Visual Acuity XL & Visual Acuity Remote

"The Visual Acuity Solution for iPad"

User Guide Version 1.5

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INTERPRETATION OF RESULTS.

This user guide does not provide guidance on the interpretation of visual acuity measurements. The experimenter must ensure to have received appropriate training in such interpretation. For this reason KYBERVISION cannot be held responsible for misdiagnosis of results.

Symbols Used

This manual uses the following symbols to indicate special information:

Symbol	Description
❖	**Indicates tips that help you better use this app.**
➡	*Indicates important information pertaining to visual acuity.*

Terminology

This user guide uses the terms ***Experimenter*** or ***User*** to refer to the person operating the iPad® device, and ***Patient*** or ***Subject*** to refer to the person undergoing the test and who may also use the remote control to provide his responses. The ***Remote Control*** refers to another iOS device (iPad, iPhone® or iPod touch®) running the **Visual Acuity Remote** app available for free on the App Store℠.

Documentation

This user manual is also available as an **iBooks "textbook"** for iPad (created with iBooks Author).

Table Of Contents

Overview

Visual acuity is the most important test used to evaluate eyesight. It measures the eye's ability to resolve details at near and far distance. It usually involves reading letters or looking at symbols of different sizes (optotypes) on a wall chart, similar to the famous Snellen chart found in most physician offices and developed by Dutch ophthalmologist Herman Snellen in 1862.

Visual Acuity XL for iPad is KyberVision's mobile solution for vision care specialists: it brings computerized versions of the "gold standard" acuity testing on this popular mobile platform in the clinical environment and it provides fast, efficient and reliable assessment of visual acuity for literate and illiterate people as well as preschool children. Moreover, **Visual Acuity XL** promotes the use of the logMAR chart design recommended by the *National Eye Institute* (NEI) and the *International Council of Ophthalmology* (ICO) to address design flaws in the Snellen chart.

Visual Acuity XL for iPad has many useful features for the clinical environment:

- Interactive LogMAR charts in landscape and portrait modes
- Randomized design to prevent subjects to memorize the test
- Near and far visual acuity testing
- Keep track of visual acuity history, subject/patient information and prescription
- Exporting of acuity data through email in HTML format
- Database backup and import with overwrite, append and merge capabilities
- Units conversion tool
- Information about common eye conditions you can share with your patient/subject
- Free remote control app **Visual Acuity Remote** for iPad, iPhone or iPod touch
- iBooks and PDF documentation available online

Many options are also available to customize acuity testing:

- Simple or ETDRS acuity scoring
- Charts composed either of single letter, single horizontal or vertical line, or multiple lines
- Standard optotypes (Landolt C, Tumbling E, Sloan, HOTV, Kid, Numbers, Cyrillic, Snellen)
- Standard acuity units (foot, meter, decimal, VAR, logMAR, cpd)
- Black letter on white background or reverse
- Confusion bars
- 4 or 8 orientations for Landolt C optotype
- Distance units and viewing distance up to 8 meters (26 feet)
- Mirror and TV-Out modes
- Custom luminance and contrast levels

The table below lists the currently supported iPads and their appropriateness for measuring visual acuity (the higher pixel resolution, *ppi* aka pixel per inch, the better):

iOS Device	Far Visual Acuity	Near Visual Acuity	TV-Out	Notes
iPad 1				Unsupported
iPad 2	✓		✓	Sub-optimal (132 ppi)
9.7” iPad with Retina Display	✓	✓	✓	Acceptable (264 ppi)
iPad mini (1st gen.)	✓		✓	Sub-optimal (163 ppi)
iPad mini with Retina Display	✓	✓	✓	Recommended (326 ppi)
12.9” iPad Pro	✓	✓	✓	Acceptable (264 ppi)
10.5” iPad Pro	✓	✓	✓	Acceptable (264 ppi)

Both **Visual Acuity XL** and **Visual Acuity Remote** are available on Apple App Store:

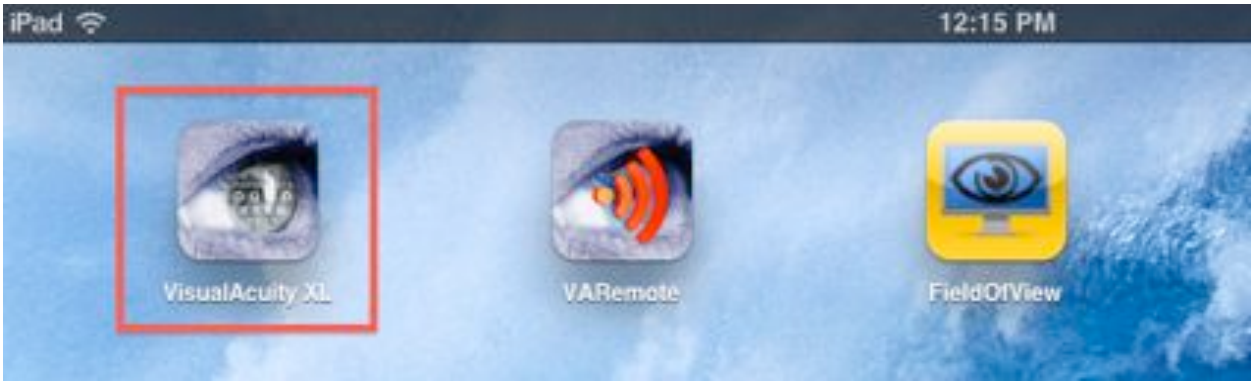
Visual Acuity XL

The most reliable acuity tests used today follow the ***logMAR design*** recommended by the *National Eye Institute* (NEI) and the *International Council of Ophthalmology* (ICO) to address design flaws in the 150 year-old Snellen chart: the charts provided by **Visual Acuity XL** follow this logMAR design by implementing a geometric progression of letter sizes and proportional spacing between letters, with standard optotypes specifically designed to appear equally recognizable and appropriate for testing literate and illiterate people as well as preschool children.

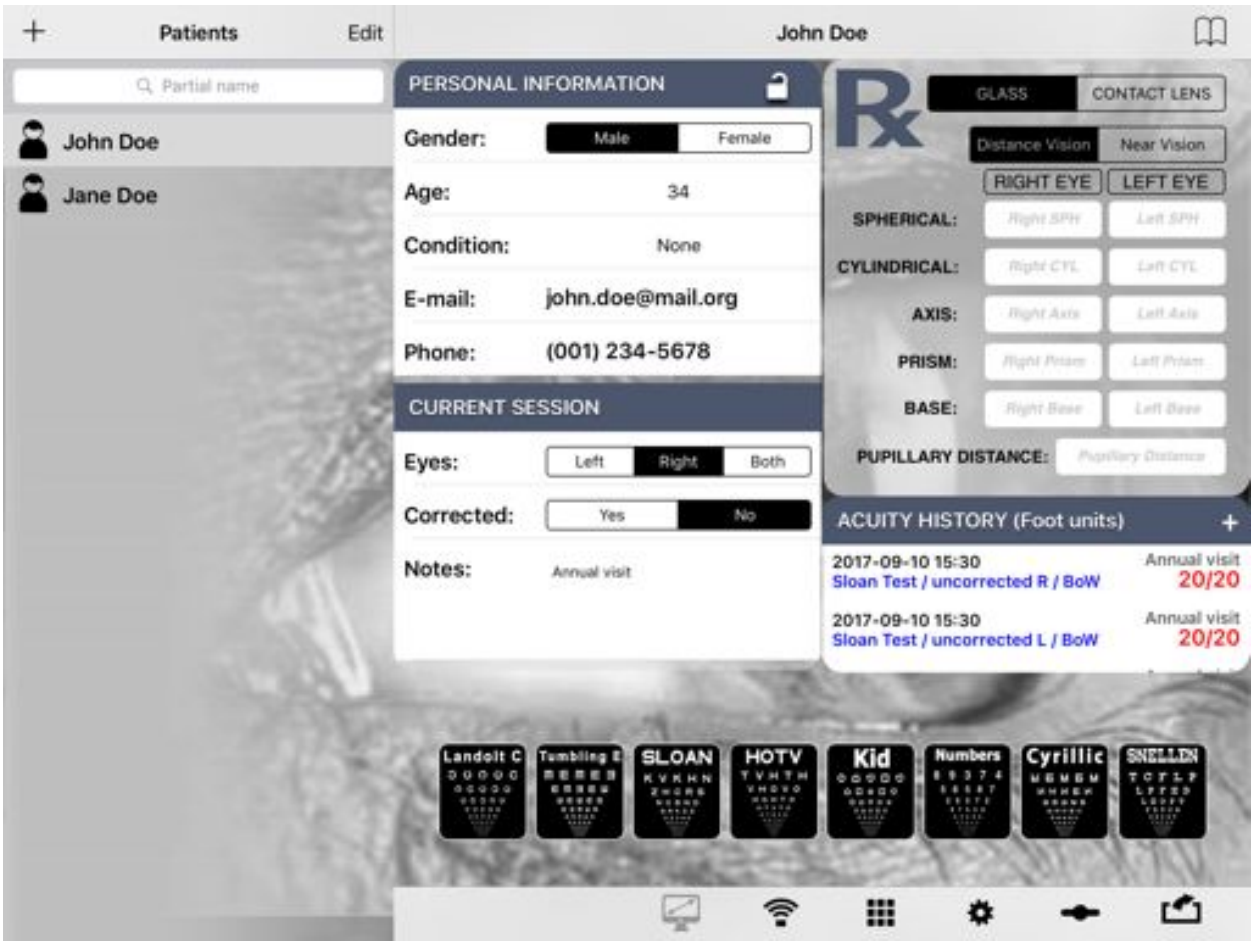
Moreover, to measure visual acuity in a precise and efficient way **Visual Acuity XL** provides unique ***interactive logMAR charts*** that are randomly generated to prevent the subjects to memorize the test, and fully exploits the potential of the iOS platform by using another device (iPad, iPhone or iPod touch) as a remote control device for the acuity testing. The **Visual Acuity XL** app runs exclusively on the iPad device to take advantage of it larger display and implements many features required for both research and clinical studies.

