EyeLink® 1000 Plus
Installation and Training

SR Research Ltd.

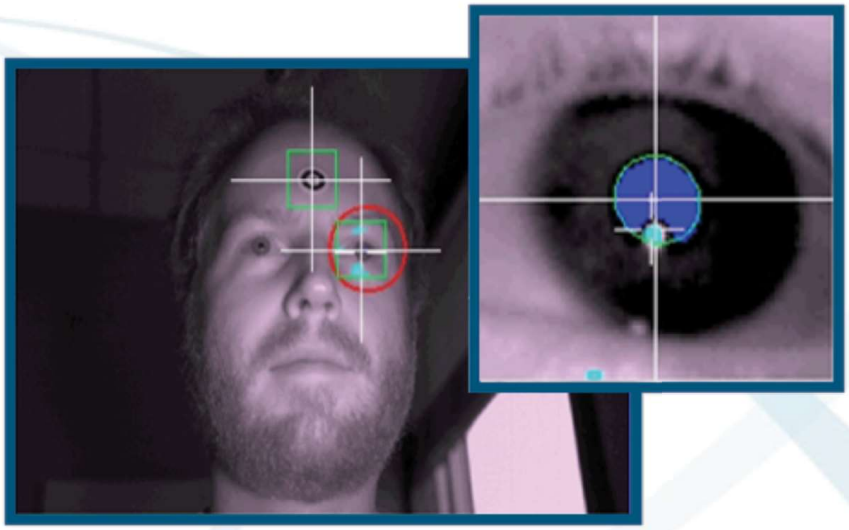
Toronto / Ottawa, Canada

Agenda

- Video-based eye tracking
- The EyeLink Platform
- EyeLink Components
- Terms and Specifications
- System Components
  - Display PC
  - Display API
  - Host PC
- Camera Setup
  - Calibration
  - Validation
- EyeLink Data Structure

Video-Based Eye Tracking

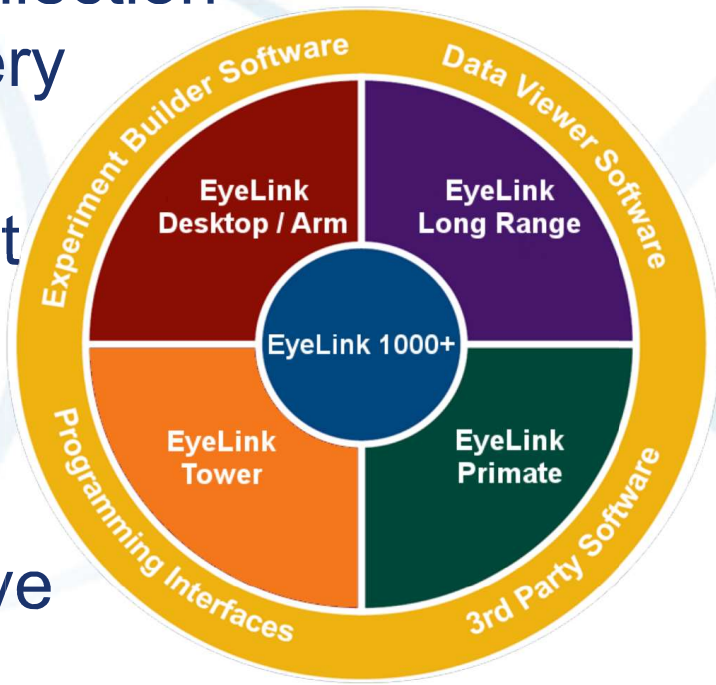
- IR camera and illuminator
  - Minimal interference with visual stimulus
- High speed video
  Image analysis
  - Determine centers of dark pupil and corneal reflection



- Calibration yields predictive model
  - Sample camera image while subject fixates several known locations
  - Induce predictive model

EyeLink Platform

- Focal Imaging Technology (FIT)
  - Point, focus and track camera
  - Real-time host computer for data collection
  - Display computer for stimulus delivery
- One camera, many mounts
  - Desktop, Tower, Primate, Arm Mount
  - Long range variants for MEG/MRI
- Multiple modes of operation
  - High-precision monocular/binocular
  - Remote mode with head free to move
- Unified software
  - Host eye tracker application
  - Application Programming Interface

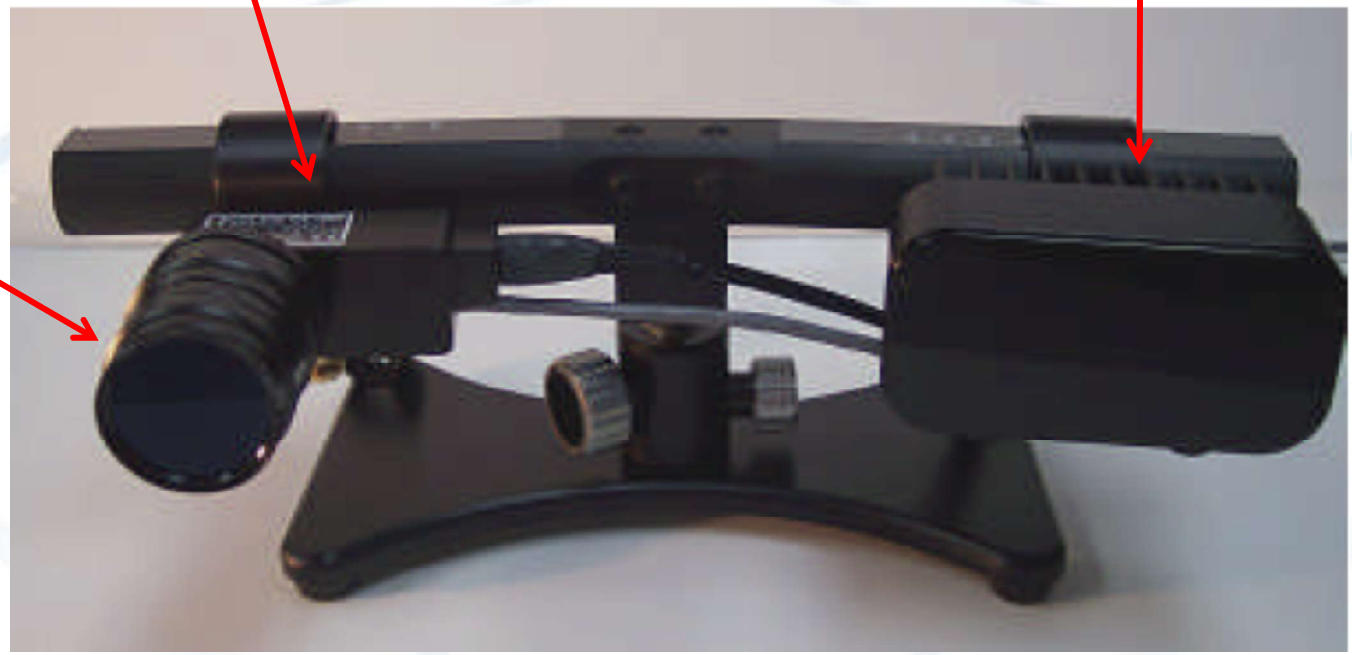


EyeLink Long Range Mount

Camera Head

Infrared Illuminator with Focusing Lens

Camera Lens



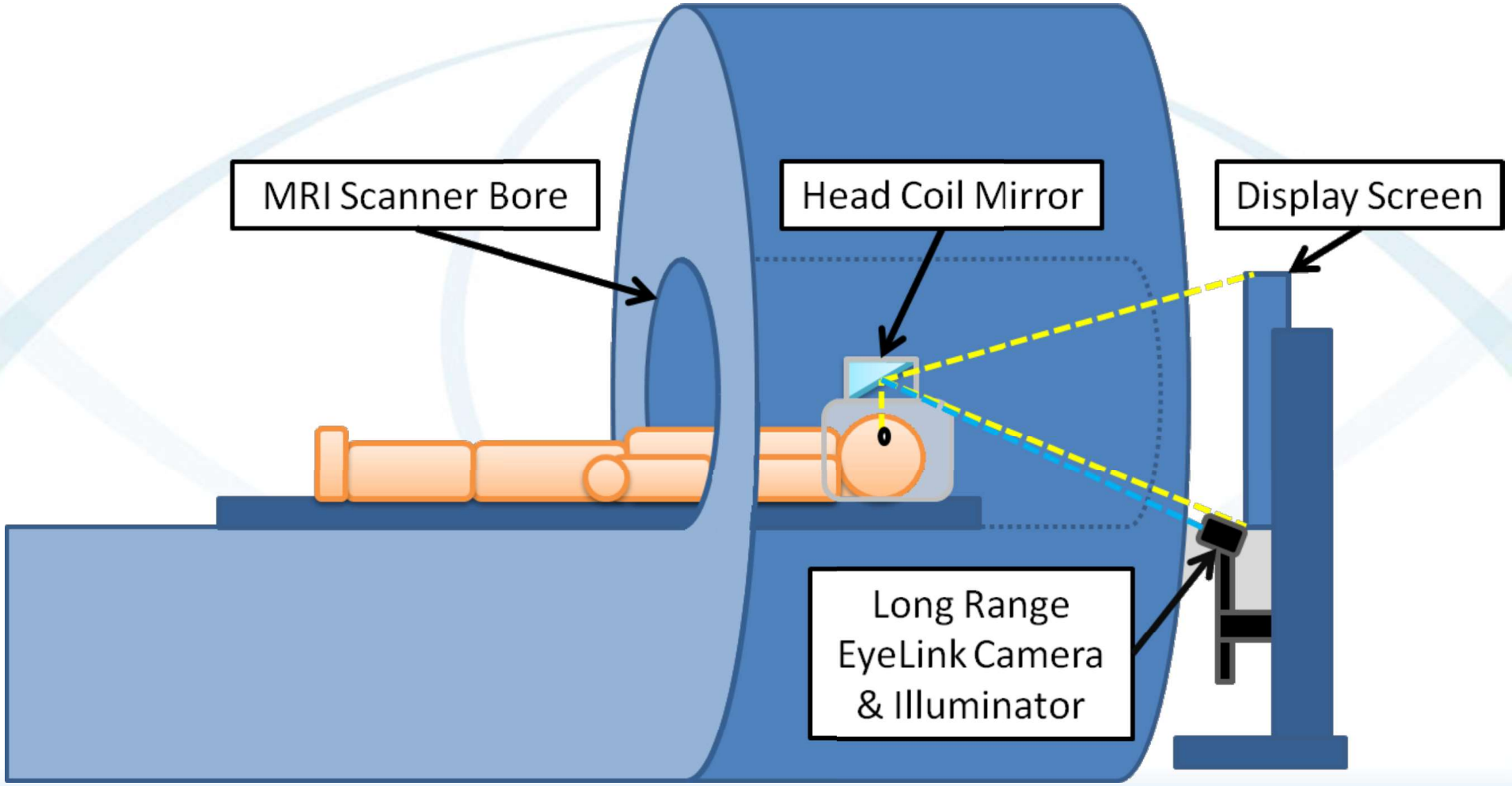
Different lenses (75mm,50mm,35mm) for
Different distances (overall range: 60-150cm).

Long Range Screen Mount

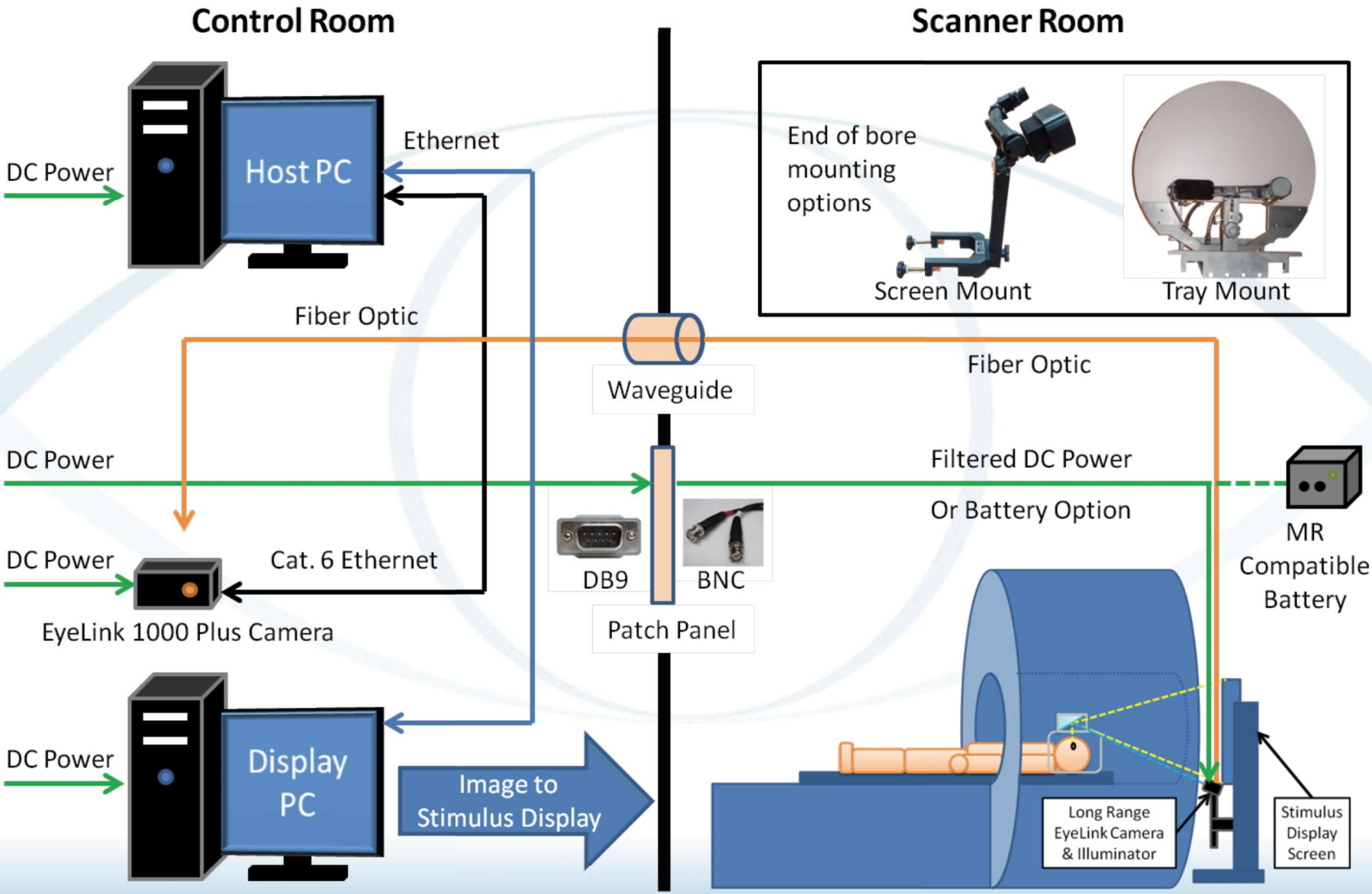
MRI Head Coil Mirror

- Make sure you use an approved front surface mirror

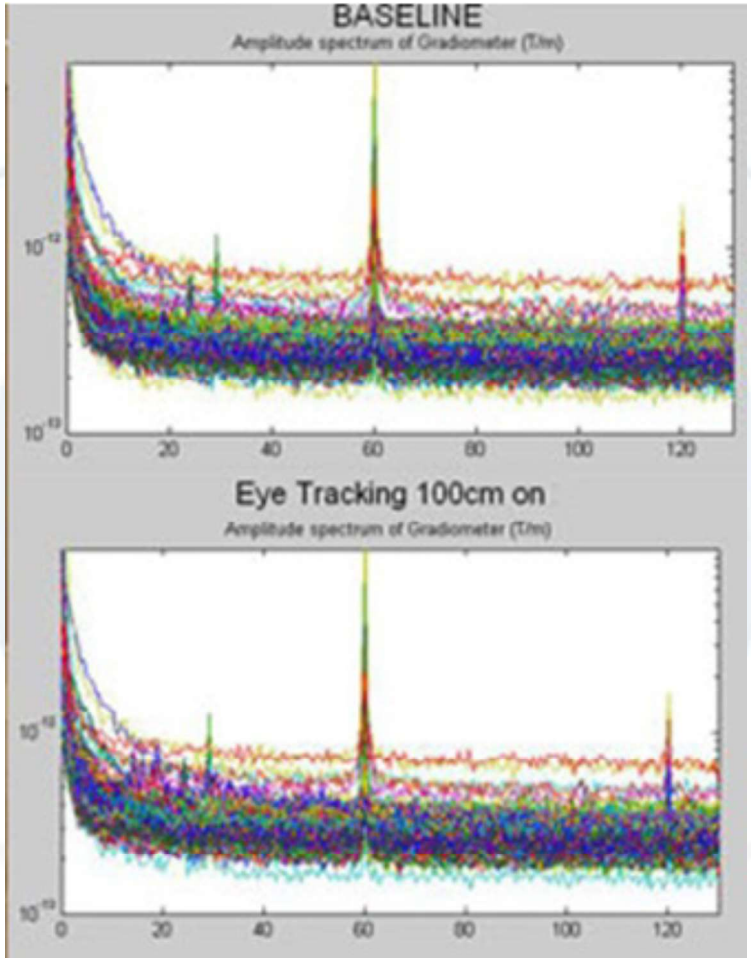
Typical MRI Configuration



Long Range System Cabling



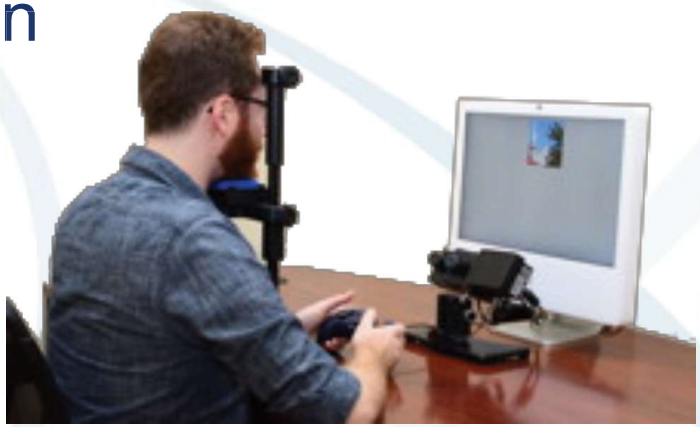
Long Range System Cabling



- No detectable noise with proper cabling
  (Graph from use with MEG)

Terms and Specifications

- Accuracy
  - Test-retest discrepancy
  - Measure of absolute spatial location
  - Will be best with dominant eye
  - Drift free, 0.25° -0.50° typical
- Spatial resolution
  - Smallest measurable movement
  - Measure of relative spatial location
  - <0.01° RMS in pupil-CR 1000 Hz tracking mode
  - Glasses increase error by about 0.01°



Terms and Specifications

- Temporal resolution
  - How many images processed per second
    - Hz = “samples” per second
  - 2000 / 1000 / 500 / 250 Hz recording
- Tracking Range
  - Portion of subject’s field of view (in degrees of visual angle) that can be accurately tracked
  - Desktop mount: 32° horizontal x 25° vertical
  - Tower mount: 55° horizontal x 45° vertical
- Blink Recovery Time
  - Recover of gaze position after missing data
  - Recover position on next sample

Terms and Specifications

- Eye Event Resolution
  - Smallest psychological event that is spatially measurable with the system
  - 0.05° microsaccades
- Head Movement Compensation
  - Tolerable level of head movements
  - Approximately 2 cm of lateral head movement compensation
- Streaming data delay
  - Time to access gaze data on Display PC via Ethernet
  - 1.4 ms delay (SD=0.4 ms) @ 2000 Hz
  - 1.8 ms delay (SD=0.8 ms) @ 1000 Hz

The Display PC

- Performs full experimental control
  - Integrate calibration and data collection into one easy step
  - Sets any tracker preference
  - Sends commands to control tracker
- Time stamps experiment events with messages
- Near real-time access to eye sample and event data structures for gaze-contingent paradigms
- Allows focus on stimulus presentation and data processing
  - Ordinary experiment delivery with calls to the underlying EyeLink libraries to interface with the eye tracker

Display PC API

- Compatible with many stimulus delivery methods
  - Experiment generating packages:
    - Experiment Builder
    - E-Pricme
    - Presentation
    - Psychtoolbox (MATLAB)
  - Programming languages:
    - C/C++
    - Python
    - Delphi
    - Any Windows COM language
  - Operating systems:
    - Windows / Mac / Linux

