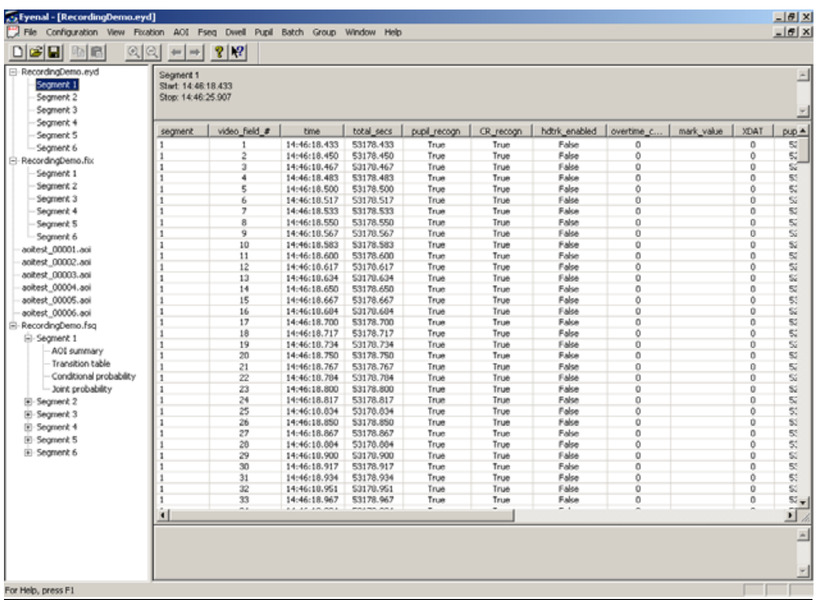
Eye Tracker System Manual

ASL EyeTrac 6

EyeNal Analysis Software

MANUAL VERSION 1.41
19 January 2007



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1 Introduction

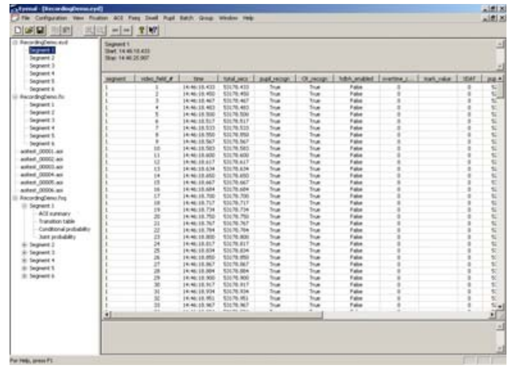
EyeNal is an off-line data analysis program for processing eye movement and pupil diameter information recorded in Eyedat (.eyd) and EyeHead (.ehd) data files. EyeNal identifies eye fixations, matches fixations with user defined areas of interest, and calculates related scan pattern statistics. Statistical data can be saved in text file formats suitable for further processing with other data, statistical, or spreadsheet programs. EyeNal can also export any of the original or analyzed data directly to Microsoft Excel.

A separate program, Fixplot, will visually plot fixations or raw data over a still image imported by the user.

2 Functional Overview

2.1 Interface Layout

The EyeNal screen is divided into two sections. The left window lists all opened files and their subcomponents (such as segments and analysis types). The right window displays the component data of the item selected in the left window. This includes raw and processed data ant statistical calculations.



All processing functions can be performed by way of the top menus. A few functions, such as data export, can be performed by right clicking on items in the left window.

2.2 Data Processing Overview

Basic processing with EyeNal is fairly straightforward. Each step generally requires the previous steps to have been completed. In many cases, the default settings for each step will be suitable.

1. Load in raw data (.eyd or .ehd)
2. **Make new fixation file**
3. Create Areas of Interest (either with **Make new AOI file** or in Fixplot)
4. **Make new fixation sequence file**
5. **Make new dwell file**
6. Optionally **Make new pupil diameter analysis file**

2.2.1 Raw Data Overview

To open a raw data file (.eyd or .ehd), select *Open* from the **File Menu**. Select the desired .eyd or .ehd file and select Open.

This will load the selected data file into the left window. For a discussion of each of the data columns see Section 3.1 Raw Data.

Data files are divided up into **Segments** which correspond to each instance of starting and stopping recording in the Eye Tracker interface. Segments are visible in the left window under their respective data file.

2.2.2 Fixation Overview

The Fixation processing function reduces raw eye position data to a series of fixation events and records them to a separate data file (.fix). The Fixation function can also be used to resegment data based on XDAT or Marker events.

The term fixation refers to a person's point-of-gaze as they look at a stationary target in a visual field. Fixations are distinguished, primarily, from saccades (rapid voluntary eye movements used to move from one fixation point to another) and very small involuntary eye movements (such as microsaccades) of several types that occur during fixation.

For details and user adjustable parameters of the fixation algorithm see Section 3.2 Calculate Fixations.

To perform the default fixation function on all segments, highlight the .eyd or .ehd data file and select **Make new fixation file** from the *Fixation* menu. Press OK to accept the default settings.

2.2.3 Areas of Interest Overview

Areas of Interest (AOIs) are regions within the scene image to which the experimenter is interested in determining gaze relationships. AOIs are usually placed around objects of interest (such as pictures, text, or objects) or regions of the scene that may be meaningful to an experimental procedure (such as a fixation holder). The AOIs will later be applied to the fixations created by Eyenal and their relationships will be output as a Fixation Sequence Analysis.

An AOI file can hold up to 50 defined areas of interest. AOIs are defined as rectangles and may be assigned labels of up to ten characters. Each AOI is defined by four sets of coordinates marking the top, left, right, and bottom borders.

An AOI file can be created using either the **Make new AOI file** item in the *AOI* menu or within the subprogram *Fixplot* (See the *Fixplot Manual*).

2.2.3.1 Determining AOI coordinates

- **For non-EYEHEAD** systems, the coordinates of each AOI top, bottom, left, and right boundaries can be determined by using the Set Target Points function in the Eye Tracker's User Interface (see the Eye Tracker Manual for the use of this feature).

  The AOI coordinates are entered in the ASL coordinate system which scales as 260x240. Using Set Target Points mode with the appropriate stimulus image displayed, line up the cursor with the desired location on the scene monitor and note the reported coordinates.

- **EYEHEAD™ Integration** AOI files can be defined for up to twenty scene planes. The coordinates for top, bottom, left, and right boundaries of each area in each scene plane are defined in inches or centimeters (matching the units in which the data was recorded) with respect to the coordinate frame defined on each EYEHEAD scene plane (See EyeHead manual for an explanation of EyeHead scene planes). Remember that each scene plane has its own coordinate system.

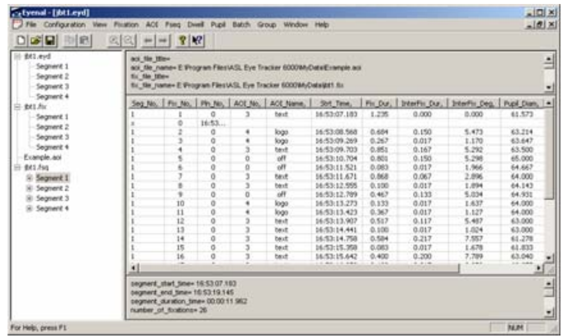
- **For both EyeHead and non-EyeHead data** the user can use Fixplot to draw AOIs over any bitmap image instead of defining them with numeric coordinates. Remember that in EHI, the scene plane needs to be specified or the AOI will not be properly applied. See the *Fixplot Manual* for more details.

2.2.3.2 Creating AOI Files

1. Select **Make new AOI file** from the AOI menu.
2. Enter the File Name. The file will be given the .aoi extention.
3. *If using EyeHead Integration (EHI) data select the EyeHead Integration Data box*
4. Enter a title for the current AOI (denoted in AOI N).
5. *If using EyeHead Integration (EHI) data enter the **Scene Plane Number** to which the AOI applies.*
6. Enter the Top, Left, Right, and Bottom coordinates of the AOI rectangle.
7. Select **New** to accept the current AOI and increment **AOI N**.
8. Repeat steps 4-7 for all desired Areas of Interest (up to 50).
9. Select **OK** to save and create an AOI file based on the input information.

See Section 3.3 Define Areas of Interest (AOIs) for more information.

2.2.4 Fixation Sequence Analysis Overview



The Fixation Sequence Analysis (Fseq,.fsq) applies a set of Areas of Interest (AOIs) to a fixation file. It reports the interaction of each fixation with the defined AOIs.

Fixation sequence will determine information such as sequence of transitions between AOIs, time spent in AOIs, percent time in AOIs, number of fixations in AOIs, and other summary statistics relating to fixations and areas of interest.

Different reports can be accessed by selecting the sub-items of the .fsq file in the left window.

2.2.4.1 Creating Fixation Sequence Files

1. Select the appropriate Fixation file (.fix) in the left window.
2. Select **Make new fixation sequence file** from Fseq menu.
3. In the FSQ dialog, select the appropriate AOI file and the output .faq file name if desired.
4. Press OK

Additional options are available, including applying different AOI files based on Segment number or XDAT value. See Section 3.4 Fixation Sequence Analysis (Fsq) for details.

2.2.5 Dwell Analysis Overview

The Dwell function further constrains the parameters of analysis form the Fixation Sequence. The function takes the results from the Fixation Sequence analysis and applies additional qualifiers.

An individual Dwell is defined as the time period during which a contiguous series of 1 or more fixations remains within an Area of Interest (AOI). That is, a dwell is defined as moving into an area of interest and moving out of an area of interest, regardless of how many individual fixations this action is comprised of.

The Dwell function creates the same set of reports as the Fixation Sequence function, however their contents are likely to be different owing to the difference in event definition.

This analysis type is generally preferred when the experimenter is interested only in the overall interaction with AOIs, not the individual fixation events within them.

