Calibrating your Experimental Display

Calibrating your stimulation display is a critical step, so make sure to fully master this procedure before collecting any experimental data.
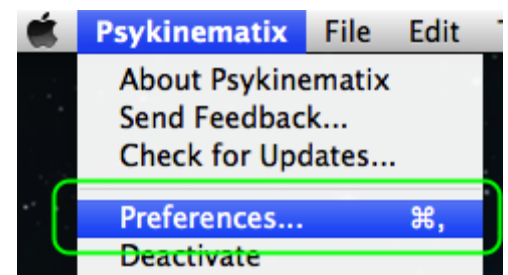
This **step-by-step** tutorial teaches you how to:

1) perform the calibration of your experimental setup using Psykinematix.
2) specify a calibration configuration for a given experiment.

Difficulty: 3/5
Duration: 30 mn

Preparation

First, open the **Display Preferences** panel to specify the default display and settings you wish to use when creating new experiments.

Click on the **Display** tab to select the Display Preferences. Select the stimulus display and resolution to be used by default. Any new selection creates a **Default** calibration configuration that could be used to run an experiment without having to calibrate the setup; however, a warning message will indicate any potential problem in this case. To properly calibrate the selected configuration, switch to the **Calibration** panel.
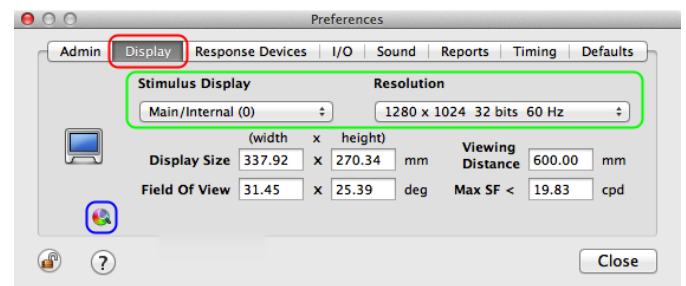
Tip: To jump directly to the Calibration panel, click on the small color wheel icon outlined in blue.

To switch to the **Calibration** panel from the main panel, click on the **Calibration** button in the toolbar.

Calibration Panel

The calibration of your experimental setup requires the calibration of three aspects of the stimulus display: its geometry, its Gamma function, and the color properties of its phosphors. You need a ruler to perform the geometry calibration along with a special device to measure the emission properties of your display (*photometer*, *colorimeter,* or *spectrometer*).
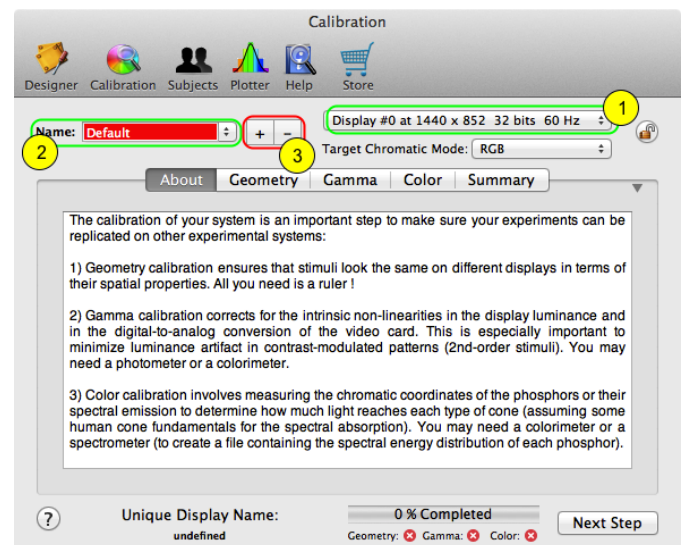
As outlined in green, this panel can manage multiple resolution configurations of a display (1) as well as multiple calibrations for a given resolution (2). In this example, the current calibration is named '**Default**', and corresponds to the display at index 0 (this generally refers to the main display) for a resolution of 1024 x 768 pixels in 32-bit mode and with a frame rate of 60 Hz. Note that a '**Default**' calibration is created each time a new display configuration is set in the **Display Preferences**.