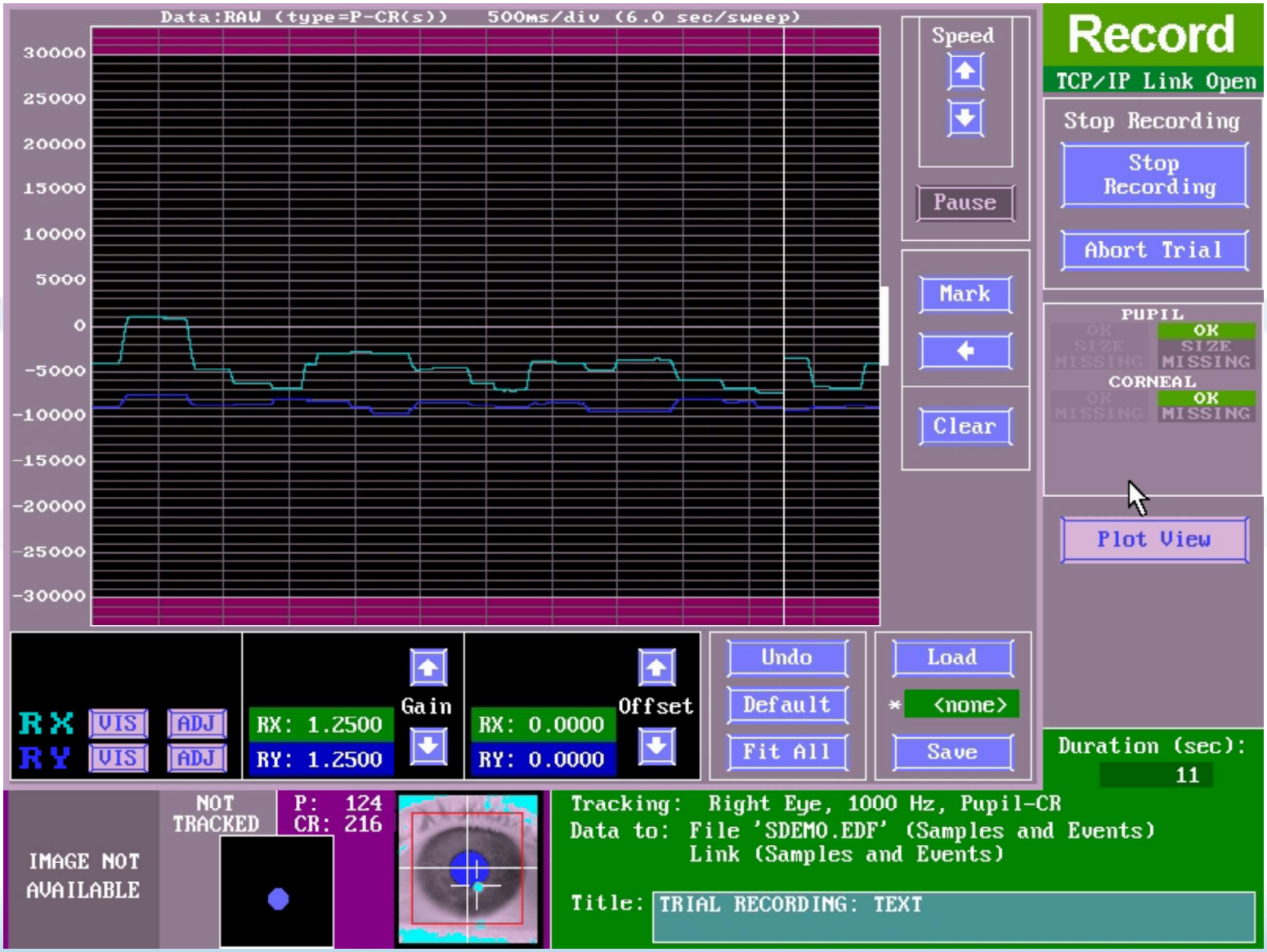
The Host PC

- Host PC application controls the eye tracker
  - Performs image analysis
  - Performs data recording
  - Performs eye event parsing
  - Configures preferences
- Provides real-time feedback
  - Gaze view: gaze cursor on background image
  - Plot view: eye traces over time
- Send and receive TTL via Parallel Port
  - TTLs received logged directly to EDF

Gaze View


Call me Ishmael. Some years ago -- never mind how long precisely -- having little or no money in my purse, and nothing particular to interest me on shore, I thought I would sail about a little and see the watery part of the world. It is a way I have of driving off the spleen, and regulating the circulation. Whenever I find myself growing grim about the mouth; whenever it is a damp, drizzly November in my soul; whenever I find myself involuntarily pausing before coffin warehouses, and bringing up the rear of every funeral I meet, I account it high time to get to sea as soon as I can. This is my substitute for pistol and ball. With a philosophical flourish Cato throws himself upon his sword; I quietly take to the ship.
Record
TCP/IP Link Open
Stop Recording
Stop Recording
Abort Trial
PUPIL
OK
SIZE
MISSING
CORNEAL
OK
MISSING
Plot View
Duration (sec):
21
IMAGE NOT AVAILABLE
NOT TRACKED
P: 124
CR: 216
Tracking: Right Eye, 1000 Hz, Pupil-CR
Data to: File 'SDEMO.EDF' (Samples and Events)
Link (Samples and Events)
Title: TRIAL RECORDING: TEXT

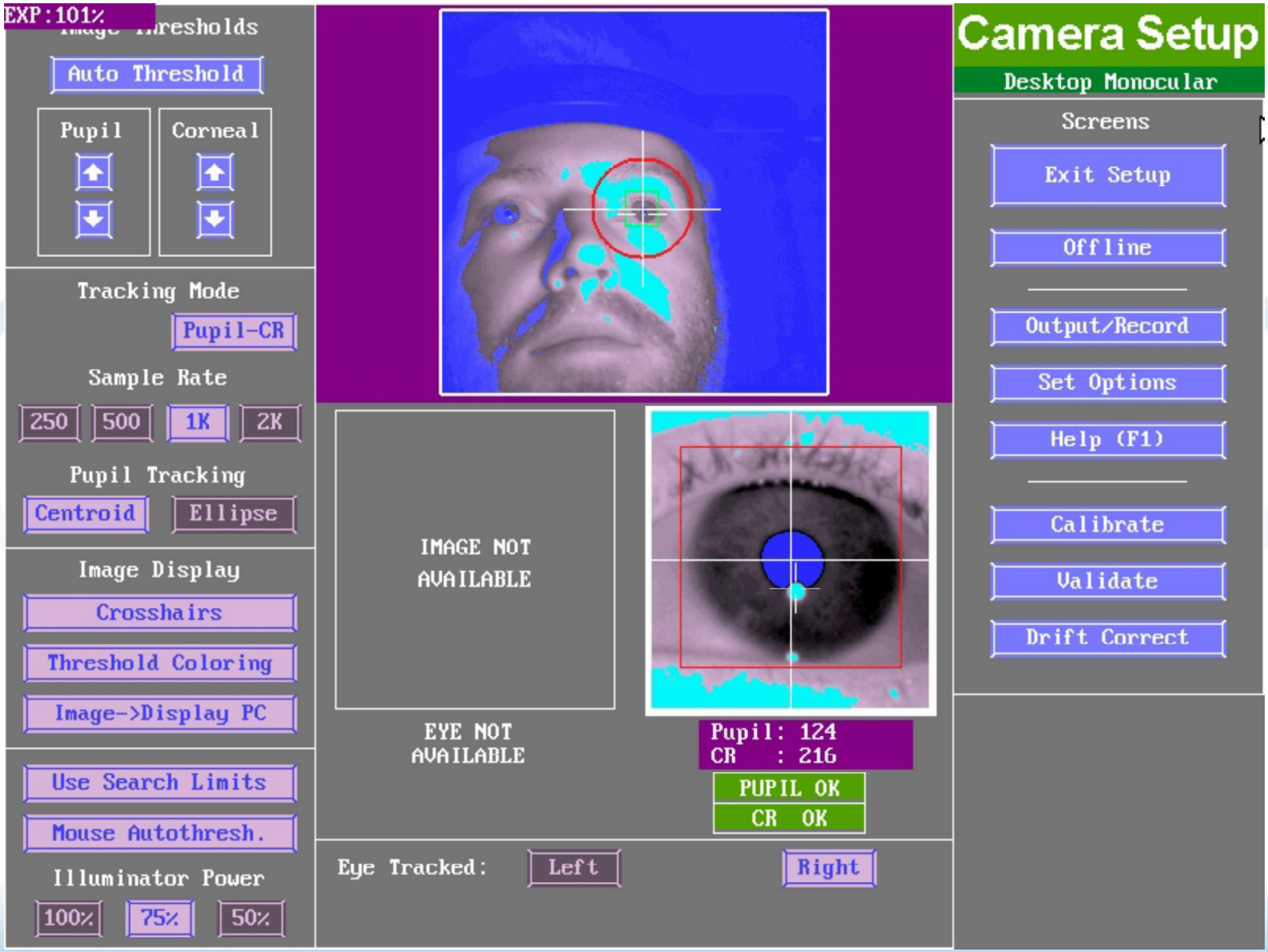
Plot View


Data:RAW (type=P-CR(s)) 500ms/div (6.0 sec/sweep)
30000
25000
20000
15000
10000
5000
0
-5000
-10000
-15000
-20000
-25000
-30000
Speed
Pause
Mark
Clear
Record
TCP/IP Link Open
Stop Recording
Stop Recording
Abort Trial
PUPIL
OK
SIZE
MISSING
CORNEAL
OK
MISSING
Plot View
RX
RY
VIS
ADJ
RX: 1.2500
RY: 1.2500
Gain
RX: 0.0000
RY: 0.0000
Offset
Undo
Default
Fit All
Load
* <none>
Save
Duration (sec):
11
IMAGE NOT AVAILABLE
NOT TRACKED
P: 124
CR: 216
Tracking: Right Eye, 1000 Hz, Pupil-CR
Data to: File 'SDEMO.EDF' (Samples and Events)
Link (Samples and Events)
Title: TRIAL RECORDING: TEXT

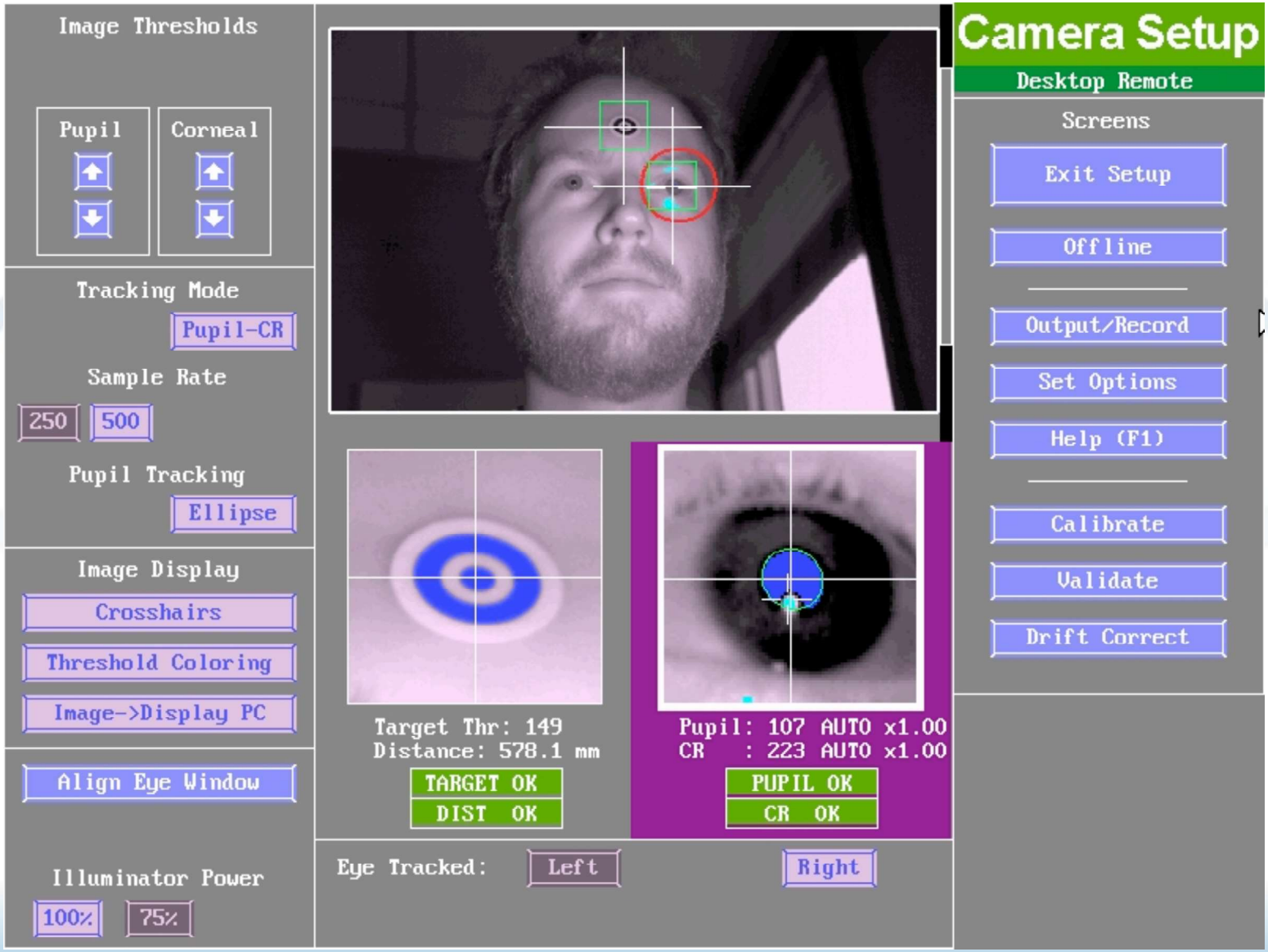
Camera Setup

- Position camera image
  - Center subject's eyes in global camera image
- Focus camera lens on surface of the eye
- Adjust Pupil and Corneal Reflection thresholds
  - Let the system know which part of the camera image should be considered as pupil and corneal reflection
- Perform Calibration and Validation
  - Calibration induces predictive model
  - Validation tests accuracy of calibrated model

Camera Setup

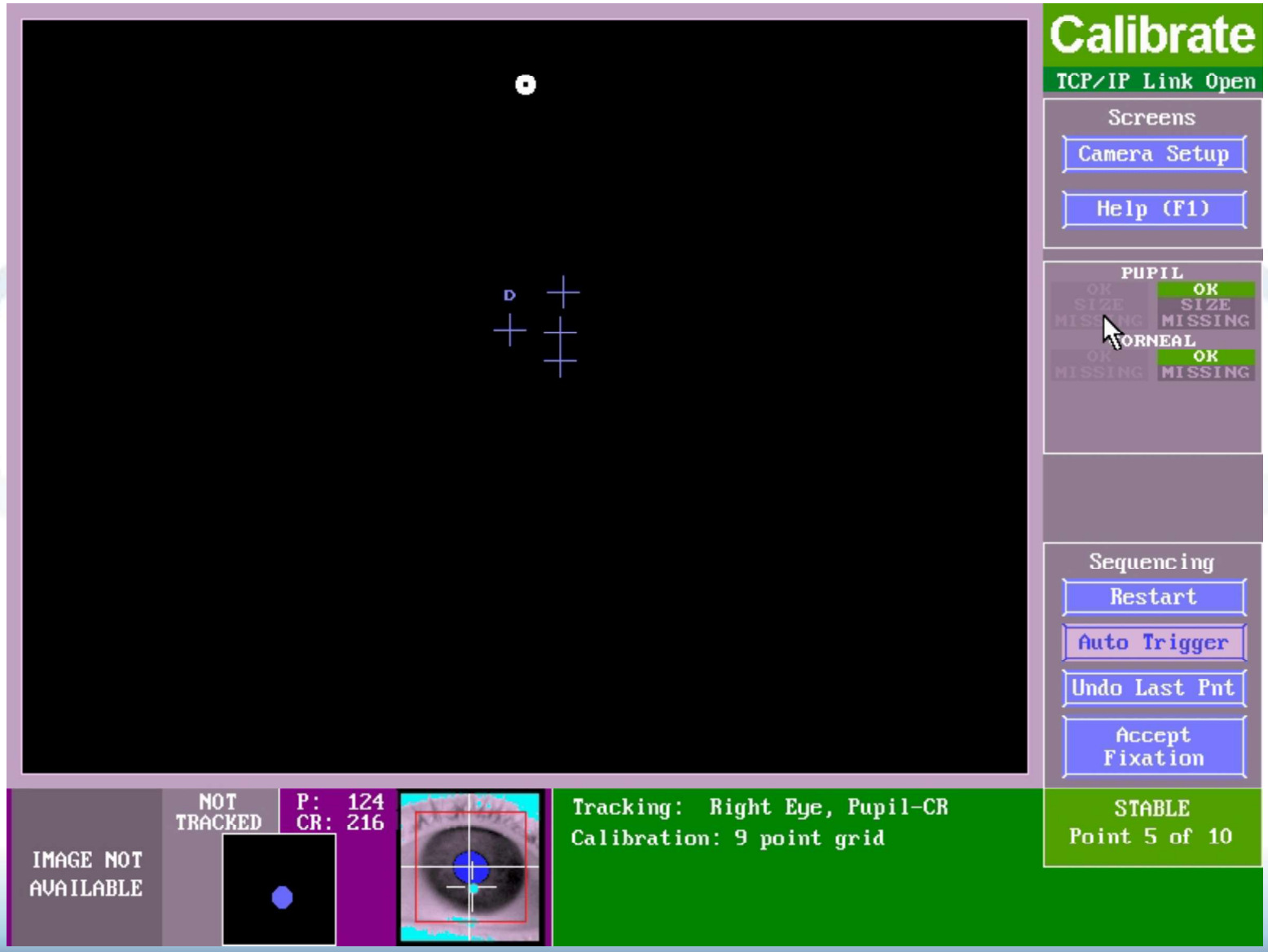


EyeLink Remote Mode



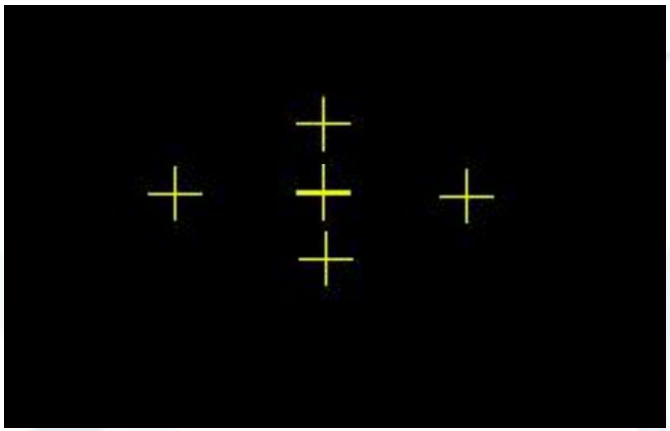
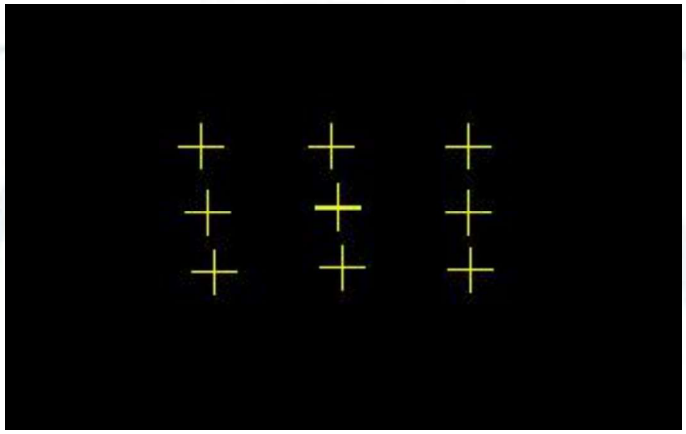
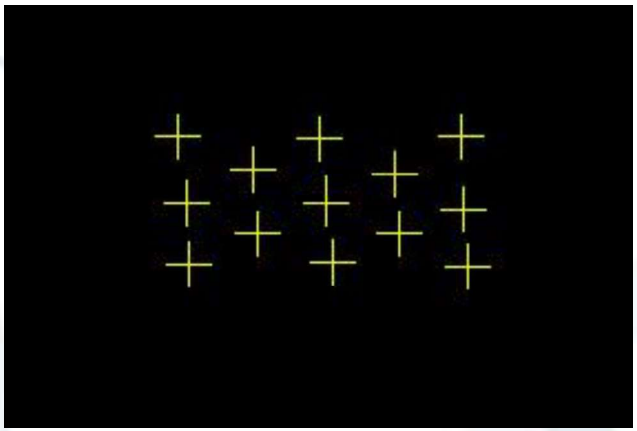
Calibration