2.2.5.1 Creating Dwell Files

1. Select the appropriate Fixation Sequence file (.fsq) in the left window.
2. Select **Make new Dwell file** from Dwell menu.
3. In the Dwell Properties dialog Press OK

See Section 3.5 Dwell Analysis for additional details.

2.2.6 Pupil Diameter Analysis Overview

The Pupil Diameter Analysis function computes various statistics related to pupil diameter including pupil average, pupil median, pupil variance, standard deviation, and blink frequency. The function allows for analysis to be specified over specific time windows and can integrate a scaling factor to convert the recorded pupil diameter measurements (in eye camera pixels) into real world units such as millimeters or inches.

2.2.6.1 Creating Pupil Analysis Files

1. Select the appropriate Raw data file (.eyd or.ehd) in the left window.
2. Select **Make new pupil diameter analysis file** from Pupil menu.
3. In the Pupil Diameter Analysis Properties dialog change desired settings such as *Start delay* and *Duration* (to set the time window) or the *Scale factor* to convert units.
4. Press OK

See Section 3.6 Calculate Pupil Statistics for additional details.

2.3 Batch Processing and Automation Overview

2.3.1 Batch Automation

The Batch function allows the user to create Fixation, Fixation sequence, and Dwell files for any number of selected EHD or EYD files in a given directory. It can be used to quickly perform the same operation on multiple data files.

The Batch routine is divided into three different independent functions for Fixation, Fixation Sequence, and Dwell.

2.4 General Configuration

2.4.1 Set Update Rate

The base system update rate (speed) is read out of the header information in the data file (.eyd and .ehd) and corresponds to the Camera Update Rate settings in the User Interface Software at the time of recording.

However, this value is the **nominal** update rate. Some camera types function at slightly different speeds depending on their manufacturer. For example, the NTSC “60 Hz” standard for North American cameras and video systems is actually 59.94 Hz. Some manufacturers of high-speed cameras function at slightly variable speeds from one brand to another.

The **Set Update Rate** window, accessible from the *Configuration* menu allows the user to set the exact update rate to be associated with each nominal rate.

3 Data Processing Functions

3.1 Raw Data

This section discusses the data columns commonly present in raw data files. Data files are divided up into **Segments**, which correspond to each instance of starting and stopping recording in the Eye Tracker interface. Segments are visible in the left window under their respective data file. When the user selects a Segment, that Segment's data will be displayed in the right window.

The contents of a data file vary slightly between Eyedat and EyeHead files. They can also vary based on the file recording selections the user makes in the Interface Software.

3.1.1 Eyedat Files (.eyd)

Eyedat files are the standard file type recorded with most of ASL's eye tracking systems (including Remote PanTilt, Remote Stationary, and Long Range optics). The exact set of fields present is user selectable in the User Interface software but must be determined at time of recording.

1. **segment**. A segment is a continuous section of recorded data. Every time data recording is paused, and restarted without closing the data file, a new data segment is created on that file. This column will list the segment currently selected..
2. **video_field_#**. A field refers to the data items recorded for a single sampling interval. A sampling interval is related to the speed of the camera and will be 1/50th, 1/60th, 1/120th, 1/240th, or 1/360th of a second depending on the system model and settings.
3. **time**. The computer's system clock time (hours: minutes: seconds) when the field was recorded.
4. **total_secs**. This matches the Time field but is displayed as the number of seconds since midnight.
5. **pupil_recogn**. This field indicates whether the system was calculating pupil position. This corresponds to the presence of the white crosshairs on the eye monitor. However, it does not necessarily indicate accurate pupil detection, as incorrectly calculated crosshairs will still yield a True value.
6. **CR_recogn**. This field indicates whether the system was calculating CR position. This corresponds to the presence of the black crosshairs on the eye monitor. However, it does not necessarily indicate accurate CR detection, as incorrectly calculated crosshairs will still yield a True value.
7. **hdtrk_enabled**. This field indicates whether a head tracking device was online.
8. overtime_count.
9. **mark_value**. This field indicates a marker value manually entered into the data file at recording time using the Marker Value feature.

10. **XDAT**. The External Data field shows the value that was being received over the 25 pin External Data (XDAT) port during the data field.
11. **pupil_diam**. Horizontal pupil diameter in pixels on the eye image.
12. **Horz_gaze_coord**. Horizontal pupil position
13. **vert_gaze_coord.** Vertical pupil position
14. **hdtrk_X**. Head tracker sensor location in the transmitter X-axis
15. **hdtrk_Y**. Head tracker sensor location in the transmitter Y-axis
16. **hdtrk_Z**. Head tracker sensor location in the transmitter Z-axis
17. **hdtrk_az**. Head tracker sensor azimuth orientation.
18. **hdtrk_el**. Head tracker sensor elevation orientation.
19. **hdtrk_rl**. Head tracker sensor roll orientation.
20. **pupil_height**. Vertical pupil diameter in pixels on the eye image.

3.1.2 EyeHead Files (.ehd)

EyeHead files are the file type recorded with when using ASL's EyeHead Integration with Head Mounted optics. The exact set of fields present is user selectable in the User Interface software but must be determined at time of recording.

1. **segment**. A segment is a continuous section of recorded data. Every time data recording is paused, and restarted without closing the data file, a new data segment is created on that file. This column will list the segment currently selected..
2. **video_field_#**. A field refers to the data items recorded for a single sampling interval. A sampling interval is related to the speed of the camera and will be 1/50th, 1/60th, 1/120th, 1/240th, or 1/360th of a second depending on the system model and settings.
3. **time**. The computer's system clock time (hours: minutes: seconds) when the field was recorded.
4. **total_secs**. This matches the Time field but is displayed as the number of seconds since midnight.
5. **pupil_recogn**. This field indicates whether the system was calculating pupil position. This corresponds to the presence of the white crosshairs on the eye monitor. However, it does not necessarily indicate accurate pupil detection, as incorrectly calculated crosshairs will still yield a True value.
6. **CR_recogn**. This field indicates whether the system was calculating CR position. This corresponds to the presence of the black crosshairs on the eye monitor. However, it does not necessarily indicate accurate CR detection, as incorrectly calculated crosshairs will still yield a True value.
7. **hdtrk_enabled**. This field indicates whether a head tracking device was online.
8. overtime_count.
9. **mark_value**. This field indicates a marker value manually entered into the data file at recording time using the Marker Value feature.
10. **XDAT**. The External Data field shows the value that was being received over the 25 pin External Data (XDAT) port during the data field.

11. **pupil_diam**. Horizontal pupil diameter in pixels on the eye image.
12. **magn**. The distance of the subject's eye to the point of gaze intersection of the scene plane.
13. **scn**. The Scene plane of gaze intersection during that field. If no defined plane is intersected then Scene Plane 0 will be reported.
14. **Horz_gaze_coord**. Horizontal pupil position on the indicated scene plane.
15. **vert_gaze_coord.** Vertical pupil position on the indicated scene plane.
16. **hdtrk_X**. Head tracker sensor location in the transmitter X-axis
17. **hdtrk_Y**. Head tracker sensor location in the transmitter Y-axis
18. **hdtrk_Z**. Head tracker sensor location in the transmitter Z-axis
19. **hdtrk_az**. Head tracker sensor azimuth orientation.
20. **hdtrk_el**. Head tracker sensor elevation orientation.
21. **hdtrk_rl**. Head tracker sensor roll orientation.
22. **pupil_height**. Vertical pupil diameter in pixels on the eye image.

3.2 Calculate Fixations

The Fixation processing function reduces raw eye position data to a series of fixation events and records them to a separate data file (.fix). The Fixation function can also be used to resegment data based on XDAT or Marker events.

The term fixation refers to a person's point-of-gaze as they look at a stationary target in a visual field. Fixations are distinguished, primarily, from saccades (rapid voluntary eye movements used to move from one fixation point to another) and very small involuntary eye movements (such as microsaccades) of several types that occur during fixation.

There is currently no precise, universally accepted definition of a fixation, but there are known parameters of ocular physiology which allow reasonable criteria to be used. Specifically, there is research documenting the minimum latency of saccades in response to visual stimuli (thus suggesting a minimum fixation duration) and data defining the maximum amplitude of involuntary eye movements during the fixation (thus establishing maximum fixation boundaries).

A fixation as computed by FIX, may be thought of as the mean X and Y eye position coordinates measured over a minimum period of time during which the eye does not move more than some maximum amount. More simply stated, point-of-gaze must continuously remain within a small area for some minimum time. If **default** values are used, maximum change in gaze point is 1-degree visual angle, and the minimum time is 100 msec.

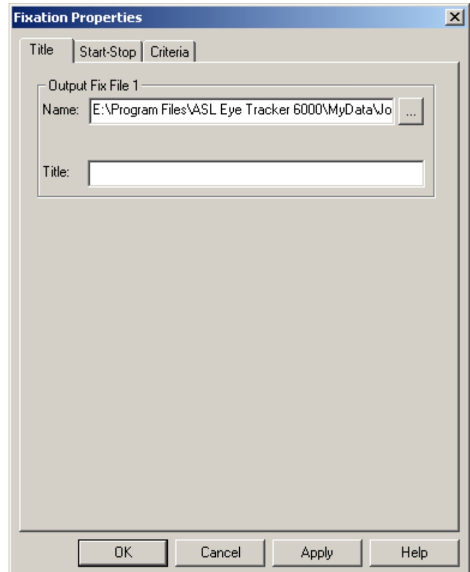
3.2.1 Fixation Properties Dialogue

To make a Fixation file:

1. Select the Fixation pull down menu.
2. Choose “Make a new Fixation file”
3. The Fixation Properties window will pop up:

    a. **Name:** This is the output file name. The default name will be taken from the current EYEDAT file and given a ***.fix*** extension. If desired rename the output file.
    b. **Title:** Information typed here shows up in the file header.