Click on the '**+**' button (3) to create a new calibration, named 'NewCal*' by default, and then rename it to better reflect the display type.
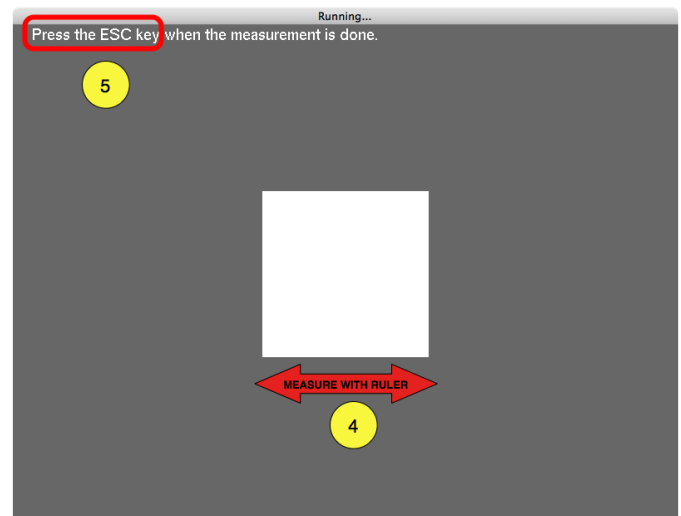
Step 1: Geometry Calibration

1) Click on the **Geometry** tab in the Calibration panel.

2) Set the size in pixels of the square patch used to perform the geometry calibration.

3) Click on **Perform Calibration.**
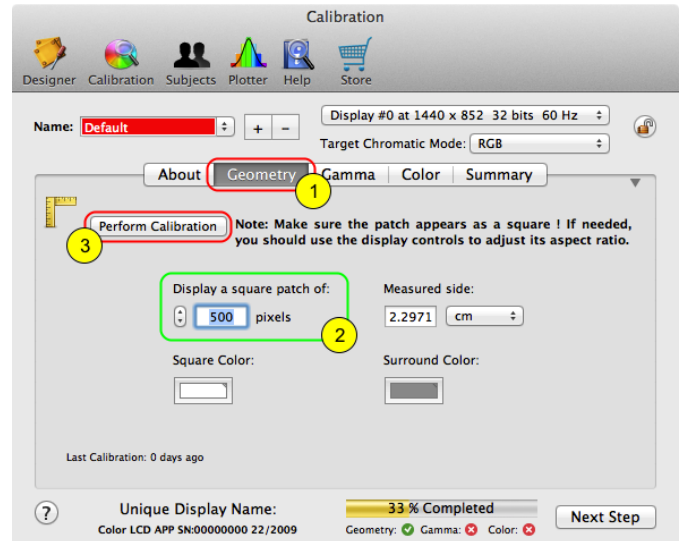
You should see this screen on the stimulus display after clicking on the **Perform Calibration** button: a square shape displayed in the center in the specified color and size.

4) Use the ruler to measure the sides of the square and make sure it's actually square.

5) Press **Esc** (escape key) to close the stimulus screen when the measurement is complete.

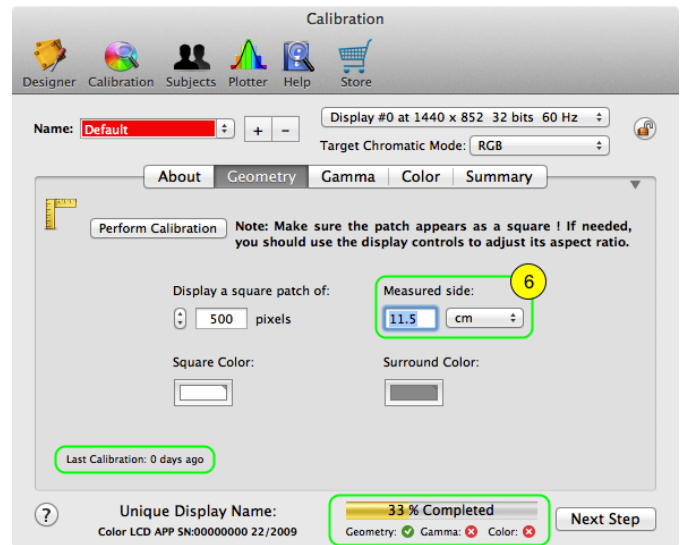Psykinematix: Visual Psychophysics Made Easy on Mac OS X

6) Select the measurement unit and enter the measured value in the **Measured side** field.