Mapping raw eye data / camera image data to predict gaze position

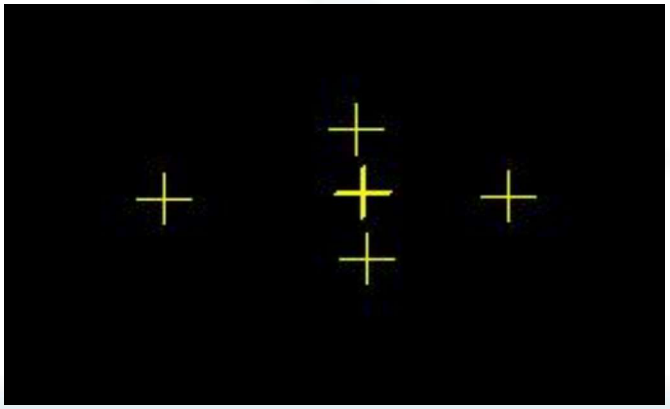
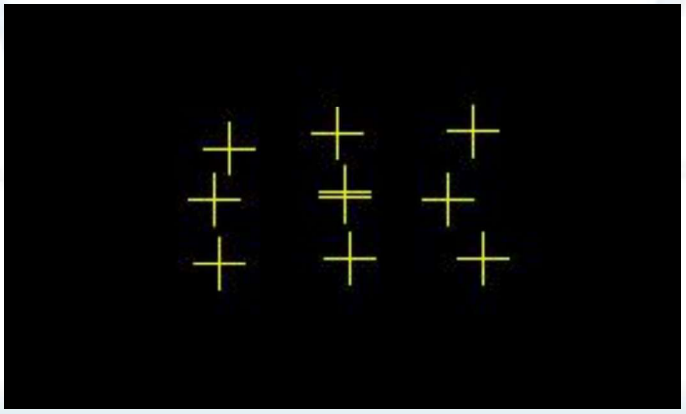
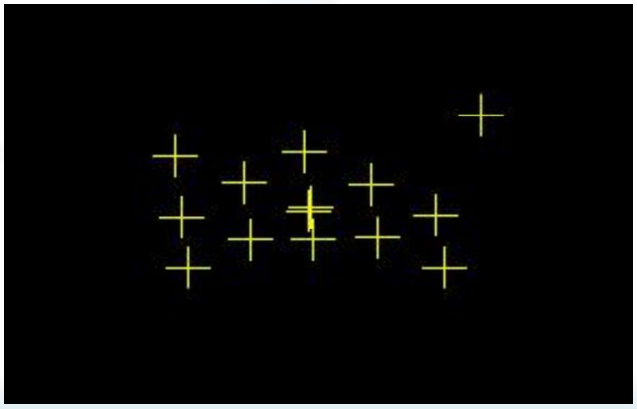


Calibration

Good Calibration models (symmetrical)

Poor Calibration models (asymmetrical)

Validation

- Evaluate predictive model's test-retest accuracy
- Subject re-fixates known locations
  - Difference between predicted gaze position and validation sample is "accuracy"
- Summarizes calibration accuracy
  - Reveals which spatial positions fit least accurately in degrees of visual angle

Validation

Checking accuracy level of the calibration

EyeLink Data

- EDF file
  - Use EDF2ASC/VisualASC converter to get ASC files
  - Use EyeLink Data Viewer for direct analysis
- What is recorded:
  - Samples
  - Events
    - Saccades, fixations, blinks, messages, buttons

(Please read Chapter 4 of the EyeLink 1000 Plus User Manual)

EyeLink Recording Data

- Samples
  - System time, x, y, and pupil size
  - Optional velocity, resolution, and CR status

6079861	503.7	680.3	972.0	.....
6079862	503.7	680.1	972.0	.....
6079863	503.8	680.1	972.0	.....
6079864	503.8	680.2	972.0	.....
6079865	503.9	680.2	971.0	.....
6079866	503.7	680.1	971.0	.....
6079867	503.7	680.1	971.0	.....
6079868	503.6	680.0	970.0	.....
6079869	503.6	680.1	970.0	.....
6079870	503.7	680.2	970.0	.....

(Please read Chapter 4 of the EyeLink 1000 Plus User Manual)

EyeLink Recording Data

- Saccades
  - SSACC: eye, start time
  - ESACC: eye, start time, end time, duration, start x/y, end x/y, amplitude, peak velocity

```
SSACC L  6079955
ESACC L  6079955   6079962    8   507.5   682.5   511.9   682.0   0.20    38
…
SSACC L  6080723
ESACC L  6080723   6080763   41  513.8   679.7   633.5   550.5   7.94   285
```

(Please read Chapter 4 of the EyeLink 1000 Plus User Manual)

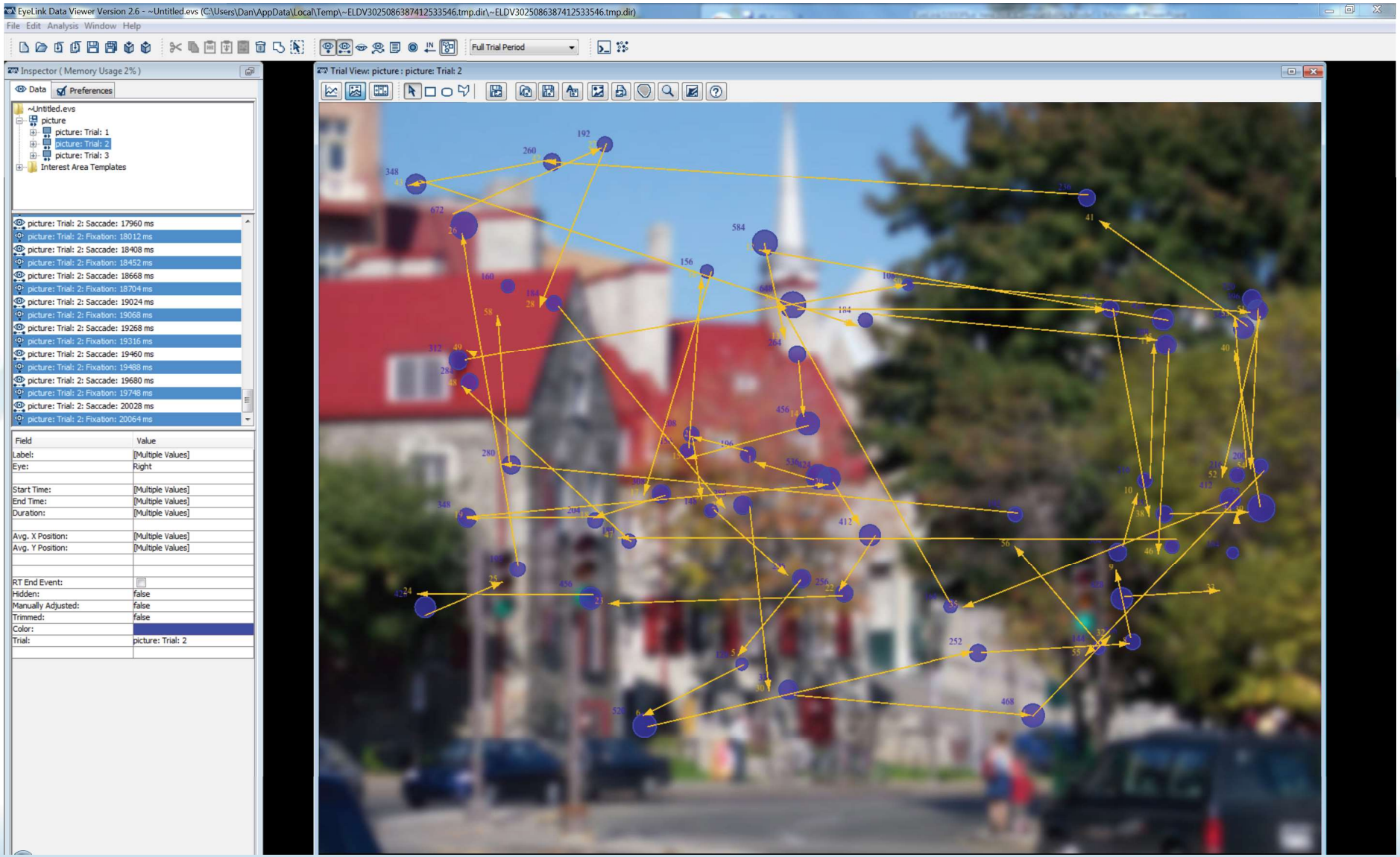
EyeLink Recording Data

- Fixations
  - SFIX: eye, start time
  - EFIX: eye, start time, end time, duration, average x/y, pupil size, resolution

```
SFIX L   1454748
EFIX L   1454748   1454907   160   510.3   4.1   1187   28.45   27.50
...
SFIX L   1454919
EFIX L   1454919   1455873   955   514.0   0.3   1361   28.40   27.50
```

(Please read Chapter 4 of the EyeLink 1000 Plus User Manual)

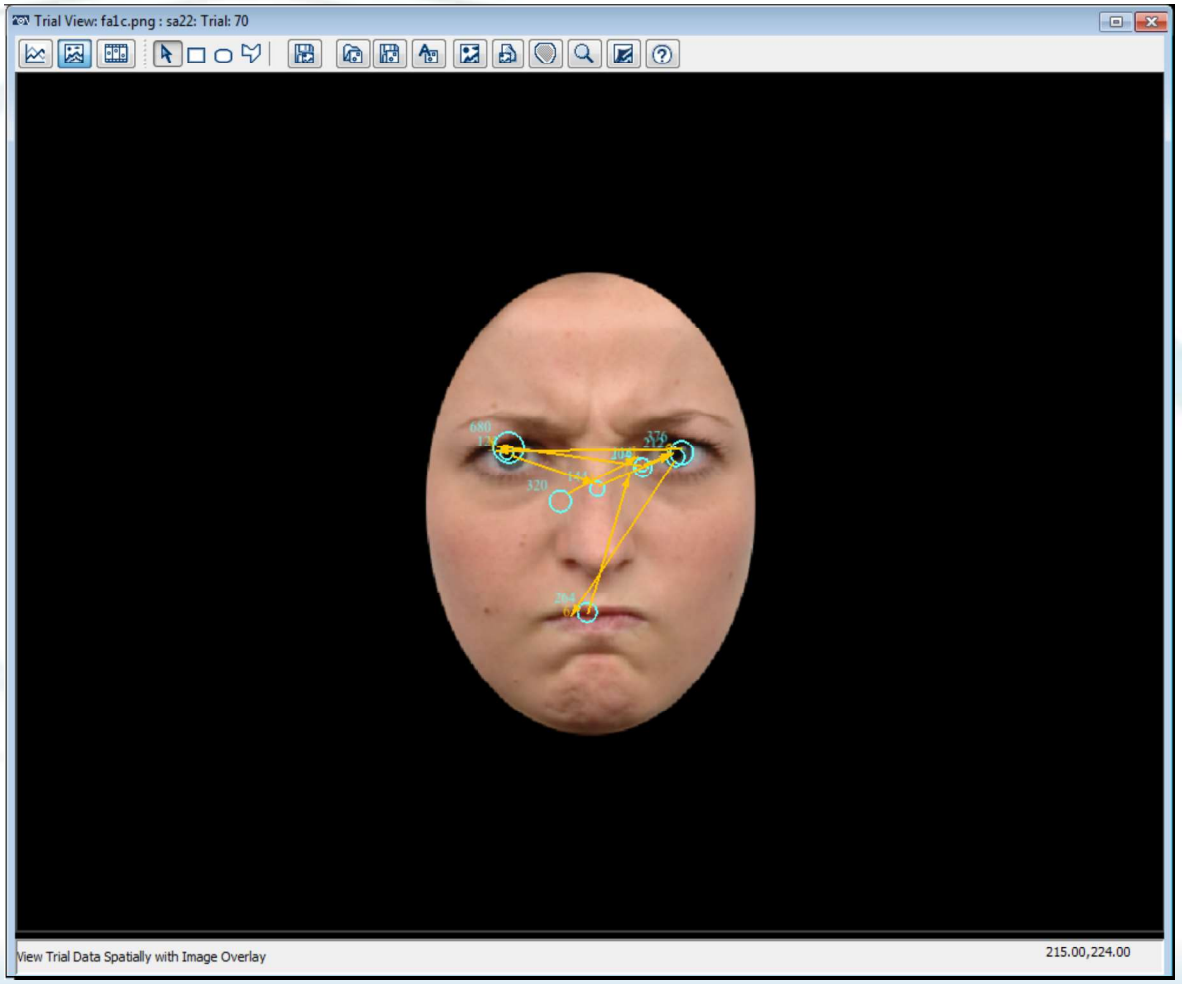
EyeLink Data Viewer



EyeLink Data Viewer

Data visualization:

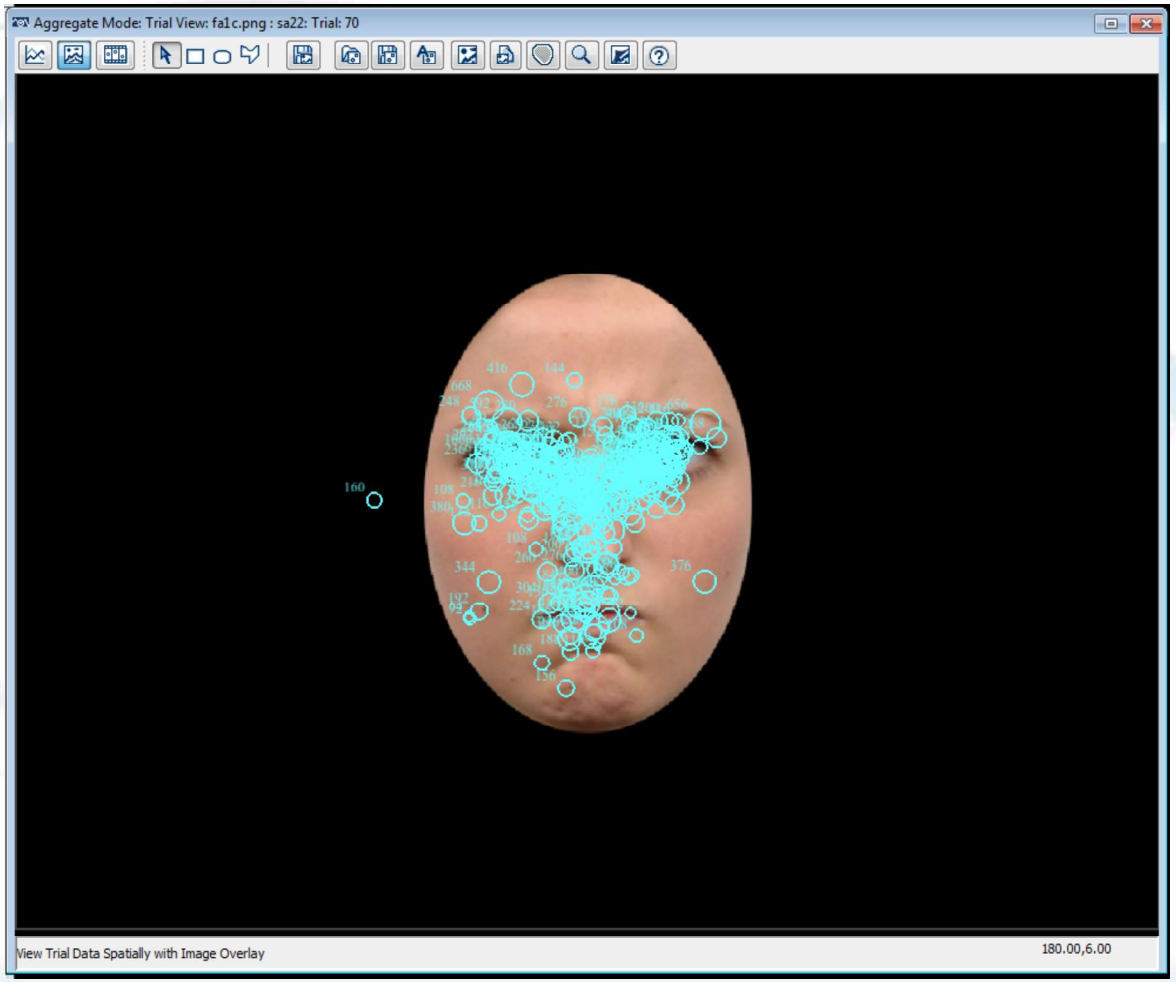
Spatial Overlay View superimposes saccade and fixation scan-path information over an image



EyeLink Data Viewer

Data visualization:

Aggregate Mode superimposes data from multiple trials / participants

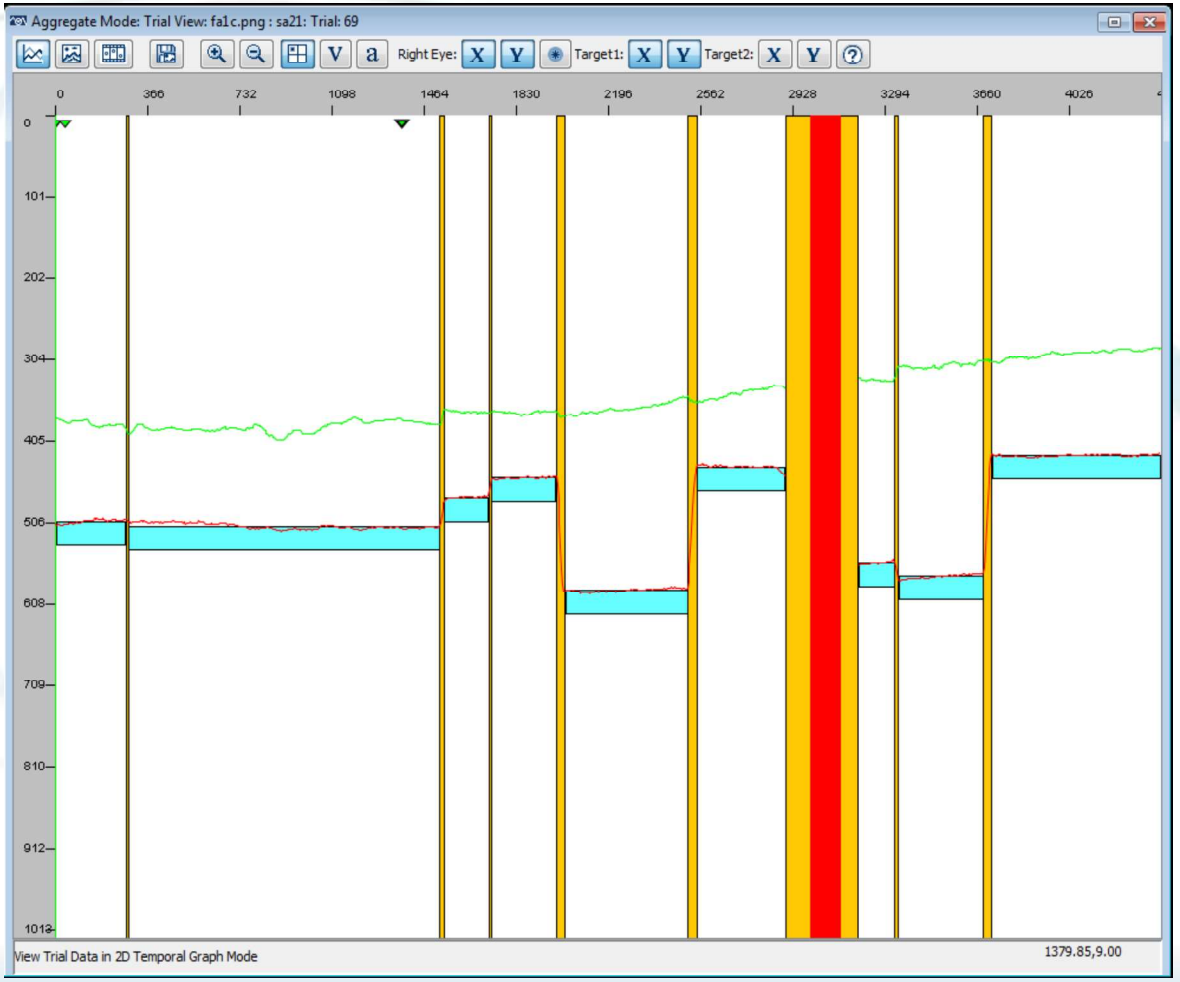


EyeLink Data Viewer

Data visualization:

Temporal Graph View supports visualization of eye data over time

Useful for seeing when messages appear and setting Interest Periods



EyeLink Data Viewer

Data visualization:

Animation Playback View shows a movie of the trial with eye movements overlaid.

