the left of the screen.

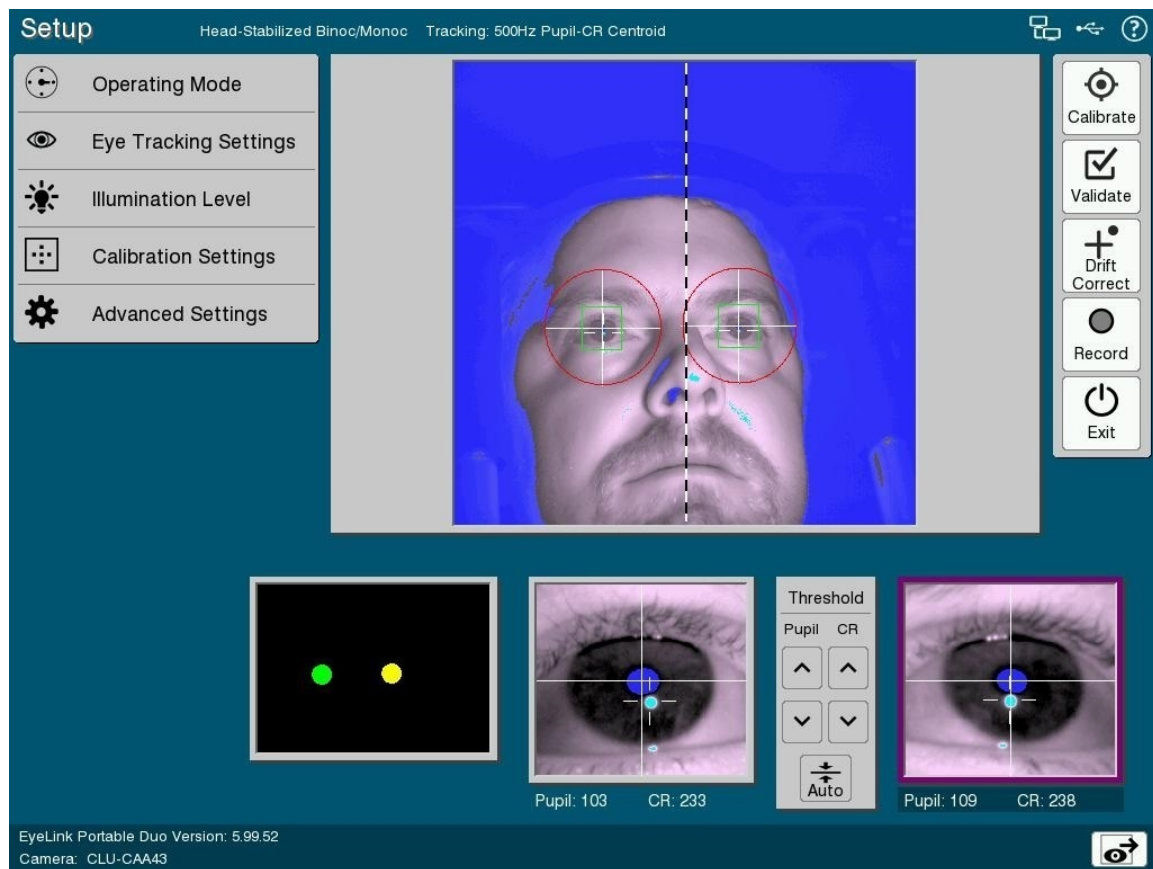


Figure 3-1: Example Setup Screen

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 (or click on the “Image to Display” button) will start displaying an image of the selected camera view on the Display PC’s monitor. In the Setup screen, you can select one of the camera views to be 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

To practice setting up the camera, you will need a participant. If none is available, you can practice this part of the procedure on yourself. It may be 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.

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

The EyeLink Portable Duo supports two operational modes – head-stabilized mode, and remote mode.

Please continue with one of the following participant setup tutorials.

Head Stabilized Monocular or Binocular Recording

3.2.1 “Participant Setup in Head-Stabilized Mode”

Head-Free, Monocular or Binocular Recording (no head support used)

3.2.2 “Participant Setup in Remote Head-Free-to-Move Mode”

3.2.1 Participant Setup in Head-Stabilized Mode

The EyeLink Portable Duo eye tracker can be configured to track eye movements at 250, 500, 10000, or 2000 Hz monocularly or binocularly. The eye tracker can be mounted either on a tripod or a Laptop Mount. Instructions vary slightly depending on which mount you are using.

Take the following steps if you plan to set up the eye tracker if you have mounted the camera on a Laptop Mount (detailed instructions for installing the

camera can be found in section 4.1 “Installing the Eye Tracker on the Laptop Mount” of the EyeLink Portable Duo Installation Guide).

- 1) Please make sure you use a height-adjustable chair so that you can raise/lower the participant to the appropriate height. When the subject is seated, tilt the screen of the laptop so that it is perpendicular to the participant’s line of sight.
- 2) Place the Laptop Mount over the keyboard area of the laptop with the two side rails resting on the edges of the laptop. You can slide the mount forward if the camera is blocking the participant’s view at the bottom of the screen; otherwise, the camera should be placed as close to the screen as possible without blocking the participant’s view. Adjust the position of the laptop so that the eye tracker is placed at a distance of about 45 cm if measuring from the front of the unit to the participant's eyes. The camera is recessed about 7 cm behind the front of the enclosure, and the ideal eye-to-camera distance is about 52 cm. Please measure the screen dimensions and viewing distance and update screen settings for the tracker (see section 5.4 of the EyeLink Portable Duo Installation Guide).
- 3) Start the EyeLink Host PC application. Check whether it displays “Head-Stabilized” at the top of the Setup screen. If not, click the “Operating Mode” panel in the top-left corner of the screen and choose the “Head-Stabilized” Mode.
- 4) After the participant is seated, check the camera image displayed on the Host PC. If the participant’s eye image is not displayed in the vertical center of the camera view, adjust the camera angle by loosening the clamping knob on the right side of the mount, holding the camera with your left hand and tilting it to the intended angle, and then tightening the clamping knob to keep the camera at the intended position. Adjust the angle/position of the laptop if the participant’s eyes are not displayed in the horizontal center of the camera view. If both eyes are tracked, 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 the dotted line is between the two eyes.

If you have the eye tracker mounted on a tripod (see section “3.1 Mounting the Eye Tracker on the Tripod” of the EyeLink Portable Duo Installation Guide for mounting instructions), please take the following steps to set up the eye tracker.

- 1) 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.

- 2) Position the monitor so that it subtends no more than 32 degrees of visual angle horizontally and 25 degrees of visual angle vertically for the participant. The eye-to-monitor distance should be at least 1.75 times the display width to ensure that it falls within the trackable range of the eye tracker. If you are using a large/wide-screen monitor, this means that there will be a gap between the camera and monitor. Please measure the screen dimensions and viewing distance and update screen settings for the tracker (see section 5.4 of the EyeLink Portable Duo Installation Guide).
- 3) The eye tracker should be placed at a distance of about 45 cm if measuring from the front of the unit to the participant's eyes. The camera is recessed about 7 cm behind the front of the enclosure, and the ideal eye-to-camera distance is about 52 cm.
- 4) Position the eye tracker so that it is centered horizontally on the front of the monitor. The eye tracker should also be raised so that the top of the unit is as close as possible to the lower edge of the visible part of the monitor without blocking the participant's view.
- 5) Start the EyeLink Host PC application. Check whether it displays "Head-Stabilized" at the top of the Setup screen. If not, click the "Operating Mode" panel in the top-left corner of the screen and choose the "Head-Stabilized" Mode.
- 6) Ask the participant to be seated. Adjust the height of the chair so that the participant is comfortable and their eyes are aligned to the upper quarter of the monitor. Ask the participant to lean her/his forehead against the forehead rest and adjust the height of the chinrest so that the participant's chin rests comfortably on the chin rest pad while maintaining the eye alignment to the top 25% of the screen.
- 7) In the global view window, the eye(s) to be tracked should appear in the center of the camera image. If both eyes are tracked, 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 the dotted line is between the two eyes. Move the eye tracker to the left or right or loosen the tripod adjustment knob and adjust the camera angle slightly so that the illumination level and pupil/CR threshold values are similar between the two eyes. (Note that the dotted line may not align with the center of the face precisely).

Once you see the camera image in the global view, move the Host PC mouse cursor on top of the tracked eye and click on the left mouse button. The camera image for the eye should now be displayed in the zoomed view. If the pupil is detected, a crosshair will now be drawn on the eye image.

Please note that for most participants, you will just need to adjust the height of the chinrest and chair to get the intended camera image without changing the eye tracking unit. However, for participants wearing glasses, depending on the shape and reflection of the glasses, you may need to make slight adjustments to the eye tracking unit (e.g., moving the camera closer to the participant, lowering the position of the camera, and/or adjusting the angle of the camera, or the participant seating) so that reflections from the glass will not interfere with pupil or CR acquisition. The left panel of the following figure illustrates a good camera setup whereas the reflections in the right panel partially block the pupil image.