The geometry calibration is now complete!

Note that the time of the last calibration is indicated in the bottom left-hand corner, and that the percentage of the calibration completion has been updated.

Step 2: Gamma Correction

To perform a proper **Gamma calibration**, a device that functions as a *photometer* is required. Psykinematix interfaces with the **Eye-One Display 2** from GretagMacbeth/X-Rite and the **Spyder 2** from Color Vision; however, any *photometer* that displays its readings on a visual output can be used. Finally, make sure your device is set up to produce luminance readings in cd/m^2. If you don't have access to a *photometer*, you can still manually set the Gamma value for each gun but your display may not be correctly calibrated.

To perform the **Gamma calibration**, follow the steps below:

1) Click on the **Gamma** tab in the Calibration panel.

The stimulus properties (3), and the measurement parameters (4) appear in this panel. The actual calibration is performed after selecting the measurement mode (5) and clicking on the measurement button (6). The plain curve in the graph shows the Gamma of the selected gun. It is also recommended to specify the preferred targeted chromatic mode before performing a Gamma calibration to optimize the process (2).
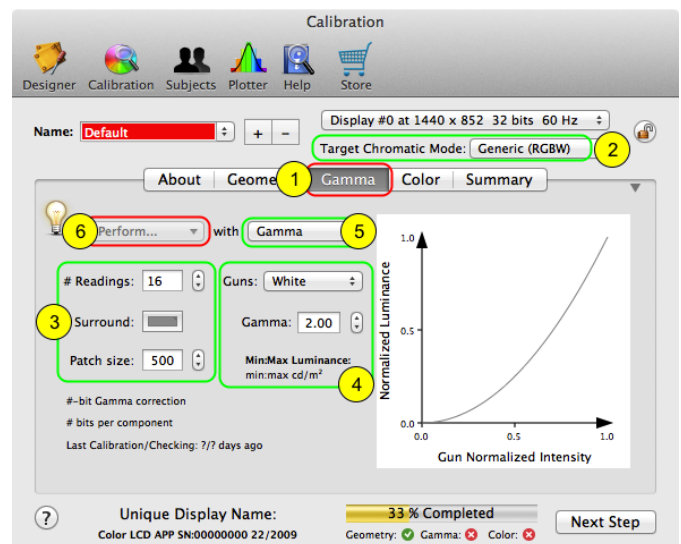
2) Specify the targeted chromatic mode: unless you intend to use one of the special modes that provide an enhanced luminance and contrast resolution (through bit-stealing, spatial dithering or a special device like the Bits# or Display++), there is no need to change the default selection "**Generic (RGBW)**" which permits the calibration of the standard (typically 8-bits) red, green, and blue guns in addition of their linear combination ("White" gun). Note it is recommend to calibrate all 4 guns with this "**Generic (RGBW)**" chromatic mode so this calibration configuration could be used in either the chromatic (RGB) or achromatic mode set in the Display settings of each experiment.
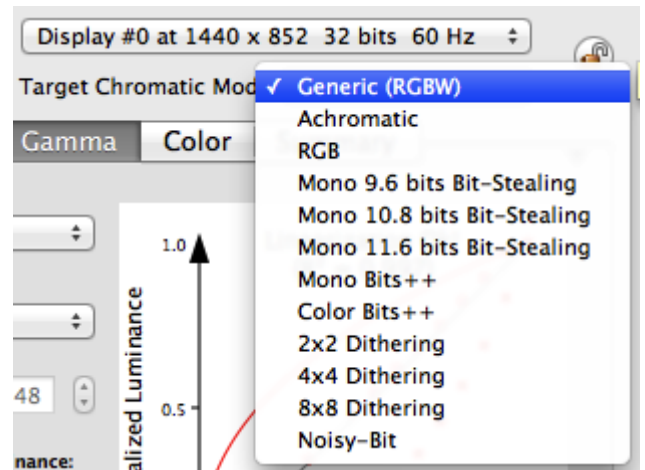
3) Set the number of luminance readings, the surround color, and the patch size in pixels.