Playback speed can be adjusted – helpful for the creation of dynamic interest areas using the Mouse Record technique.

EyeLink Data Viewer

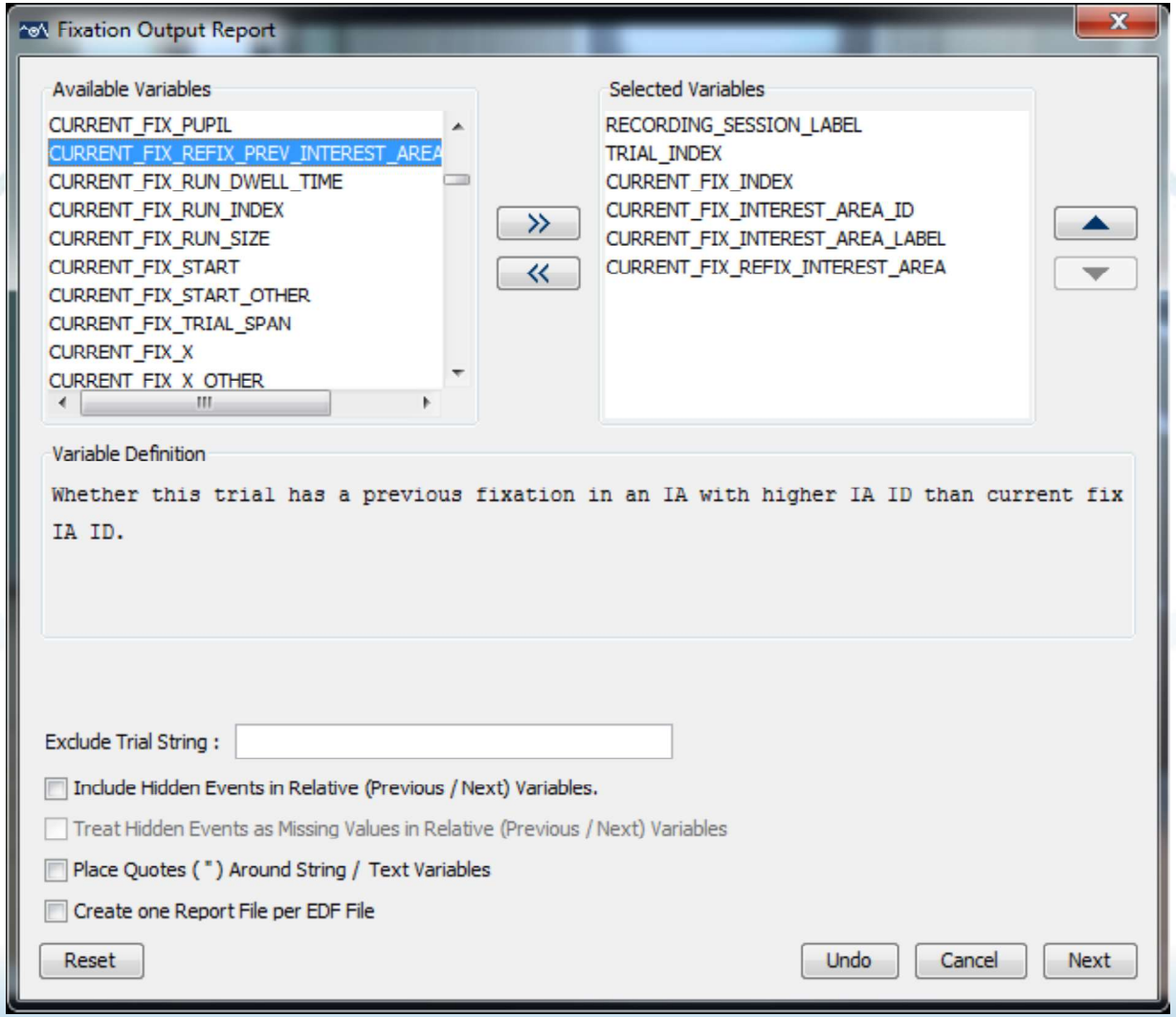
In Aggregate Mode, Animation Playback view can show bee-swarm and dynamic heat maps.

EyeLink Data Viewer

- Supports both static and dynamic interest areas (rectangular, elliptical, or freeform polygons)
- Create interest periods for temporal data filtering
- Group data using existing or new variables
- Generate heat maps / dynamic heat maps for selected trials
- Output eye sample, fixation, saccade, interest area, or trial-based reports for statistical analysis
- Output binned data for time-series analysis (Visual World Tasks / Dynamic Stimuli)
- Calculate hundreds of dependent measures including most common reading measures
- Highly integrated with SR Research Experiment Builder, E-Prime, Presentation, and any custom stimulus display solution
- Available on Windows, Mac OS X, and Linux

EyeLink Data Viewer

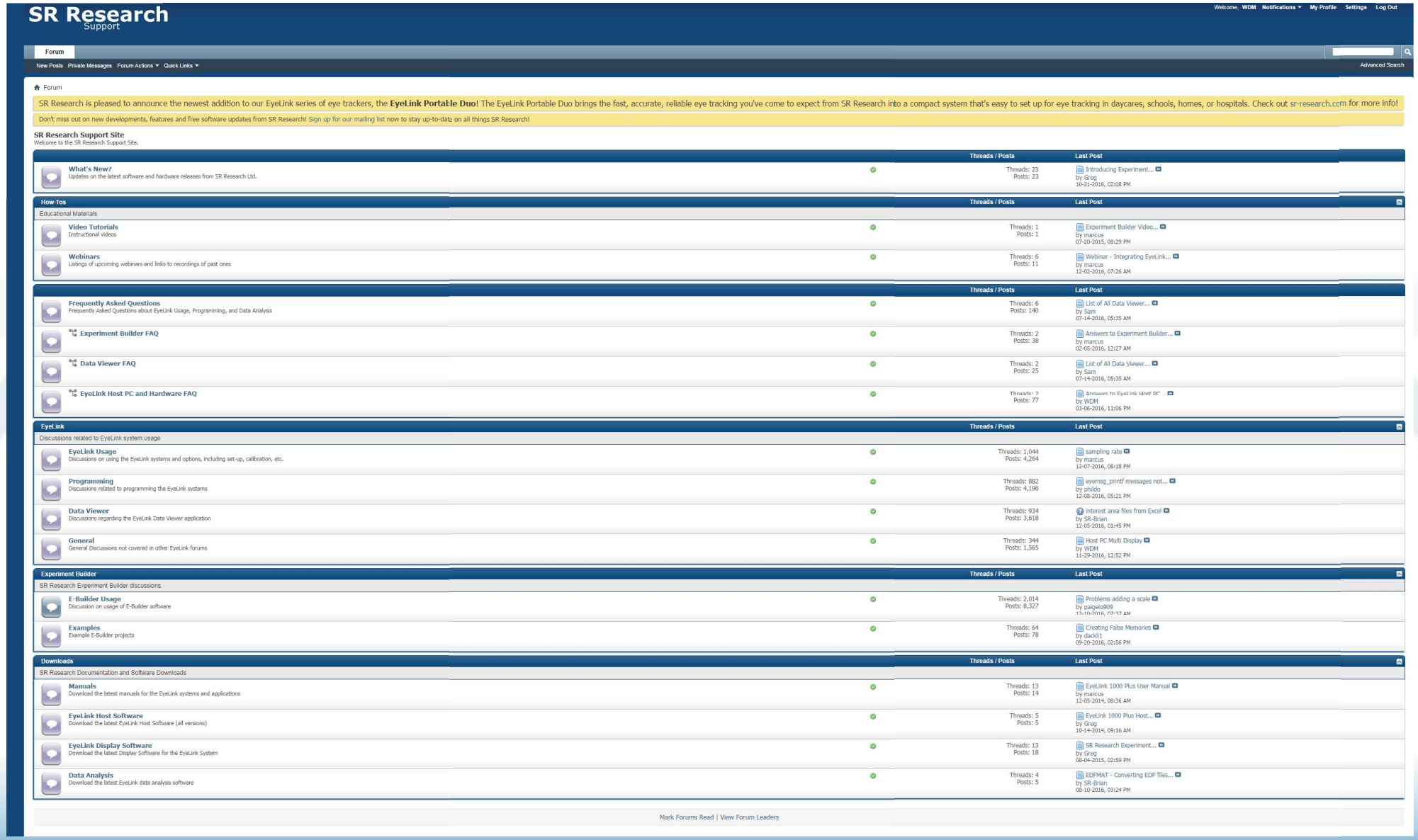
Generates detailed Fixation, Saccade, Interest Area, Sample and Trial reports



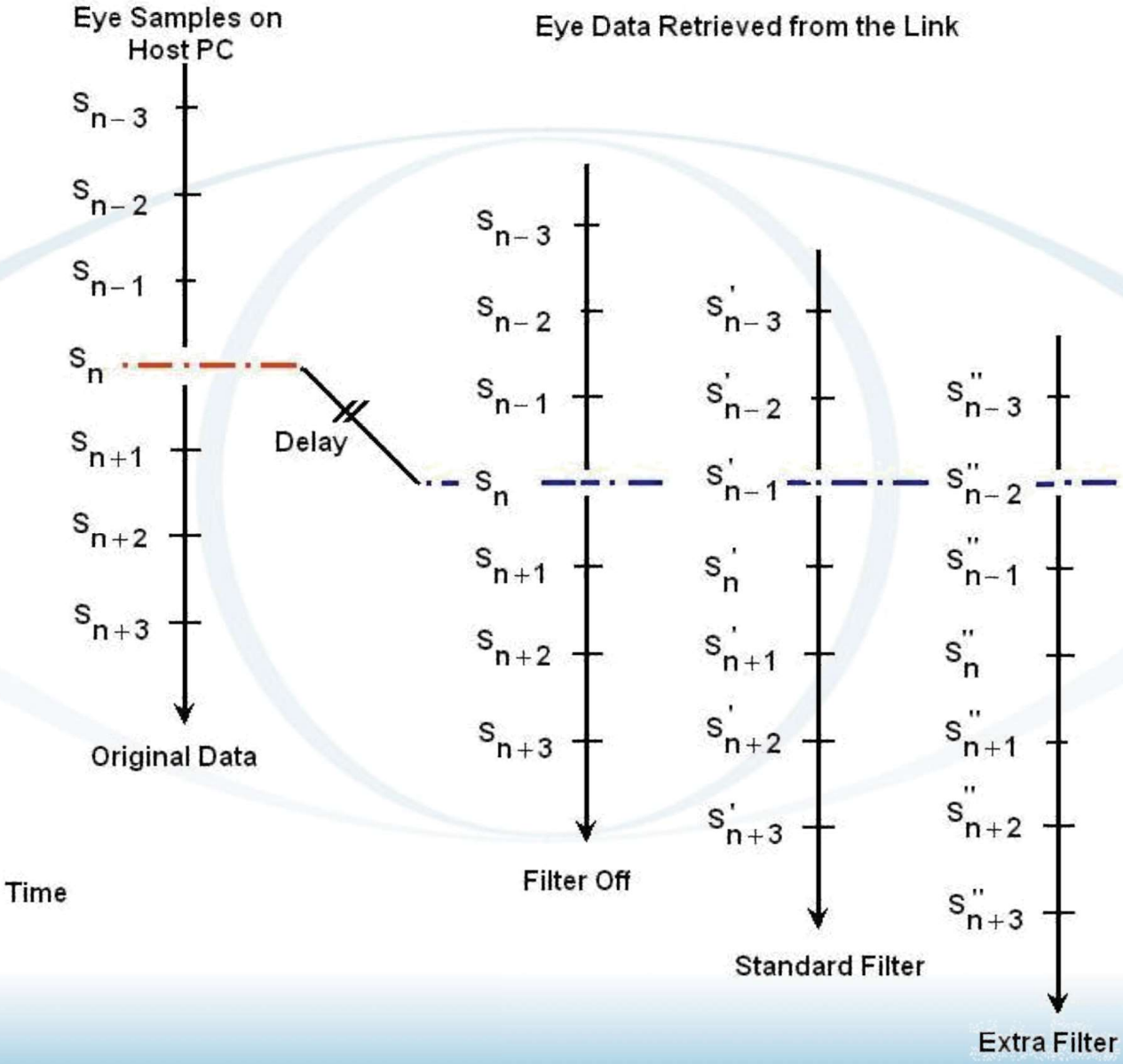
EyeLink Support

- Documents
  - EyeLink 1000 Plus User Manual
  - EyeLink 1000 Plus Installation Guide
  - EyeLink 1000 Plus Quick Start Guide
  - SR Research Experiment Builder User Manual
  - EyeLink Programmer's Guide
  - EyeLink Data Viewer User Manual
- Contact Information
  - Email: support@sr-research.com
  - Phone: 1-613-826-2958 / 1-866-821-0731
  - Support Forum: www.sr-support.com

EyeLink Support Forums



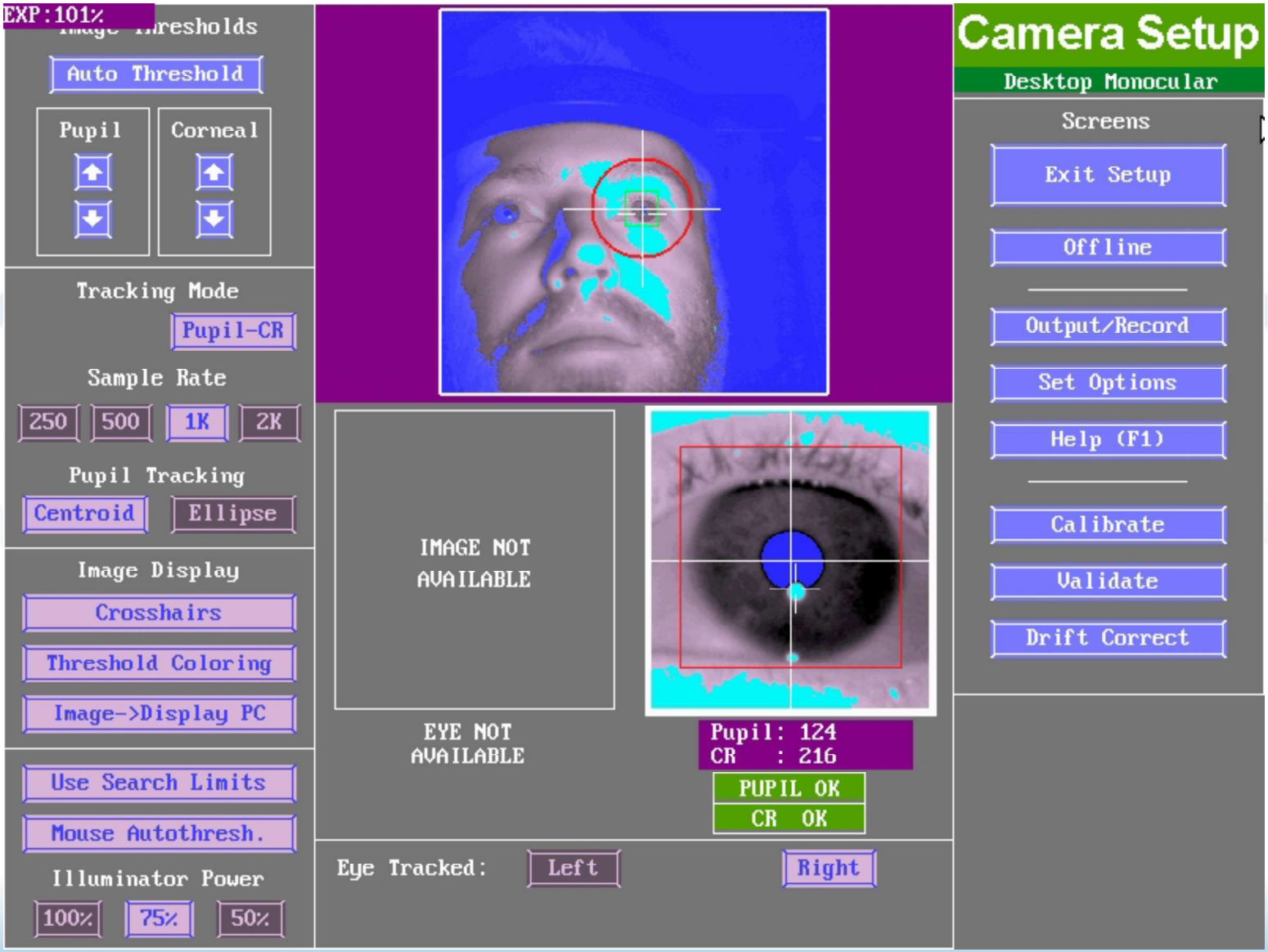
Smart Data Filter



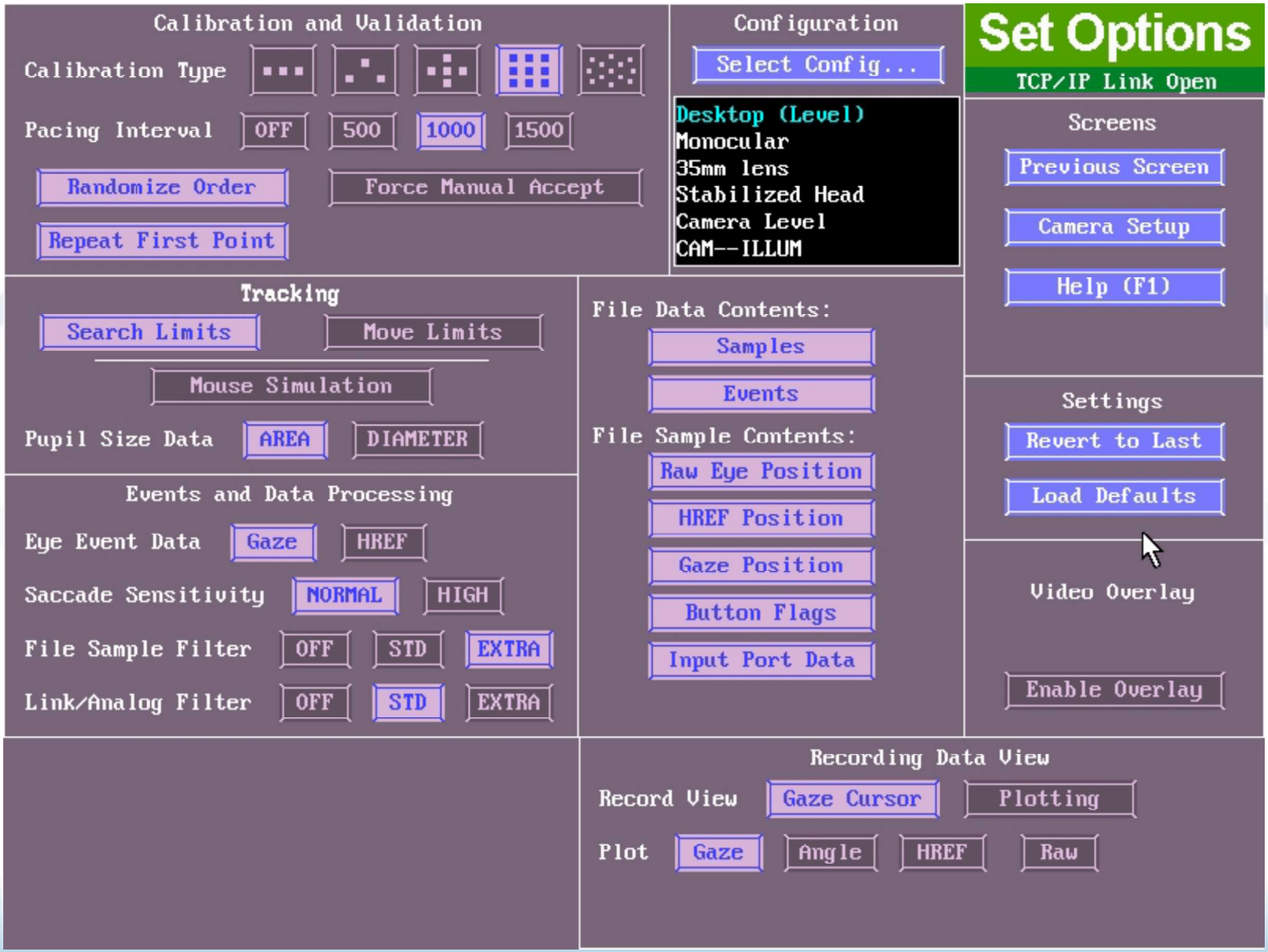
Host Application

- Camera Setup screen
  - Adjust camera image
  - Calibration
  - Validation
  - Drift Check
- Set Options screen
  - Select preferences / options
  - Set method of recording
- Record screen
  - Real-time gaze cursor / Plot View