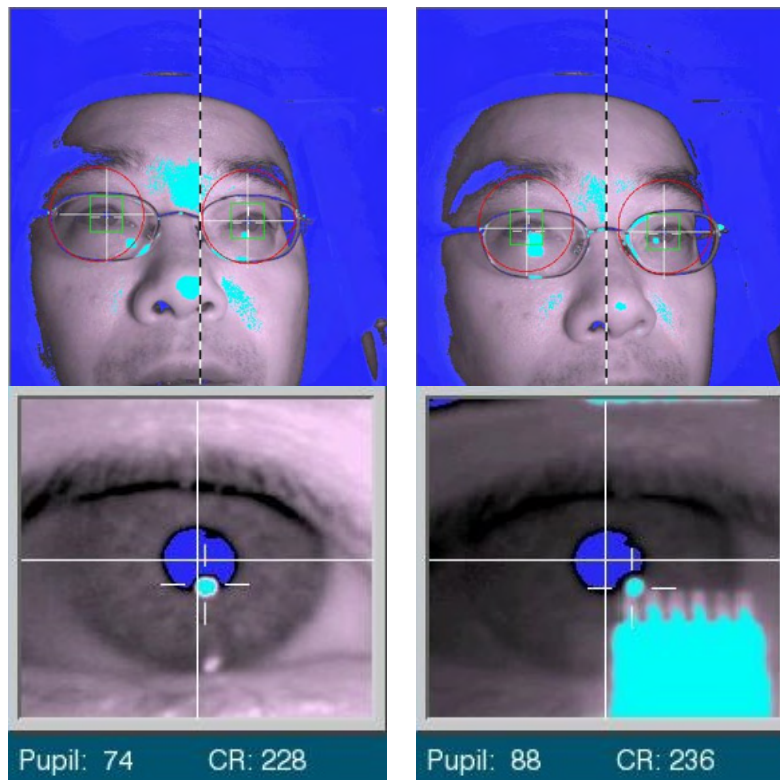


Figure 3-2: Camera Setup with Participants Wearing Glasses

If the image becomes too dark or too light, wait one second while the auto-contrast adjusts itself. To obtain the sharpest image of the participant's eyes, the camera should be focused by rotating the focusing wheel (installed at the underside of the eye tracker - about 3 cm from the front and 4 cm from the left side of the unit). The experimenter can access the control by placing one hand under left side of the camera, with thumb on top of the unit. Be sure the hand is not blocking the optical window on the front of the unit. Feel with the index finger for a slot with a recessed ribbed wheel. Use the index finger to push the wheel left or right slightly, until the best focus is achieved. Do not over-adjust

the focus. It may only require 1 or 2 millimetres of motion to reach the correct focus position. If a turquoise (CR signal) appears near the pupil, the best focus will minimize the size of this colored circle.

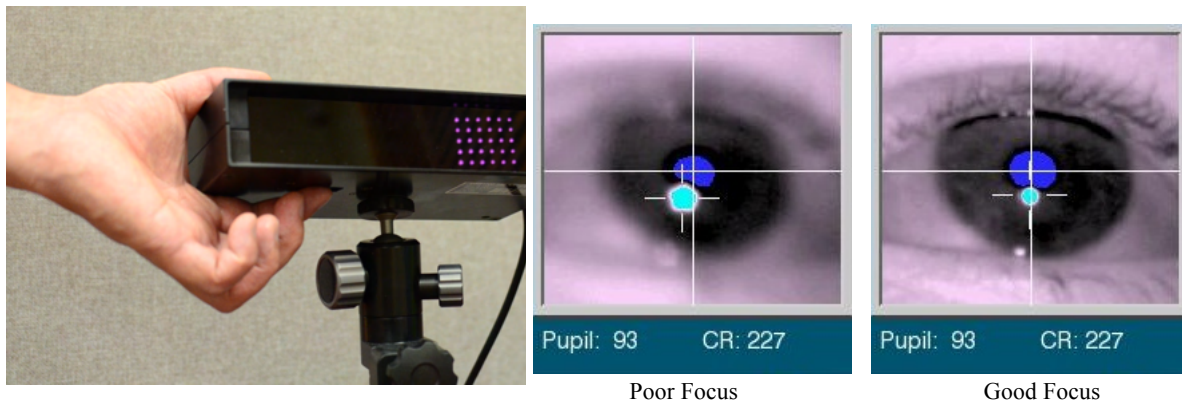


Figure 3-3: Focusing the Camera Image

At the recommended distance, the “Illuminator Power” level in the Setup screen should be set to 100%. If the participant wears glasses, or if the thresholds are low, you may consider moving the eye tracking unit closer to the participant.

Now proceed to section 3.3 “Setting Pupil Thresholds”.

3.2.2 Participant Setup in Remote Head-Free-to-Move Mode

The Remote Mode of the EyeLink Portable Duo eye tracker is designed for applications where a chin rest or head mount is not desirable or perhaps not even possible (e.g., patient work, gerontology, studies on young children, etc.). The Remote Mode provides up to 1000 Hz tracking as well as up to 1000 Hz head distance estimation via the use of a small target sticker placed on the participant’s forehead. Sections 3.2.2.1 and 3.2.2.2 discuss setup instructions specific for when the camera is installed on a tripod or a Laptop Mount. Section 3.2.2.3 continues with a general discussion on operating the eye tracker in the Remote mode.

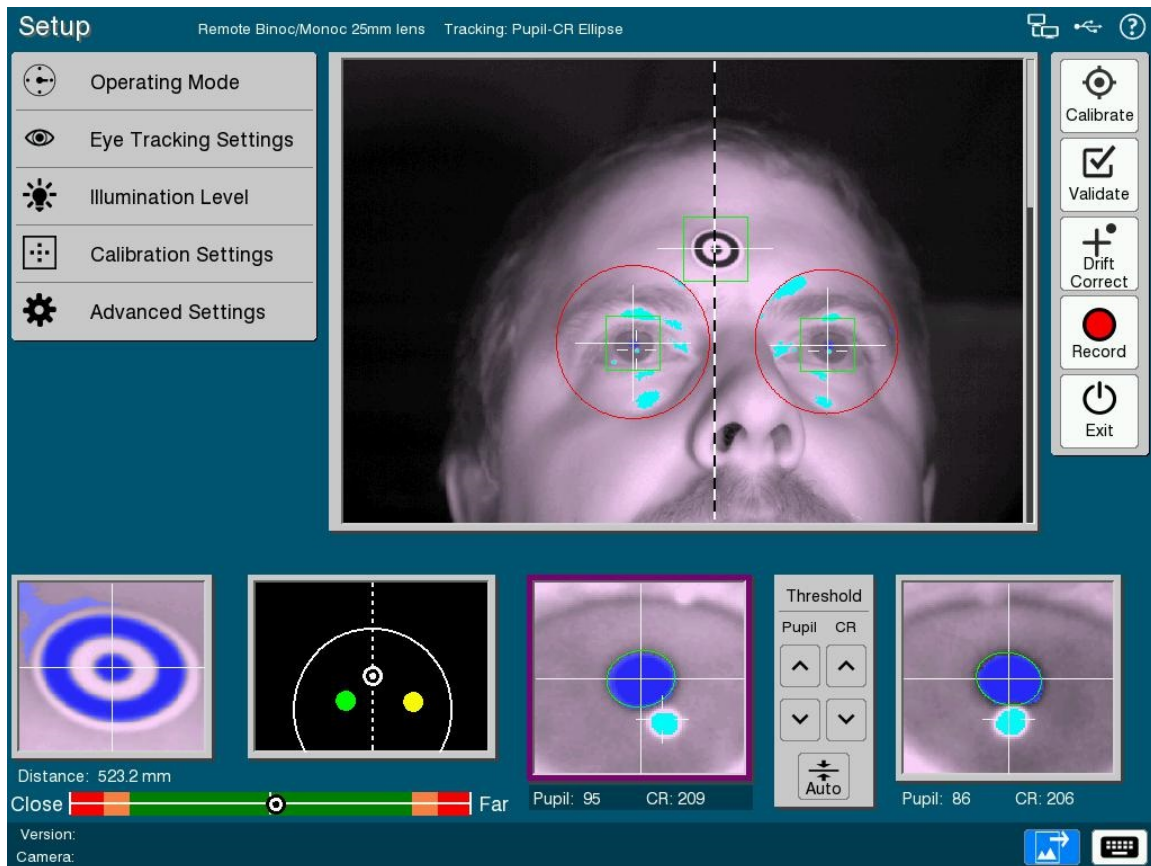


Figure 3-4: Setup Screen in the Remote Mode

3.2.2.1 Eye Tracker Setup with a Tripod

Please take the following steps to adjust the eye tracker if it is mounted on a tripod.

- 1) 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 quarter of the monitor.
- 2) Ideally the camera should be placed at a distance of about 50-55 cm from the participant's eyes. This means that if you are using a monitor smaller than 20", the eye tracker can be placed right in front of the monitor with no extra space between them. If you are using a larger monitor, it will be necessary to move the monitor back while keeping the eye tracker at its optimal distance from the participant, so as to increase the distance between the participant and the screen while still ensuring that the eye tracker can track the participants properly (the maximum viewing angle of the display should be within 32° horizontally and 25° vertically). In such cases, measure the shortest distance (in millimeters) from the back of the

camera case to the Display monitor and update all sections of the “Screen Settings” configuration tool (“Camera-to-Screen Distance” section in particular; see section 5.4 of the EyeLink Portable Duo Installation Guide). This step is very important for the head movement compensation when recording the eye position data in the Remote Mode.

- 3) The eye-tracking unit should be aligned with the horizontal center of the monitor. For maximum eye tracking range, the unit should be raised so that the top of the unit is parallel with, and as close as possible to, the lower edge of the visible part of the monitor without blocking the participant’s view of the screen. To keep the viewing distance relatively constant throughout a recording session, a comfortable, high-backed, stable chair for the participant is recommended.
- 4) Start the Host PC application. Check whether it displays “Remote” at the top of the Setup screen. If not, click the “Operating Mode” panel in the top-left corner of the screen and choose the Remote Mode option.
- 5) A camera image should now be displayed in the global view of Setup screen. Ask the participant to be seated. Adjust the height of the chair so that the participant is comfortable and his/her line of sight is aligned to the top 25% of the screen. Adjust your eye tracker position so that the eye to be tracked appears in the center of the global camera view (see Figure 3-4).
- 6) Now continue with instructions in section 3.2.2.3 “Participant Setup in the Remote Mode”.

3.2.2.2 Eye Tracker Setup with a Laptop Mount

Take the following steps if the eye tracker is mounted on a Laptop Mount.

- 1) Please make sure you use a height-adjustable chair so that you can raise/lower the participant to the appropriate height. When the subject is seated, tilt the screen of the laptop so that it is perpendicular to the participant’s line of sight.
- 2) Place the laptop mount over the keyboard area of the laptop with the two side rails resting on the edges of the laptop. You can slide the mount forward if the camera is blocking the participant’s view at the bottom of the screen; otherwise, the camera should be placed as close to the screen as possible without blocking the participant’s view. Adjust the position of the laptop so that the eye tracker is placed at a distance of about 45 cm if measuring from the front of the unit to the participant's eyes. The camera is recessed about 7 cm behind the front of the enclosure, and the ideal eye-to-camera distance is about 52 cm.