Getting Started

To start using **Visual Acuity XL**, tap its icon to launch it:



The main panel shows subject specific information in the top half and optotype specific buttons in the bottom half. The subjects list is shown on the left side in landscape mode only. To get access to it in portrait mode tap the "Patients" button in the top toolbar to present the subject list in a popover window.

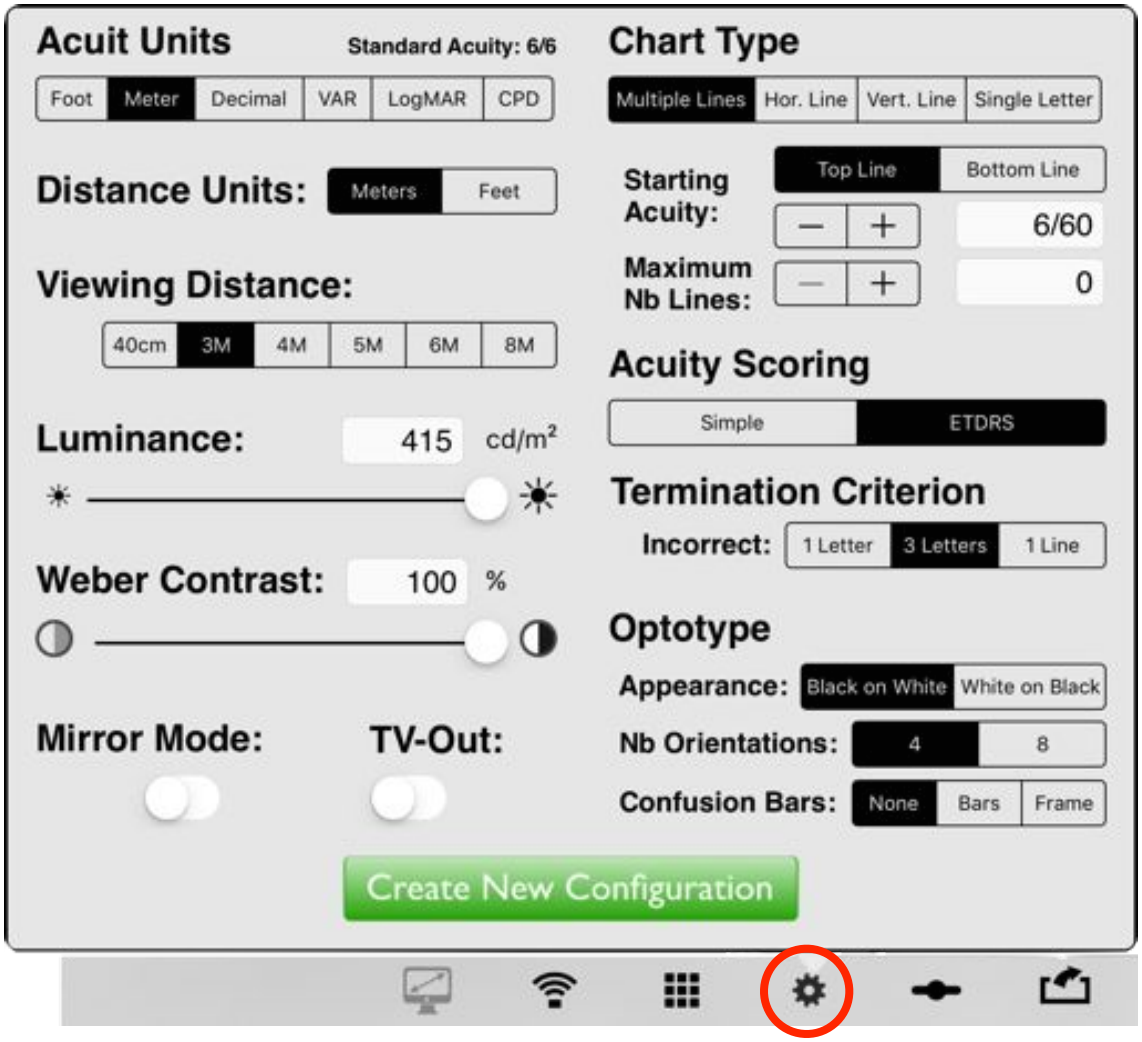


The bottom toolbar provides access to additional functions:

- to calibrate the external monitor when the TV-Out mode is turned on,
- to establish a Bluetooth or WiFi connection between the iPad and another iOS device running the optional **Visual Acuity Remote** app,
- to manage your own custom testing configurations,
- to customize the settings of the acuity testing (acuity units, optotype appearance, chart type, acuity scoring, termination criterion and distance units, etc),
- to convert between various acuity units,
- to export the acuity data through e-mail in HTML format or as a database backup file.

Configuring the Acuity Testing

To configure the test settings, tap the ⚙ icon in the bottom toolbar. This opens a popover window with customizable settings. The general settings are displayed in the left column and the test-specific settings in the right column:



- The acuity units (Foot, Meter, Decimal, VAR, LogMAR, CPD). Note that the standard acuity is indicated in the selected unit (e.g. 20/20 in foot units),
- The viewing distance and its unit (metric or imperial),
- The luminance expressed in cd/m² and the contrast relative to the background expressed as a Weber fraction (%),
- The mirror and TV-Out modes,

- The chart type: multiple lines, single horizontal or vertical line, or single letter,

- The starting acuity at the top line or bottom line and the number of lines (0 if automatic selection),

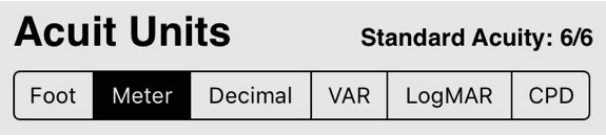
- The acuity scoring method (simple or ETDRS). Note that changing the method selection resets by default some other settings (For example selecting the ETDRS method resets the chart type to 'Multiple Lines' and the termination criterion to 3 incorrect letters),

- The termination criterion for the selected method (1 letter, 3 letters or an entire line incorrect for the ETDRS method for example),

- The optotype appearance: black letters on white background or white letters on black background, the number of orientations (only applies to Landolt C and Tumbling E optotypes), the presence and type of confusion bars (none, bars or frame type).

The large green button allows the creation of a new configuration based on the current selected settings. Multiple configurations can be created to enhance your practice and best match your patients' needs.

Acuity Units



Visual Acuity XL can measure and report visual acuity in various standard units, either as Snellen fractions in foot, meter or decimal units, as logarithmic scales in logMAR or VAR units, or as resolution in cycle per degree (CPD):

- Foot units are used in the US: visual acuity is expressed as Snellen fractions in foot relative to 20/20, the standard definition of "normal" visual acuity, that is the ability to resolve a spatial pattern separated by a visual angle of one minute of arc. If you have a visual acuity of *20/x*, then if you stood 20 feet away from an object and the "normal" person stood *x* feet away, you would both see the same thing. If *x* is more than 20 feet, you have worse eyesight than normal, and if it is less than 20 feet, you have better than "normal" vision.