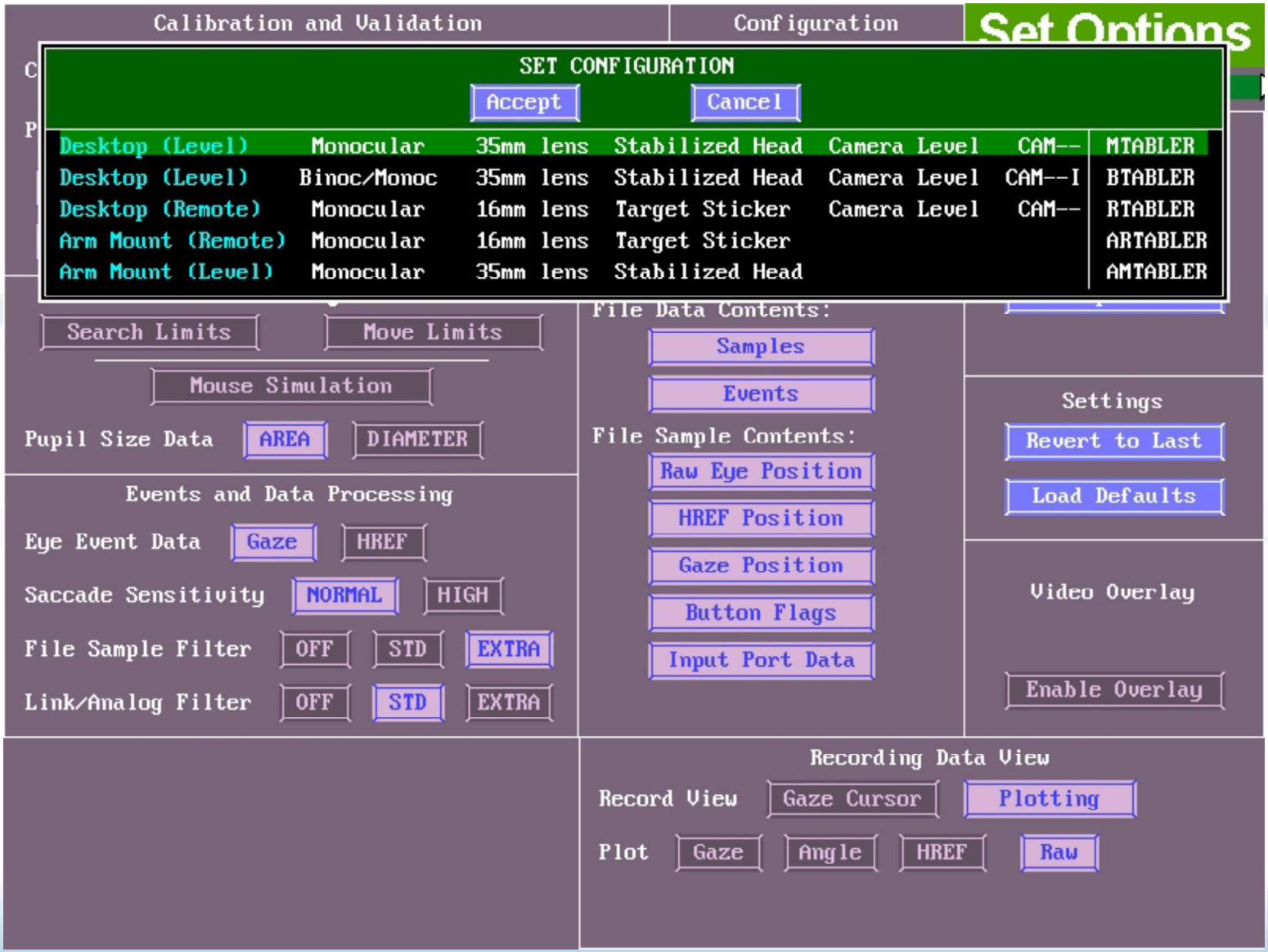
Camera Setup screen



Set Options screen

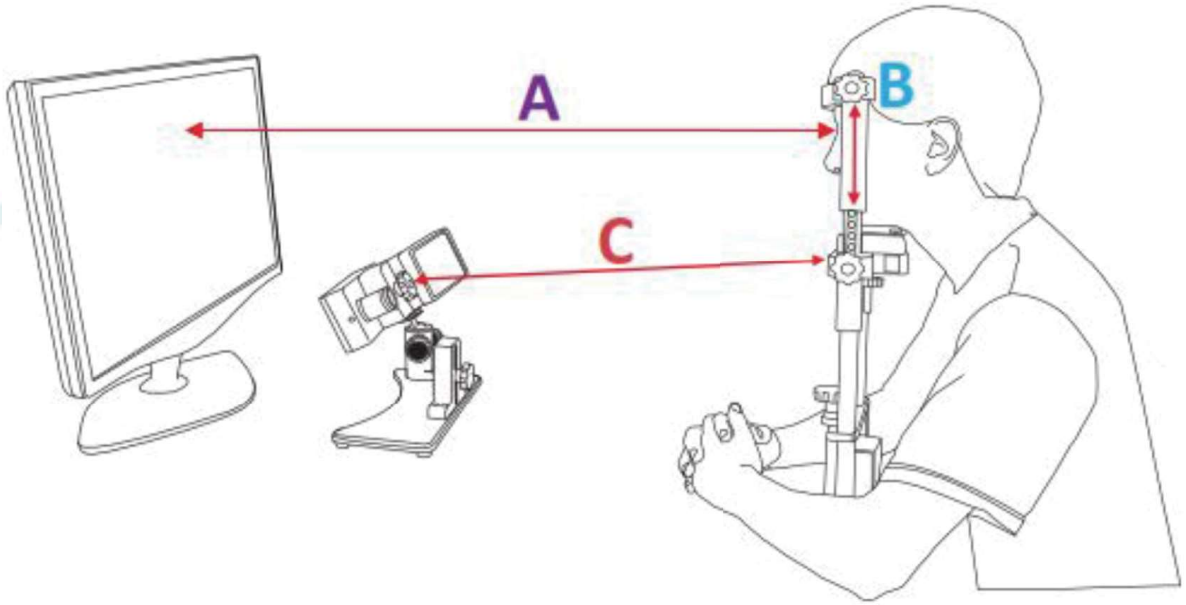


Set Configuration menu



Record screen

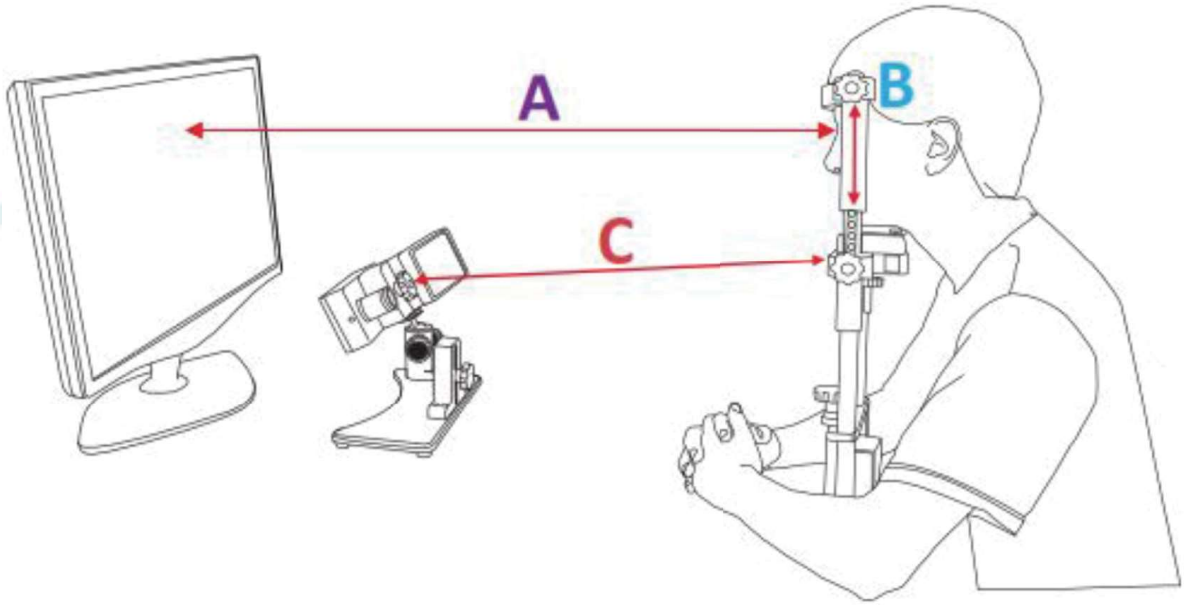
Physical Setup



A) 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-screen distance should be at least 1.75 times the width of the display to ensure that it falls within the trackable range

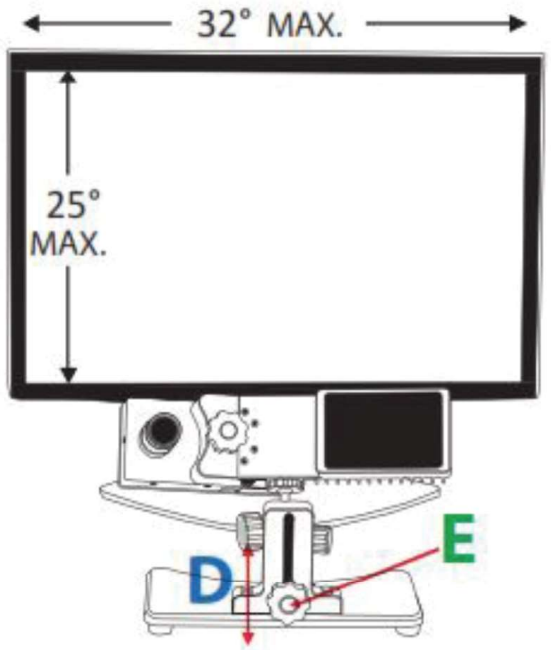
Physical Setup



B) Position the participant so that the eyes align with the top quarter of the monitor – adjust the chair and/or the head support to ensure this alignment

C) Position the eye tracker so that the distance from the top knob on the front of the Desktop Mount to the front of the chinrest is 50-55 cm. If using remote mode make sure that the reported target distance on the Host PC is around 60cm (55-60 is ideal for calibration)

Physical Setup



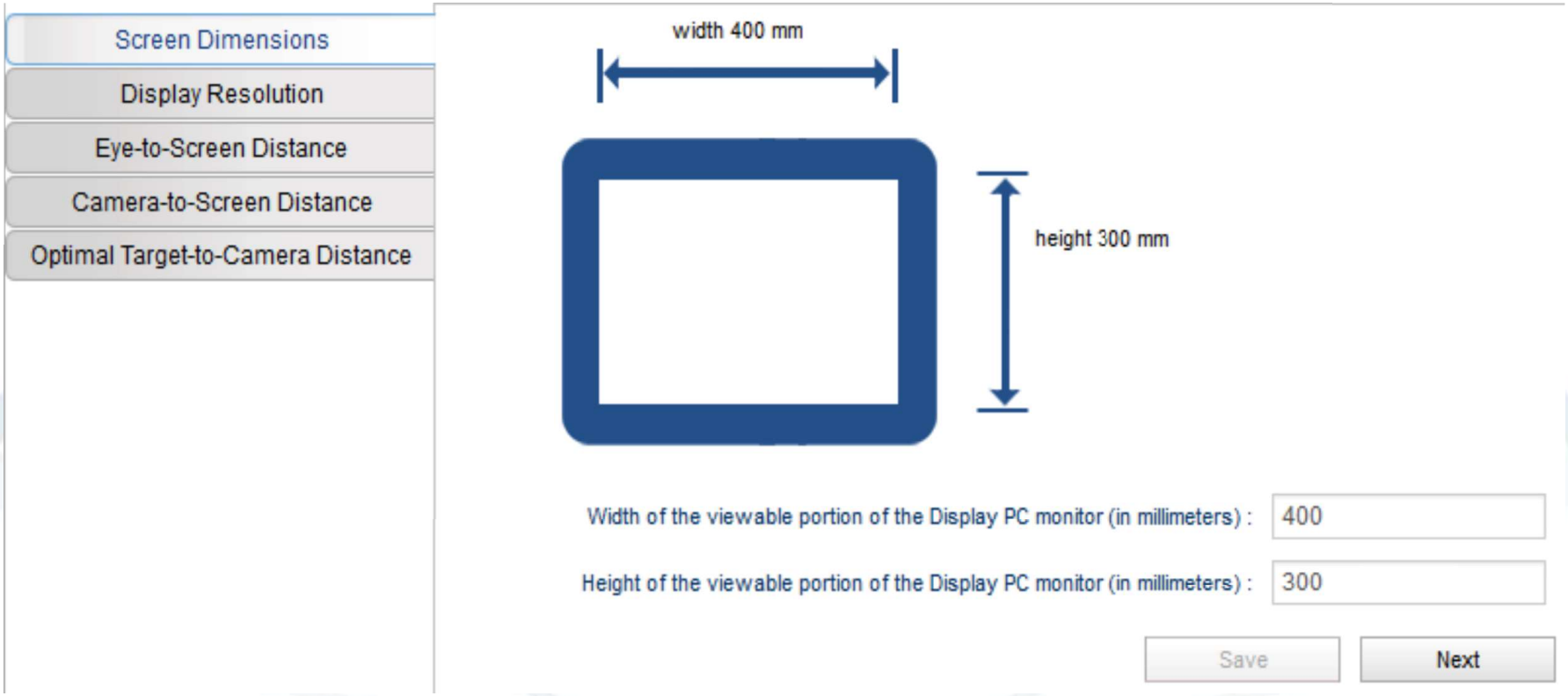
D) Adjust the height of the eye tracker so that it is as high as possible without blocking the participant's view of the display

E) Position the eye tracker so that its bottom knob is centered horizontally with the front of the display

File Manager

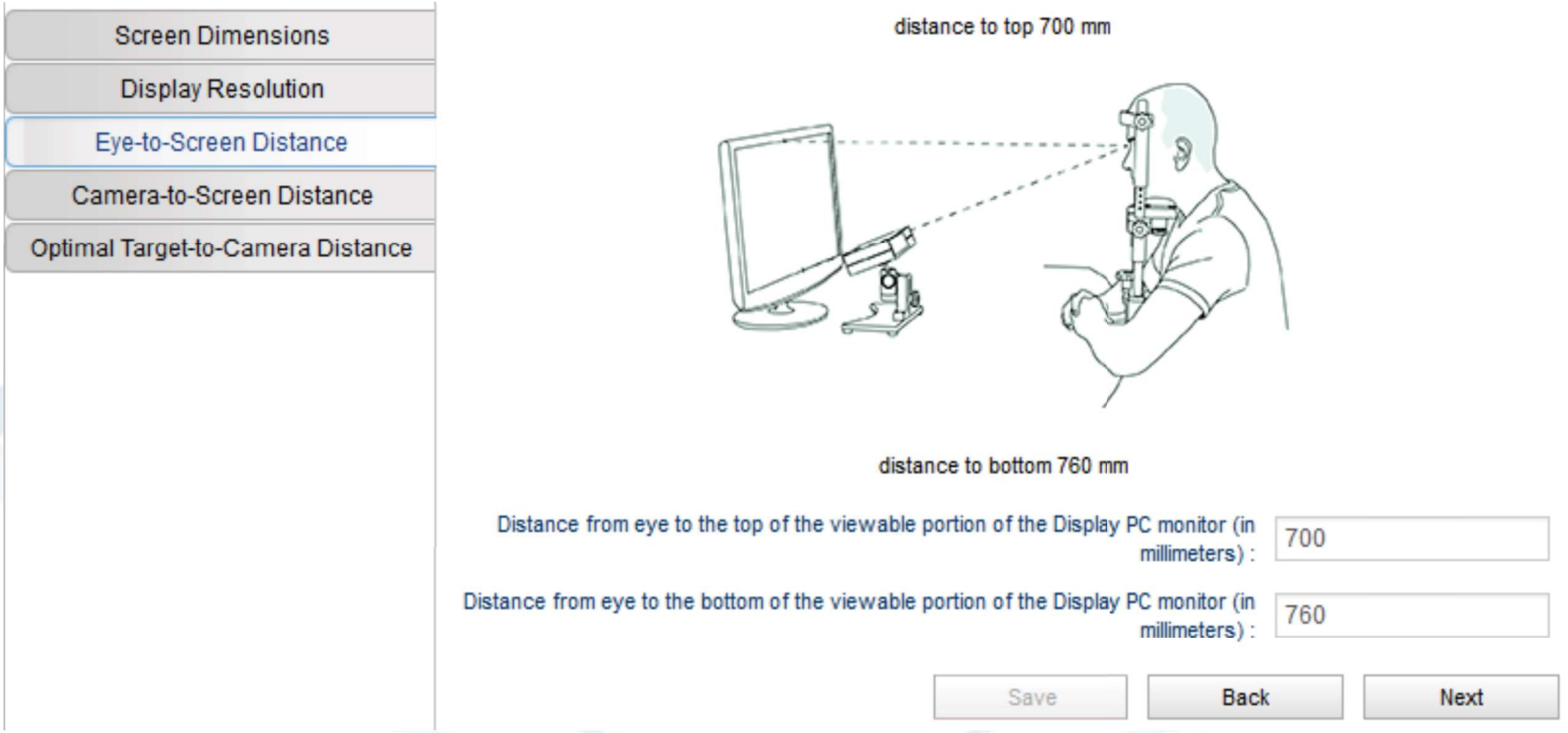
- For the Host software press CTL+ALT+Q to exit back to the File Manager interface
- To access configuration setting select gear icon in top left corner

Screen Setting



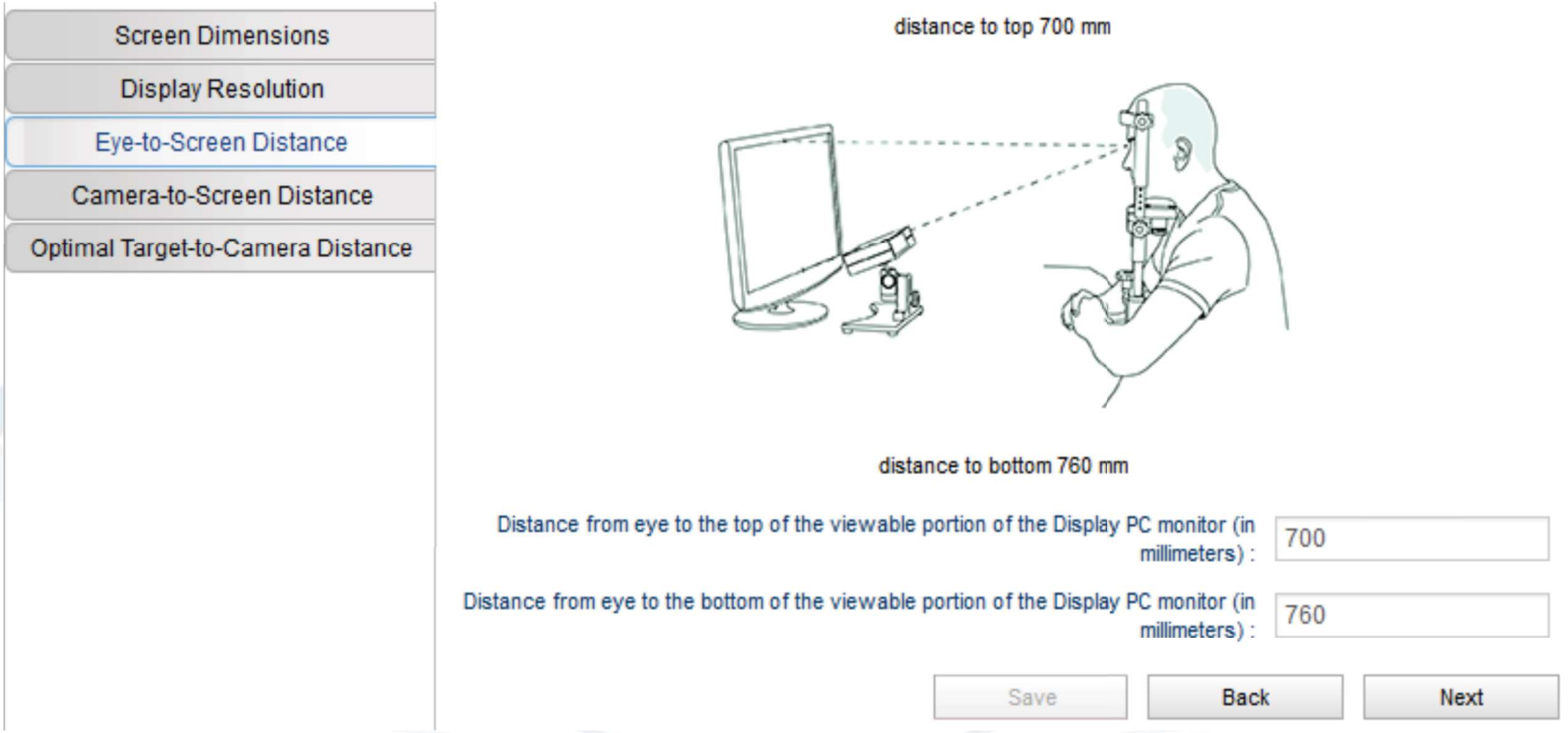
- Enter the physical dimensions of the stimulus display into the screen settings wizard.