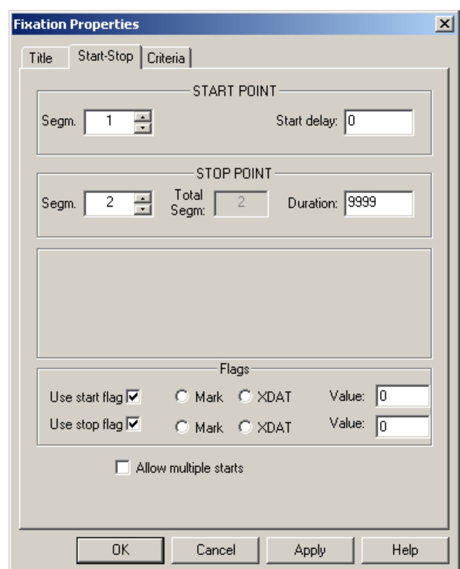
4. Click “Start-Stop” tab and set Start and Stop properties.
5. Click the “Criteria” tab and set properties.
6. Click “OK”



3.2.1.1 Start-Stop Criteria

The Start-Stop Criteria menu allows the user to constrain the new fixation file to portions of the original raw data. This allows the removal of segments, the reduction of segments, and resegmenting around XDAT or marker values.

- **Start Point:** The Start Point field defines where the new Fixation file will begin. Both the first segment and the time delay within that segment can be specified.
- **Stop Point:** The Stop Point field defines where the new Fixation file will terminate. Both the last segment to be used and the total (max) time to include can be specified.



Common Usages

2. Use Start and Stop Point to only create a fix file with specific segments.
3. Use Start delay and Duration to exclude portions of the data file for long continuous recordings.

- **Use start flag: C**hecking this box and specifying a Value will cause the Fixation function to resegment the data with the Segment's start time based on the specified Flag type and value.
- **Use stop flag: C**hecking this box and specifying a Value will cause the Fixation function to resegment the data with the Segment's end time based on the specified Flag type and value.
- **Allow multiple starts:** Checking this box will cause the Fixation function to accept multiple XDAT or Marker events within the same segment. This may have the effect of creating additional segments in the data. The Fixation function will start a new segment in the new Fix File at the first occurrence of a specified start flag and stop at the specified stop flag. It will then continue to look for subsequent occurrences of the specified start flag and create multiple segments on the resulting Fixation file.

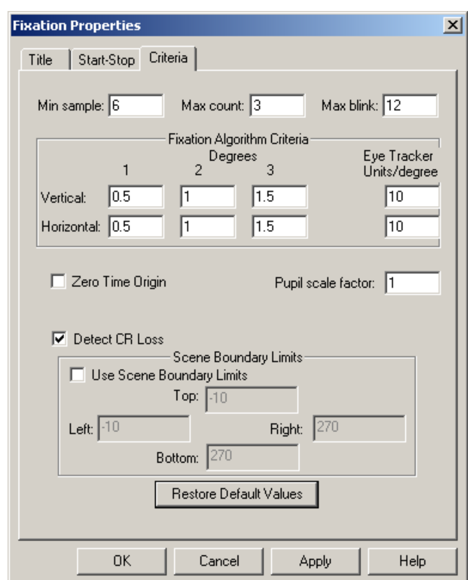
Note that it is possible to combine Start/Stop point criteria with Flag criteria to resegment the data in more complex ways.

Common Usages

1. Create a fixation file with multiple segments from a single long recording. Resegment the data based on an XDAT or Marker flag value that either terminates at another flag value or runs for a specified Duration. (Combine Start flag, Stop flag (or duration), and Allow multiple starts).

3.2.1.2 Fixation Criteria

The Fixation Criteria menu allows the user to set parameters used by the algorithm to detect a fixation.



The fixation calculation algorithm is defined by 5 basic parameters: Minimum sample, Maximum Count, and three concentric ellipses (more commonly circles) of differing diameters.

The basic explanation of the fixation calculation is as follows:

- When *Min Sample* consecutive data points fall within *Ellipse 1* a fixation is started at the first of those samples.
- The fixation will continue to be considered active until *Max Count* consecutive data points fall outside of *Ellipse 2*. The last data sample considered for the

fixation calculation is the sample immediately preceding the first of these fixation-ending samples.

- The Fixation Duration is calculated as the amount of time between the first data sample of the Starting-samples and the sample immediately preceding the first of the Ending-samples.
- The Fixation Position is calculated as the mean position of all samples that fall within *Ellipse 3*.

With the default settings, this means that a fixation is started when 6 consecutive samples fall with .5 degrees and ends when 3 consecutive samples fall outside of 1 degree. All samples within 1.5 degrees are included to compute the fixation location.

For more information about fixation calculation, see Section 5.3 Fixation Algorithm Criteria Description.

> **Note:** It is uncommon for users to change the fixation calculation criteria.

3.2.1.3 Fixation Criteria Menu Options

The following is a list of the adjustable settings of the Fixation Criteria Menu including those for the fixation detection algorithm described above.

- **Min Sample** To "start a fixation" the function looks for a specified number of consecutive data samples (MIN SAMPLE) during which gaze has a standard deviation of no more than the amount specified in Criteria 1 (Ellipse 1).

- **Max Count** To end the fixation, the function looks for a specified number of consecutive gaze position samples (MAX COUNT) to be farther than the amount specified in Criteria 2 (Ellipse 2) from the initial fixation position.

- **Max Blink** If the number of consecutive lost data fields (pupil diameter =0) in an EYEDAT data sample is less than the defined Max Blink then the lost time is considered a blink. A number of consecutive lost fields greater than the maximum then the loss is considered a loss of tracking. A “blink” does not end a fixation. A loss of tracking does end a fixation at the last valid data sample before the loss.

- **Vertical 1 2 3 and Eyetracker Units/degree** This row contains the values (in degrees) for criteria 1-3 (ellipses 1-3) pertaining to the vertical axis. The box in the last column is for the number of Eye tracker units that equal 1-degree visual angle in the vertical axis.

- **<u>Horizontal 1 2 3 and Eyetracker Units/degree</u>** This row contains the values (in degrees) for criteria 1-3 (ellipses 1-3) pertaining to the horizontal axis. The box in the last column is for the number of Eye tracker units that equal 1-degree visual angle in the horizontal axis.

- **<u>Zero Time Origin</u>** If this box is checked, the time value at the start of the segment processed will be set to 00:00:00.000. This option only affects the output file.

- **<u>Pupil scale factor</u>** Pupil diameter may be scaled from the recorded pupil measurements (in eye camera pixels) to more meaningful units such as millimeters. See Section 3.6 Calculate Pupil Statistics for details on how to compute a scale factor.

- **<u>Detect CR Loss</u>** Head mounted eyetrackers (such as the H6 or 501) can measure line of gaze, although with reduced accuracy, even when only the pupil is recognized. Remote (non head-mounted) systems, which permit motion of the head with respect to the eye camera such as the R6 or 504), **<u>cannot</u>** make a reasonable gaze measurement unless both the CR and pupil are recognized.

  When a remote system recognizes the pupil but not the CR, it continues to report a valid pupil diameter, but sets eye position values to default values. These default coordinates are zero (0) for series 6000 and 5000 systems and twenty (20) for series 4000 systems. If "Detect CR Loss" is enabled, eye position coordinates of these default values will be interpreted as "not valid data" (even though pupil diameter is not zero) and the data will not be incorrectly interpreted as fixations at these positions.

  In most circumstances it is best to leave this mode active. It should not be turned off when using remote optics, and should only be turned off with head-mounted optics under limited circumstances.

- **<u>Scene Boundary Limits</u>** If this feature is enabled and if the eye point of gaze position is outside of the defined scene boundary limits, this is treated as "not valid data". This provides a means of filtering out impossible or unwanted data values that may occur, for example, if some extraneous reflection is recognized as the pupil or CR.

  It makes most sense to use this feature when analyzing data from a remote eye tracker which we know can make valid measurements only when the subject looks within about 25 degrees visual angle of the optics module. If, for example, the subject was looking at a computer monitor scene, data values that would indicate gaze points many feet from the scene are unlikely to be valid data and can be filtered out. Set boundary limits which define a region within which it is reasonable to expect valid gaze data

  Check the box to enable the scene boundary limit feature, then type in the top, bottom, left and right coordinates of the scene boundaries. The ASL system divides any scene plane into a grid space of 260 by 240; thus all gaze coordinates reported beyond 0,0 and 260,240 are theoretically outside the plane of interest. Default values are *top: -10, left: -10, right: 270, and bottom: 270* because it is possible for the system to make valid gaze measurements just beyond the boundary limits and taking into account the systems accuracy.

For details on visual angle calculation see Section 5.3.2 Visual Angle Computation (non-EyeHead Data).

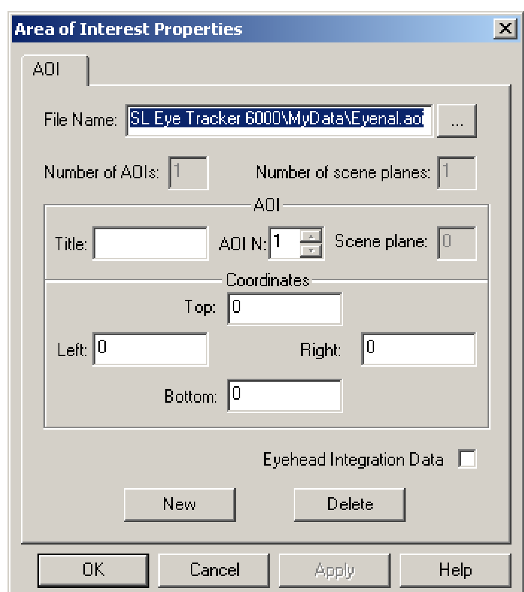
3.3 Define Areas of Interest (AOIs)

Areas of Interest (AOIs) are areas of the visual scene that are defined as being of interest to the experimenter. Areas of interest are defined as rectangles in the coordinate system being used in the data recording (260x240 display for .eyd files; scene plane coordinates for .ehd files). Usually, AOIs are defined around objects and stimuli of interest (such as images components or text). Later functions in Eyenal (See Section 3.4 Fixation Sequence Analysis (Fsq)) combine the defined AOIs with the fixation data (See Section 3.2 Calculate Fixations) to calculate how the subject's gaze interacted with the areas of interest to the experimenter.