- 3) Please measure the screen dimensions, the shortest distance in millimeters from the back of the camera case to the screen (for the “Camera-to-Screen Distance” setting), and update all sections of the “Screen Settings” configuration tool (see section 5.4 of the EyeLink Portable Duo Installation Guide).
- 4) Start the Host PC application, click the “Operating Mode” panel and choose “Remote Mode” if the eye tracker is not set to the intended mode.
- 5) After the subject is seated, check the camera image displayed on the Host PC. If the participants’ eyes are not displayed in the vertical center of the camera view, adjust the camera angle by holding the camera with your left hand and tilting it to the intended angle, and then tightening the clamping knob on the right side of the mount to keep the camera at the intended position. Adjust the angle of the laptop if the participants’ eyes are not displayed in the horizontal center of the camera view (see Figure 3-4).
- 6) Now continue with instructions in section 3.2.2.3 “Participant Setup in the Remote Mode”.

3.2.2.3 Participant Setup in the Remote Mode

Place a target sticker on the participant’s forehead (see Figure 3-5). This small target sticker allows tracking of head position even when the pupil image is lost (i.e., during blinks or sudden movements). Ideally, it should be just above the eyebrow of the tracked eye if tracking monocularly or on the forehead between the two eyes if tracking binocularly. If the target sticker is placed too much towards the side of the forehead (see bottom panel of Figure 3-5), the tracker may report a BIG ANGLE error in the target thumbnail image when the participant rotates the head in the direction of the sticker.

For optimal performance, adjust the participant’s seating so that the tracker reports a target-to-camera distance of about 520 mm under the zoomed target view. The distance scale at the lower left corner of the Setup screen provides instantaneous feedback about the current viewing distance.

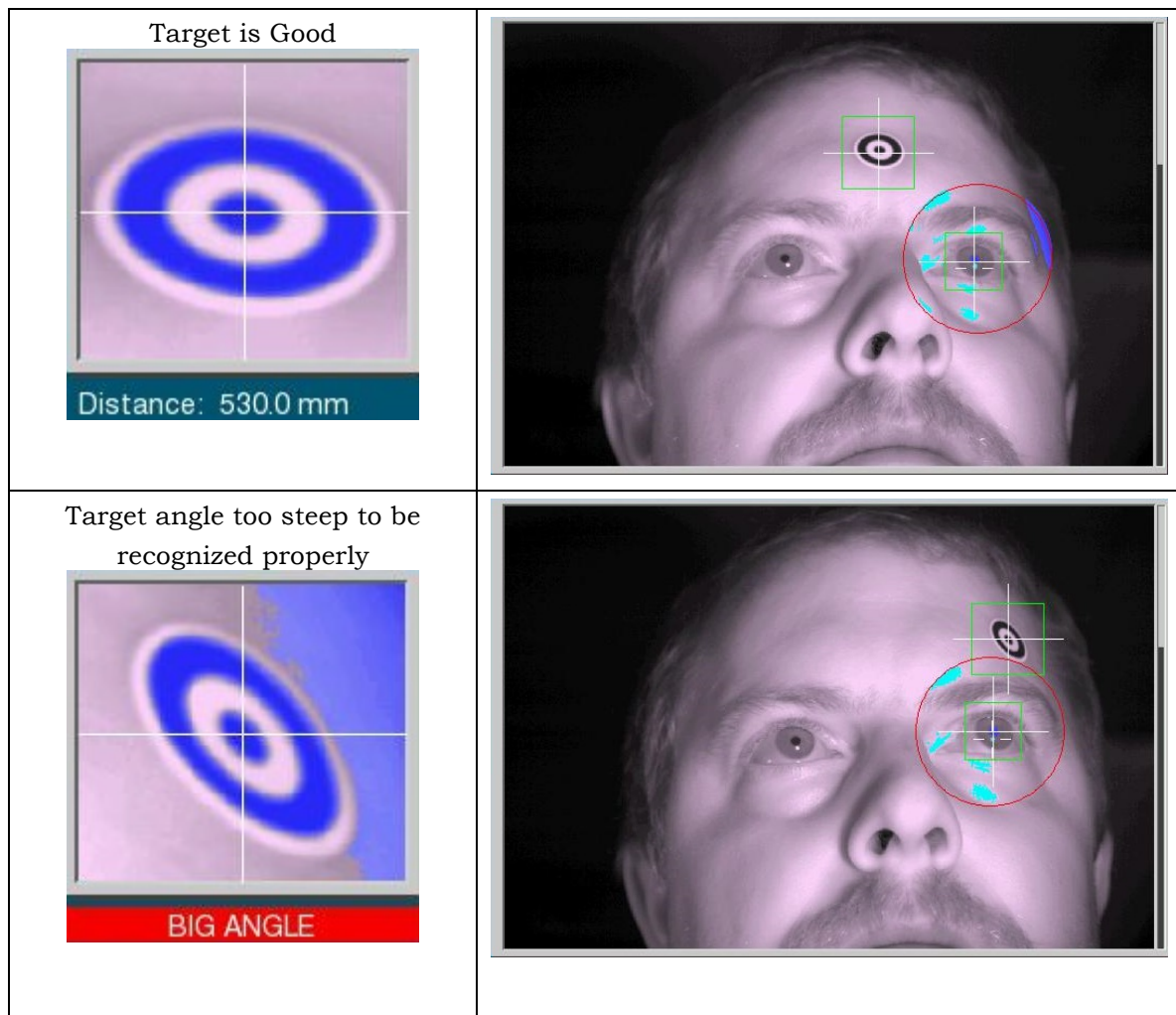


Figure 3-5: EyeLink Remote Target Placement

Adjust the position/angle of the eye tracker so that the eyes appear in the center of the global view of the camera image. If tracking binocularly, a dotted vertical line will be drawn centered on the target sticker - make sure the target sticker is placed on the forehead between the two eyes. In the global view window of the camera image (Host or Display PC), click on top of the tracked eye(s). To obtain the sharpest image of the participant's eyes, the camera should be focused by rotating the focusing wheel (installed at the underside of the eye tracker - about 3 cm from the front and 4 cm from the left side of the unit). The experimenter can access the control by placing one hand under left side of the camera, with thumb on top of the unit. Be sure the hand is not blocking the optical window on the front of the unit. Feel with the index finger for a slot with a recessed ribbed wheel. Use the index finger to push the wheel left or right slightly, until the best focus is achieved. Look closely at the eye image on the zoomed view while adjusting the focusing wheel until the eye

image is clear. The best focus will minimize the size of the corneal reflection circle (colored turquoise). Please do not over-adjust the focus. It may only require 1 or 2 millimetres of motion to reach the correct focus position.

The experimenter can easily tell if the pupil has been detected because the image on the Host PC will have a crosshair drawn indicating its center. A green ellipse, updated each refresh, is drawn in the zoomed view based on the elliptical pupil-fitting algorithm (see section 3.6 “Pupil Tracking Algorithm”). A properly thresholded pupil should be solidly blue, with minimal blue elsewhere in the image. If the threshold is too low, the blue area will be smaller than the pupil, and the eye image will show excessive movement. If the threshold is too high, there will be shadows at the edges and corners of the eye, especially when the eye is rotated. If a shadow interferes with pupil detection, or if the eye image is severely under-thresholded, the crosshair and ellipse fitting will disappear and the pupil will be lost. On the Host PC, an error message “PUPIL MISSING” will appear in the zoomed eye image. Therefore, it is important that the experimenter have the participant look at the four corners of the monitor, and watch for potential pupil thresholding problems. One common problem is for shadows at the corners of the eye, which can disrupt tracking of the pupil.

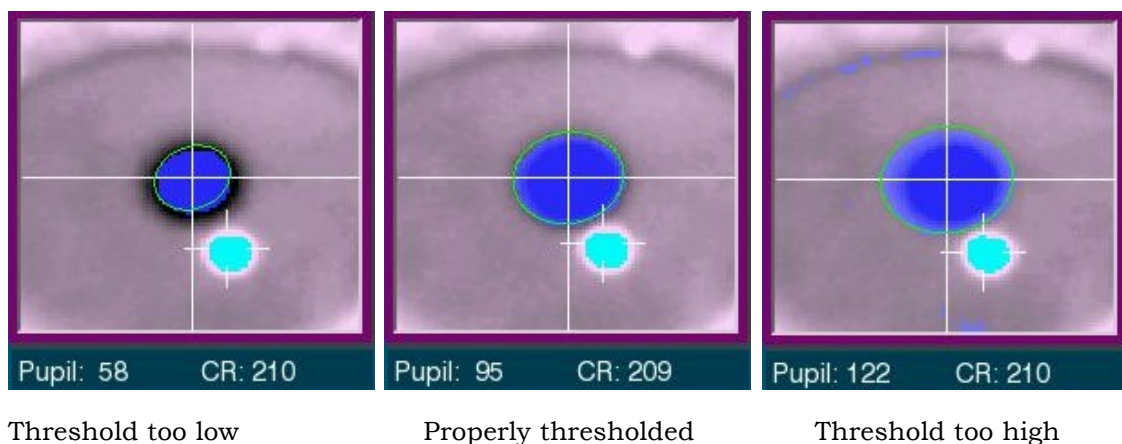


Figure 3-6: Pupil and CR Thresholds and Bias Values

The pupil threshold value is displayed under the zoomed eye image. Unlike the Head-Stabilized tracking mode of the eye tracker, the threshold values are automatically updated in the Remote Mode. Nevertheless, users can still adjust the bias of pupil thresholding – the extent to which the pupil threshold is modulated – by clicking on the pupil threshold adjustment buttons or with the UP and DOWN keys. Raising the bias increases pupil coverage (i.e., increasing the blue area) while lowering the bias decreases the pupil coverage (i.e., decreasing the blue area). Pressing the AUTO button resets the pupil threshold bias.