Screen Setting



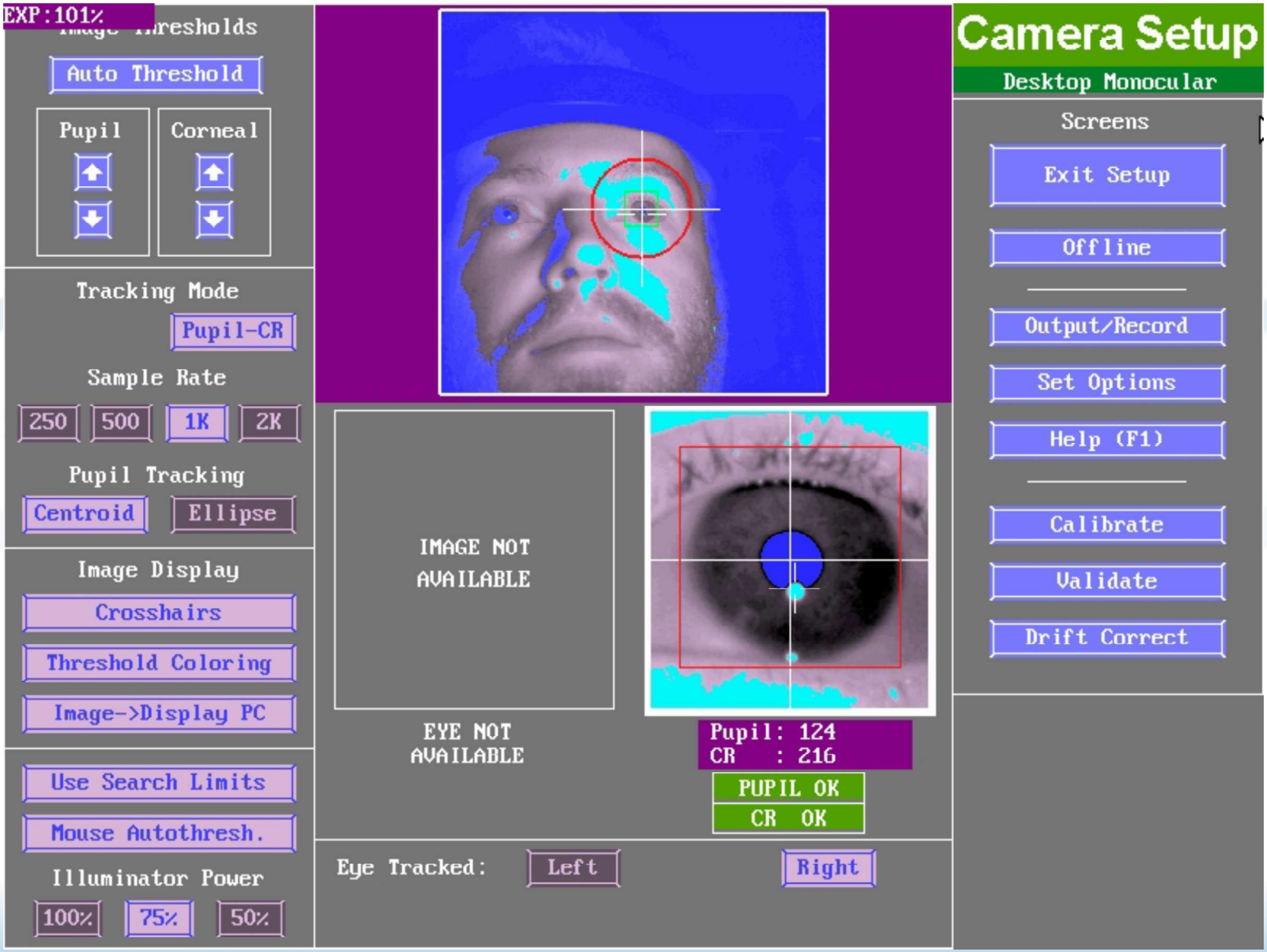
- Enter in the distance from the participant's eye to the top of the display image and the bottom of the display image.

Screen Setting



- Enter in the distance from the participant's eye to the top of the display image and the bottom of the display image.

Participant Setup



Participant Setup - Desktop

1) Adjust camera angle and position to get a good view of the eye(s)
2) Click pupil in the global view to autothreshold
   (Host or Display PC)
3) Focus the camera - minimize size of teal CR circle
4) Autothreshold and adjust pupil and CR thresholds
   - If cautious or troubleshooting, check the setup by asking the subject to look at four corners
   - If the CR is smeared move the Desktop Mount toward the problematic corner until CR is tracked
5) Calibration
6) Validation
7) Recording

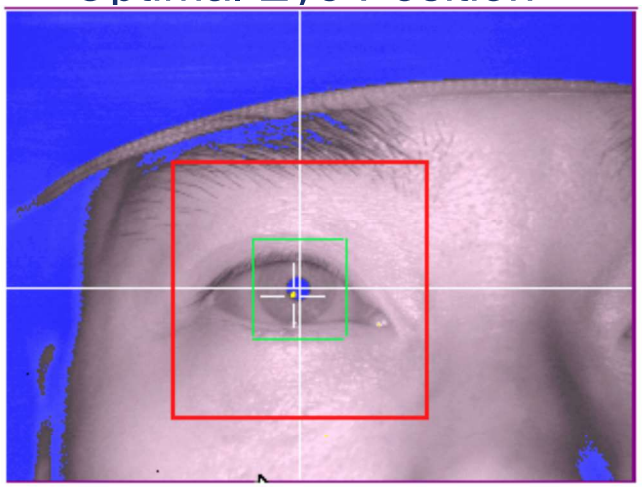
Participant Setup - Tower

Never adjust the Tower Mount with subject's head in place

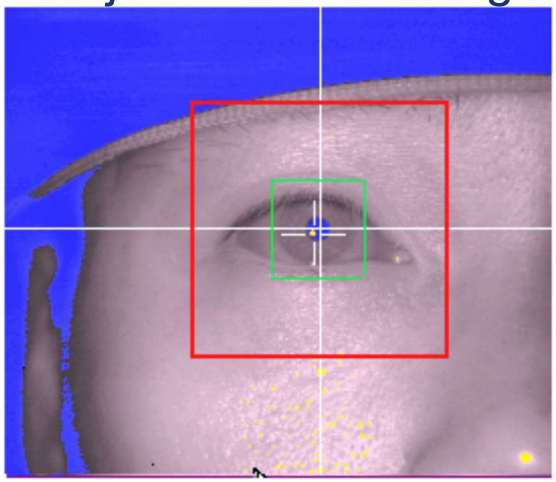
1) Set the eye-selection knob to track the dominant eye
2) Adjust the mirror angle to get a good view of the eye, or to avoid glasses reflections; adjusting chin position may help too
3) Click pupil in the global view to autothreshold (Host Display PC)
4) Focus the camera - minimize size of teal CR circle
5) Autothreshold and if necessary, adjust pupil and CR thresholds
   - If cautious or troubleshooting, check the setup by asking the subject to look at four corners while monitoring threshold quality at all positions
6) Calibration
7) Validation
8) Recording

Participant Setup

Optimal Eye Position

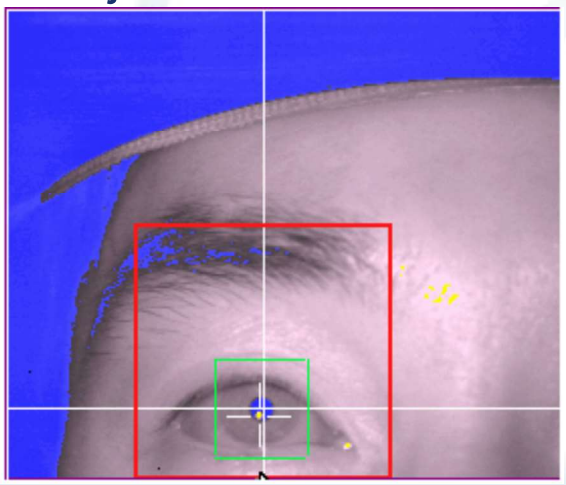


Subject seated too high

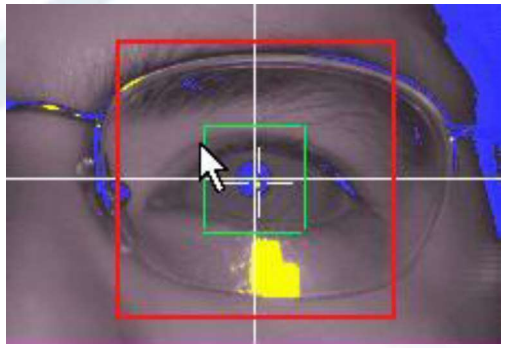


- Adjust chair height so the subject is comfortable and has line of sight to upper part of monitor
- Forehead rest should be just above the eyebrow.

Subject seated too low



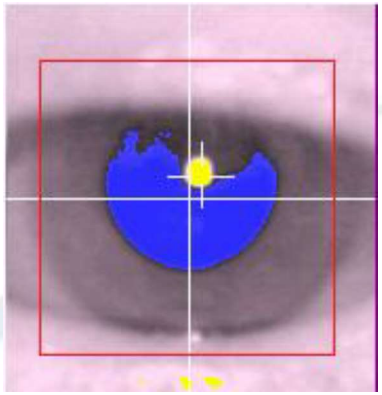
Participant Setup

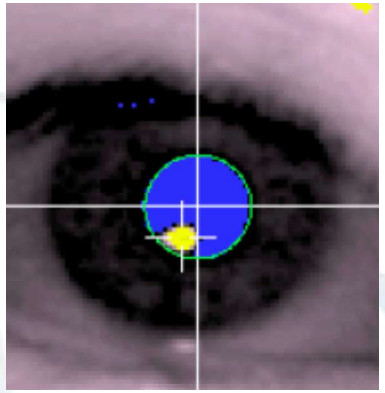


- Search Limits (red box) can be used to reduce the area of the image that is searched to find the eye.
- Prevents system from switching to opposite eye.
- You can hold ALT + arrow keys to adjust the size and shape of the search limits.
- Use SHIFT + arrow keys to adjust the position of the search limits

Participant Setup

Centroid vs. Ellipse pupil tracking modes





Centroid model fitting:

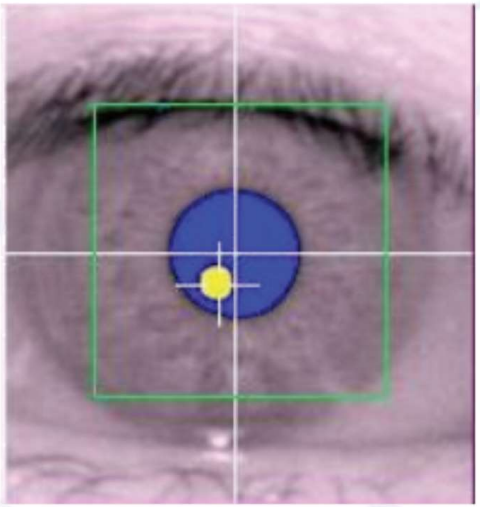
- Tracks center of a circle fit to thresholded pupil
- Advantages:
  - Highly stable
  - Low noise
- Disadvantage:
  - Position drift if pupil is occluded by eyelid

Ellipse model fitting:

- Tracks center of an ellipse fit to thresholded pupil.
- Advantages:
  - Decreased drift
  - Overcomes pupil occlusion
- Disadvantage:
  - Slightly higher noise level

Participant Setup

Setting Pupil Threshold



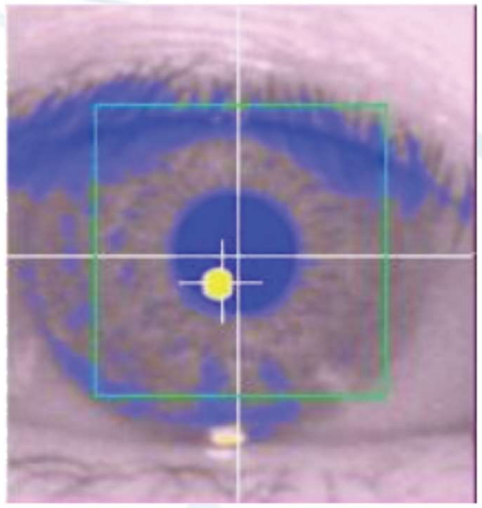


Fig. 1

Pupil threshold can be adjusted automatically, through the Auto-Threshold command, or manually, through the up and down arrows. A threshold too high will result in shadows (Fig. 1), while a threshold too low will result in a noisy signal (Fig. 2).

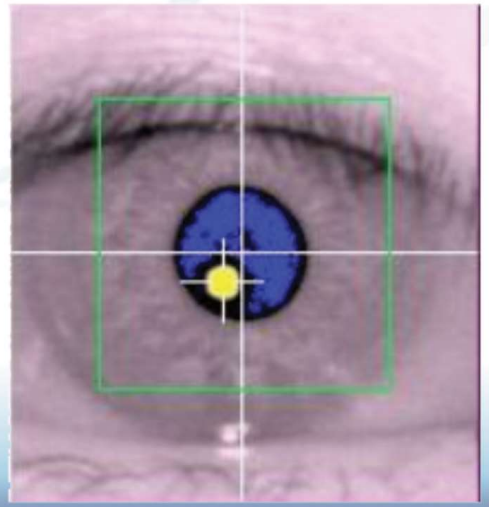
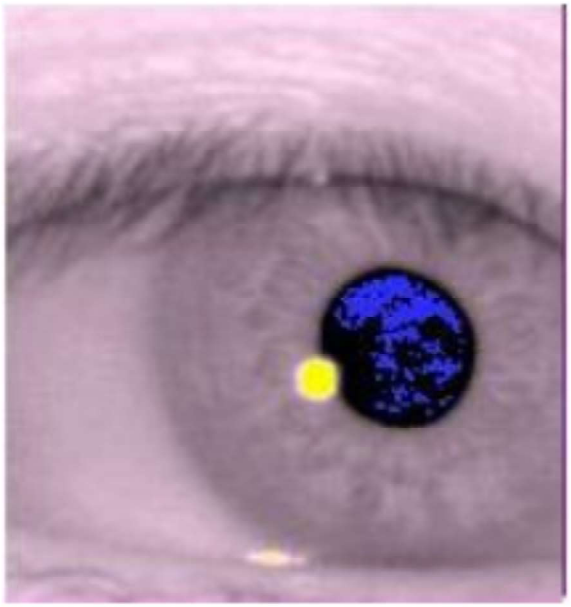


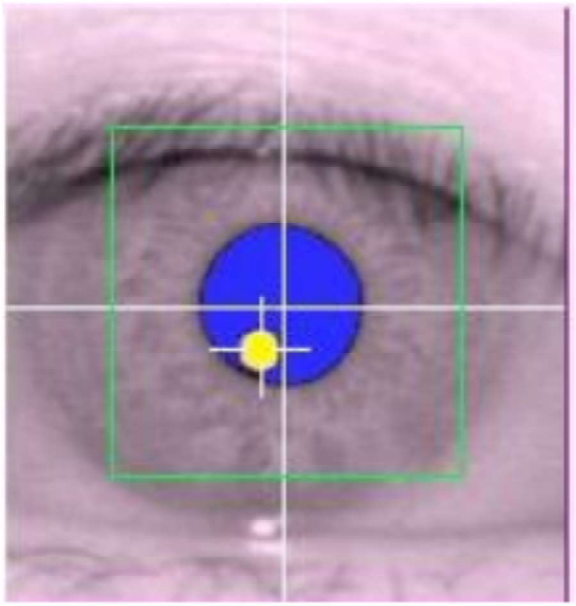
Fig. 2

Participant Setup

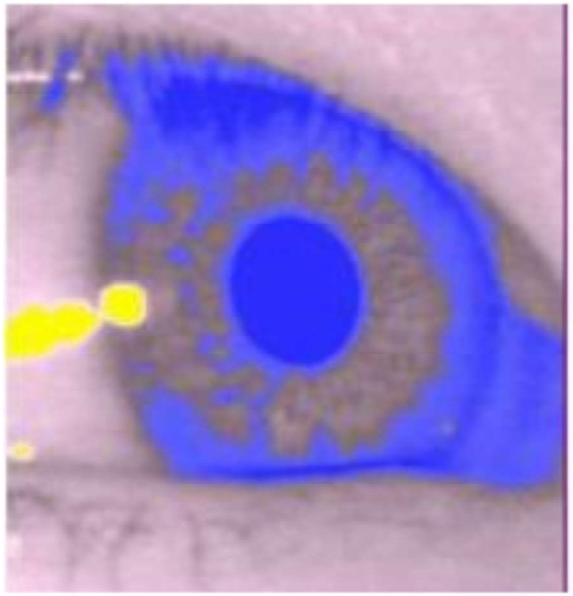
Symptoms of Poor Pupil Threshold



Pupil clipped and lost



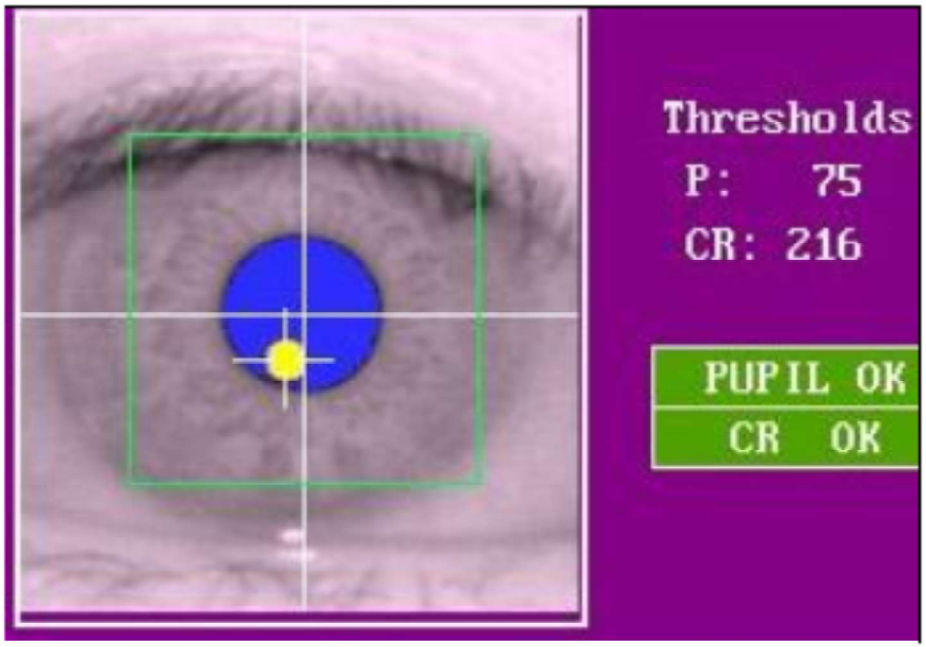
Good



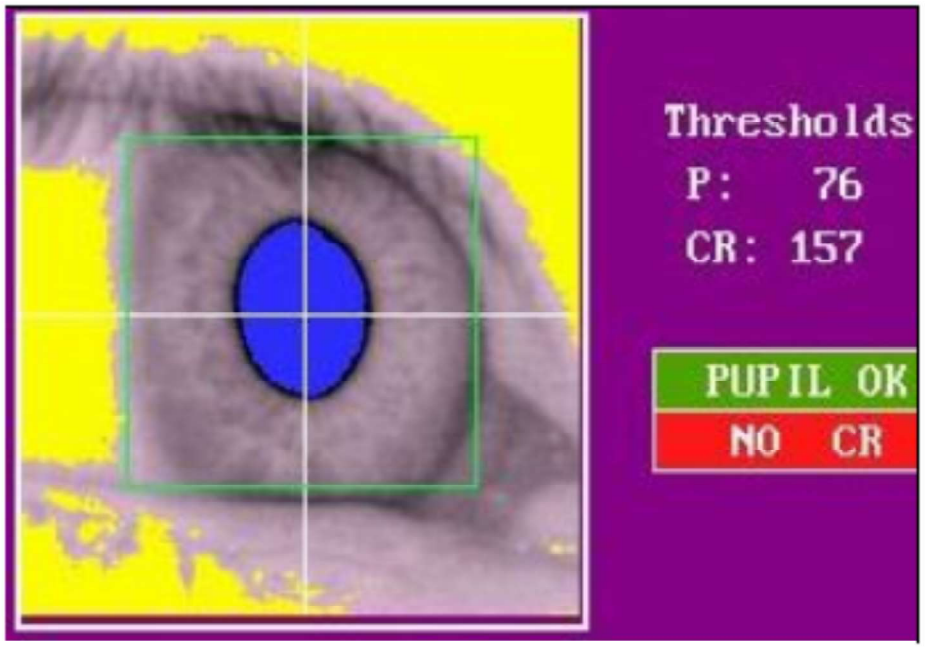
Corner shadow captures pupil

Participant Setup

Setting Corneal Reflection (CR)