Up to 50 Areas of Interest can be defined in an AOI file. Each AOI can be assigned a label of up to ten characters. AOIs can be defined either with the Make new AOI file command from the AOI menu or within the subprogram *Fixplot* by drawing over a bitmap image with attached coordinates (See the Fixplot manual).

When creating AOIs, the user must know the coordinates for the boarders of each AOI. **For non-EyeHead** systems, the coordinates can be determined using the *Set Target Points* mode in the Eyetracker's User Interface software. **For EyeHead Integration** systems, the coordinates are in the coordinate system (cm or inches) and coordinate frame of the scene plane on which they are defined (See the EyeHead Integration manual for information about EHI coordinates).

3.3.1 Creating New AOI File



To create a new AOI file using EyeNal:

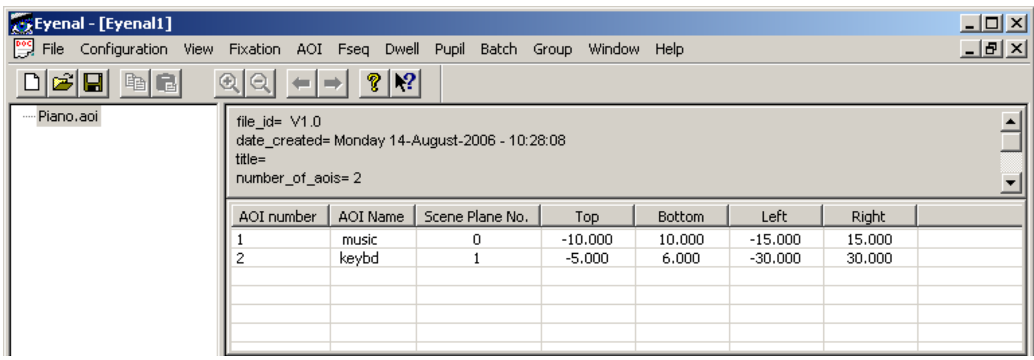
1. Select *Make new AOI file* from the **AOI** menu.
2. Fill in the appropriate information in the Area of Interest Properties dialog.
    a. **File Name:** Enter a name for the new AOI file to be created. If eye tracking data files are currently open the program will display a default name.

b. **EyeHead Integration Data:** Select the Eyehead Integration Data box if the data is from EHI.
c. **Title:** Each area of interest has a ordinal designator (AOI N) and can have a descriptive title. Enter a name for the AOI being defined (noted in AOI N).
d. **Scene Plane:** If using EyeHead Integration data, specify the scene plane (0-19) to which the current Area of Interest (AOI N) applies. If the appropriate scene plane is not specified, the data/AOI comparison will not be performed properly.
e. **Top, Left, Right, Bottom:** Each AOI is defined as a rectangle. These four fields indicate the positions of each of the boarders and must be defined.

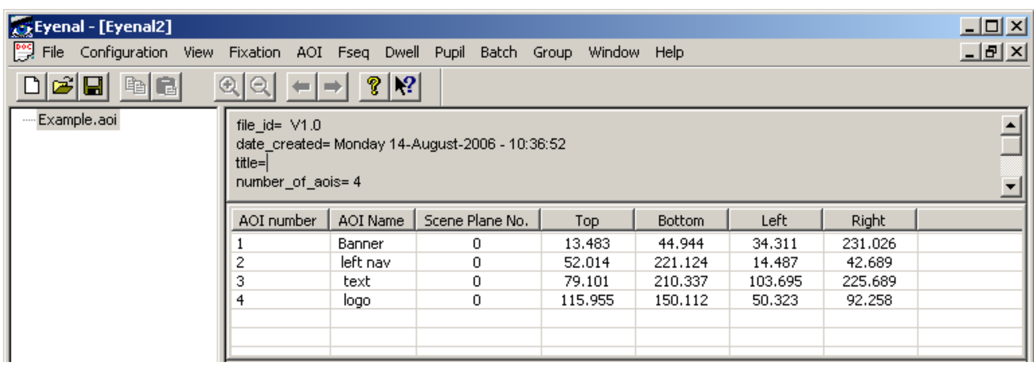
3. Select the **New** button to store the current Area and create an additional (AOI N+1) area in the same file, then repeat steps 2 c-e.
4. When finished defining Areas, select **OK** to save and create an AOI file (.aoi) based on the information defined.

Example AOI files:

EYEHEAD™



Non-EYEHEAD



3.3.2 Editing AOI File

To edit a previously created AOI file using EyeNal:

1. Select *Open* from the **AOI** menu and select the desired .aoi file. This will open the AOI file into the Left Window
2. Select (highlight) the AOI file in the Left Window and select *Edit* from the **AOI** menu.
3. The Area of Interest Properties dialog will open allowing you to edit any of the parameters of the AOI file, add, or delete AOIs. Use the **AOI N** arrows to select a specific AOI. See Section 3.3.1 Creating New AOI File for information about the AOI parameters.
4. When finished editing the AOI file, select **OK** to save the changes. It may be necessary to refresh the screen to view changes in the Right Window.

3.4 Fixation Sequence Analysis (Fsq)

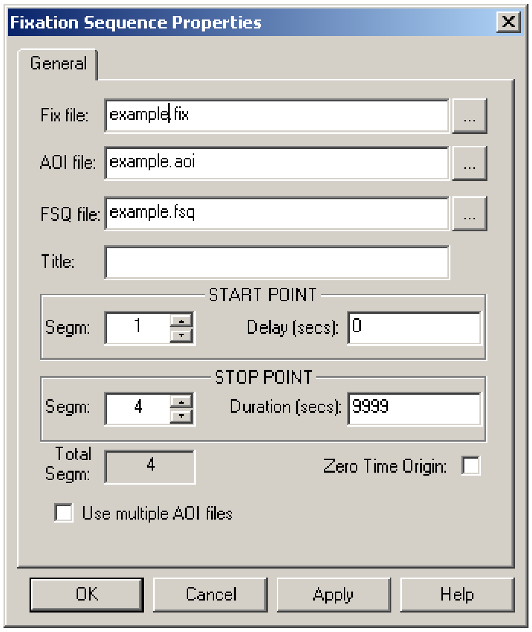
The Fixation Sequence Analysis (fsq) function computes information on the interaction between fixation data (See Section 3.2 Calculate Fixations) and areas of interest (See Section Define Areas of Interest (AOIs)). It is used do compute how a subject's gaze falls on and transitions between defined AOIs.

FSQ determines the sequence of the areas fixated, a summary of the total time and percent of time spent fixating each area, and other summary statistics. In addition, the program calculates joint and conditional probability distribution between areas of interest.

3.4.1 Creating New Fixation Sequence File

To make an FSEQ file:

1. Open the desired Fixation (.fix) file.
2. Open the desired AOI (.aoi) file.
3. Select *Make new fixation sequence file* from the **Fseq** menu.
4. Select the desired parameters in the Fixation Sequence Properties dialog. For a basic FSEQ analysis, the default values are probably sufficient. See below for parameter details.
5. Press OK to create the Fseq file.



3.4.1.1 FSQ Creation Parameters

- The Fseq Properties window allows for specification of different **FIX** (input), **AOI** (input), and **FSQ** (output) file names. The default FSQ file name is based off of the input Fix file.
- **Title:** Information typed here is added to the Fsq file header.
- **Start Point:** An Fseq file can be made from only a portion of the fixation source file. The start point is designated by the starting segment in the **Segm** field or by a time in the **Delay (secs)** field.
- **Stop Point:** An Fseq file can be made from only a portion of the fixation source file. The stop/end point is designated by the final segment in the **Segm** field or by a time in the **Delay (secs)** field.
- **Total Segm:** This field displays the total number of segments contained within the selected Fixation file.
- **Zero Time Origin:** Selecting this box will cause the time value at the start of each processed segment to be set to 00:00:00.000. This option only affect the output .fsq file.
- **Use multiple AOI files** enables the Multiple AOI Files operation for creating the FSQ file (See Section 3.4.1.3 FSQ Based on Multiple AOI Files).

3.4.1.2 FSQ Based on Single AOI File

The default (and standard) behavior for the Fixation Sequence function is that one AOI file applies to all portions and segments of the input FIX file.

This is appropriate if every segment being analyzed has the same set of Areas of Interest (because they are based on the same stimulus, or on different stimuli with similar screen area layouts of interest).

3.4.1.3 FSQ Based on Multiple AOI Files

Different AOI files (.aoi) can be applied to different Segments within a Fixation file (.fix). The AOI file assigned to each FIX file can be determined either by Segment number or by XDAT values

To enable this feature, select the **Use multiple AOI files** box in the FSQ Properties window while making a new fsq file. Then select either **Select by Segment Number** or **Select by XDAT value**.

Each AOI file used must have the same base filename with the suffix “_nnnnn”, where “nnnnn” is the selection value (for example, *experiment_00001.aoi*, *experiment_00002.aoi*, *experiment_00003.aoi*, etc). The FSQ algorithm will apply the AOI file with the matching numeric suffix to each Segment based on the selected method (**Select by Segment Number** or **Select by XDAT value**).