- Meter units are used in UK: visual acuity is expressed relative to 6/6 (meters), roughly equivalent to 20/20 (feet).

- Decimal units are used in France: acuity is defined as the reciprocal value of the size of the gap (measured in arc minutes) of the smallest Landolt C that can be

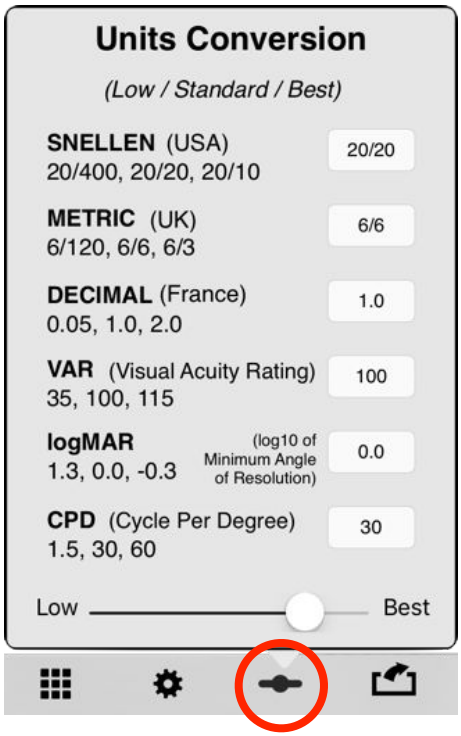
reliably identified. A value of 1.0 is equivalent to 20/20. Values lower than 1.0 mean worst acuity, and values higher than 1.0 mean better acuity than "normal".

- VAR (Visual Acuity Rating) units provide a more intuitive scoring: the VAR scale is similar to the logMAR scale, but represented as a percentage. A value of 100 is equivalent to 20/20. Values lower than 100 mean worst acuity, and values higher than 100 mean better acuity than "normal".

- LogMAR units are used in clinical research where acuity is expressed as the logarithm of the minimum angle of resolution. LogMAR scale converts the geometric sequence of a traditional chart to a linear scale. It measures visual acuity loss: positive values indicate vision loss, while negative values denote normal or better visual acuity. A value of 0.0 is equivalent to 20/20. Though this scale is rarely used clinically, it is more frequently used in statistical calculations because it provides a more scientific equivalent for the traditional clinical statement of "lines lost" or "lines gained", which is valid only when all steps between lines are equal, which is not usually the case.

- CPD (Cycle Per Degree) units express visual acuity in term of angular resolution. A value of 30 cpd corresponds to a resolution of 2 arc minutes per line pair (i.e. a 1 arc minute gap in an optotype) and is equivalent to 20/20. Values lower than 30 cpd mean worst acuity, and values higher than 30 cpd mean better acuity than "normal". The upper limit is directly related to the resolving power of the cone photoreceptors in the retina center (fovea) and by the imperfect optics of the eye: for a human eye with excellent acuity, the maximum theoretical resolution is 50 CPD (equivalent to 20/12).

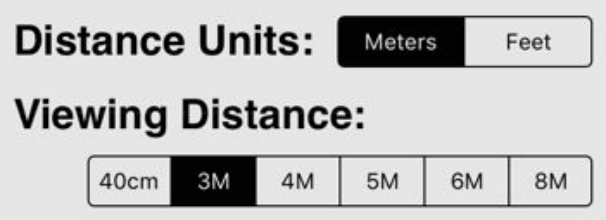
The selected acuity unit in the settings is used by default in all acuity tests. Note that a tool is available in the bottom bar to easily convert between the different visual acuity units (see button) as illustrated below:



➡ *As emphasized above it is important to note that despite being referred as the normal or standard visual acuity, 20/20 and its equivalents in other units do not indicate a perfect vision but should be thought of as the lower limit of the normal visual acuity, the maximum acuity of a healthy human eye being approximately 20/16 to 20/12.*

Viewing Distance

The viewing distance (from the patient eyes to the iPad display) can be expressed either in meter or foot units, and can set to some preset values (40 cm, 3, 4, 5, 6, 8 m or 16 in, 10, 13, 16, 20, 26 ft) under the chart panel or using the remote. The last set value is used every time the application is launched and is displayed in the settings if not a preset value. The viewing distance can be also set to any other value using the bottom slider or by taping on the distance label and entering a new value (chart panel only).



Near visual acuity is typically measured at a viewing distance of 40 cm or 16", while ***far visual acuity*** is measured for much farther viewing distance, "close enough" to optical infinity, where there is no significant accommodation by the crystalline lens, typically at 6 m or 20 ft away. Note that without a lens correction, a myopic (nearsighted) person generally will have better visual acuity at near than at far, while a hyperopic (farsighted) person generally will have better acuity at far than at near. Until the early to mid-forties, a person with 20/20 distance acuity usually also has 20/20 acuity at near. However, once presbyopia sets in, one's uncorrected near visual acuity decreases, creating the need for reading glasses or bifocals.

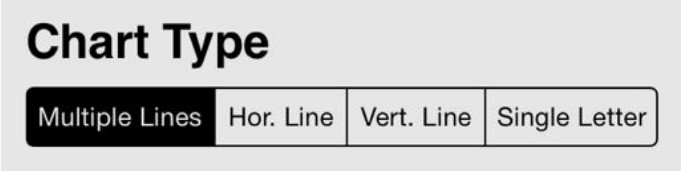
Note that because of the limited pixel resolution of their screen, the iPads WITHOUT a Retina Display are NOT more appropriate for measuring ***near visual acuity***. However there are appropriate for measuring ***far visual acuity*** at a minimum viewing distance of 1.35 meters (53" or 4ft 5"). For measuring ***near visual acuity*** at a typical viewing distance of 40 cm or 16" we recommend using instead an iPad mini with a Retina Display (see the **Adequacy of the iPad** section in the Support chapter).

> ➡ *It is important to select the most appropriate viewing distance and it is even more critical to ensure that the patient is located at the specified distance from the iPad display since the precision of the acuity measurement depends on it.*

Measurement Protocol

Visual Acuity XL offers several protocols based on a combination of chart types, acuity scoring, and termination criterion. Are available:

- 4 types of charts:



- Multiple lines: multiple lines of optotypes are presented according to the logMAR design (which specifies the spacing between optotypes and between lines, typically the size of a single optotype),
- Single horizontal line: a single line of optotypes is presented horizontally with up to 5 optotypes (with a spacing corresponding to the size of a single optotype),
- Single vertical line: a single line of optotypes is presented vertically with up to 5 optotypes (with a spacing corresponding to the size of a single optotype),
- Single letters: a single optotype is presented in the center of the display,

- 2 acuity scoring methods:

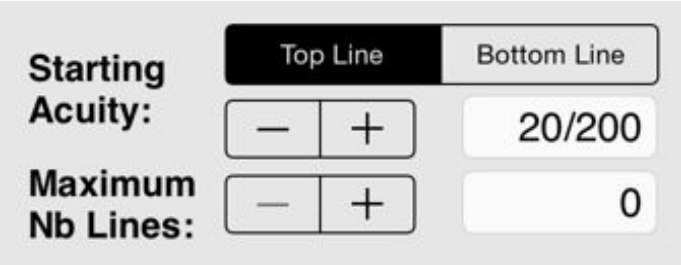
- Simple: the easy and fast way to measure visual acuity though less precise,
- ETDRS: the standard way to measure visual acuity in clinical environment,

- 3 termination criteria based on incorrectness:

- 1 letter: the test stops after 1 incorrect letter,
- 3 letters: the test stops after 3 incorrect letters on the same line (this is the default termination criterion for the ETDRS scoring),
- 1 line: the test stops after a whole incorrect line.

❖ **The protocol defined in the settings is only followed when running a session through the remote mode. The protocol is otherwise considered as 'manual' as the progress across the chart is under the control of the experimenter through the touch screen interactions and the measurement determined by the line taped by the experimenter which should correspond to the smallest line the patient can fully read.**

Note that for multiple lines chart type only, the starting visual acuity can be specified either for the top line or bottom line of the chart as well as the number of lines by pressing the +/– stepper buttons (0 line meaning automatically selected):

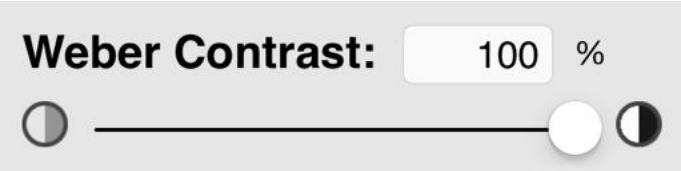


Luminance Level

The luminance of the bright portion of the charts can be specified in cd/m² and should always be set to an appropriate level: the *International Council of Ophthalmology* and the *American National Standards Institute for ETDRS* recommend a **minimum luminance of 85 cd/m²**. Note that it is also important to make sure that the "Auto-Brightness" option is turned off in the "Brightness & Wallpaper" section of the "Settings" app (see the Configuration and Adequacy sections).