Good corneal reflection

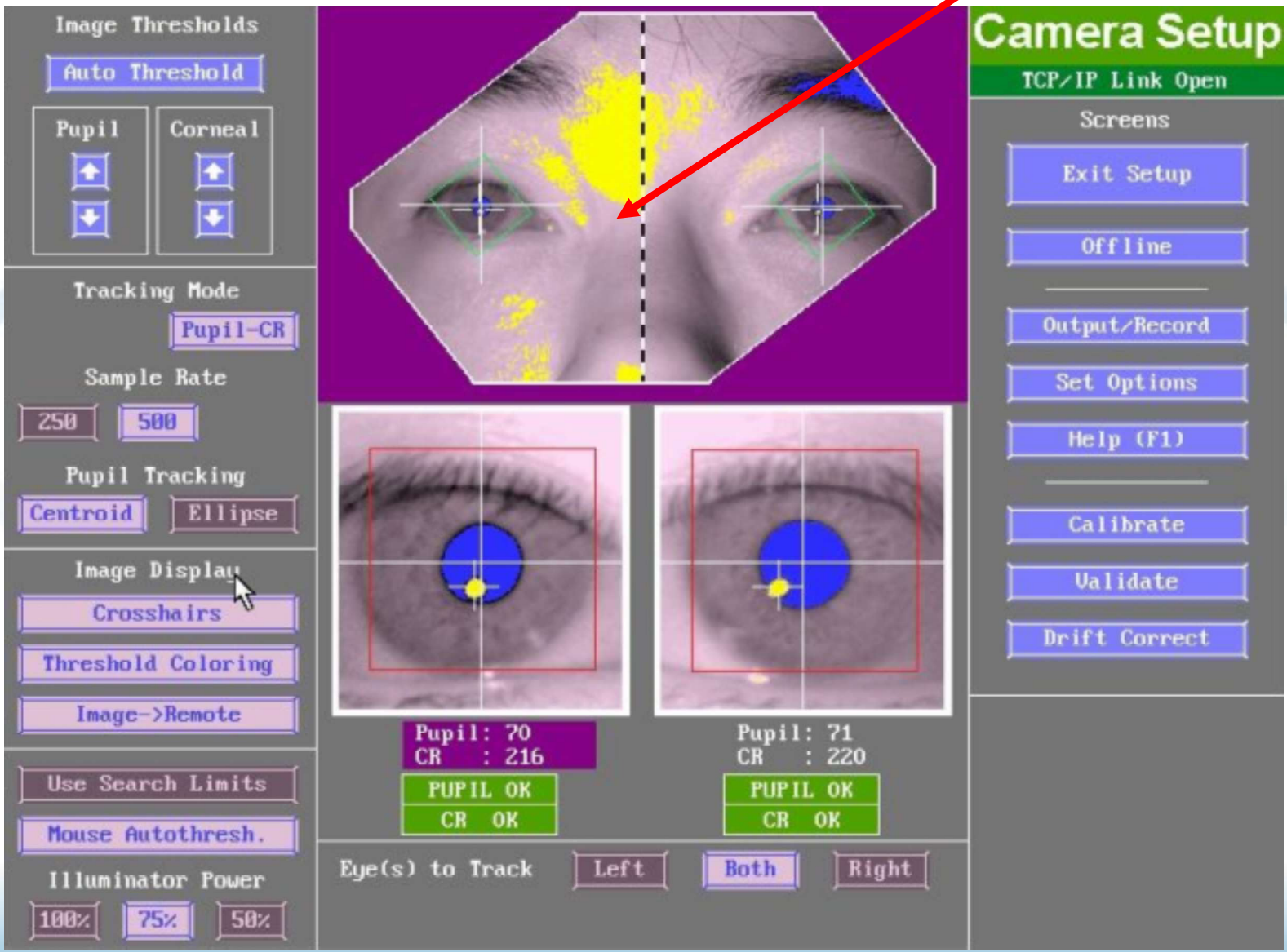


Poor corneal reflection

Adjust corneal reflection using + and – keys. Note that the – key increases the thresholded area.

Participant Setup

Binocular Mode



Status Panel

Monitor the status of camera image of the tracked eye throughout setup, calibration, validation and recording phases.

Pupil:

OK: Pupil present and can be tracked at selected sample rate

SIZE: Occurs when pupil size is larger than the maximum allowed pupil size

MISSING: Pupil not present

Corneal reflection:

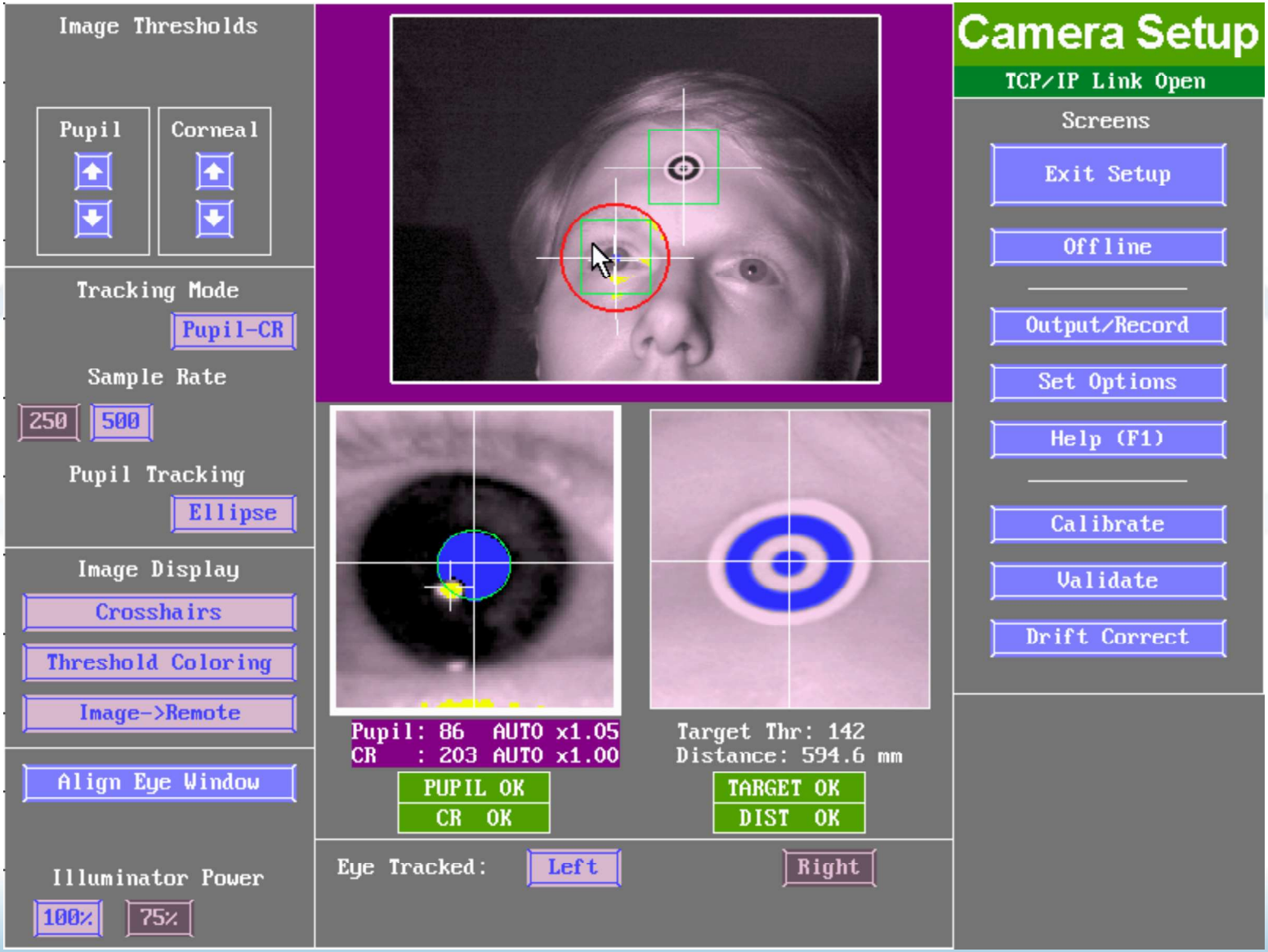
OK: CR present and can be tracked

MISSING: CR is not present

Participant Setup - Remote

1) Place the target on the subject's forehead
2) Adjust camera angle and position to get a good view of the eye and sticker; capture as wide a range of subject movement as possible
3) Click pupil in the global view to autothreshold (Host Display PC)
4) Focus the camera - minimize size of teal CR circle
5) Adjust thresholding bias for pupil and CR
   - If cautious or troubleshooting, check the setup by asking the subject to look at four corners
   - If the CR is smeared move the Desktop Mount toward the problematic corner until CR is tracked
6) Calibration
7) Validation
8) Recording

Participant Setup - Remote

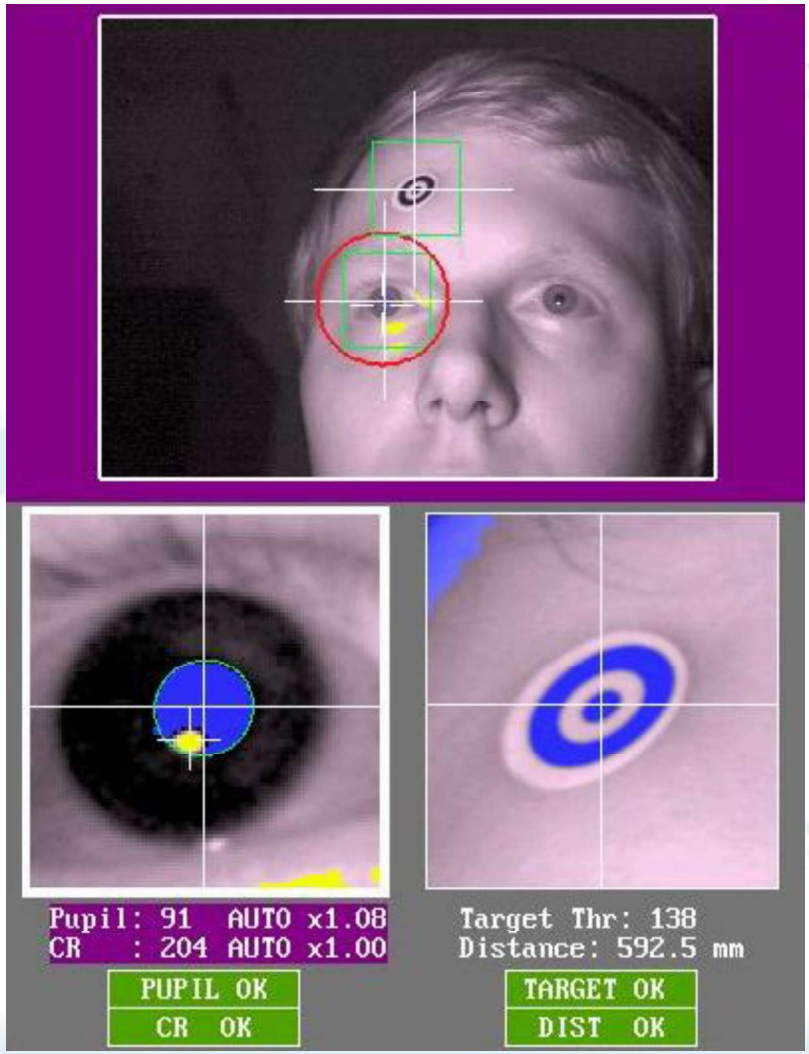


Participant Setup - Remote

Participant setup becomes a smooth and fast procedure with practice. Follow these steps:

1) Use proper lens and set ELCL configuration to “Desktop (Remote)”
2) Set the height of the monitor; eye-to-screen distance of about 70 cm
3) Place camera right in front of the monitor
4) Raise desktop mount to maximize tracking range
5) Seat the subject and place the target sticker
6) Find the pupil by clicking on the eye image
7) Adjust the thresholding bias for pupil and CR
8) Check setup by asking subject to look at four corners
9) Calibration, validation and recording

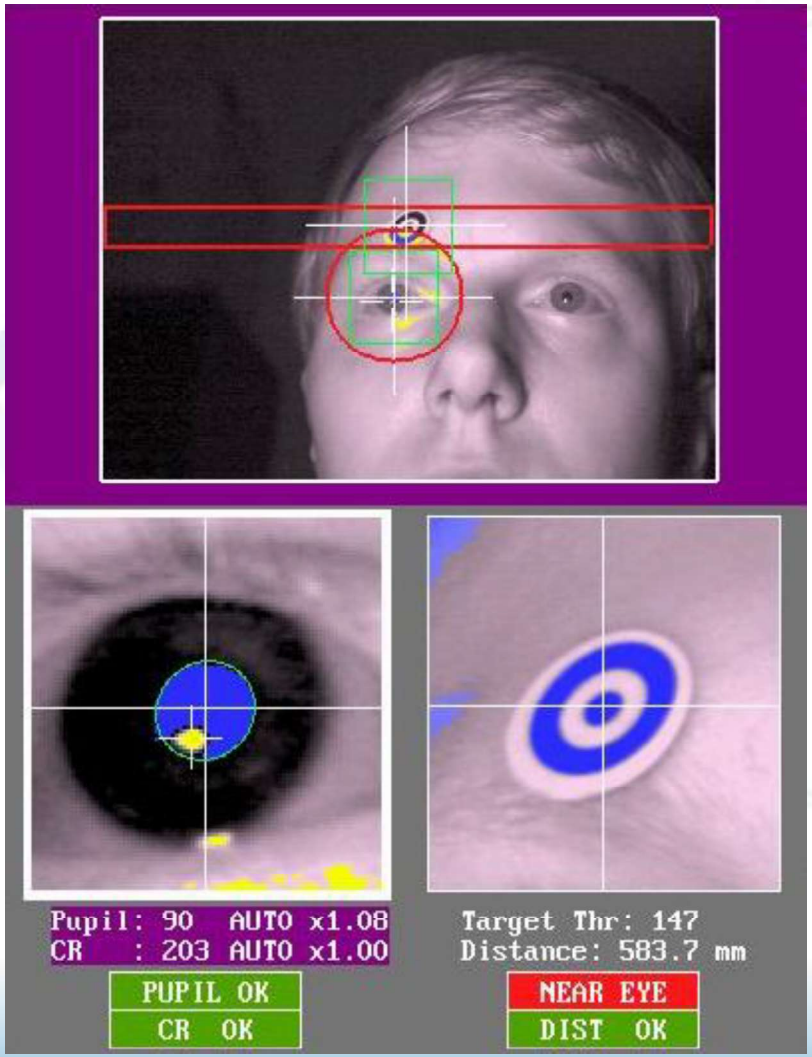
Participant Setup - Remote



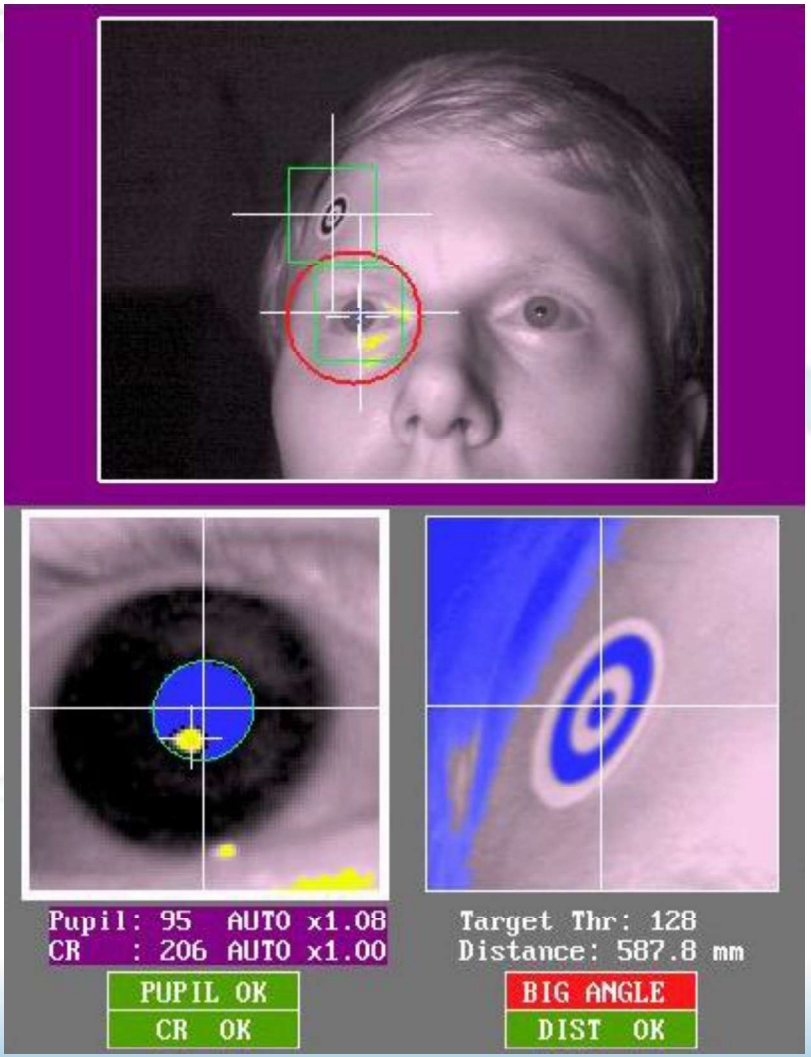
- Place target sticker on the subject's forehead
- The eye and sticker should stay within the camera image when the subject moes
- Ideal target-to-camera distance is 550mm to 600mm for calibration
- For highest accuracy use 13-point calibration