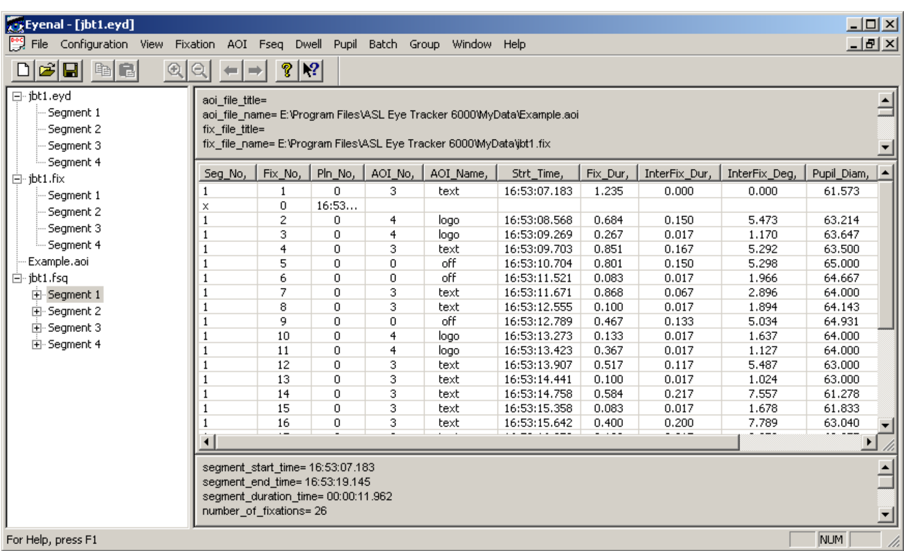
3.4.2 FSQ Reports

After creation, Fixation Sequence files can be loaded into the Left Window. The file can be expanded to view each Segment and each Segment can be expanded to view four types of analysis reports. Selecting the Segment or any of the analysis types will display their contents in the Right Window.

3.4.2.1 FSQ Segment Summary

Selecting a Segment in an FSQ file will display a list of the contained fixations similar to the Fixation file display. Each row is a fixation.

- **Seg_No:** Lists the segment number.
- **Fix_No:** Lists the ordinal Fixation number.
- **Pln_No:** Lists the EyeHead Integration Scene Plane. This is only applicable to EHI data.
- **AOI_No** and **AOI_Name:** Lists the number and name of the area of interest in which the fixation falls.
    - o By definition, if the fixation is in an area not specified as an area of interest, it is designated as being in AOI 0 "OFF."



- If overlapping Areas of Interest are defined and a fixation falls within the overlapping areas, the Fixation number will be repeated on subsequent lines and all relevant areas will be listed.

- **Strt_Time:** Fixation start time in hours, minutes, and seconds (HH:MM:SS.SSS)
- **Fix_dur:** Fixation Duration in seconds
- **InterFix_Dur:** Interfixation length. The time between the end of the previous fixation and the beginning of the current fixation in seconds.
- **InterFix_Deg:** Interfixation distance between the current and the previous fixation in degrees visual angle
- **Pupil_Diam:** Scaled pupil diameter. If no scale factor was defined, then the scale defaults to 1 and the value is reported in pixels on the eye camera.
- **Eye/Scn_Dist:** The distance between the subject's eye and the calculated Scene Plane distance in inches or centimeters. This item is valid only for EYEHEAD data.
- **No_of_flags:** The number of XDAT value changes that occurred during a fixation.

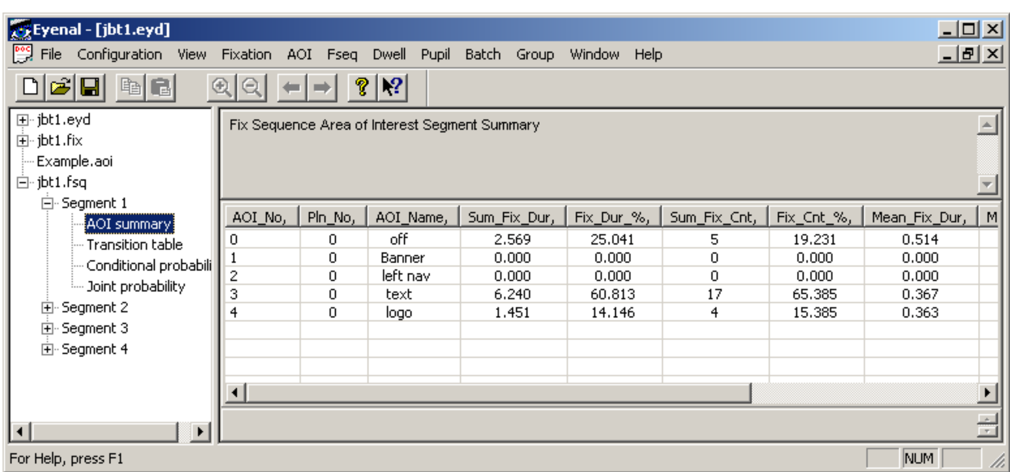
"X rows"

A row with only three column values is a special case row indicating a change in XDAT value. It does **not** indicate a fixation.

- The first column contains an **"X"** to indicate an XDAT value change
- The second column denotes the XDAT numeric value
- The third column is the time at which the XDAT value changed

3.4.2.2 AOI Summary

Instead of organizing by fixations (as in the FSQ Segment Summary), a Segment can be viewed organized by Areas of Interest. Select **AOI Summary** from the file tree.

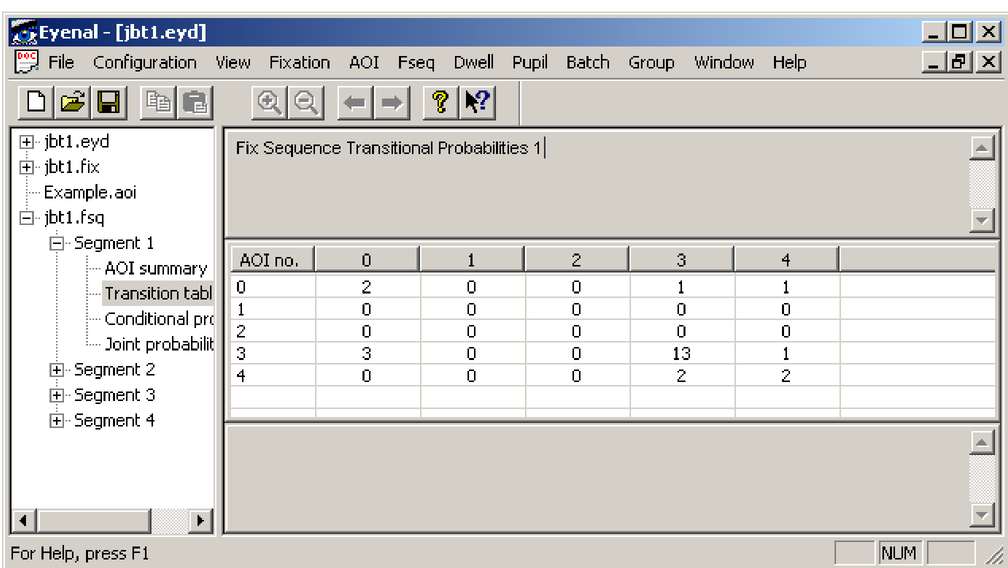


- **Sum Fix Duration:** Total time in each AOI. This refers to the total time spent fixating within a given area of interest during the data segment. Fixation time for each area of interest is listed both in seconds and as a percent of total fixation time during the data segment.
- **Sum Fix Cnt:** Total Number of fixations in each area.
- **Fix Cnt%:** Percent of fixations in each area (number of fixations on a given area divided by the total number of fixations).
- **Mean Fix Dur:** The mean duration in seconds, of fixations on each area (Fix time divided by number of fixations).
- **Mean Interfix Dur:** Mean interfixation length (in seconds) while subject was fixating in each AOI.
- **Mean Interfix Dist:** Mean interfixation distance (in degrees) while subject was fixating in each AOI.
- **Mean PD:** Mean pupil diameter for each AOI while subject was fixating on each AOI.

3.4.2.3 Transition Table

The Transition Table is a matrix representing the actual amount of transitional activity between Areas of Interest (AOIs). A transition from **i** to **j** is the change from a fixation in Area **i** to a new fixation in Area **j**. To view the Transition table left click on “Transition table” in the Fseq file tree.

The left most column of numbers and the topmost row of numbers in a Transition Table represent each AOI number. In the example shown below there are four areas. There were 0 transitions between Area 0 (off the scene) to Areas 1, 2, and 4. There was 1 transition between Area 0 and Area 3. There were 2 transitions from Area 0 to within area 0. There were 2 transitions from Area 4 to Area 3. The highest transitional activity was within Area 3.



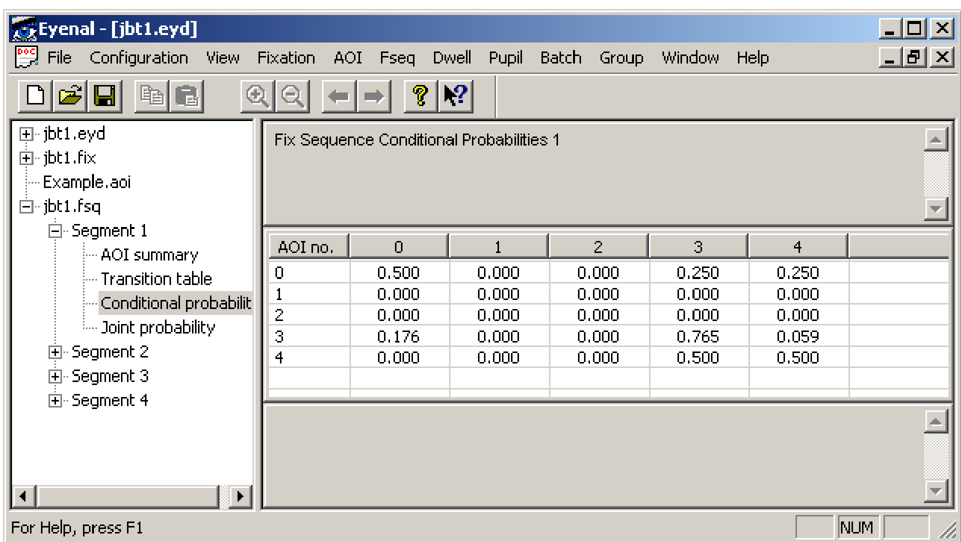
3.4.2.4 Conditional Probability Table

To view the Conditional probability table, left click **Conditional probability** in the Fseq file tree. Conditional probability is the likelihood that given a fixation on one specific area, the next fixation will be on another specific area.

$$\mathbf{Pc(i/j) =} \frac{\textbf{No. of fixation transitions from Ai to Aj}}{\textbf{No. of fixations on Ai}}$$

This table reads the same way as the transition table except that it is a matrix representing the conditional probability of transitional activity between Areas of Interest (AOI's).