4) Select the gun you want to calibrate: the **red**, **green** and **blue** guns can be calibrated individually or combined to form the **white** gun. Note however that only the guns compatible with the **targeted chromatic mode** selected in step 2 above will be available for calibration.
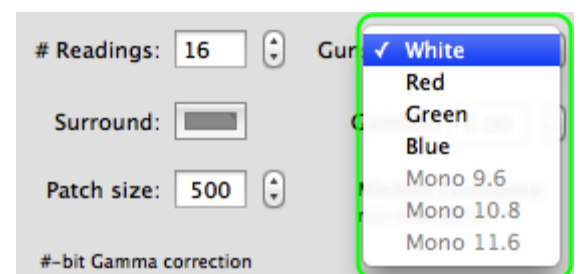
5) Specify the source of the measurement; by default, it is set to **Gamma** and its value can be directly edited in the field just below.

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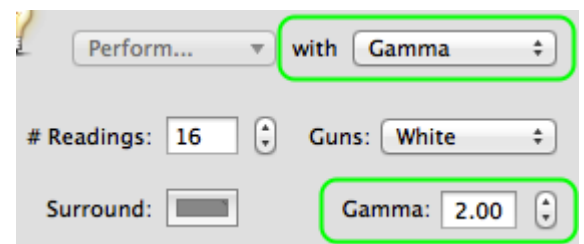
Assuming you have access to a supported *photometer* (for example a **i1** or **Spyder** device), select it and the readings will be automatically sent to Psykinematix as you take the measurements. If your *photometer* is not in the list of supported devices, then it is still possibe to use it by entering manually its luminance readings. In this case, select the **Readings** option.
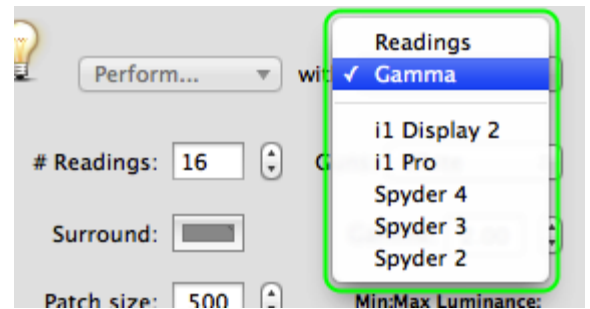
6) Select **Gamma Measurement** from the **Perform...** pop-up menu. The Gamma measurement should be performed first, followed by a verification of the linearity of the Gamma correction (see **Correction Checking**, step 10 below). When you become more familiar with the calibration process, you may choose the other available options to speed up the calibration.
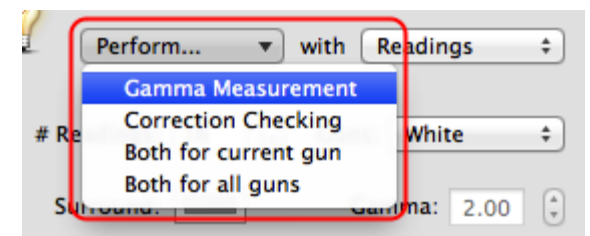
You should see this screen on the stimulus display when selecting one of the **Perform...** actions: a square shape displayed in the center in the specified color and size, as well as its surround.

7) Place the *photometer* head in the center of the white square. The square should be larger than the light sensitive area of the photometer; if it is not, press **Esc** twice (short followed by a long press), increase the square size, and re-select **Gamma Measurement**.
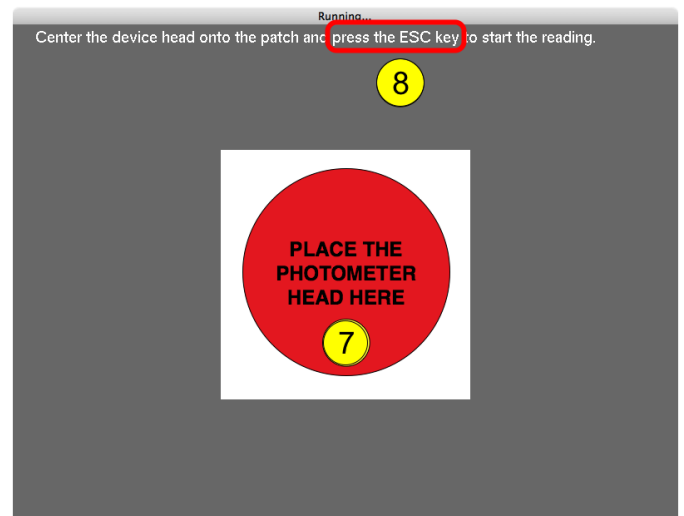
8) To start the measurement process, press **Esc** when the photometer head is in place.