Participant Setup - Remote

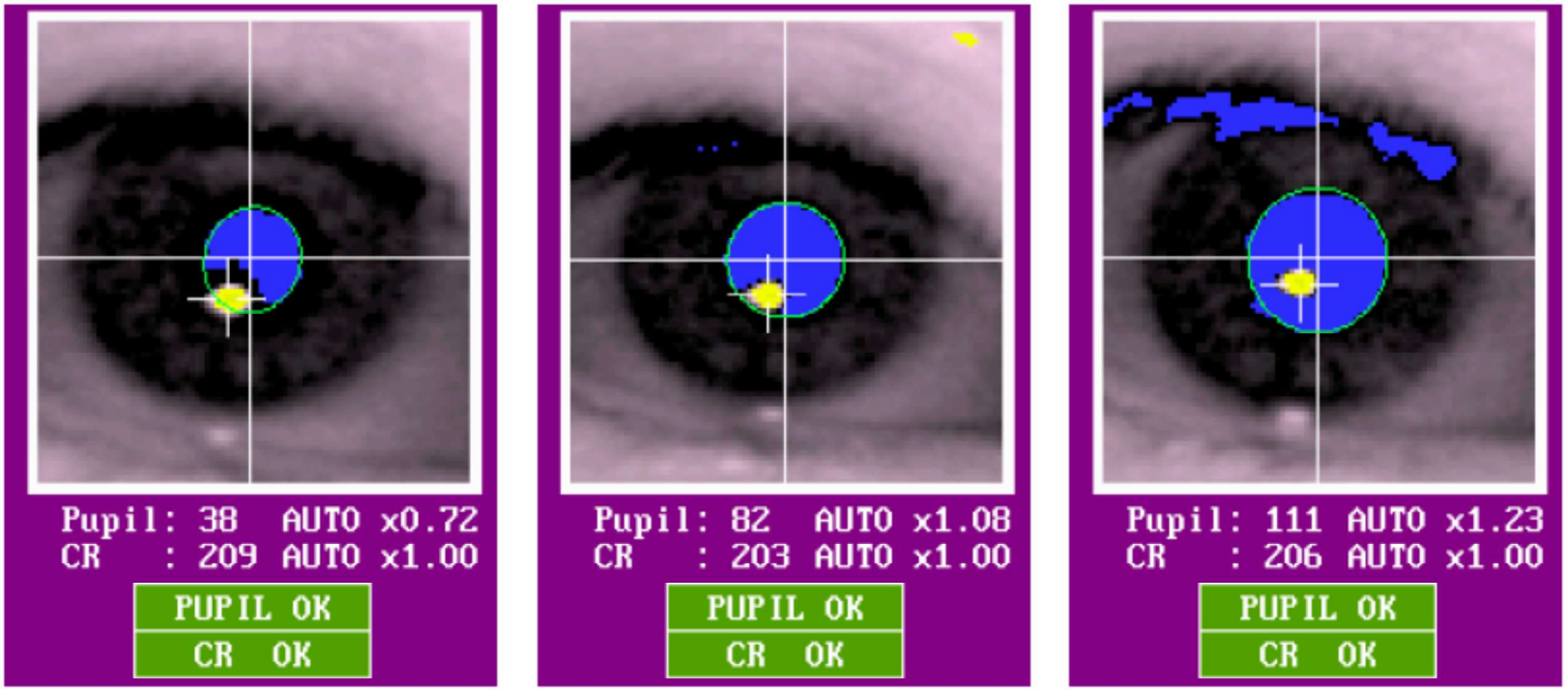
Target too close to the eye vertically



Target has a large angle



Participant Setup - Remote



Threshold bias too low | Properly thresholded | Threshold bias too high

Pupil threshold bias adjusted by up and down arrow keys (1.08 typical)

CR threshold adjusted by + and – keys (1.00 typical)

Participant Setup - Remote

- Monitor the thumbnail camera images at the lower left corner of the tracker screen.
- The two dots in the middle panel reflect the target dot and eye position in the camera image
- For reliable tracking, both dots should stay within the red box

Participant Setup - Remote

Pupil

OK: Pupil present and can be tracked at selected sample rate

SIZE: Occurs when the pupil size is larger than the maximum allowed

MISSING: Pupil not present

Corneal

OK: Corneal reflection is present and can be tracked

MISSING: Corneal reflection is not present

Target

OK: Target is present and can be tracked

MISSING: Target is not present

NEAR EYE: Target is placed too close to the eye on the vertical dimension

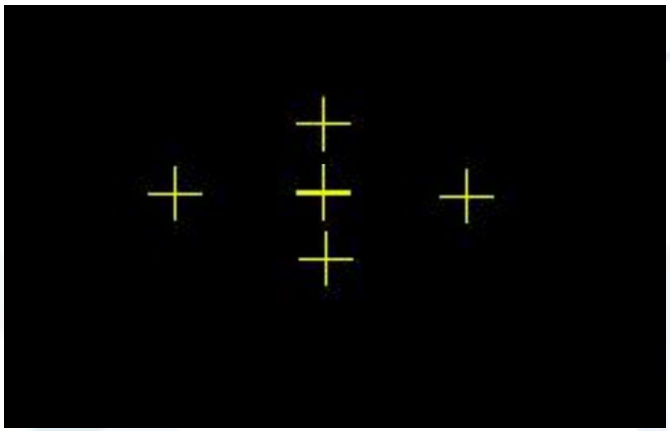
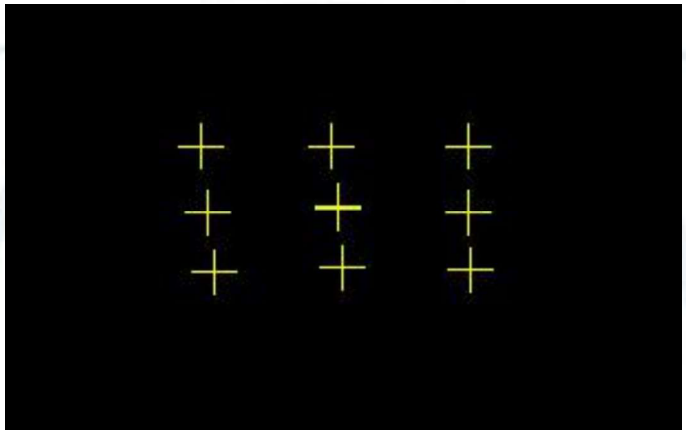
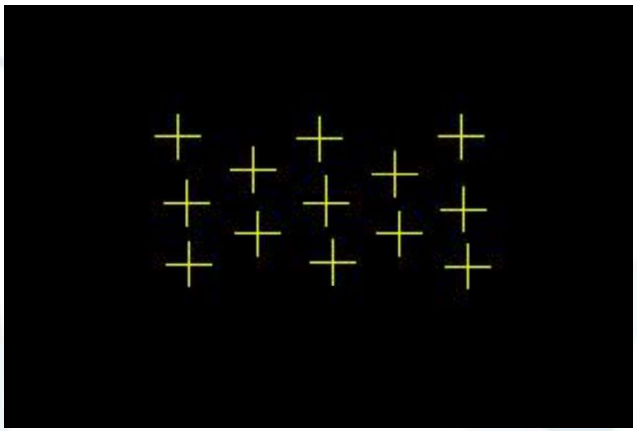
ANGLE: Target has too low an angle to be recognized properly

Status Panel

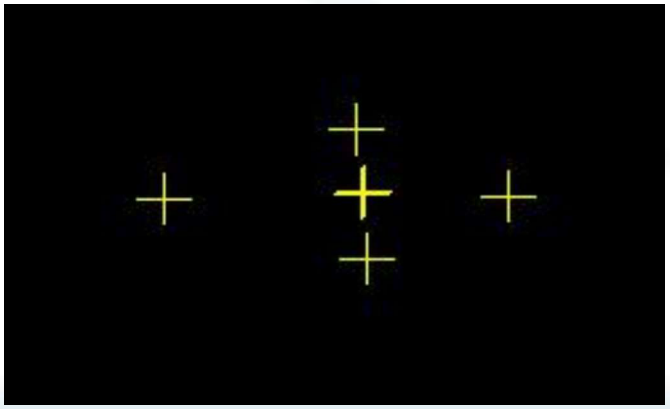
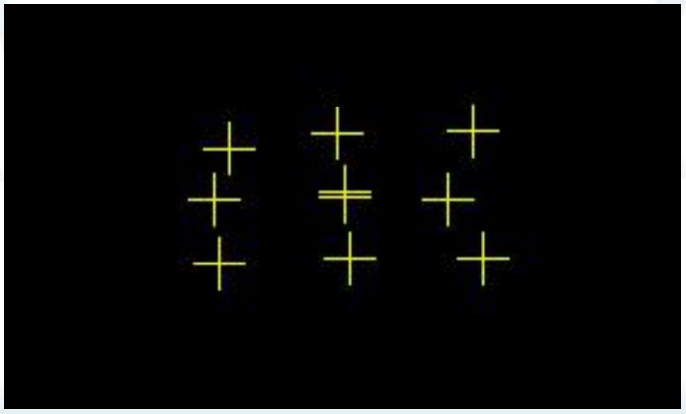
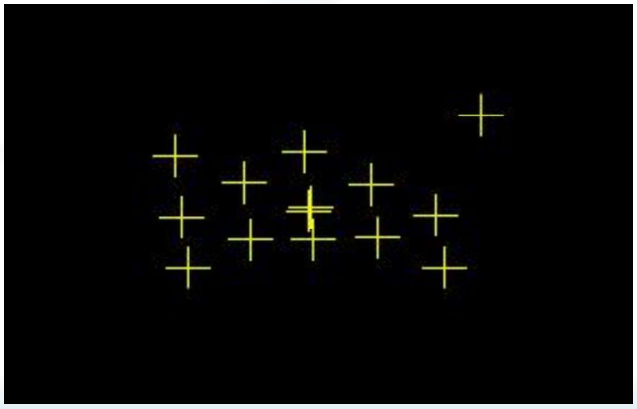
Calibration

Calibration

Good Calibration models (symmetrical)

Poor Calibration models (asymmetrical)

Calibration

- To improve calibration accuracy:
  - Check pupil and CR as the subject looks at all four corners of the display. They should always be visible, well-thresholded, and tracked.
  - Encourage subject to sit still—no head turning!
  - Redo targets by pressing the backspace key
  - Turn on manual accept mode by pressing the SPACE key twice to ensure subject is fixating calibration target
  - Match background color of calibration/validation screen to test displays—change in pupil size due to large brightness differences can cause drift

Validation

Checking gaze accuracy of the calibration

Validation Results

Validation Results

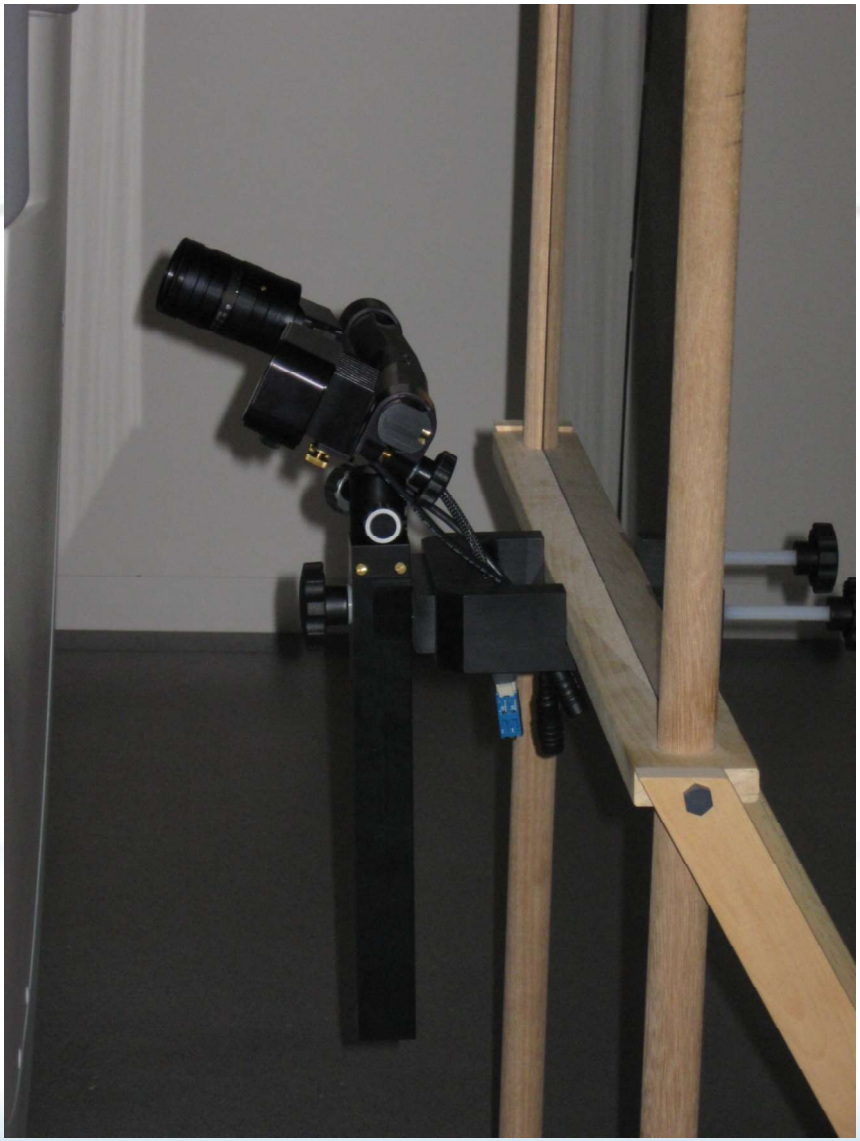
- GOOD (green background): Level of error is acceptable
- FAIR (grey background): Error is moderate; calibration should be improved
- POOR (red background): Error is too high for useful eye tracking

In general, ensure that the average gaze error is within 0.5° and maximum error is within 1.0°

Validation Results

- Optional card for Host PC – usually used for devices like EEG
- Converts Digital Data to Analog Voltages
- Output Gaze X, Y, and Pupil size as voltages over BNC connectors
- Voltage range configurable
- Three Channels per eye being tracked
    - Horizontal Position
    - Vertical Position
    - Pupil Size
- Also allows for extra Digital In/Out (in addition to Parallel Port)
- Quick –
    - Data can be inserted into empty EEG channels
    - Allows for easy alignment with EEG data
- Dirty –
    - Noise is added by D/A and A/D conversion
    - Saccade/Fixation information is lost

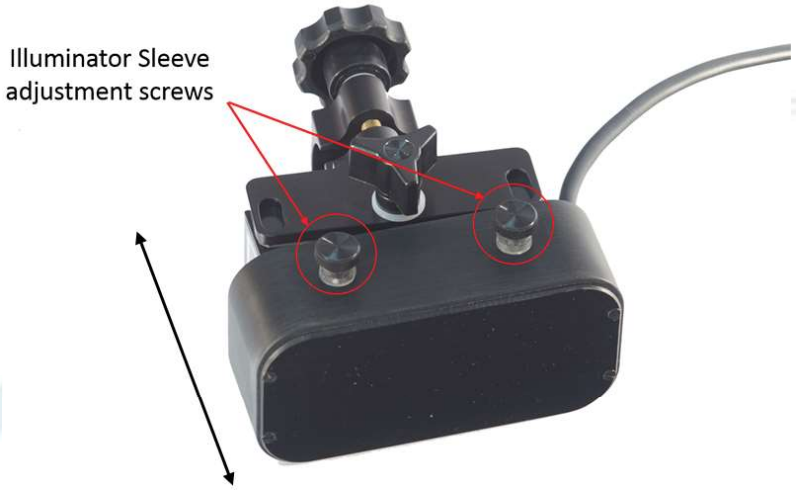
Long Range Screen Mount



Long Range Tray Mount

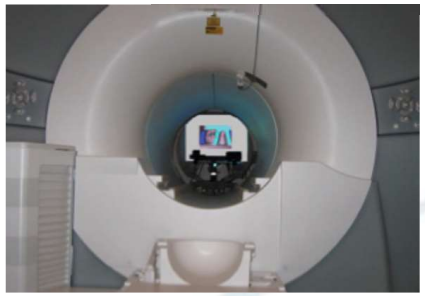
Long Range Tripod Mount

Long Range Illuminator



- Adjust illuminator sleeve to furthest position.
- Adjust horizontal position.
- Adjust vertical position.
- Adjust illuminator sleeve to prescribed distance.

MRI / Eye Tracker Setup



TTL Pulse

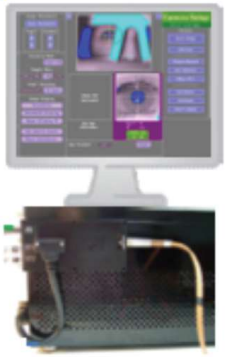
EyeLink Display PC

Display PC Updates Screen

EyeLink Display PC

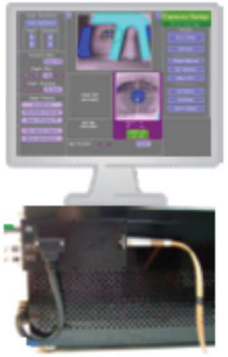
Message When Pulse Received

EyeLink Host PC



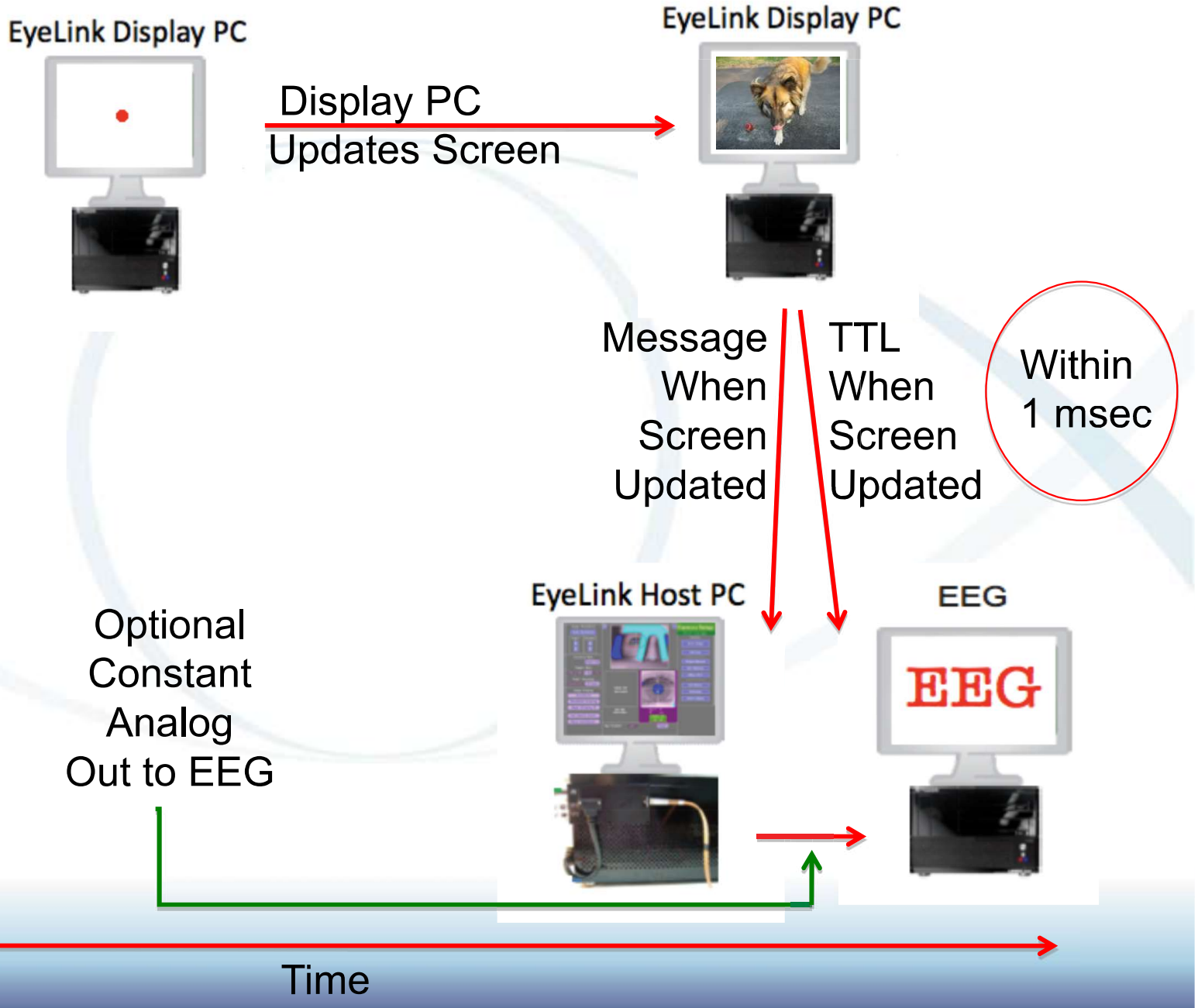
Message When Screen Updated

EyeLink Host PC



Time

EEG / Eye Tracker Setup



EEG / Eye Tracker Setup