The Remote Mode exclusively uses Pupil-CR tracking mode. The CR is identified by a filled (turquoise) circle marked by a crosshair. The CR threshold value is displayed under the zoomed camera view. The CR threshold is updated automatically and CR bias can be manually adjusted using buttons, or with the + and – keys. Pressing the AUTO button resets the CR threshold bias. Once the CR threshold bias is adjusted, have the participant slowly look along the edges of the display surface and ensure that the CR signal is consistently detected and tracked. If the CR is not consistently detected or lost entirely, a red warning message will appear below the small camera image for the eye indicating “CR MISSING” on the Host PC.

The EyeLink Portable Duo Host software also implements exposure control, which is used to adjust the brightness of the camera image when the eye-to-camera distance changes and to improve the dynamic range of the camera. Unlike the head-stabilized tracking mode, the distance between the participant and the eye tracker and the position of the tracked eyes in the camera image can vary quite a bit during recording in the Remote Mode. Since the effective brightness of the illuminator output changes as a function of distance squared, this means that the brightness of the camera image and thus the pupil and target thresholds can vary a lot if the viewing distance and image position changes. Exposure control in the EyeLink Host software is used to adjust the exposure duration of each camera frame to avoid getting overexposed or underexposed camera images. In the Remote Mode, an automatic exposure control is implemented using the brightness of the target sticker as a reference. This adjustment in the exposure duration is primarily based on the target-camera distance but can also be influenced by other factors (e.g., position in the camera sensor, eye rotation angle, etc).

The auto exposure control can be enabled or disabled by pressing CTRL + E (auto exposure is turned off if "AUTO" is missing from the exposure control text). When operating in the Remote Mode, it is recommended that the default settings are used (i.e., auto exposure enabled) so that the eye tracker automatically adjusts the exposure duration of the camera image frames to keep the threshold of the target and pupil relatively constant. CTRL and UP/DOWN arrow keys adjust the bias value (multiplier) of the auto exposure control. Pressing the CTRL and UP arrow keys may help if the pupil threshold is too low because of a dark camera image; pressing the CTRL and DOWN keys will help if you are getting an overexposed camera image. It is recommended that the default bias value of 1.0 be kept. The current auto exposure settings can be read from the lower right corner of the “Advanced Settings” box in the Setup screen.

The Remote Mode draws a red search limit ellipse which is automatically updated and moves along with the eye(s). This search limit area is used to

exclude regions of the camera image (e.g., frame of the glasses, eyebrow) that may otherwise be detected as a pupil/CR reflection pattern. If the search limit area isn't placed on the center of the pupil, press "A" or the "Align Eye Window" button to center it. The size and shape of the search limit area can be adjusted by first having the zoomed eye image selected and then 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 with SHIFT and cursor keys or by clicking in the global view to move them to the click location.

The operation of the Remote Mode is influenced by ambient lighting. In general, the pupil shrinks under bright light and dilates in a dark environment. It's important that users check the pupil size reported in the thumbnail camera image periodically throughout recording. If a yellow size warning is constantly observed, it is likely that the pupil size is too small and as a result, the recorded data may be noisy. If this happens, first check whether the participant is seated at the recommended eye-target distance of 520 mm. Dimmer room lighting will also help alleviate this issue.

Now proceed to section 3.7 "Calibration". For the best recording accuracy in the Remote Mode, please use a 13-point calibration type.

3.3 Setting Pupil Thresholds

The camera image 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, with no other color in the image when the threshold is properly set. If large areas other than the pupil are colored, the participant may have blinked during the 'Auto Threshold' procedure: press A to do Auto Threshold again.

If the participant wears eyeglasses, reflections may block the image of the pupil. You may need to make slight adjustments to the eye tracking unit (e.g., moving the camera closer to the participant, lowering the position of the camera, and/or adjusting the angle of the camera) so that reflections from the glasses will not interfere with pupil acquisition (the idea is to make the plane of the glasses less perpendicular to the line of sight of the eye tracker; however 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.

The pupil threshold should be checked by closely examining the blue area in the zoomed camera image. Figure 3-7 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.

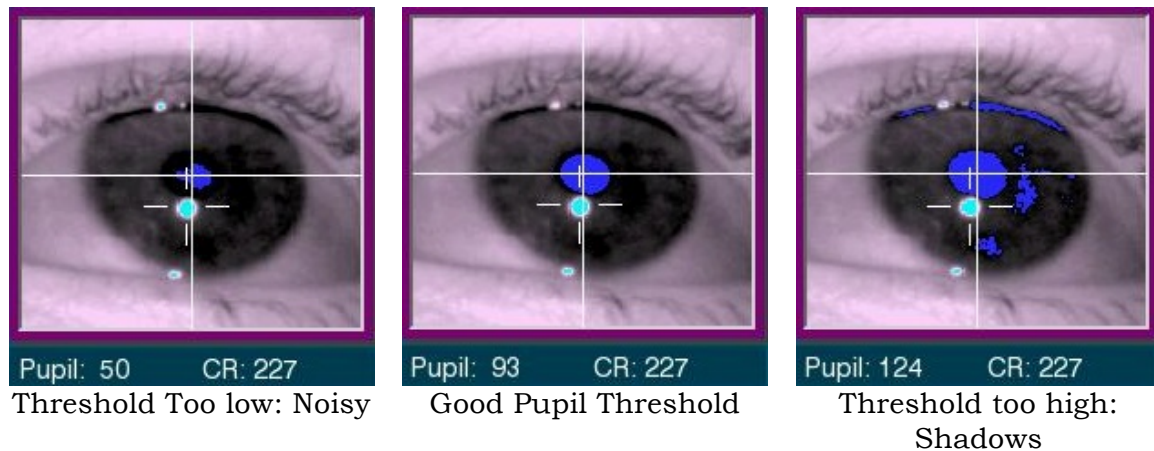
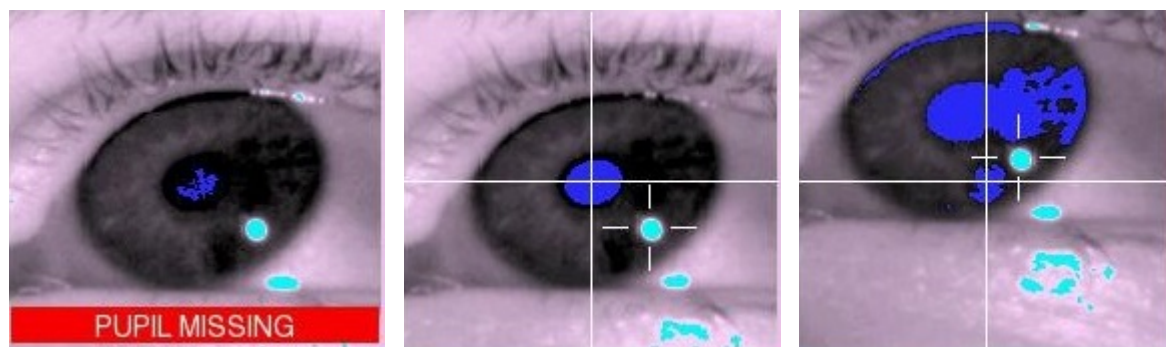


Figure 3-7: Symptoms of Poor Pupil Threshold

The Setup display is updated very rapidly, so noise, shadows, etc. will be easily detected. You can have the participant look at the corners of the monitor, 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 3-8). 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 3-8), 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.



Pupil severely under-
thresholded

Good

Corner shadow captures
pupil

Figure 3-8: Potential Pupil Threshold Issues when Viewing Screen Corners

In general, after threshold adjustment, pupil thresholds should be between 70 and 115 and corneal thresholds should not exceed 240. If the pupil threshold is too low, try decreasing the eye-camera distance by moving the eye tracking unit closer to the eyes. If the pupil threshold or corneal thresholds are too high, try reducing the illuminator output or increase the eye-to-camera distance.

3.4 Setting the Corneal Reflection (CR) Threshold

EyeLink Portable Duo uses the pupil-CR tracking mode, regardless whether you plan to use head support or not. The corneal reflection, if present, is identified by a circular shape in turquoise.

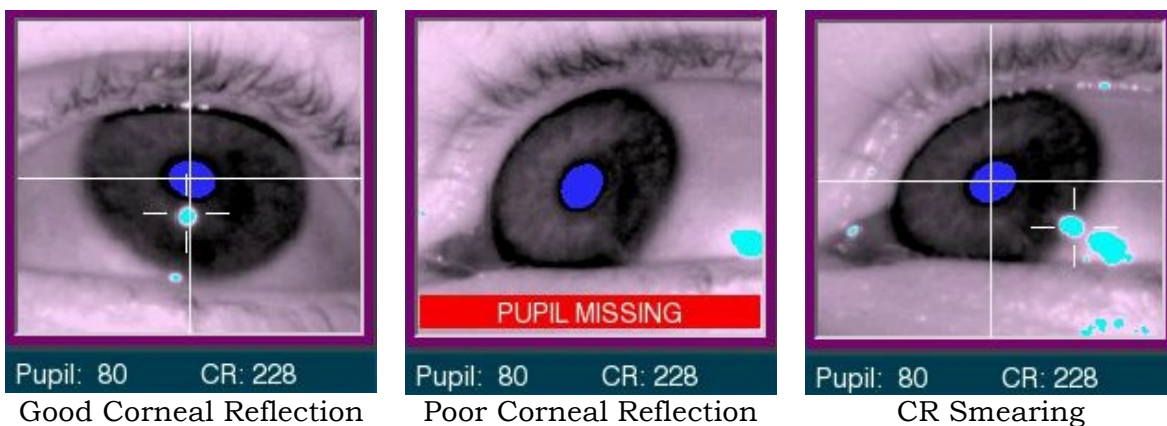


Figure 3-9: Corneal Reflection

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.
- 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.
- 3) Have the participant slowly look along the edges of the display surface 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 (see the middle panel of Figure 3-9).

- 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 right panel in Figure 3-9). This is an indication that the viewing angle is too large for the setup. If you see this, try raising the eye tracker unit and/or increasing the distance from the participant to the monitor.

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 eye tracker, or reseating the participant. 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 Portable Duo eye tracker 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 position. 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 (e.g., the participant walks away and then comes back reseated to continue the experiment). While the “Use Search Limits” feature is optional for participants who don’t wear glasses, this should be enabled for those participants wearing glasses. The search limits can be used to exclude regions of the camera image (e.g., 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 head from the head support 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 search limits are always enabled for the Remote Mode.