9) In manual mode, enter the *photometer* reading using the keypad after each change in the square's luminance, followed by the **Return** key to move to the next luminance level. The reading index and entry are displayed in the bottom right-hand corner of the stimulus display. Use the **Delete** key to modify the entry before it is validated with the **Return** key.
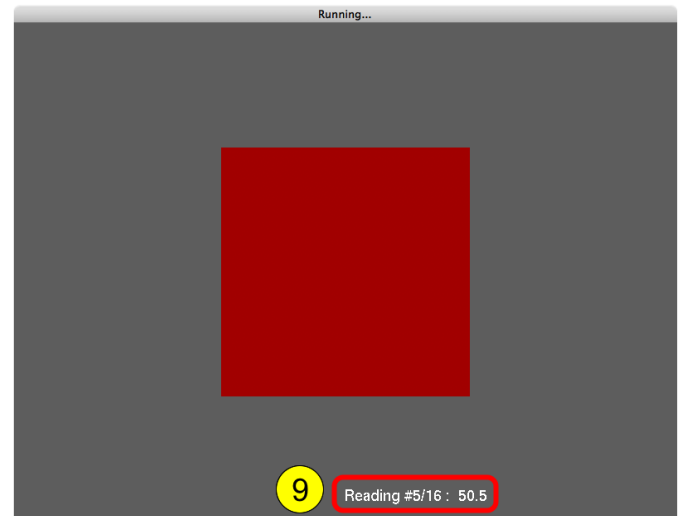
When using a supported photometer device, the reading is sent directly to the computer and the next luminance level is automatically displayed. In this case, the reading index is displayed in the top left-hand corner of the stimulus display.

Press **Esc** to close the screen when the luminance measurements are completed (or press **Esc** for 1 second to abort the measurement process).

When the **Gamma** measurement for the selected gun is completed, the graph shows the luminance readings as solid squares.

The **Gamma** field shows the Gamma value that best fits these data.

The inverse plain curve shows the resulting **Gamma correction** to be applied.
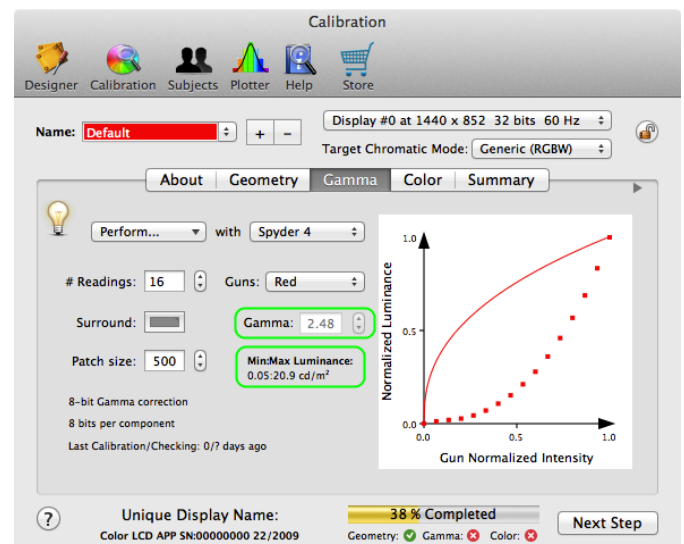
The graph always shows the normalized intensities, so note that the minimum and maximum measured luminance levels are displayed below the **Gamma** field.

10) The last step of the **Gamma calibration** is the verification of the linearity of the **Gamma correction**. Select **Correction Checking** from the **Perform...** pop-up menu, and follow the same steps as above to perform the measurement process of Gamma corrected luminance.