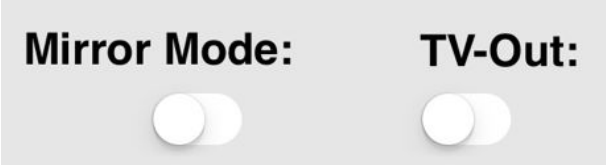
❖ **Note that the specified luminance is only an approximation based on the light emitted by an iPad without a screen protector. Slight variations are normal between different iPads of the same model. Since different iPad models may have different display technologies, the app uses your iPad model to determine the maximum luminance available based on Apple official specifications.**

Contrast Level



The contrast of the optotypes relative to the background luminance can be expressed as a Weber fraction between 0.5 and 100%. Like luminance, contrast is known to significantly affect visual acuity in an age-dependent manner (explaining for example why the need of older people for increased lighting during indoor tasks and night driving).

Miscellaneous Options



- Mirror Mode: the mirror mode involves the use of a mirror to increase the viewing distance which would be otherwise limited by the depth of your testing room. In this mode the presented optotypes are mirror-inverted so they appear normally presented to the patient when viewing through the mirror.

  ❖ **It is important to note that the specified distance should be the 'virtual' viewing distance between the patient and the display, that is twice the physical distance between the patient and the mirror!**

- TV-Out Mode: the TV-Out mode implies the use of an external monitor instead of the iPad display to present the charts to the patient. This may be necessary when the iPad display is too small relative to the available viewing distance (for example when using the mirror mode as described above). TV-Out is supported by all iPad devices by using either:

  - *Video Mirroring* where your iPad is directly connected to a TV, monitor, projector, or LCD display through the **Apple VGA or Digital AV Adapter** (see Apple support note: "iOS: About Apple AV Adapter compatibility"),

  - *AirPlay Mirroring* where your iPad is connected wirelessly to an Apple TV on the same Wi-Fi network (see Apple support note: "Apple TV: How to use AirPlay Mirroring") or an Airplay-enabled Macintosh or PC computer (using for example the 3rd party AirServer software).

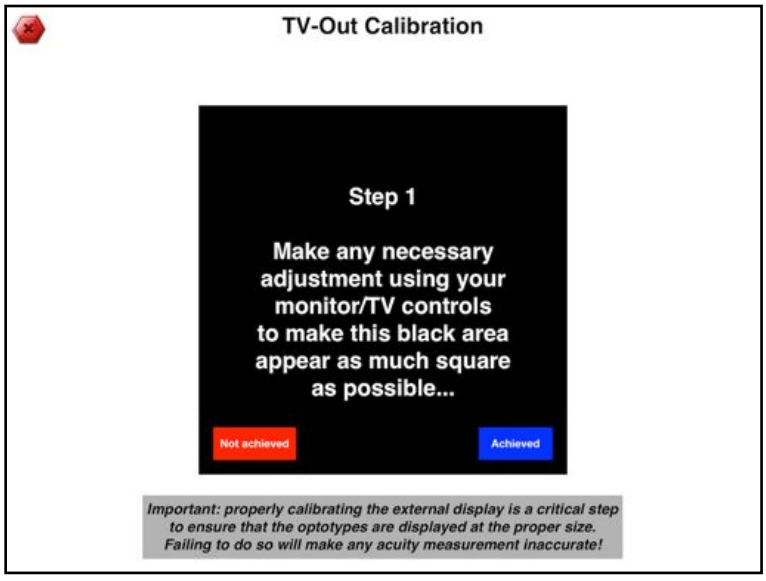
Note that *AirPlay Mirroring* to Apple TV (2nd and 3rd generation) is limited to the 720p resolution (1280 x 720). For help about Airplay Mirroring through an Apple TV see the following Apple article: Troubleshooting AirPlay and AirPlay Mirroring. For step-by-step instructions, see the **Airplay Mirroring Setup** section in the Support chapter.

❖ **Although the charts are presented on the external monitor, they are also presented on the iPad but at a scale that is not related to the viewing distance between the patient and the external monitor. Make sure the patient only look at the external monitor!**

It is important to note that when using TV-Out, it is mandatory to perform a calibration of the external monitor by ensuring that the pixels have a square aspect-ratio and by measuring the diagonal size of the chart area. This is a critical step to ensure that the optotypes are displayed with the correct size. Failing to properly calibrate the external display will make any acuity measurement inaccurate! The calibration panel is available from the button in the bottom toolbar (greyed out if the "TV-Out" option is turned off) or is automatically displayed when connecting an external monitor:

- In the 1st step you are asked to make any necessary adjustment using the monitor/TV controls so the presented black area appear as much square as possible.

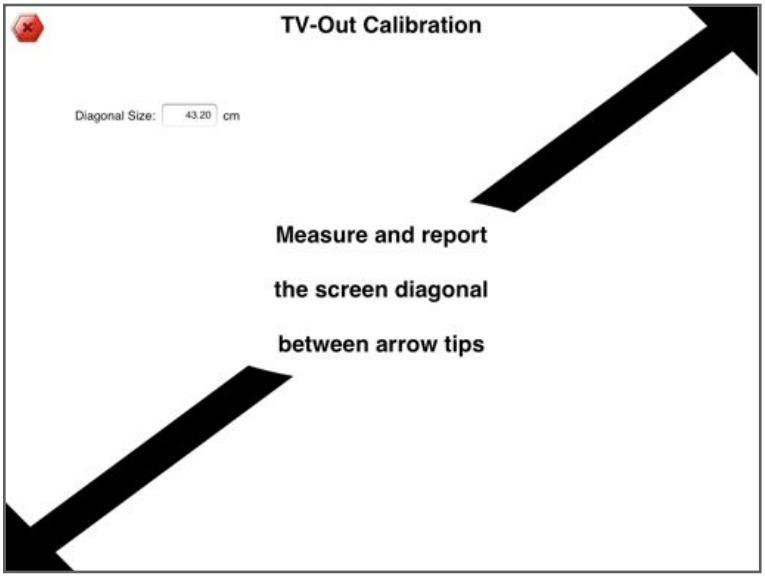
➡ *The squareness of the display pixels is critical to ensure precise measurements of the visual acuity.*



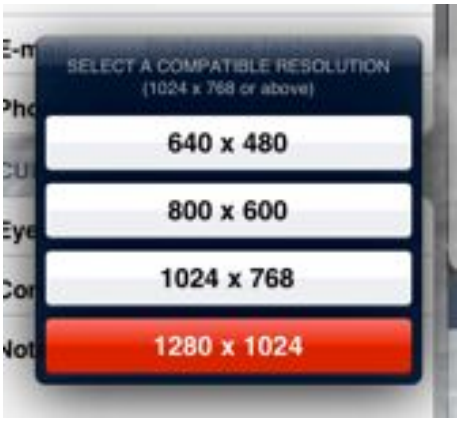
- The 2nd step consists in reporting the diagonal size in the same unit as

the distance unit specified in the settings.

➡ *Similar to the viewing distance, the accuracy of the diagonal size is critical to ensure precise measurements of the visual acuity.*



If the TV-Out mode is enabled and an external monitor gets connected to the iPad while the Visual Acuity app is running, you are presented with the list of available resolutions for this monitor (the current one is highlighted in red) and asked to select a resolution compatible with the iPad display (1024 x 768, 720p or better):



❖ **Do not try to adjust the monitor or TV settings so the iPad content completely fills the external screen (through overscan for example). This would affect the aspect ratio of the pixels and make the visual acuity measurements less precise. Stick instead to a 4:3 aspect ratio setting if available.**

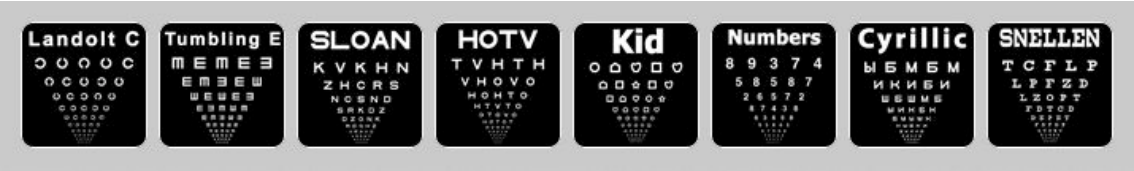
Various warning messages may be displayed when dealing with TV-Out:

- if the iPad is connected to an external monitor while “TV-Out” is turned off, you will be asked whether to turn it on;

- if “TV-Out” is turned on with no external monitor connected, you will be asked to connect it before being able to perform a calibration or present a chart;

- if “TV-Out” is turned off while an external monitor is connected, you will be asked to disconnect it before being able to present a chart.