The size of the search limit area for the selected eye can be adjusted 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 with SHIFT and cursor keys. In a binocular setup, size/position of the search limits need to be adjusted for each eye separately.

3.6 Pupil Tracking Algorithm

The EyeLink Portable Duo eye tracker 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 higher noise level.

EyeLink Portable Duo uses the Centroid algorithm in the head-stabilized mode by default whereas the remote tracking exclusively uses the Ellipse-Fitting pupil tracking method.

3.7 Calibration

The preceding steps set up the EyeLink Portable Duo eye tracker 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 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, in head fixed mode, 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. When using the Remote Mode, the default 13-point calibration type provides the best recording 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.

In the “Calibration Settings” panel of the Setup screen, check to ensure the following option is selected.

- Calibration type: 13-point for the Remote Mode, 9-point for the Head-stabilized Mode

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 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. Head movements during calibration should be discouraged: small head movements are corrected, but large movements will severely degrade calibration accuracy, due to distortion of the calibration data pattern and range.

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 (right panel).

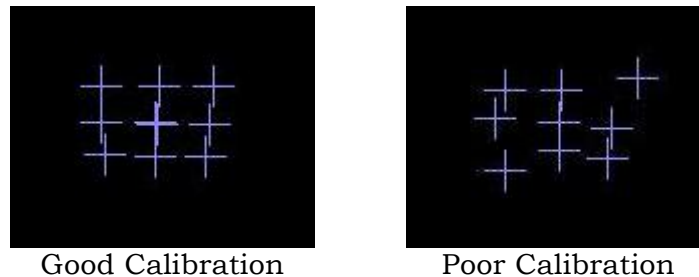


Figure 3-10: Calibration Grid

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 Last Point" 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

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. 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, corneal-reflection, and target sticker (the latter only in the Remote Mode) 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
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. For the Remote Mode, the pupil “SIZE” warning typically suggests that the pupil size is too small because of the ambient lighting or the eye tracker is placed too far away from the participant.

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.

3.8 Validation

It is important that any problems with the calibration be identified and corrected before eye-movement recordings containing inaccurate and poor quality data are collected. By running a validation immediately after each calibration, the accuracy of the system in predicting gaze position from pupil position can be established. If performance 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 small 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, select the “Validate” button or press the ‘V’ key in the Setup screen. 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 colored 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.

Note, this categorical scoring of calibration accuracy is a general guideline and different fields of research may choose to use different cut-offs than what is 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.

3.9 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 doing so, 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 and raising the camera 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.
- For the Remote Mode, use the 13-point calibration for the best accuracy. For the Head-Stabilized Mode, use the 9-point calibration type.
- 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. 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.
- 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.
- When writing your own applications, try matching 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 will 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 illumination 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 illumination level and the pupil dilates or constricts.

3.10 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 red cursor on the participant’s display. The cursor can be toggled on and off by the ‘G’ key on the Display PC keyboard. To implement this feedback, TRACK requests that EyeLink send it up to 2000 samples per second of gaze-position via the EyeLink Display Software. This data is used to move the gaze cursor.

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.

3.11 Drift Checking and Drift Correction

The “Drift Correct” screen displays a single target to the participant and then measures the difference between the computed fixation position during calibration and position of the current target. Unlike earlier EyeLink I and II eye trackers, correcting the calibration map based on the drift correction result has no significant effect on gaze accuracy. Therefore, the default drift correction behavior of the EyeLink Portable Duo system is to only report the calculated fixation error from the drift correction procedure and to not actually adjust the calibration map in any way. Therefore the drift correction procedure is better viewed as a “Drift Checking” procedure in the EyeLink Portable Duo in its default configuration.

We strongly recommend that users keep the default “drift checking” behavior, but true drift correction can be enabled if desired. Drift correction can be

performed at the beginning of each trial, or part-way through a trial while data are being collected. Regardless of when a drift correction is performed, if true drift correction is enabled, a fixation sample is acquired to a known location and a corrective offset to the raw eye-position data is computed and applied. True drift correction can be enabled by changing the "driftcorrect_cr_disable" command setting in CALIBR.INI file, according to the instructions in the following section. It is important that before performing a drift correction the participant be instructed to sit still and fixate on the drift correction target carefully.

3.11.1 Enabling Drift Correction

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 Drift Check screen, and click on the "Apply Correction" button. This will toggle on the button and change the screen mode to "Drift Correct" instead of "Drift Check". Alternatively, the following EyeLink command should be placed in the FINAL.INI or sent across the link. The default setting in the behavioral laboratory setting is to turn ON the disabling of the drift correction when the CR is being used on the EyeLink Portable Duo. We are turning this disabling OFF so that the drift correction adjustment will take place.

```
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 Setup mode (ESC on the keyboard) and undertake a new camera setup or calibration procedure.

3.11.2 Online Drift Correction

While enabling the standard Drift Correction procedure to update the calibration parameters based on fixating a target between trials can be a useful solution, it is not always ideal. For instance, some experiment sessions, such as in a blocked design, do not lend themselves to the normal drift correction procedure of having the participant frequently look at a target while a sample is taken. For such situations it may be desirable to perform an Online Drift Correction while data recording is underway.

With Online Drift Correction, eye movement recording does not have to be disrupted to introduce an adjustment to the calibration parameters. Some

method does however have to be arranged whereby the experimenter knows that the participant is looking at a particular aspect of the stimulus at a particular point in time, so that the drift correction fixation sample at that known location can be acquired. Pre-arranging that the participant look at a particular aspect of the stimulus display that will act as a fixation target (e.g., a fixation cross) allows the experimenter to perform such drift corrections during the actual recording.

Using Online Drift Correct to a fixed location requires that the coordinate that the participant should fixate is set using an EyeLink command (or predefined in the software). When a drift correction is to be applied the experimenter initiates the correction by clicking the “Drift Correct” button on the Recording Screen of the Host PC or by pressing a prearranged key that will initiate the drift correction.

If the participant regularly fixates some known entity in the displayed image then this could be used to perform the drift correction. When the participant is known to be looking at a fixation cross for instance, simply click the “Online Drift Correct” button (or press the assigned key – F9 by default) to execute the drift correction. If the attempted correction is above an acceptable distance then the drift correction will fail and a message will appear in the text box reporting the size of the attempted drift correction and noting it failed such as “DCORR FAILED: offset of 14.6 degrees rejected”.

To enable online drift correcting to a fixed location, the Host PC needs to be configured manually by adding some commands to the FINAL.INI file or it can be configured through software sending the commands across the link. The commands required are:

```
driftcorrect_cr_disable = OFF
online_dcorr_refposn 512,384
online_dcorr_button = ON
normal_click_dcorr = OFF
```

After enabling drift correction, these commands set the reference position to which the drift correction will take place (in this example, at the coordinate 512, 384 on the Display PC screen). Next the “Drift Correct” button is enabled on the Recording Screen by turning it on. Finally, the drift correction will be executed by clicking the button.

The drift correction can also be executed when an assigned key is pressed. To do this the following command defines the F9 key to be used to trigger the drift correction action.

```
key_function F9 "online_dcorr_trigger"
```

The variable `online_dcorr_maxangle` specifies the maximum distance in degrees of visual angle that is an acceptable drift correction. This can prevent adjustments greater than this size. The default value is 5.0 degrees of visual angle:

```
online_dcorr_maxangle = 5.0
```

3.12 Exiting the Host Application

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.

3.13 EyeLink Portable Duo Setup Summary

It is suggested that you try the procedures in this section until you feel comfortable with the EyeLink Portable Duo setup, and can reliably get good calibrations.

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

- 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.
- Select the appropriate Operating Mode (Head Stabilized vs. Remote Mode). When using the Remote mode, put the target sticker on the participant's forehead and adjust the position/angle of the eye tracker unit.
- From the Setup screen, press ENTER to transfer the camera image to the Display PC.
- Click on the eye image in the global view to properly acquire the pupil to track.
- Focus the camera image if it looks blurred.
- 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.

- 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 the gaze cursor on and off.
- 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.

3.14 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, sometimes 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.

3.15 Next Steps: Other Sample Experiments

For both Windows and macOS, the EyeLink Developer’s Kit contains several sample experiments that are valuable demonstrations of how the EyeLink eye tracker system can be used and programmed. On Windows, each sample experiment can be launched from the “Start -> All Programs -> SR Research -> EyeLink Examples -> C Examples -> GDI Graphics (or SDL Graphics)” menu item. 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 bitmaps to display pictures (BMP files).
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.
--	---------

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 7, 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 the 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.

Video	Illustrates creating an experiment displaying video clips using XVD codec.
-------	--

4 Data Files

The EDF file format is used by the EyeLink tracker and supporting applications to record eye-movements 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 EyeLink Portable Duo EDF file format is backwards-compatible with the earlier EyeLink I, II, 1000, and 1000 Plus EDF file format.

The EDF file format is a platform-portable binary record of eye-position 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). This file 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: 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”).

4.1 File Contents

The EDF files contain two streams of data: eye-position samples (up to 2000 samples per second produced from the EyeLink tracker) and events (eye-movement events such as saccades and fixations, participant responses, and synchronizing events from the experimental application). Both streams are time-synchronized for easy analysis. The file is organized into blocks of data, one for each recording session. 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). Pupil sizes 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 on-line 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 periods 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 Portable Duo tracker, recording eye-position data, events from the on-line parser, and button and input events. These are recorded only when the tracker is in output (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 sessions in output mode, and closing the file. These operations can be performed manually using the EyeLink Host application on the Host PC, or remotely from the Display PC through the Ethernet. For both applications, it is important that the screen settings are set up properly for accurate recording of data resolution and velocity calculation.

4.2.1 Recording from the EyeLink Portable Duo Host PC

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 Portable Duo tracker's Output Screen, files may be opened and closed, and recording sessions may be started and stopped. Refer to Chapter 2 of this manual *"EyeLink Portable Duo 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 EyeLink Programmer's Guide or SR Research Experiment Builder User Manual for details on how to use the Display PC software to set up and record EDF files.

4.3 The EyeLink On-Line Parser

As with all EyeLink systems, the Portable Duo Host Software incorporates a unique on-line 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 the 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 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. Velocity data is also converted into units of degrees per second using real-time resolution information. 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 was designed for on-line, low delay identification of saccades and blinks. Detection of very small saccades may require off-line processing, as the special filtering and computation of global velocity cannot be performed on-line. 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 to prepare data during analysis. 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 specific applications such as smooth pursuit or reading research. 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

The saccadic detection parameters for the EyeLink on-line parser may need to be optimized for the type of experimental investigation being performed. For example, neuropsychophysical researchers may need to detect small saccades amid pursuit or nystagmus, while reading researchers will need 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. The user 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` (`REMPARSE.INI` for the EyeLink Remote) 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, and gaze position (see the section 4.4 “File Data Types” for more information). The parser can use any one of these 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
```

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 larger 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 the onset of a saccade until the eye has moved significantly. A threshold of 0.1° to 0.2° is sufficient for shortening saccades. Larger values may be used with caution to eliminate short saccades: for example, a threshold of 0.4° will always merge fixations separated by 0.5° or less, but may eliminate some 1° saccades as well. The threshold should be set to zero for non-cognitive research, or where statistics such as saccadic duration, amplitude and average velocity are required.