When the checking process is completed, the corrected Gamma is added to the graph as empty circles. The closer they are to the diagonal line, the more accurate the correction is. Moreover an objective measurement of this linearization is provided through a R2 value. Note that a warning will be emitted if this R2 value is less than 0.99, indicating a less than optimal Gamma correction (it is then recommended to re-do the calibration, maybe with a larger number of readings, see step 3 above).
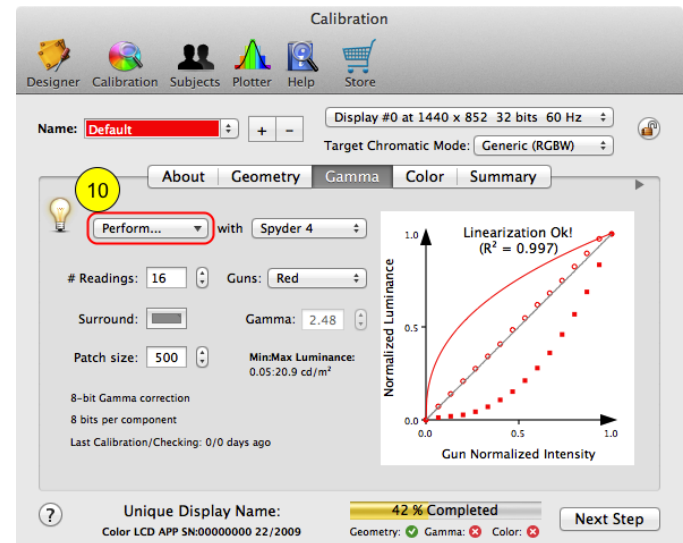
Important: Make sure to disable beforehand any display option in "System Preferences" that may affect automatically the brightness or color appearance of the display (e.g. "Automatic adjust brightness", "Night Shift" in macOS Sierra 10.12.4 or "True Tone" in macOS High Sierra 10.13.6).

You should repeat the **Gamma calibration** for all the other guns, after which the process is complete!

Step 3: Color Calibration

For proper color calibration, a device that functions as a *colorimeter* or *spectrometer* is required. Psykinematix can directly interface with several colorimeters (for example a **i1** or **Spyder** device); however, any *colorimeter* that displays its readings on a visual output or any *spectrometer* with a file output can be used.

If you don't have access to a *colorimeter* or a *spectrometer,* you can still set color properties that may be close to your display characteristics, but your display may not be correctly
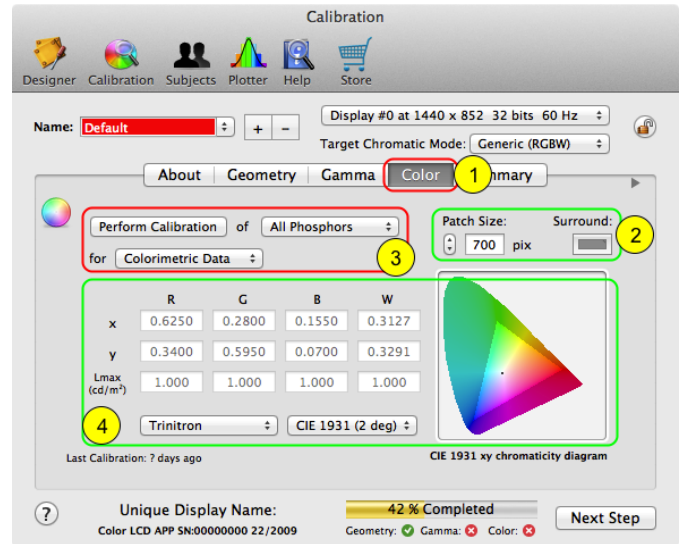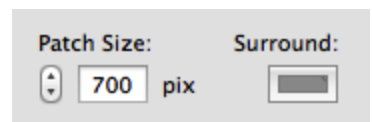
calibrated.

To perform the color calibration, follow the steps below:

1) Click on the **Color** tab in the Calibration panel.

The stimulus properties (2), and the measured color properties represented graphically as well as in a table (4) appear in this panel. The actual calibration is performed after selecting the phosphor along with the measurement mode and clicking on the measurement button (3).

2) Set the surround color and the patch size in pixels.