Available Optotypes



Visual Acuity XL provides the most standard optotypes to test visual acuity in literate and illiterate people as well as preschool children, including the Landolt C and Tumbling E symbols considered as the reference optotypes by the *International Council of Ophthalmology* in its ***Visual Acuity Measurement Standard***. The standard optotypes have been specifically designed to appear equally recognizable contrarily to those used in the Snellen chart. The available optotypes are represented as large icons in the bottom half of the main panel and are from left to right:

Landolt 'C'

The Landolt ‘C’ optotype is a broken ring symbol that has only one element of detail, the gap, which varies only in its orientation. This gap subtends 5 minutes of arc in the 20/20 optotype and has an opening (oriented in the top, bottom, right or left) measuring 1 minute of arc. Edmund Landolt proposed the Landolt C in 1888 based on the fact that not all of Snellen's optotypes were equally recognizable. In its *Visual Acuity Measurement Standard*, the *International Council of Ophthalmology* considers the Landolt C the purest research standard and requires all other research approaches to be calibrated against the Landolt C. It is the recommended reference optotype for testing visual acuity, and the preferred visual acuity measurement symbol for laboratory experiments but gained only limited acceptance in clinical use.

Tumbling 'E'

The Tumbling ‘E’ optotype follows the same design principles as the Landolt C, but uses a stylized letter E instead. Charts based on this single optotype in various orientations were created by Hugh Taylor in 1976 to test visual acuity of Australian Aborigines. The use of the Tumbling 'E' has become standard for testing of illiterates and populations not familiar with the Roman alphabet or too young to read letters since, like for the Landolt 'C' , they simply need to indicate the orientation of the symbols. Note, however, that this optotype contains 3 times more information about its orientation than the Landolt 'C'.

Sloan optotypes

The Sloan optotype set consists in 10 letters (C, D, H, K, N, O, R, S, V and Z) specifically designed by Louise Sloan in 1959 in order to avoid the problem that not all letters are equally recognizable in the Snellen chart. The Sloan chart were also specifically designed to follow a geometric progression of letter sizes forming the basis of the logMAR design.

HOTV optotypes

The HOVT optotype set consists in only 4 letters (H, O, T and V) which are more appropriate for testing visual acuity in preschool children under 5-6 years old. These optotypes are also assumed to be equally recognizable and maximally distinguishable. A child should be first taught the four symbols and then tested against the HOTV chart.

Kid optotypes

The Kid optotype set consists in outlines of 6 figures (apple, house, circle, square, heart and star). It is adapted from the LEA™ Symbol and Patti Pics™ charts used to measure visual acuity in preschool children too young to perform the HOTV test. The “Kid” chart follows the same logMAR design as the other charts.

Numbers optotypes

The Number optotype set consists in 8 digits (2, 3, 4, 5, 6, 7, 8, 9) found in the "Feinbloom Number Chart" designed by Dr. William Feinbloom in 1935 to test people with low vision. The “Numbers” chart follows the same logMAR design as the other charts.

Cyrillic optotypes

The Cyrillic optotype set consists in the 7 Cyrillic letters (Ш, Б, М, Н, К, Ы, И) found in the Golovin—Sivtsev table developed by Soviet ophthalmologists S. Golovin and D.A. Sivtsev in 1923. It is still used in some post-Soviet states. The “Cyrillic” chart follows the same logMAR design as the other charts.

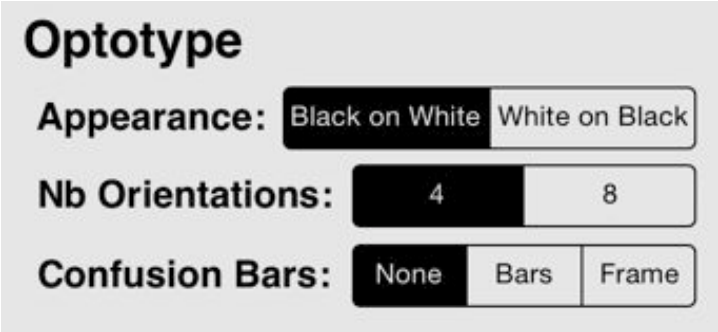
Snellen optotypes

The Snellen optotype set uses the 9 letters (C, D, E, F, L, O, P, T, Z) found in the original Snellen chart. However it is adapted to the same logMAR design as the other charts (i.e. follows a geometric progression of letter sizes and proportional spacing between letters).

> ➡ *It is important to select the most appropriate optotype set based on the patient abilities. The Landolt 'C' and Tumbling 'E' optotypes only require the patients to indicate their orientations while all other optotypes need to be identified. Using the remote control may greatly facilitate the acquisition of the patient’s responses.*

Optotype settings

The optotypes presentation can be customized in the settings section:



- Appearance: the optotypes can be displayed either as black letters on white background or white letters on black background. If there is no counter-indication, acuity testing should be performed preferentially with black letters on white background,

- Orientations: Landolt C and Tumbling E optotypes have always their orientation randomized among 4 (C & E) or 8 directions (C only). The use of 8 orientations for the Landolt C can improve the reliability of the acuity measurement,

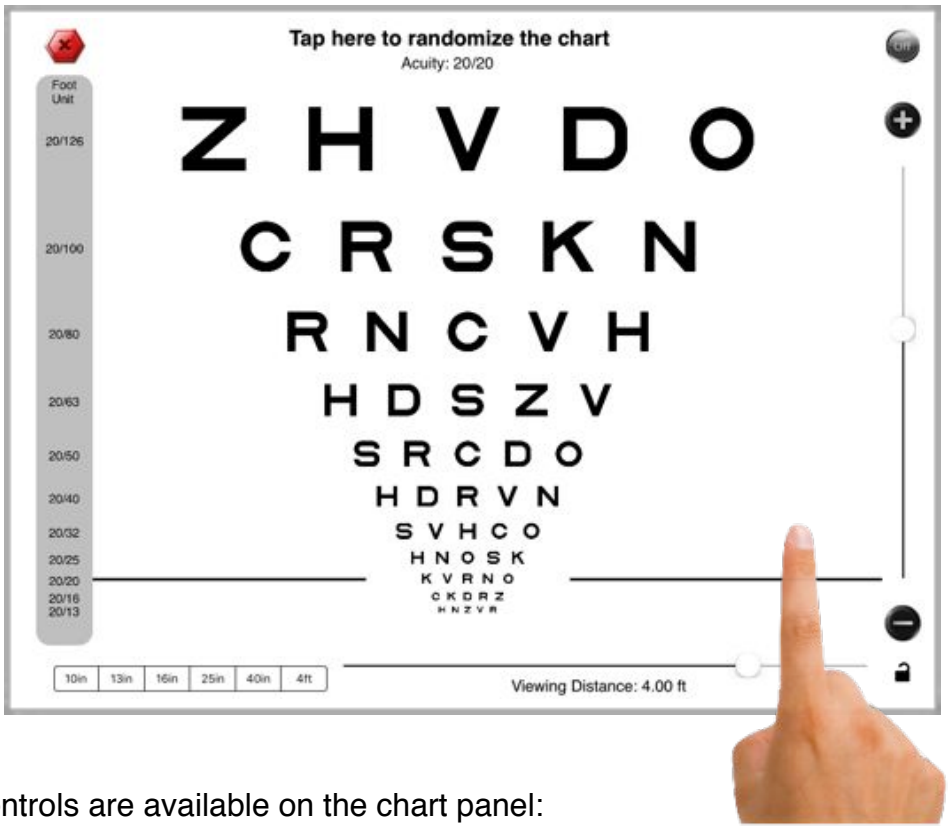
- Confusion Bars: the optotypes can be surrounded to investigate the crowding effect (interaction between target in its surround) which is particularly important in Amblyopia. The surround can be either bars or a frame, and applies on the single letter, whole line or entire chart depending on the chart type, with a spacing corresponding to half the size of a single optotype.