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 Thresholds

During smooth pursuit and nystagmus, saccades must be detected against a background of smooth eye motion as fast as $70^{\circ}/\text{sec}$. 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 during pursuit by the average velocity over the last 40 milliseconds. This is reliable, and does not degrade parser performance during non-pursuit eye movements.

During long saccades such as a return sweep in reading, this fix-up causes the saccadic velocity threshold to be raised. This is not a problem as long as the adjustment is limited, as it helps to prevent prolongation of these saccades by overshoots and glissades. The pursuit threshold limits the amount that the saccadic threshold can be raised. A limit of $60^{\circ}/\text{sec}$ 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 better estimates 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 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 on-line 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, pupil size, and button or input states. Some versions of EyeLink trackers can record up to 2000 samples per second in a monocular tracking mode or up to 1000 samples per second in a binocular tracking mode (actual sampling rate depends on your system model, configuration and licensing). 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 will create very large EDF files: about 15K 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
- Pupil size, monocular or binocular
- Button or input port state bits

All samples contain a timestamp, recorded in milliseconds. The time is measured from the time when the tracker software was started. This 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 Position Data

Eye position data is produced by the EyeLink tracker every 0.5, 1, 2 or 4 milliseconds depending on the tracking model, and system configuration. It is then processed to compute eye rotation angles and to compensate for participant head motions. The processed data in one or all of these forms 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

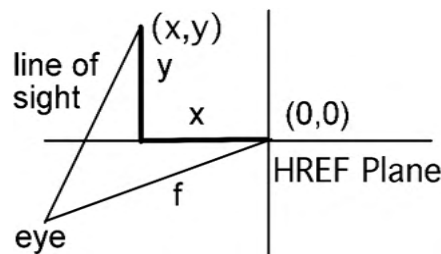
Pupil position data are raw (x, y) coordinate pairs from the camera. They have not been converted to eye angles or to gaze position. There may be a non-linear relationship between these data and true gaze position. Pupil position is reported in integer values, with 200 to 400 units per degree of visual 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 directly measure eye rotation angles relative to the head. They do not take into account changes in participant head position and angle, or distance from the display. However, they may be more accurate for neuro-psychophysical research, as they reflect real eye movement velocities and amplitudes.

The (x, y) coordinate pairs in HREF data reflect the line of sight in the geometric model below:



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

The (0, 0) point in the coordinate system is arbitrary, as the relationship between display positions and HREF coordinates changes as the participant's head moves. Even when a chinrest is used to support the participant's head, head rotations of several degrees can occur. HREF coordinates are best used for determining angles relative to a known eye position, or to measure 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 angular distance (eye rotation magnitude) between any two HREF points is directly computable. See the formula below. Remember to 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 may be computed as the first derivative of the rate of change of HREF position with angle. It is sufficient to compute the resolution separately for the x- and y- coordinate directions. These may be used to compute true eye-movement velocities, by dividing computed velocity in HREF units by the resolution for the sample. These formulas give the x and y resolution in units of change in HREF position per degree of visual angle:

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

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

4.4.2.3 GAZE

Gaze position data reports the actual (x, y) coordinates of the participant's gaze on the display, compensating for distance from the display. 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, and noted in the gaze-position section.

4.4.3 Pupil Size Data

Pupil size is also measured by the EyeLink eye tracker system. 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 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. As well, since pupil size is largely affected by luminance, cognitive load, and emotional responses,

those factors not being explicitly manipulated must 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.

4.4.4 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 on-line processing of eye-movement data to identify and record events such as fixations and saccades. This eliminates the need for recording of sample data for many types of research, and achieves a data compression of 20:1 or greater. Samples need only be recorded for data validation or if sample-by-sample eye position or velocity is required.

Events can record 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, up to a maximum of 300 bytes. Messages are created by the application software, and sent over the link to the EyeLink tracker, which timestamps the data 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. For text data, a zero byte at the end of the text is recommended for compatibility with applications written in C. A message data length field provides Pascal string compatibility, and allows binary data to be recorded in the message. Current EyeLink applications only support text messages with zero-terminated strings. It is also recommended that messages be shorter than 120 characters.

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 condition. The end time is actually the time of the last sample in the condition, so length of a condition 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 on-line EyeLink tracker parser processes eye-position data, identifying saccades and fixations and compiling data on these conditions. For fixations, these data include:

- The time of the first and last sample in the fixation
- The eye that generated the event

- Average HREF or gaze position data
- Average pupil size
- Gaze-data angular resolution

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 saccadic 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
- Peak eye-movement velocity
- Start and end gaze-data angle
- Gaze-data angular resolution

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. This is more easily done by multiplying average velocity by the saccadic duration:

$$\text{dist} = 1000.0 * (\text{end_time} - \text{start_time} + 1.0) * \text{avg_velocity};$$

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
HTARGET	target distance and X/Y position (EyeLink Remote only)
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,AREA,HTARGET,STATUS,INPUT
```

Usually, data for both eyes are enabled, and the menus in the EyeLink tracker 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.

For the EyeLink Remote, the HTARGET flag should always be included in the recording.

4.6.2 Event Data

Eye-movement events are generated by processing one of the types of eye movement data (PUPIL, HREF, or GAZE) 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 PUPIL, HREF, or GAZE>
```

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

with the EyeLink Developers Kit for macOS (<https://www.sr-support.com/thread-13.html>).

EyeLink Data Viewer 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.

4.8 Using ASC Files

The EDF file format is an efficient storage format for eye movement data, but is relatively complex for third-party data analysis applications to work with. To make the data in EDF files accessible, the translator EDF2ASC converts the files 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.

EDF2ASC converter utility can be run from the GUI interface assuming that you have installed the EyeLink Data Viewer software. Users can also run the EDF2ASC converter from the DOS command line prompt, assuming that Windows Display Software 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

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. Usually the preamble is ignored during analysis.

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 word processor or print it out.

4.9.2 Sample Line Format

Sample lines contain time, position, and pupil size data. Optionally, velocity and resolution data may be included. Each sample line begins with a timestamp. Recordings done with a 2000 Hz sampling rate will have two consecutive rows with the same time stamps. The second row refers to the sample collected at 0.5 ms after the reported time stamp. (To avoid identical time stamps in a 2000 Hz recording file, you may consider adding the -ftime switch if you do the file conversion from the command prompt, or enable the "Output Float Sample" option in the GUI version of the EDF2ASC converter.) 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, and resolution X and Y values. 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:
 <time> <xp> <yp> <ps>
- Monocular, with velocity
 <time> <xp> <yp> <ps> <xv> <yv>
- Monocular, with resolution
 <time> <xp> <yp> <ps> <xr> <yr>
- Monocular, with velocity and resolution
 <time> <xp> <yp> <ps> <xv> <yv> <xr> <yr>
- Binocular
 <time> <xpl> <ypl> <psl> <xpr> <ypr> <psr>
- Binocular, with velocity
 <time> <xpl> <ypl> <psl> <xpr> <ypr> <psr> <xvl> <yvl> <xvr> <yvr>

- Binocular, with resolution
`<time> <xpl> <ypl> <psl> <xpr> <ypr> <psr> <xr> <yr>`
- Binocular, with velocity and resolution
`<time> <xpl> <ypl> <psl> <xpr> <ypr> <psr> <xvl> <yvl> <xvr> <yvr>
<xr> <yr>`

DATA NOTATIONS

<code><time></code>	timestamp in milliseconds
<code><xp>, <yp></code>	monocular X and Y position data
<code><xpl>, <ypl></code>	left-eye X and Y position data
<code><xpr>, <ypr></code>	right-eye X and Y position data
<code><ps></code>	monocular pupil size (area or diameter)
<code><psl></code>	left pupil size (area or diameter)
<code><psr></code>	right pupil size (area or diameter)
<code><xv>, <yv></code>	instantaneous velocity (degrees/sec)
<code><xvl>, <yvl></code>	left-eye instantaneous velocity (degrees/sec)
<code><xvr>, <yvr></code>	right-eye instantaneous velocity (degrees/sec)
<code><xr>, <yr></code>	X and Y resolution (position units/degree)

4.9.2.1 Samples Recorded in Corneal Reflection Mode

If the data file being processed was recorded using corneal reflection mode, each sample line has an added 3 (monocular) or 5 (binocular) character fields after all other fields (including resolution and velocity if enabled). These fields represent warning messages for that sample relating to the corneal reflection processing.

- MONOCULAR Corneal Reflection (CR) Samples

"..." if no warning for sample
first character is "I" if sample was interpolated
second character is "C" if CR missing
third 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 "C" if LEFT CR missing
third character is "R" if LEFT CR recovery in progress
fourth character is "C" if RIGHT CR missing

fifth character is "R" if RIGHT CR recovery in progress

4.9.2.2 Samples Recorded with the EyeLink Remote

Data files recorded using the Remote Mode have extra columns to encode the target distance, position, and eye/target status information. The first three columns are:

- <target x>: X position of the target in camera coordinate (a value from 0 to 10000). Returns "MISSING_DATA" (-32768) if target is missing.
- <target y>: Y position of the target in camera coordinate (a value from 0 to 10000). Returns "MISSING_DATA" (-32768) if target is missing.
- <target distance>: Distance between the target and camera (in millimeters). Returns "MISSING_DATA" (-32768) if target is missing.