> **NOTE:** Be careful about interpreting conditional probability results. If, for example, there are five areas of interest and out of 200 fixations a given subject looked at area 2 only once followed by a fixation on area 3, then the conditional probability (2,3) = 1.0 (or 100%). Obviously this does not mean that there was a lot of visual "traffic" between areas 2 and 3, but rather that whenever there was a fixation on area 2 the next fixation was on area 3. In the example cited, the result is insignificant because of the small number of fixations on area 2.



AOI no.	0	1	2	3	4
0	0.500	0.000	0.000	0.250	0.250
1	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000
3	0.176	0.000	0.000	0.765	0.059
4	0.000	0.000	0.000	0.500	0.500

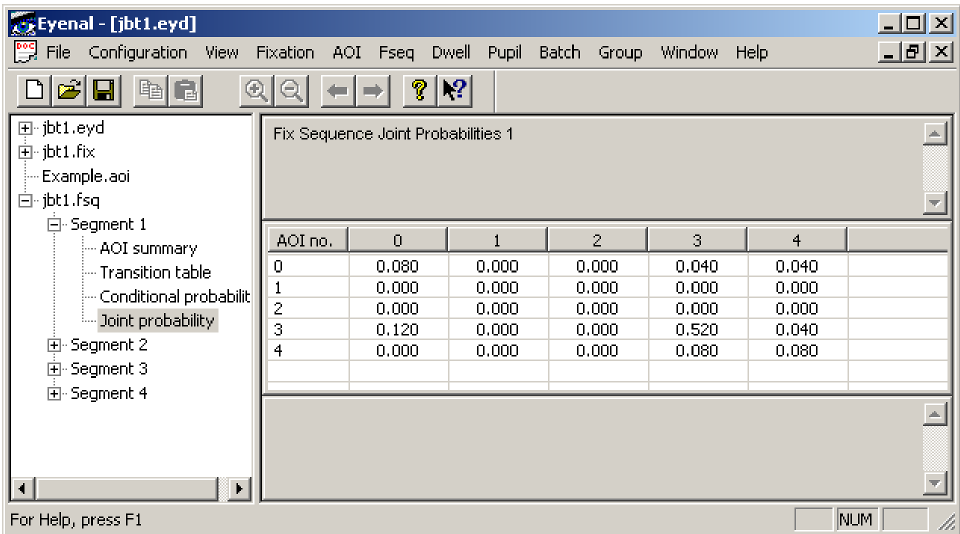
3.4.2.5 Joint Probability Table

To view the Joint probability table, left click **Joint probability** in the Fseq file tree.

Joint probability is the relative likelihood (or relative frequency) of a transition between two particular areas as compared to transitions between other pairs of areas.

$$\mathbf{Pj(i,j)} = \frac{\textbf{No. of fixation transitions from Ai to Aj}}{\textbf{Total number of transition pairs}}$$

This table reads the same way as the transition table except that it is a matrix representing the joint probability of transitional activity between Areas of Interest (AOI's).



3.5 Dwell Analysis

The Dwell function further constrains the parameters of analysis from the Fixation Sequence. The function takes the results from the Fixation Sequence analysis and applies additional qualifiers.

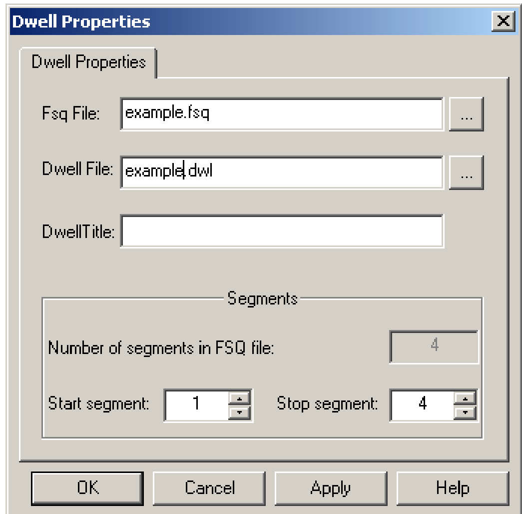
An individual Dwell is defined as the time period during which a contiguous series of 1 or more fixations remains within an Area of Interest (AOI). That is, a dwell is defined as moving into an area of interest and moving out of an area of interest, regardless of how many individual fixations this action is comprised of.

The Dwell function creates the same set of reports as the Fixation Sequence function, however their contents are likely to be different owing to the difference in event definition.

This analysis type is generally preferred when the experimenter is interested only in the overall interaction with AOIs, not the individual fixation events within them.

3.5.1 Creating New Dwell File

1. Select *Make new Dwell file* from the **Dwell** menu.
2. In the Dwell Properties window, select the appropriate properties and select OK. In most situations, the default values will be adequate.



3.5.1.1 Dwell Properties Window

- **Fsq File:** This is the input data file. Browse to the desired Fseq file. If an Fseq file is currently open in the EyeNal Left Window, this will be the default file.
- **Dwell File:** This is the name for the Dwell file that will be output. It will default to the same name as the Fseq file changing the extension to .dwl.
- **Dwell Title:** Any information typed here will show in the file header.
- **Segments:** If desired select a start and stop point based on the input file segments.

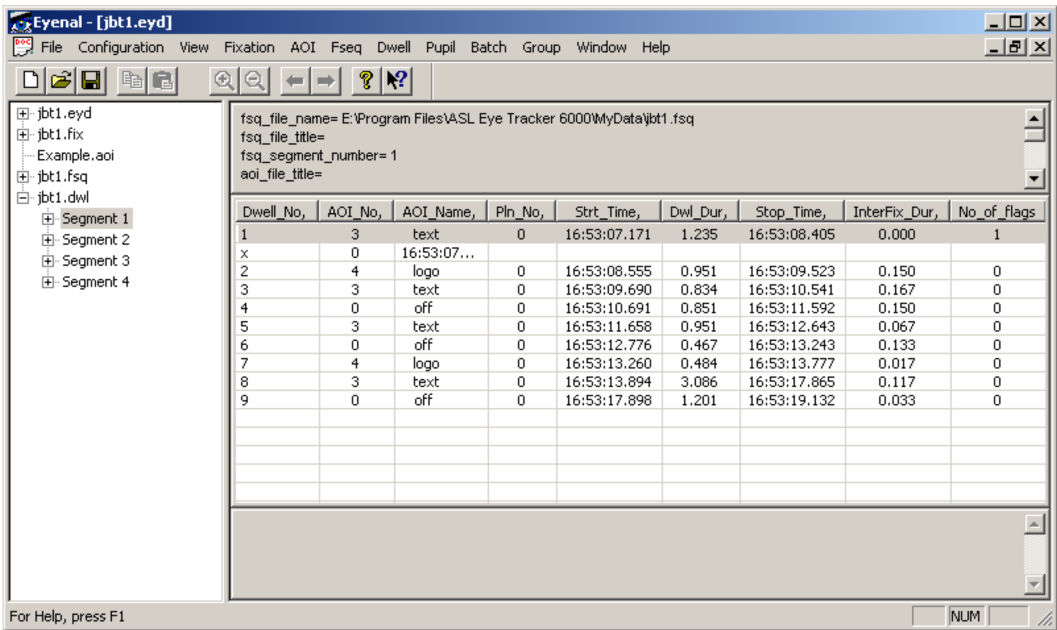
3.5.2 Dwell Reports

3.5.2.1 Dwell Sequence List

Selecting a Segment in a DWL file will display a list of the contained fixations similar to the Fixation Sequence file display. Each row is a dwell. Note that the number of dwell events is likely to be different than the number of fixation events from the original file.

- **Dwell No:** Dwell number
- **AOI No./Name:** Area of Interest (AOI) number, label, and scene plane number (scene plane numbers only apply for EYE-HEAD data files) that contained the dwell.

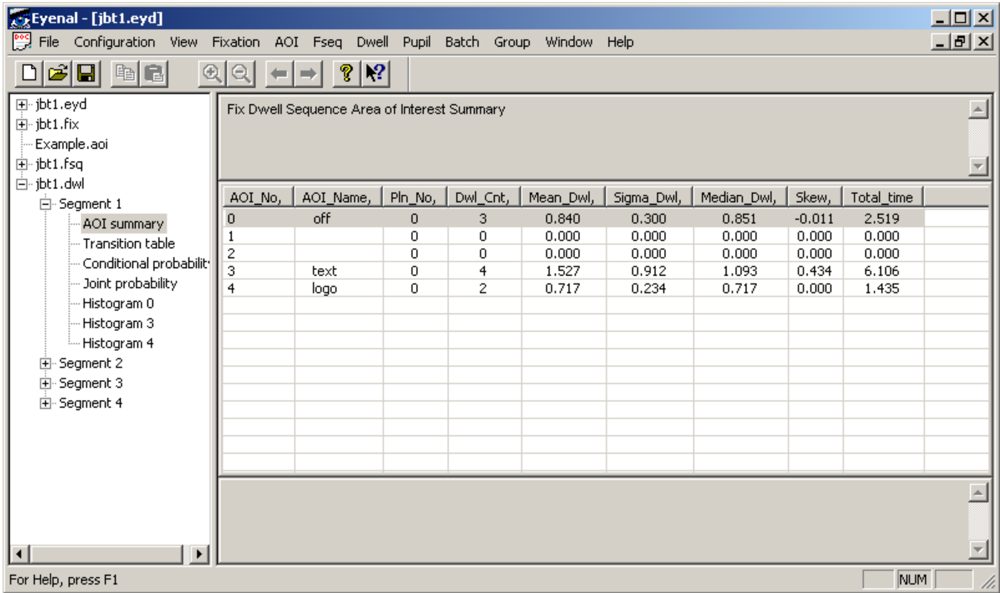
- **Start Time:** Dwell start time listed in hours, minutes, and seconds (HH:MM:SS.SSS).
- **Dwl Dur:** Dwell duration in seconds. This is the sum of all the Fixation durations that make up the dwell.
- **Stop time:** Dwell stop time listed in hours, minutes, and seconds (HH:MM:SS.SSS).
- **InterFix Dur:** Inter-fixation length in seconds for each dwell shift between two AOI's.
- **No. of flags:** The number of XDAT value changes that occurred during the dwell event.