❖ **Tap the icon corresponding to the desired optotypes to switch to the chart panel and start the testing!**

Measuring Visual Acuity

Chart Panel

After starting the acuity test, you are presented with the chart panel that displays optotypes to be discriminated by the patients, similar to the one shown below. The top or bottom line are displayed at the starting acuity size specified in the settings.



Several controls are available on the chart panel:

The label above the chart to generate a whole new chart each time one taps it.

Stop the session and return to the previous panel (no data is saved),

Hide the controls on the iPad display,

Generate a new chart with optotype size decreased or increased by 0.1 log unit. Use the slider between these two buttons to set the size of the top line to any valid value (displayed in red above the chart).

Lock and unlock the chart generation: once locked the same chart (i.e. composed of the same sequence of optotypes) is presented each time a test is run.

The acuity bar on the left side indicates the acuity value for each line of a multiple line chart. This bar is updated each time the chart is changed. This bar can be shown or hidden by taping on it.

Set the viewing distance to one of the preset distances. Use the slider on its right to set the viewing distance to any value up to 8 meters (26 ft).

Tap the “Viewing Distance” label to enter a specific value. The chart is then automatically scaled to maintain the acuity level.

The split horizontal line on the left and right sides of a multiple lines chart points to the current line the patient is asked to read. When interacting directly with the touch screen, the experimenter can drag up or down this line. On its release the test is stopped and the experimenter is asked whether to save the acuity score associated with this line.

❖ **Make sure to properly configure your iPad and remote device before running a session in terms of power, settings, brightness, and orientation (see the chapter Configuring your iPad & iPhone/iPod touch).**

Procedures

The general procedures for assessing visual acuity follow these basic steps (though methods may vary from practice to practice):

1. Position the patient at the appropriate distance,
2. Cover the eye not being evaluated (starting with the worst of the two eyes if known),
3. Ask the patient to read the optotypes from left to right starting with the top line,
4. Decrease the size of the optotype until the patient is unable to read or misses some of the characters on any one line,
5. Note the last line successfully read and record the incorrect result,
6. Repeat the above procedure for the fellow eye, then for both eyes together with and without corrective lenses.

The computerized solution provided by **Visual Acuity XL** for the iPad supports two ways to enter/validate the patient responses:

- ***Manual mode*** where the experimenter interacts directly with the iPad through touch screen interactions,
- ***Remote mode*** where the experimenter or the patient interacts remotely with the iPad through another iOS device running the free **Visual Acuity Remote** app which acts as a remote control.

- **Not all protocols are supported by these 2 modes: only the chart type is considered in the manual mode, and the remote mode should be used instead to fully take advantage of the acuity scoring and termination criterion options.**

Manual Mode

In the manual mode the experimenter interacts directly with the iPad through touch screen interactions. Follow these steps to run a test in manual mode:

1. Configure your test in the settings section (units, optotype appearance, protocol),

2. Create or select the patient and customize the session (tested eye, correction, notes) in the "Current Session" section of the subject panel,

3. Tap one of the optotype icons to switch to the chart panel,

4. Set precisely the viewing distance using the bottom slider or using one of the preset values,

5. Adjust the vertical slider on the right to select a range of letter sizes that can be easily seen by the patient (for a multiple lines chart, this would be a range for which the subject can easily identify all letters in the first line but fails for the last one). This step can be skipped by starting with the default initial acuity level (20/200),

6. Ask the patient to read the optotypes from left to right starting with the top line,

7. If the subject can correctly identify all letters on that line, then ask the subject to read the next smaller line, and so on until the subject fails at least once. If the last line is reached without error, then press the '–' button to generate a new chart with smaller letters and repeat this step until the subject fails at least once. If the subject fails on the first line, press the '+' button to generate a new chart with larger letters and repeat this step.

8. Once an error occurs, tap and release the smallest line the patient can successfully read, i.e. whose letters were all correctly identified (the acuity estimate is then displayed above the chart) to save the corresponding acuity score (referred here as the simple scoring method),

9. Abort a test at any time by taping the button  in the top left corner of the chart panel.

❖ **If the patient shows some difficulty to locate the line to read, then the experimenter can activate a line indicator by touching on the side of the line as show below (this indicator is always shown when the remote is used):**

Maintain and drag the touch up or down to shift the indication bar, and release the touch outside the chart area to hide the line indicator.

Remote Mode

The remote mode requires another iOS device (iPad, iPhone or iPod touch) and the free companion app **Visual Acuity Remote** that transforms this device into a remote control for the acuity testing running on the iPad. You can then use this remote control to provide the patient responses or self-administer the test a distance away from the iPad. To learn more about the capabilities of the remote control see the **Visual Acuity Remote** chapter in this user guide.

Note that in remote mode, all the controls are hidden and disabled by default because they are either unnecessary or available from the remote. However they can be activated on demand.

Two roles are available when using the remote:

- The experimenter role where the remote can be used to browse across the chart similarly to the manual mode described above or to validate the subject responses and follow the specified protocol (i.e. the correct responses are available to the experimenter on the remote device). With this role, the test is user-terminated or self-terminating,

- The patient role where the remote is only used to indicate the patient responses using touchable icons representing the possible choices. With this mode, the test is self-terminating following the specified protocol: the test continues until the patient cannot reliably indicate the letter orientation or identify the letter, and stops automatically once the termination criterion is reached.

Follow these steps to run a test in remote mode with the Experimenter role:

1. Configure your test in the settings section (units, optotype appearance, protocol),

2. Create or select the patient and customize the session (tested eye, correction, notes) in the "Current Session" section of the subject panel (tested eye and correction can also be set through the remote),

3. Tap the button on both iPad and remote control to establish a Bluetooth or WiFi connection between the 2 devices,

4. Select the Experimenter role on the remote control,

5. Using the remote, set the tested eye and whether it is corrected if not already done from the iPad in step 2. Set the viewing distance as well,

6. Select the optotype set to switch the iPad to the chart panel and start the measurement session,

7. Use the remote to browse across the chart or validate the subject responses,

8. The test will normally self-terminate based on the termination criterion selected in the iPad settings and the acuity score will be saved to the iPad database,

9. Abort the test at any time by taping the button and optionally save the current score to the iPad database.

Follow these steps to run a test in remote mode with the Patient role:

1. Change the user role to Patient on the remote control,

2. Tap the "Start" button to switch the iPad to the chart panel and start the measurement session,

3. Use the remote to enter the patient responses,

4. The test will automatically stop when the termination criterion is reached and the acuity score will be saved to the iPad database,

5. Abort the test at any time by taping the button (no score will be saved).

❖ **The test should be first initialized with the Experimenter role to establish the connection, specify the optotype set or customize the session options. The Patient role can then be used until the optotype set or some options need to be changed.**

Scoring Methods

The procedure for measuring visual acuity consist in presenting optotypes of decreasing size until the subject is unable to discriminate between them. The scoring method is determined by the termination criterion, and the same scoring method can be applied irrespective of the chart type (multiple lines, single line and single letter).

The simple method provides an easy and fast way to measure visual acuity though less precise. The simple scoring method is the one used in the manual mode: the acuity score is the acuity level of the smallest line that can be read without any error. The advantages of this method are its simplicity and speed. However it has the main disadvantage to be prone to inaccuracy if the patient's responses are unreliable due to other factors than their limited acuity (for example due to communication errors or limited recognition and interpretation skills), and can lead to erroneously low estimates of visual acuity.

The **ETDRS** scoring method (developed in the context of "Early Treatment for Diabetic Retinopathy Study") provides a simple solution to this problem, and is the standard way to measure visual acuity in clinical environment: the termination criterion is based on several incorrect responses on the same line (typically 3 incorrect letters) rather than a single one to ensure that the subject has indeed reached their acuity limit. Moreover, the ETDRS method takes the contribution of each failed letter into account when calculating the acuity scoring (in a logMAR design with 5 letters per line and with a difference of 0.1 logMAR units between successive lines, each letter contributes for 0.1/5 = 0.02 logMAR units).