The next thirteen fields represent warning messages for that sample relating to the target and eye image processing.

"....." if no warning for target and eye image
first character is "M" if target is missing
second character is "A" if extreme target angle occurs
third character is "N" if target is near eye so that the target window and eye window overlap
fourth character is "C" if target is too close
fifth character is "F" if target is too far
sixth character is "T" if target is near top edge of the camera image
seventh character is "B" if target is near bottom edge of the camera image
eighth character is "L" if target is near left edge of the camera image
ninth character is "R" if target is near right edge of the camera image
tenth character is "T" if eye is near top edge of the camera image
eleventh character is "B" if eye is near bottom edge of the camera image
twelfth character is "L" if eye is near left edge of the camera image
thirteenth character is "R" if eye is near right edge of the camera image

For a binocular recording, there will be seventeen target/eye status columns, with the last eight columns reporting the warning messages for the left and right eyes separately.

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)

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>
- EFIX <eye> <stime> <etime> <dur> <axp> <ayp> <aps>
- EFIX <eye> <stime> <etime> <dur> <axp> <ayp> <aps> <xr> <yr>

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>
- ESACC <eye> <stime> <etime> <dur> <sxp> <syp> <exp> <eyp> <ampl> <pv>
- ESACC <eye> <stime> <etime> <dur> <sxp> <syp> <exp> <eyp> <ampl> <pv> <xr> <yr>

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>. Optionally, the eye-position angular resolution (in units per visual degree) is given as well.

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>
- EBLINK <eye> <stime> <etime> <dur>

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, 1000, or 2000 Hz), file sample filter (0 – filter off; 1 – standard filter; 2 – extra filter), link/analog 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
MTABLER	Head-Stabilized Mode, Monocular
BTABLER	Head-Stabilized Mode, Binocular/Monocular
RTABLER	Remote mode, Target Sticker, Monocular
RBTabLER	Remote mode, Target Sticker, Binocular/Monocular

- 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).

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 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:

"RES" for resolution data (both may be present)
 "RATE" for the sample rate (250.00, 500.00, 1000.0, or 2000.0)
 "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, 1000.0, or 2000.0)
 "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

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.

WARNING: The EyeLink Portable Duo is always powered while the Host PC is connected and powered on. Therefore observe these precautions for participant safety:

- Before performing any cleaning other than wiping the optical window, power off the Host PC or disconnect both plugs of the USB cable of the EyeLink Portable Duo (see sections 5.2 and 6.1).
- Do not cover or place any items on top of the EyeLink Portable Duo while the Host PC is powered on, unless the eye tracker cable is disconnected from both USB ports. Operating the unit while covered could cause it to overheat and possibly cause a burn hazard.
- If the EyeLink Portable Duo fails to operate properly, is running at a higher than normal temperature, or fails the cable or illuminator inspection, disconnect the USB cable or turn off the Host PC, until the operator can troubleshoot the system.

To ensure performance and safety, inspection and cleaning need to be performed regularly. Refer to section 5.1 for daily and weekly maintenance and inspection.

Cleaning and disinfection is covered in section 5.2. Do not perform any inspection (except checking or dusting of the optical window with a dry anti-dust cleaning cloth) with the participant present or seated. It is important to keep the optical window clean for proper operation.

5.1 Periodic Inspection

The following tasks should be performed by the operator or service personnel at least weekly while the system is in regular use, or before use after an extended period of disuse.

Inspection should not be performed in the presence of a participant, except for examining the optical window for dust or smudges.

1) Optical Window (Daily, or if tracking issues are observed):

- Check the optical window for scratches, fingerprints, or clouding.
- This is best performed by looking at the window in a lit room, and observing the reflection of a black object in the window (example: black paper)
- Dust or smudges will appear as bright spots or smears in the dark reflection.
- The most critical area is the left third of the window, which covers the camera lens. Dust or smudges here may degrade eye tracking.

- If dirt is found, follow the cleaning instructions in section 5.2 of this document. If the window is deeply scratched or cannot be cleaned, return the unit for repairs.

2) USB Cable (Weekly):

- Check any exposed parts of the USB cable for cuts or nicks in the cable jacket.
- Any damage within 120 cm of the participant will compromise the electrical safety of participants, should they come into contact with exposed cable interior wiring. If such defects are found, and especially if bending the cable shows any silver shield wire, the unit should be taken out of service IMMEDIATELY and returned for repairs.

3) Illuminator (Weekly, or if eye tracking issues are present):

- Inspect the illuminator LEDs for even brightness.
- Turn out the room lights and look at the right side of the optical window of the EyeLink Portable Duo
- Operators who are red-green color-blind should not perform this inspection, as they are less sensitive to near-infrared light; instead, use a digital camera or a cell phone camera.
- The illuminator will show the 6×6 grid of LEDs clearly as red dots.
- If these are seen, return the unit immediately for repairs.

5.2 *Cleaning and Disinfection*

WARNING: Cleaning with a wet cloth, sprays applied directly to unit, or pouring fluids onto the EyeLink Portable Duo 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 to participant before reconnecting.

Do not perform any cleaning (other than wiping with dry cloth) while a participant is using the equipment. Participant should remain at least 120 cm from the unit while any other cleaning is in progress, and should not return until unit has dried completely.

Use only the approved products and methods in this section for cleaning and disinfecting the eye tracker. Any other cleaning or disinfection products may damage the unit, or compromise participant safety, and such damage will not be covered under warranty. Table 2 lists several such cleaning hazards and safe alternatives.

DO NOT USE:	DO USE:
<ul style="list-style-type: none"> Spraying canned air or duster spray close to window (cold liquid enters) 	<ul style="list-style-type: none"> Use duster or canned air from at least 15cm away
<ul style="list-style-type: none"> Spraying cleaner or disinfectant directly onto unit 	<ul style="list-style-type: none"> Spray onto cloth, then wipe unit with cloth
<ul style="list-style-type: none"> Wet (saturated) cloth or liquids poured onto unit 	<ul style="list-style-type: none"> Damp cloth (wring out)
<ul style="list-style-type: none"> Wiping of enclosure across seams (top to bottom). This can force fluid into unit. 	<ul style="list-style-type: none"> Wipe front to back along seams.
<ul style="list-style-type: none"> Pure alcohol (can damage optical window) 	<ul style="list-style-type: none"> 70% isopropyl alcohol
<ul style="list-style-type: none"> Abrasive cleaners, vinegar, or glass cleaners with ammonia (These will damage optical window) 	<ul style="list-style-type: none"> Water, mild detergent, or 10% bleach solution, applied with damp cloth (wring out) Wipe several times with clean damp cloth and let dry

Table 2: Cleaning and Disinfecting Rules

Table 3 lists cleaning methods to cover requirements, and their risks. The risk of damage or of temporarily compromising participant safety increases from low to high risk levels. Only risk level 0 (cleaning window with a dry cloth) may be used with participant present.

Cleaning Type	Risk Level	Procedure
Window Dust	0	<ul style="list-style-type: none"> Use an anti-dust cleaning cloth to wipe the window gently. Shake cloth before and after use to remove dust. This is safe for use with participant seated.
Window Dust	1	<ul style="list-style-type: none"> Use canned air or “duster” to blow dust off the optical window, from a distance of at least 15 cm. Do not use with participant in position, as dust could blow into eyes.
Most dirt	2	<ul style="list-style-type: none"> Wipe the enclosure or window with a dampened cloth or tissue, and let dry thoroughly. This may leave particles on the optical window, which should be removed by dusting with anti-dust cloth or canned air. Let dry thoroughly before allowing participants near the unit.

Fingerprints, smudges, routine disinfection.	3	<ul style="list-style-type: none"> Wipe the window and/or enclosure with pre-packaged 70% isopropyl alcohol swabs. DO NOT USE saturated cotton balls or >70% strength alcohol. Let dry thoroughly before allowing participants near the unit.
Grease, oily or dried deposits.	4	<ul style="list-style-type: none"> Mix mild detergent in water, apply to cloth and wring out so cloth is damp (not wet). Wipe front to back several times. Rinse cloth and wring out, and wipe unit several times to remove detergent and dirt. Let dry thoroughly before allowing participant in area.
Thorough disinfection (exposure to disease agents)	5	<ul style="list-style-type: none"> Prepare a solution of 10% household bleach (< 0.6% sodium hypochlorite). Saturate and wring out cloth (must be damp, not dripping). Wipe front to back on enclosure and left to right on window. DO NOT LET BLEACH SOLUTION DRY ON UNIT. Wipe several times with cloth dampened with water. Let dry thoroughly before allowing participant in area.

Table 3: Approved Cleaning and Disinfecting Methods, Ordered by Risk

6 Important Information

6.1 Electrical Safety

WARNING: The Host PC, and all peripherals connected to it with cables, should be positioned out of reach of the participant (at least 120 cm away). Only devices included with the system and clearly identified as suitable for contact with the participant (such as a response device) should be within the participant's reach.

WARNING: The operator should avoid simultaneously contacting the participant and the computer, or any device connected with cables to the Host PC, such as a keyboard or mouse, that were not included with the system and clearly identified as suitable for contact with the participant.

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.

WARNING: This unit is drip-proof and spill-resistant; it is not watertight or waterproof. 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 unit, and unit should be returned for inspection and repairs.

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

WARNING: After contact with any running or dripping liquid, let the unit dry thoroughly before allowing participants near it with the USB cable connected. If fluid has puddled in any area of the unit, (such as below the window), clean and dry the unit and return it for repair and inspection.



Class II Equipment — No protective earth connection required.

6.1.1 Power Source and Isolation

WARNING: Do not use any power source except the computer or other device supplied with the EyeLink Portable Duo eye tracker or the system 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.