3.5.2.2 Dwell Sequence Summary

To view the Dwell Sequence Summary, select **AOI Summary** in the Dwell file tree. The program lists the following summary information for each dwell event in the selected segment

- The total number of Dwells occurring in the Area of Interest.
- The mean (average) Dwell duration and standard deviation in seconds.
- The median dwell duration in seconds.
- The skew value (difference between the mean and median duration) for the Area of Interest.



3.5.2.3 Dwell Transition Table

The Transition Table is a matrix representing the actual amount of transitional activity between Areas of Interest (AOI's). A transition from **i** to **j** is the change from a dwell period in Area **i** to a new dwell period in Area **j**.

To view the Dwell Transition Table select **Transition table** in the Dwell file tree.

3.5.3 Dwell Conditional Probability Table

Conditional probability is the likelihood that given a dwell on one specific area, the next dwell will be on another specific area.

$$\mathbf{Pc(i/j)} = \frac{\textbf{No. of dwell transitions from Ai to Aj}}{\textbf{No. of dwells on Ai}}$$

3.5.4 Dwell Joint Probability Table

Joint probability is the relative likelihood (or relative frequency) of a transition between two particular areas as compared to transitions between other pairs of areas.

Pj(i,j) = **No. of fixation(or dwell) transitions from Ai to Aj**
--
Total number of transition pairs

3.6 Calculate Pupil Statistics

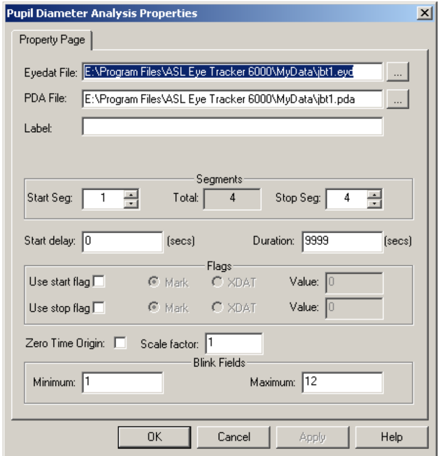
The Pupil Diameter Analysis function computes various statistics related to pupil diameter including pupil average, pupil median, pupil variance, standard deviation, and blink frequency. The function allows for analysis to be specified over specific time windows and can integrate a scaling factor to convert the recorded pupil diameter measurements (in eye camera pixels) into real world units such as millimeters or inches.

3.6.1 Making a Pupil File (.pda)

- Select *Make new pupil diameter analysis file* from the **Pupil** menu.
- Review the properties settings in the Pupil Diameter Analysis Properties window. In most situations, all of the defaults except **Scale Factor** will be adequate.
- Enter the appropriate Scale Factor. See Appendix 5.4 Calculating Pupil Diameter Scale Factor for details on how to calculate this value.
- Press OK to create the .pda file.

3.6.2 Pupil Diameter Properties Window

- **Eyedat File:** The source data file**.**
- **PDA File:** The output file name. If desired change the output file name or keep the default name.
- **Label:** Information typed here shows up in the file header.
- **Segments:** A PDA file can be made with only a portion of the source file. A start and stop point can also be designated by Eyedat file segment.
- **Start Delay:** It is also possible to delay the analysis start point in seconds. When using a start delay one can also specify a **Duration** of the file (seconds) to be analyzed.



- **Use start flag:** Marker or X-DAT values may be used as flags to trigger the beginning of fixation calculations. Check this box to use a start flag then specify the appropriate flag in one of the two boxes to the right.
- **Use stop flag:** Marker or X-DAT values may be used as flags to trigger the end of fixation calculations. Check this box to use a stop flag then specify the appropriate flag in one of the two boxes to the right.
- **Zero Time Origin:** If this box is checked, the time value at the start of the segment processed will be set to 00:00:00.000. This option only affects the output file.
- **Pupil Scale factor:** Pupil diameter may be scaled to meaningful units, such as millimeters. To compute a scale factor for pupil diameter, see Appendix 5.4 Calculating Pupil Diameter Scale Factor.
- **Blink Fields:** If the number of consecutive lost data fields (pupil diameter =0) in an EYEDAT data sample is between the defined Blink Minimum and Blink Maximum number of fields than the losses are considered a blink. A number of consecutive lost fields less than the minimum or greater than the maximum are considered losses.
    - The Blink frequency result for an EYEDAT data sample selection is calculated as:

$$\textbf{blink frequency} = \frac{\textbf{number of blinks in data sample}}{\textbf{sample duration in seconds}}$$

3.6.3 Pupil Diameter Sequence List

The Pupil Diameter Summary lists the number of samples, mean, median, and standard deviation of pupil diameter values for the selected data sample. The Blink Frequency calculation is also included in the data summary.

Note: Pupil diameter values of zero (loss) are not included in calculations of the statistical values listed above.

4 Batch Processing

The Batch function allows the user to create Fixation, Fixation sequence, and Dwell files for any number of selected EHD or EYD files in a given directory. It can be used to quickly perform the same operation on multiple data files.

The Batch routine is divided into three different independent functions for Fixation, Fixation Sequence, and Dwell.

4.1 Fixation Batch Routine

1. Select *Batch Fixation* from the **Batch** menu.
2. Select the **Source Directory** for the location of the data files (.eyd or .ehd).
    a. All **.eyd** and .**ehd** files located in the Source Directory will be listed.
3. Select the desired **Output Directory** for the resulting files (.fix).
4. Select desired source files to include in the analysis.
    a. A file with a red check will be included.
    b. **Double click** on the check to add or remove the file from the process.
5. **(Optional)** To add or change **Output File Name, Title, Code, Start Point** (by Segment or delay in secs), or **Stop Point** (by segment or duration in secs) the for individual output files:
    a. Double click on the desired output file name.
    b. Change or adjust desired field in the resulting Properties pop up window and click APPLY.
6. To set Fixation Criteria for the selected files left click the tabs labeled ***Start-Stop*** and ***Criteria*** at the top of the Batch properties pop up menu. See Section 3.2.1 Fixation Properties Dialogue for information about Fixation Criteria.
7. Click OK

The Batch function will now create fixation files for each selected source file based on the specified parameters and criteria. These files will be located in the specified source directory.

4.2 Fixation Sequence Batch Routine

1. Select *Batch Fix Sequence* from the **Batch** menu.
2. Select the desired AOI file (.aoi) from the Windows browser. And select **OK**.
3. Select the **Source Directory** for the location of the data files (.fix).
    a. All **.eyd** and .**ehd** files located in the Source Directory will be listed.
4. Select the desired Output directory for the resulting files (.fsq)

5. Select desired source files to include in the analysis.
    a. A file with a red check will be included.
    b. **Double click** on the check to add or remove the file from the process.
6. **(Optional)** To add or change **Output File Name, Title, Code, Start Point** (by Segment or delay in secs), or **Stop Point** (by segment or duration in secs) the for individual output files:
    a. Double click on the desired output file name.
    b. Change or adjust desired field in the resulting Properties pop up window and click APPLY.
7. Click OK.

The Batch function will now create Fixation Sequence files for each selected source file based on the specified parameters. These files will be located in the specified Source Directory.

4.3 Dwell Batch Routine

1. Select *Batch Dwell* from the **Batch** menu.
2. Select the **Source Directory** for the location of the data files (.fsq).
    a. All **.fsq** files located in the Source Directory will be listed.
3. Select the desired Output directory for the resulting files (.dwl).
4. Select desired source files to include in the analysis.
    a. A file with a red check will be included.
    b. **Double click** on the check to add or remove the file from the process.
5. **(Optional)** To add or change **Output File Name, Title, Code, Start Point** (by Segment or delay in secs), or **Stop Point** (by segment or duration in secs) the for individual output files:
    a. Double click on the desired output file name.
    b. Change or adjust desired field in the resulting Properties pop up window and click APPLY.
6. Click OK.

The Batch function will now create Dwell files for each selected source file based on the specified parameters. These files will be located in the specified source directory.

5 Appendices

5.1 Frequently Asked Questions (FAQ)

5.1.1 How do I resegment data based on XDAT or Marker values?

See Section 3.2.1.1 Start-Stop Criteria on Page 14.

5.1.2 How are fixations computed?

See Section 5.3 Fixation Algorithm Criteria Description on Page 37.

5.1.3 How do I apply different AOI files to different segments?

See Section 3.4.1.3 FSQ Based on Multiple AOI Files on Page 21.

5.1.4 How does EyeNal handle blinks?

See the Max Blink item in Section 3.2.1.3 Fixation Criteria Menu Options on Page 16.

5.1.5 How do I scale pupil diameter?

See Section 5.4 Calculating Pupil Diameter Scale Factor on Page 40.

5.1.6 How do I analyze video with Eyenal?

Eyenal is not designed to work with video files.

5.1.7 What is the row with a Seg_No labeled “x” in each segment of a fixation, fixation sequence, or dwell file?

See the **X Rows** box on Page 23.