3.1) Select the phosphor you want to calibrate: the **red**, **green** and **blue** phosphors can be individually calibrated or combined to form the **white point**. It is mandatory to calibrate all 4. If you have one of the supported devices, the 4 can automatically be calibrated in one step by selecting **All Phosphors**.
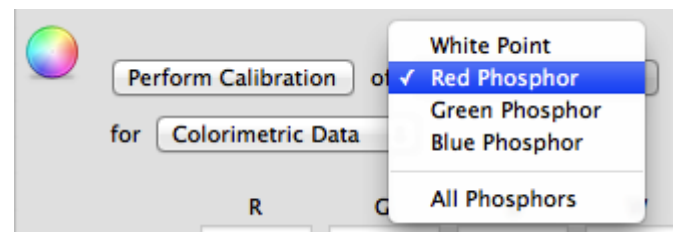
3.2) Select the type of measurement to perform for each phosphor: **radiometric** or **colorimetric** properties. For the most accurate calibration, both types of measurement should be carried out.
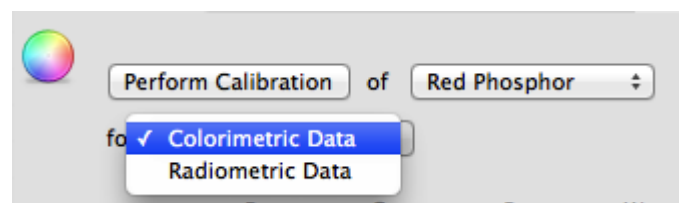
You need a device with a *spectrometer* function for radiometric measurements and a *colorimeter* function for colorimetric measurements.

Colorimetric Data

Select the **Colorimetric** mode.

This mode allows you to specify the source of the colorimetric measurement of your display (1) while the measured chromatic properties are presented in the table (2): the **xy** chromatic coordinates and maximum luminance (**Lmax**) for each phosphor which form the Maxwell triangle (or gamut) of the display (3).

1) This pop-up menu provides several choices. If you own a *colorimeter*, use one of the top options: **Custom...** allows you to manually edit the table (2) with readings obtained from a device not directly supported by Psykinematix while the supported colorimeters (for example a **i1** or **Spyder** device) allow you to automatically obtain the readings from the *colorimeter*. Click on **Perform Calibration** to get the colorimetric measurements for the specified phosphors.


All the other choices in this pop-up menu correspond to various standard displays and should only be selected if you do not have access to a *colorimeter* AND you are familiar with your display characteristics. On selection of one of these, the table (2) is filled with pre-defined colorimetric data for the specified display type and the gamut is updated (3).

Radiometric Data

Select the **Radiometric** mode.

This mode allows you to specify the source of the spectral measurement of your display (1) and the cone fundamentals (2), both shown in the graph (3), in order to generate an **LMS to RGB** conversion matrix (4).
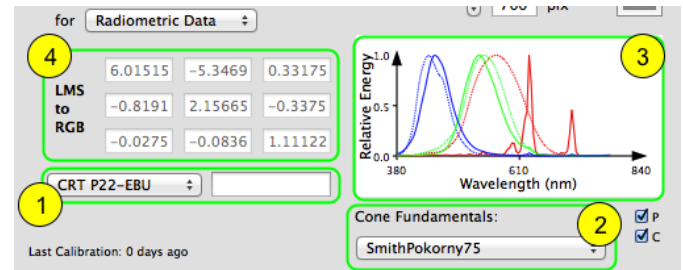
1) The source of the radiometric measurement is specified through a pop-up menu which offers three choices: to produce a custom **LMS to RGB matrix** by editing the matrix (4), to select a file containing the spectral power distribution for each phosphor, or to select a phosphor standard that closely matches that of your display.
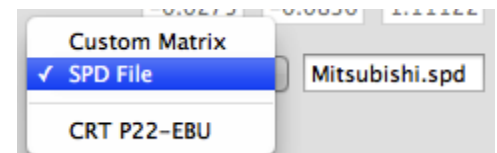
2) The **cone fundamentals** specify the spectral absorption for each cone and are used in combination with the spectral emission of the display to produce the **LMS to RGB matrix** which is automatically updated with the selection.
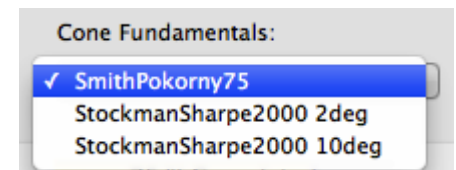
3) The spectral power distributions of both display emission and cone absorption are represented graphically (continuous lines for phosphor emissions, broken lines for cone absorptions) and updated with any change in the selections.

4) The resulting **LMS to RGB matrix** is displayed in the table and updated with any change in the selections.