The EyeLink Portable Duo is intended to be powered by two USB 3.0 ports on the Host PC. Desktop and laptop computers are typically certified to IEC 60950 or equivalent, which provides electrical protection for the operator. However only IEC 60601-1 power sources or computers meet the level of safety required for patient contact in medical environments. 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. However, the participant is still at risk to indirect contact with the computer and its peripherals, for example by contact with the operator. See section 6.1.3 for rules to prevent this.

6.1.2 Disconnection

Should disconnection of the EyeLink Portable Duo eye tracker be required for safety (for example, during maintenance or a fault in the eye tracker, the Host PC, or other networks or devices connected to the Host PC), the eye tracker may be rendered safe by unplugging both USB connectors from the Host PC. This ensures complete isolation from all ports of the Host PC, including network and power.

If accidental reconnection could cause a hazard (e.g., if someone who is not aware of the issue reconnects the USB connectors to the power source), it is recommended that the connector end of the USB cable be coiled up, marked with a tag, or placed in a plastic bag to prevent reconnection by unauthorized persons.

6.1.3 Maintaining Participant Isolation

WARNING: The operator should avoid simultaneously contacting the participant and the computer, or any device connected with cables to the Host PC, such as a keyboard or mouse, that were not included with the system and clearly identified as suitable for contact with the participant.

It is the responsibility of those involved with the patient's case, and the responsible organization (e.g. hospital) to decide if a participant is allowed to be exposed to the same levels of risk of electrical shock as the operator of the eye tracker and other IT equipment. For this reason, the rules below should be followed by operators and maintenance personnel to ensure that participants remain safely isolated from the Host PC and its peripherals:

- 1) Keep all devices connected by cables to the Host PC (including mouse and keyboard), and the computer itself, out of the participant accessible area (defined to be within arm's reach [120cm] of the participant. This includes participant response devices unless a USB isolator is used, the device is wireless, or the device is certified to EN 60601-1.

- 2) Operators should avoid simultaneous contact with the participant and the Host PC (including non-isolated devices attached to it). This should be arranged by the physical layout of equipment, and the Host PC or other devices should be kept at least 120 cm from the participant. Wireless keyboards may be an exception.
- 3) The USB cable to the unit must be protected from damage, and inspected regularly (at least weekly). Any nicks or cuts in its insulation must be in an area inaccessible to the participant (more than 120 cm from the participant), or the unit will need to be returned IMMEDIATELY for servicing.

6.1.4 Exposure to Fluids and Spills

WARNING: This unit is drip-proof and spill-resistant, but is not watertight or waterproof. Any exposure to substantial quantities of fluids carries the risk of danger to participants. The unit should be taken out of service IMMEDIATELY after immersion or substantial spills onto unit, and should be returned for inspection and repairs.

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

WARNING: After contact with any running or dripping liquid, let the unit dry thoroughly before allowing participants near it with the USB cable connected. If fluid has puddled in any area of the unit (such as below the window), clean and dry the unit and return it for repair and inspection.

The EyeLink Portable Duo eye tracker has been designed and tested to be drip-proof and spill-resistant, but is not waterproof. Though fluid will not penetrate if poured onto the unit in normal operating position, there is still a risk of fluid entering the enclosure due to splashes or in an abnormal position, especially if the unit is moved before being dried, or a substantial quantity of fluid (or immersion) was involved.

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 for repair and inspection.

Note that since the EyeLink Portable Duo is powered by the USB ports of the Host PC, there is no danger to the operator if the computer and its power source were not involved in the spill. It is up to those involved in the patient's care, or the responsible organization (e.g. hospital) to decide if a participant can be exposed to the same risk as operators.

6.2 Eye Illumination Safety

6.2.1 Eye Safety and Comfort

The EyeLink Portable Duo complies with the IEC-62471 lamp safety standards, and meets requirements as an “exempt” device, which is safe under any conditions, including using optical viewing devices and lenses. The internal illuminator emits near-infrared (NIR) radiation. Though safe, this radiation may still cause slight discomfort due to its warming and drying effect on the eye, so some additional precautions are given below.

- Do not look at the illuminators (which are positioned on the right side of the optical window) from closer than 100 mm for extended periods of time. This will result in excessive IR exposure, resulting in “dry eye” discomfort.
- Minimize time participants spend using the eye tracker, to reduce any discomfort to sensitive or irritated eyes.

6.2.2 Visibility of Illuminator

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

6.2.3 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 not expressly approved by SR Research Ltd. will void the warranty and authority to operate the equipment. This includes modification of cables or opening unit without express instructions from the manufacturer.

WARNING: Opening or modifying the eye tracker, including exchanging cables, 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.

In the event of failure, cable damage, or immersion in fluids, the EyeLink Portable Duo should be replaced as a unit, as there are no user serviceable

parts inside. Please contact SR Research for repair or replacement if the cable or optical window are damaged, or if you suspect the unit is defective.

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

Fax: (613) 482-4866
Phone: (613) 271-8686
Toll Free: 1-866-821-0731 (North America only)
Email: support@sr-research.com
Sales: <http://www.sr-research.com>
Support: <http://www.sr-support.com>

6.4 *Electromagnetic Compliance and Immunity*

WARNING: Use of this equipment adjacent to or stacked with other equipment should be avoided because it could result in improper operation. If such use is necessary, this equipment and the other equipment should be observed to verify that they are operating normally.

WARNING: Changes or modifications not expressly approved by the manufacturer will void the warranty and authority to operate the equipment. This includes modification of cables or opening unit without express instructions from the manufacturer.

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.

WARNING: Portable RF communications equipment (including peripherals such as antenna cables and external antennas) should be used no closer than 30 cm (12 inches) to any part of the EyeLink Portable Duo, including cables specified by the manufacturer. Otherwise, degradation of the performance of this equipment could result.

WARNING: This equipment was not tested for degradation of performance during immunity testing. If degradation of performance is observed that is unacceptable, check for sources of interference that may be responsible.

6.4.1 *Suitable Electromagnetic Environments*

The EyeLink Portable Duo eye tracker has been tested for electromagnetic compliance in medical environments. Medical equipment needs special attention to electromagnetic compatibility, as improper installation,

modification, or improper use could affect other sensitive equipment nearby, resulting in harm to patients.

The EyeLink Portable Duo eye tracker has been found suitable for:

- Most medical environments, including hospitals and doctor's offices.
- Commercial or residential environments.

It is not suitable for:

- Use near sources of interference like electro-surgery or other RF sources
- Use near strong RF transmitters
- Use in shielded areas with sensitive equipment.

6.4.2 Sources of Interference and Degraded Performance

This equipment was tested for its ability to function in the presence of interference (through power sources or RF fields). Under certain conditions, however, it may show some degradation of performance (e.g., noise in camera image). In addition, certain other equipment in a medical system (such as displays or Host PC) could temporarily malfunction in an unacceptable manner.

It is up to the operator of the equipment to determine when performance is unacceptable. The symptoms (caused by the eye tracker, Host PC, display, or other devices) may include:

- Noisy eye position data
- Intermittent or total loss of eye tracking
- Visible patterns or changes in brightness of the images
- Loss of USB connection to Host PC
- Freezing or crashing of Host PC and software

If these occur, especially if synchronized with use of other devices in or near the room (such as electro-surgery equipment, cell phones, or other RF devices), electromagnetic effects may be to blame. Careful troubleshooting and correlation of times of the interference is the best method for finding the source of the issue.

6.4.3 Preserving Electromagnetic Compatibility

The EyeLink Portable Duo eye tracker was designed to meet all electromagnetic compatibility requirements, both immunity to interference and to avoid producing interference to other devices. To maintain this, ensure the following rules are met:

- Do not remove any ferrites on cables.
- Do not change or extend any cables.
- Do not operate equipment with covers off or enclosures open.

6.4.4 Other Electromagnetic Compatibility Statements

The following statements may apply, depending on the country of import or use.

FCC DECLARATION OF CONFORMANCE

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Statement 2022—Class B Notice for Canada

This Class B digital apparatus complies with Canadian ICES-003.
Cet appareil numérique de la classe B est conforme à la norme NMB-003 du Canada.

FCC Class B Information

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and the receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Modifying the equipment without the manufacturer's authorization may result in the equipment no longer complying with FCC requirements for Class B digital devices. In that event, your right to use the equipment may be limited by FCC regulations, and you may be required to correct any interference to radio or television communications at your own expense.

6.5 Limited Hardware Warranty

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

EyeLink Portable Duo Product Hardware – 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 Portable Duo Camera and Illuminator Module – Two (2) year parts and labor.
EyeLink Portable Duo Head Support System (excluding gel pads) – 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.

Computer system components used with the EyeLink Portable Duo system are excluded from this warranty unless expressly agreed to be otherwise in writing by SR Research Ltd.; contact the original computer manufacturer for service and support of computer components.

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.

THIS EXPRESS, LIMITED WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, EXCLUDING ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

IN NO EVENT WILL SR RESEARCH LTD. BE LIABLE FOR ANY SPECIAL, INDIRECT, OR CONSEQUENTIAL DAMAGES.

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

6.6 Limited Software Warranty

SR Research Ltd. warrants that the software disks and CD's 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 damage 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.

SR Research Ltd. does not warrant that the functions of the software will meet your requirements or that operation of the software will be uninterrupted or error free. You assume responsibility for selecting the software to achieve your intended results, and for the use and results obtained from the software. SR Research will fix reported software error in a best-effort fashion and cannot provide a guarantee of solution availability time.

THIS EXPRESS, LIMITED WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. IN NO EVENT WILL SR RESEARCH LTD. BE LIABLE FOR ANY SPECIAL, INDIRECT, OR CONSEQUENTIAL DAMAGES.

Some jurisdictions do not allow limitations on the duration of an implied warranty, so this limitation may not apply to you.

In no event shall SR Research Ltd. or its suppliers be liable for any damages whatsoever (including, without limitation, damages for loss of business profits, business interruption, loss of business information, or other pecuniary loss) arising out of use or inability to use the software, even if advised of the possibility of such damages. Because some jurisdictions do not allow an exclusion or limitation of liability for consequential or incidental damages, the above limitation may not apply to you.

6.7 Copyrights / Trademarks

EyeLink is a registered trademark of SR Research Ltd.

All other company and / or product names are trademarks of their respective manufacturers.

Product design and specifications may change at any time without notice.