5.2 File Naming Conventions

File Type	File Extension	Description
EyeDat	.eyd	Eye data recording. Created by EyeTrac 6, 6000, and 5000 interface software.
EyeHead	.ehd	Eye data recording. Created by EyeTrac 6, 6000, and 5000 interface software when performing EyeHead Integration.
Fixation	.fix	Files created by EyeNal’s **Make new fixation file** function. Contains data reduced into fixations and interfixation time periods.
Areas of Interest	.aoi	Files created by EyeNal’s **Make new AOI file** function. Contains Areas of Interest, notations for scene regions of interest to an experiment.
Fixation Sequences	.fsq	Files created by EyeNal’s **Make new fixation sequence file** function. Contains fixation data as related to an AOI set.
Dwells	.dwl	Files created by EyeNal’s **Make new dwell sequence file** function. Contains

		fixation data as related to an AOI set reduced to transitions into and out of AOIs.
Pupil Diameter Analysis	.pda	Files created by EyeNal's **Make new pupil diameter analysis file** function. Contains scaled pupil diameter information
Plot	.plt	Data plotting files created by the Fixation Function to facilitate making plots of fixation position versus time within an external graphing program (such as Excel).

5.3 Fixation Algorithm Criteria Description

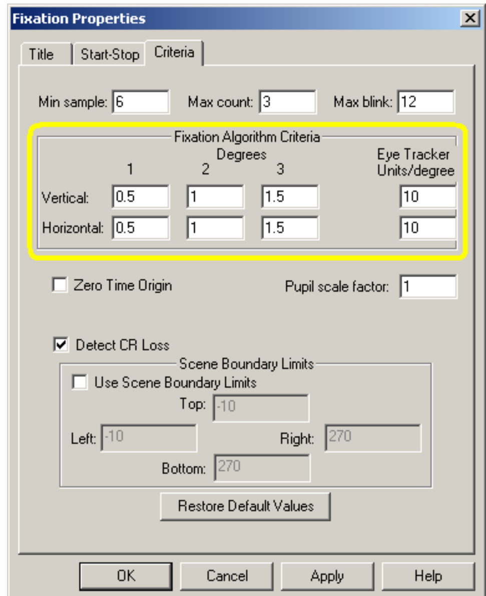
5.3.1 Criterion Description

Criteria 1, 2 and 3 are defined in terms of visual angle (eyeball rotation angle). These criteria are user adjustable.

For small visual angles in the center of the scene, **d = s * tan x** where:

- **d** is the distance on the scene,
- **s** is the subject's eye to scene distance,
- **x** is the visual angle.

Thus if the subject were seated 57.3 inches from the scene a square covering 1-degree visual angle would measure 1 inch by 1 inch.



5.3.2 Visual Angle Computation (non-EyeHead Data)

Eyedat files, (.eyd) do not contain the information about subject to scene distance or scene camera position and magnification that is required to express the point of gaze data in terms of visual angles (degrees of eye ball rotation). **The program must be told how many “eye tracker data units” correspond to a degree of visual angle.** This ratio (eye tracker units per degree visual angle) must be determined for both the horizontal and vertical axis and is entered under a label named “Eye tracker Units/degree”. The following subsection explains how this parameter can be determined.

The following is a suggested procedure for determining eye tracker units per degree of visual angle. Please note that this computation is not necessary for EYEHEAD data. In addition there is a Visual Angle Calculator application that can perform this operation. The Visual Angle calculator application is available for download on from ASL’s Technical Support Website.

1. Measure the distance in inches (or centimeters) from the subject eye to the center of the scene plane. Call this “s”.
2. Measure the distance in inches (or centimeters) horizontally between two known scene points, such as the points 5 and 6 on the calibration chart. Call this “dh”.
3. Measure the distance in inches (or centimeters) vertically between two known scene points, such as the points 5 and 2 on the calibration chart. Call this “dv”.

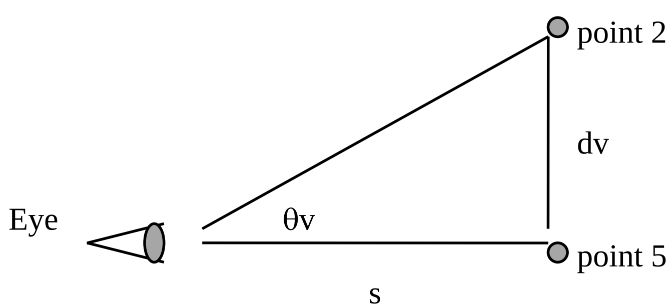
4. Use the Set Target mode of the Eyetracker Software while observing the scene monitor. Now measure the distance in Eyetracker units horizontally between the two known scene points (points 5 and 6 on the calibration chart). Call this "ETh".
5. Next measure the distance in Eyetracker units vertically between the two known scene points (points 5 and 2 on the calibration chart). Call this "ETv".
6. Find the angle whose tangent is dh/s and call this "θh".
7. Find the angle whose tangent is dv/s and call this "θv".
8. Divide ETh by θh
9. This is the value of eye tracker units per degree visual angle along the horizontal axis.
10. Divide ETv by θv. This is the value of eye tracker units per degree visual angle along the vertical axis.

5.3.2.1 Sample Calculations of Eye Tracker Units per Degree Visual Angle

The following are sample calculations to determine eye tracker units per degree of visual angle.

<u>Sample Measurements</u>

s = Eye to center of scene distance = 28 inches
dh = Horizontal distance from calibration point 5 to point 6 = 8 inches
Eth = number of horizontal eyetracker units between points 5 and 6 = 120 Eyetracker units.
dv = Vertical distance from calibration point 2 to point 5 = 7 inches
Etv = number of vertical Eyetracker units between points 2 and 5 = 105 eyetracker units



<u>Sample Calculations:</u>

$\theta h = \tan^{-1}(dh/s) = 15.9$ deg   Horizontal eyetracker units per degree = 120/15.9 = 7.5

$\theta v = \tan^{-1}(dv/s) = 14$ deg   Vertical eyetracker units per degree = 105/14 = 7.5

5.3.3 Detailed Fixation Determination Algorithm

A three-boundary approach is used to define fixations. The recommended values for the three boundaries (called criterion 1, 2, and 3) are 0.5 degrees, 1.0 degree, and 1.5 degrees respectively. These values may be reset as described in Section 3.2.1 Fixation Properties Dialogue.

The program uses a moving window technique to find the fixation start point. The first “min sample” data samples are examined. “Min sample” is adjustable as described in Section 8.4.1, but it is usually set to the number of fields that will correspond to about 100 msec. If the standard deviations of the X (horizontal) and Y (vertical) eye position coordinates is less than “criterion 1”, the means of this sample are used as temporary fixation coordinates (XT, YT). If the standard deviation was greater than criterion 1, then the min-sample window is moved up one field and the calculations repeated until a min-sample window that passes criterion 1 is found.

Once a fixation start point is determined, the program calculates the horizontal and vertical distance (DX, DY) of the next data sample from the temporary means (XT, YT). If (DX, DY) is less than criterion 2, the sample is included in the fixation. If it does not pass criterion 2, then the next sample is tested against criterion 2.

This process is continued until a measurement sample passes criterion 2 or until “max count” sequential samples (default value of three can be changed by the user) have been tested. If one of these measurements does fall within criterion 2, previous samples that did not are tested against criterion 3. All of the samples that pass criterion 2 or 3 are then considered to be "included in the fixation." This means that they will be used in the final calculation of fixation position.

If DX and/or DY from “max-count” sequential samples exceed criterion 2 then the X and Y means of these samples are calculated. If the means do not differ from XT and YT by more than criterion 2, they are all included in the fixation; otherwise the fixation is closed at the last acceptable data sample.

Blinks, defined as pupil losses of “max blink”samples or less, are ignored and do not terminate a fixation. Note that a number of samples equal to about 200 msec is the recommended value for maximum blink duration. This value may be reset as described in Section 3.2.1 Fixation Properties Dialogue. Pupil loss for periods longer than “max-blink” does cause a fixation to close at the last acceptable data sample.

5.4 Calculating Pupil Diameter Scale Factor

The following procedure can be used to compute a scale factor for converting recorded pupil diameter values to millimeters.

One of the accessories supplied by ASL is a model eye, or "target bar", that can be used to simulate the image received from a real eye. It consists of a thin, 2 inch by 6 inch piece of aluminum, painted black; and containing a white, 4 mm diameter circle, and a small ball bearing. When viewed by the eye tracker optics, the white circle looks like a bright pupil image, and the reflection from the ball bearing looks like a corneal reflection. The model pupil and corneal reflection (CR) images will not mimic the relative motion of the pupil and CR when a real eye rotates. They do, however, provide stationary models that can be used to test eye tracker discrimination functions, to practice discrimination adjustments, and to calibrate pupil diameter.

Start by placing the 4mm model pupil (target bar) supplied by ASL so that the white 4mm circle is at a normal eye distance from the optics. If optics focus is left unchanged after running a real subject, this will be the distance at which the model pupil is in sharp focus on the eye monitor. In the case of head mounted optics, this can be most easily accomplished by swinging the visor out of the way, and placing the model eye directly below the optics module. It is suggested that the model be oriented so that the corneal reflection (ball bearing) appears below the pupil (white circle).

Using the Interface software, discriminate on the model pupil image just as on a real pupil. With the model pupil properly discriminated, note the pupil diameter value on the computer screen digital display window. To compute a scale factor, divide this value by 4 (the size of the pupil-representing white circle in mm). Convert recorded pupil diameter values to millimeters by applying this scale factor (value in millimeters = scale factor * recorded value).

For head mounted optics (Models 501 or H6) this scale factor will usually be in the vicinity of 0.1. For pan/tilt optics there may be a more substantial variation since there is more possible variation in the camera to eye distance, but the value will often be in the vicinity of 0.2.

This procedure can be performed on any circular object of known size that the system can be made to discriminate upon.