Note that Psykinematix does not support any *spectrometer* yet, but it can import a file containing the data produced by a *spectrometer* (usually a text file conforming to a specific format described in the documentation). However, Psykinematix can present an appropriate stimulus patch so the spectrometer is able to perform its measurements for each phosphor. To do this, click on **Perform Calibration**.

Specify a Calibration Configuration for an Experiment

After finishing an experiment design, you should specify the calibration configuration to be used for each session. To do so, select your experiment in the **Designer** table (**Experiment** category with the red psi mini-icon), and click on the blue **INFO** button to inspect its properties.
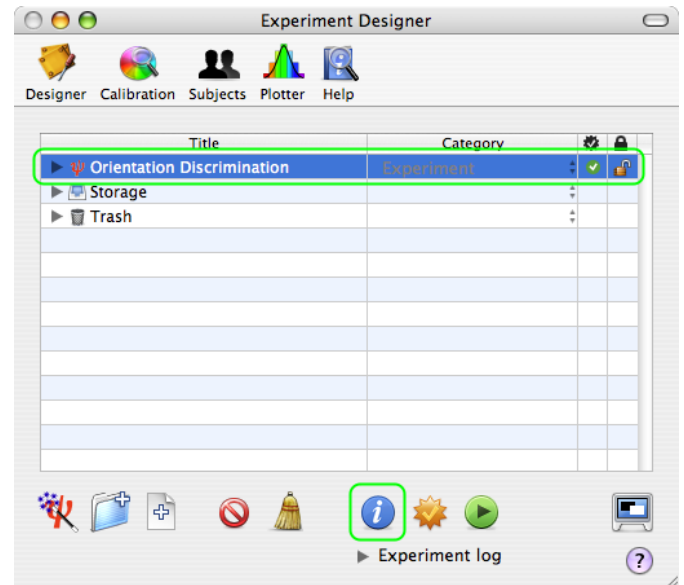
On the properties page, click on the **Display** tab to view/edit the experiment Display settings. By default, the display settings (stimulus display and resolution) are those defined in the **Display Preferences**. To change them for the currently edited experiment, use the two pop-up menus provided and outlined in green. Each time these display settings are changed, the content of the pop-up menu entitled **Calibration Name** (outlined in blue) is updated with all the calibration configurations available for these settings.
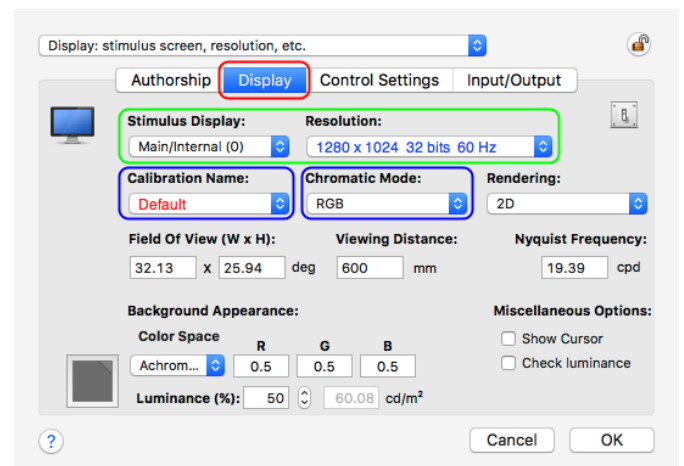
If none is available, the selection in the pop-up menu remains blank with a small warning icon attached to it. Click on this warning icon to reset the display settings to the ones in the **Display Preferences**, or close this panel and return to the **Display Preferences** and **Calibration panel** to create a configuration for the new display settings (see beginning of this tutorial).

Note that the chromatic mode selected for a specific experiment needs to be compatible with the targeted chromatic mode specified in the calibration configuration (Psykinematix will emit

an error message at run-time if it is not). For example as already indicated in step 2.2 above, selecting the target chromatic mode "**Generic (RGBW)**" would be compatible with the **RGB** and **achromatic** modes.

Conclusion

In this tutorial, you learned how to: calibrate the geometry of your display, measure and linearize its Gamma, measure its color properties, and set the calibration configuration used during an experiment. Again, calibrating your stimulation display is a critical step, so make sure to fully master this procedure before collecting any experimental data.