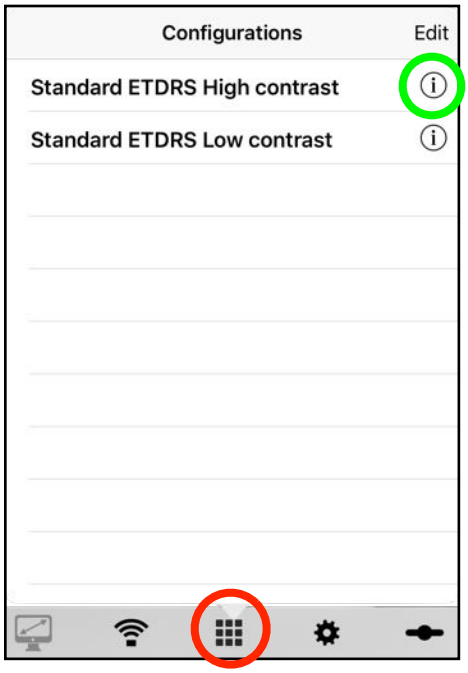
Based on the selected termination criterion, either scoring methods can be used in the remote mode. Note that since a computerized acuity test has the ability to randomly generate a new chart, retesting the same line with different optotypes could be a more efficient way to ensure that the subject error does not result from a false alarm: thus the reliability of the simple scoring method can be easily improved by retesting the erroneous line with a new set of optotypes (tap the label above the chart to generate a new random one) before deciding to terminate the test.

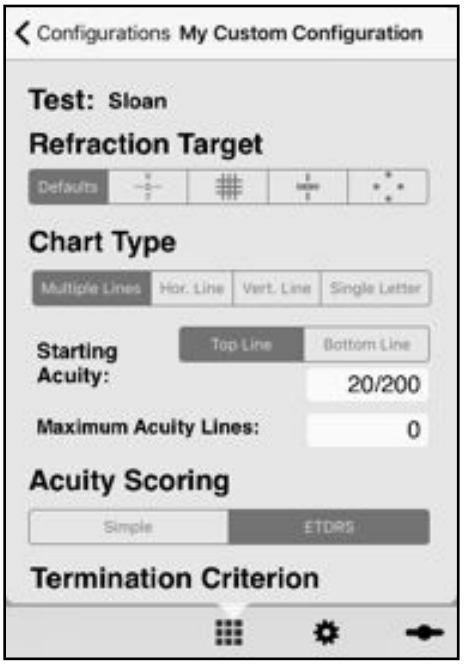
Creating Configurations

When running multiple charts with the same patient or different charts for different patients, specifying manually each chart settings can become cumbersome and prone to errors. To simplify this process, configurations can be created in advance using the button entitled "Creating New Configuration" in the Settings section ⚙:

Taping this button create a new configuration, based on the current settings, which can be named and associated with one of the available acuity tests.

The created configurations can be managed by taping the button ⠿ in the bottom toolbar. Taping one of the configuration will run the associated test whose settings can be inspected by taping the ⓘ button:





Managing the Subjects

The top part of the main panel is updated with the currently selected patient or group specific information, whose name is always indicated in the title of the top toolbar.
The patient or group information includes:

- Some personal information (gender, age, eye condition, e-mail and phone number),
- The eye prescription (for glasses and/or contact lenses),
- The history of acuity measurements,
- The settings for the current session (tested eye, correction, notes).

Patients List

The patients list is available in the left section in portrait mode, and is available through a popover window in landscape mode by taping the "Patients" button in the top toolbar. New subjects can be added by taping the '+' button in the Patients section and entering their name. Tap the 'Edit' button to remove, rename, or reorder a patient. Then tap the "Done" button to validate these changes. Note that the list is displayed in alphabetical order by default and a search field is also included. If you are not interested to keep a list of patients, you may simply add a group name instead.

Personal Information

The personal information consists of:

- The patient gender,
- The patient age,
- The patient eye condition (several common conditions are available),
- The patient email and phone number.

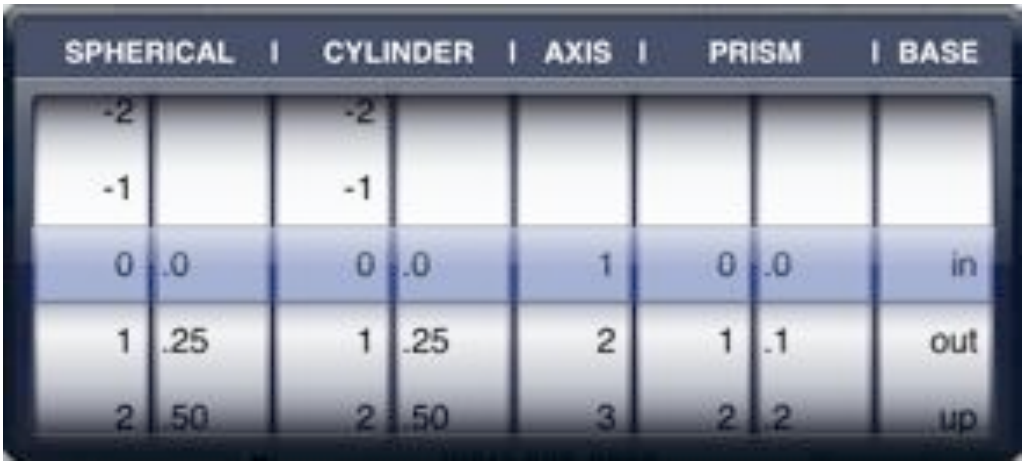
All this information is mandatory. The personal information is locked by default. To unlock them, tap the locker icon.

Eye Prescription

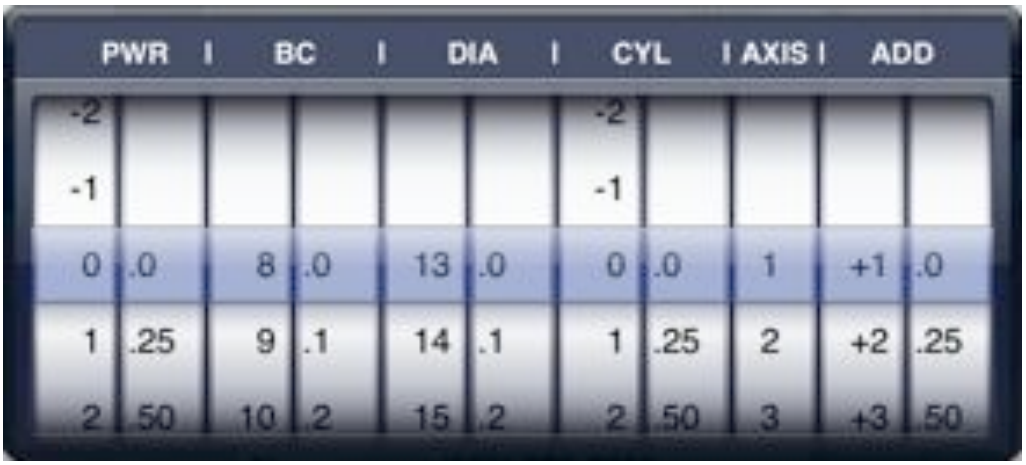
If known, the eye prescription can be entered for either glasses or contact lenses. For eyeglass prescription, both distance and near vision prescriptions can be provided. The prescription format includes all standard parameters found in the prescription provided by an eyewear prescriber, such as an optometrist or ophthalmologist.

The prescription information can be entered either using the numerical keyboard by taping individually each data field or using a picker panel by taping the small “RIGHT EYE”/ ”LEFT EYE” buttons.

For an eyeglass prescription:



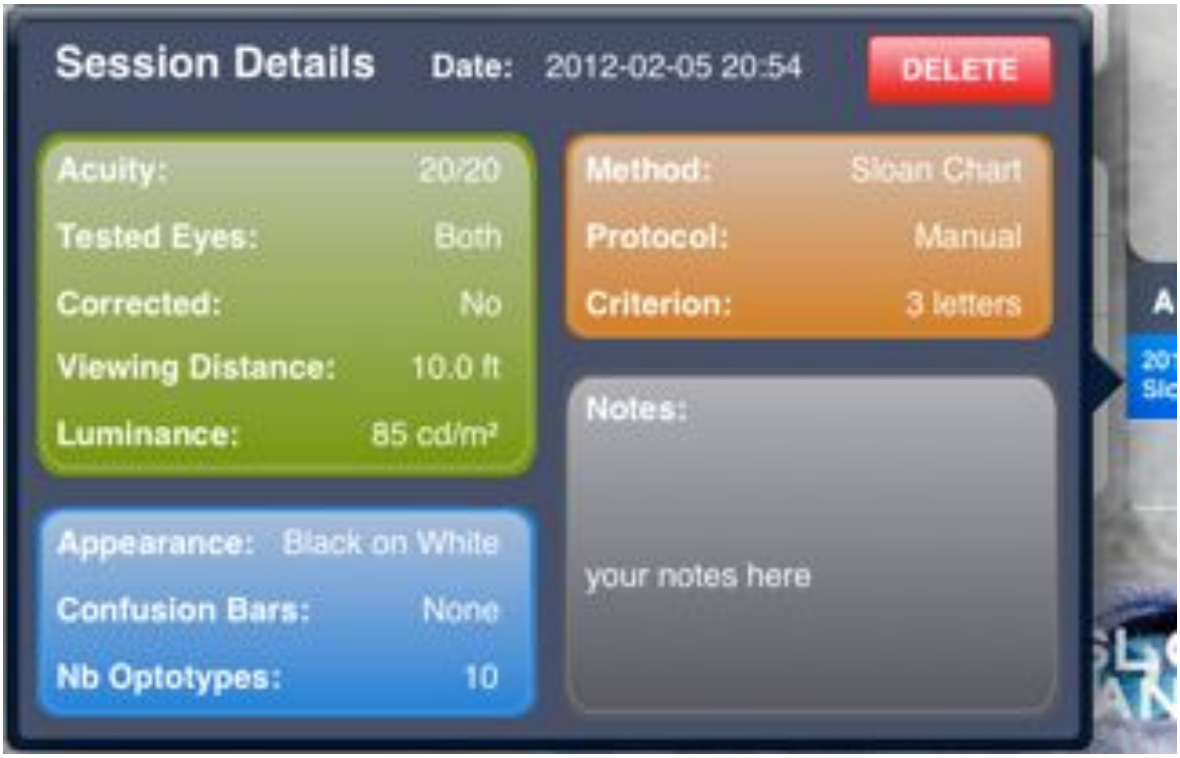
For a contact lens prescription:



Acuity History

Each new acuity measurement is added to the acuity history. The history can be expanded or collapsed by taping the '+' or '–' sign in the table header.

Tap any entry in this table to inspect the detail of the measurement. Tap the "Delete" button in the session details to delete this entry.

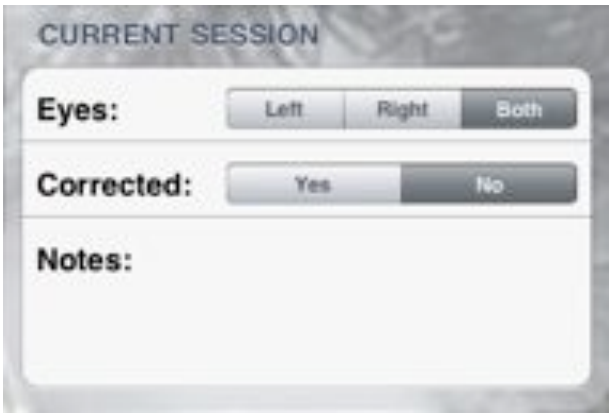


Session Information

Information for the current session consists of:

- The tested eye(s),

- Whether the eye(s) is corrected,
- Any other information that would be useful to note.

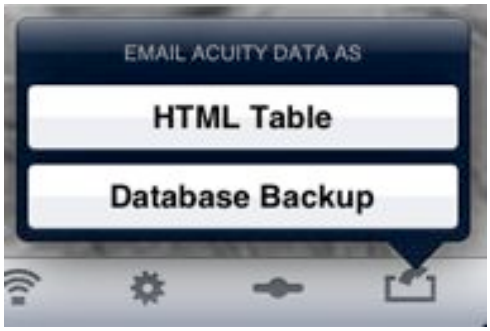


This information is recorded along with the acuity score measured for the current session so it is important to make sure it is correctly specified before running a session. This information can be retrieved through inspection of the measurement details in the acuity history. Note that the tested eyes and whether they are corrected can be also customized from the remote when using it as the experimenter.

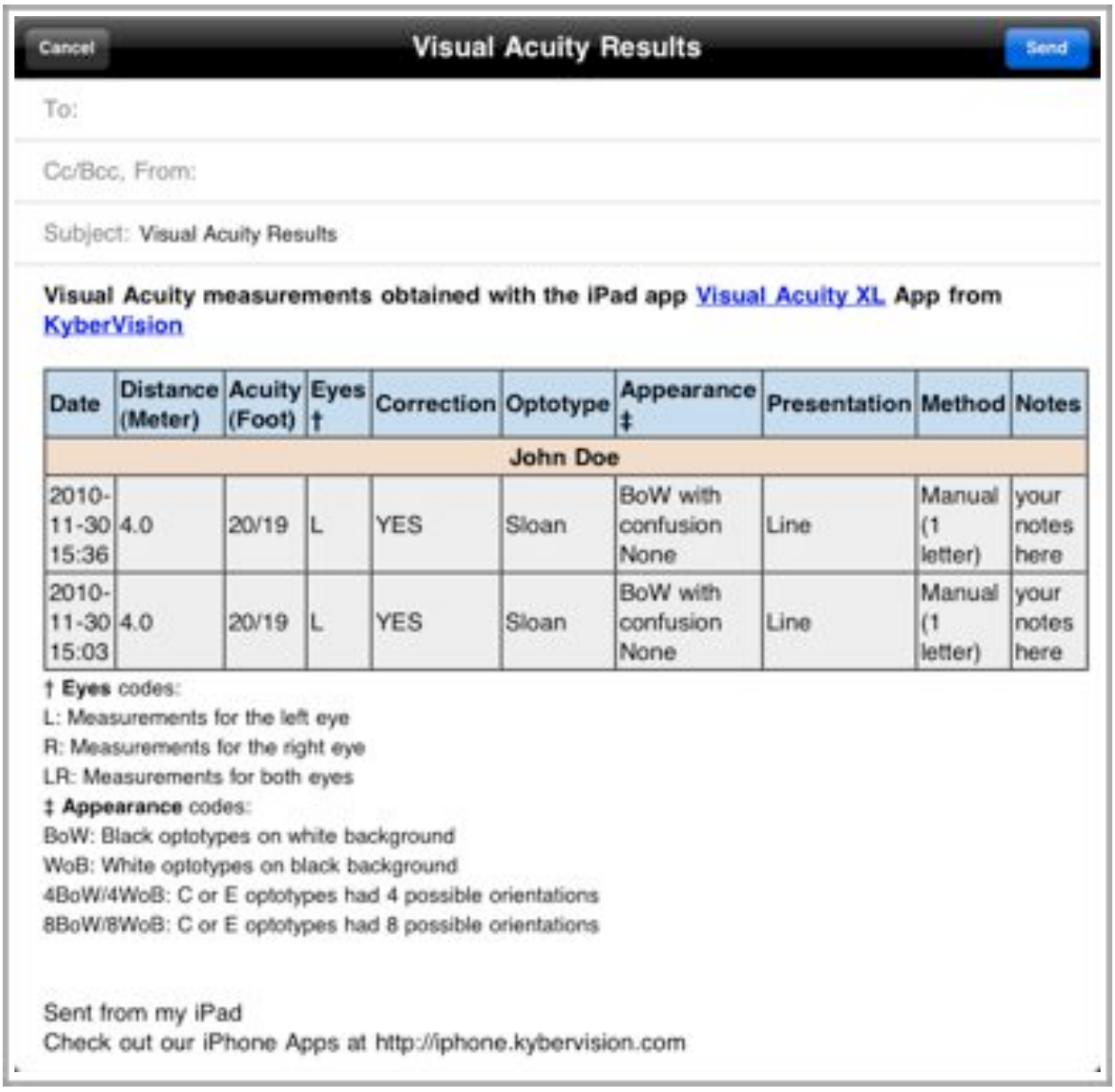
Exporting & Importing Acuity Data

The acuity history can be exported through email either as an HTML table or a database backup file:

When exporting as an HTML table, the acuity history can be emailed either for the currently selected patient or for all patients:



The selected acuity data is then presented and sent as an HTML table where each session is represented as a row where each column indicated a parameter value as shown below:



Cancel

Visual Acuity Results

Send

To:

Cc/Bcc, From:

Subject: Visual Acuity Results

Visual Acuity measurements obtained with the iPad app Visual Acuity XL App from KyberVision

Date	Distance (Meter)	Acuity (Foot)	Eyes †	Correction	Optotype	Appearance ‡	Presentation	Method	Notes
John Doe									
2010-11-30 15:36	4.0	20/19	L	YES	Sloan	BoW with confusion None	Line	Manual (1 letter)	your notes here
2010-11-30 15:03	4.0	20/19	L	YES	Sloan	BoW with confusion None	Line	Manual (1 letter)	your notes here

† **Eyes** codes:
L: Measurements for the left eye
R: Measurements for the right eye
LR: Measurements for both eyes
‡ **Appearance** codes:
BoW: Black optotypes on white background
WoB: White optotypes on black background
4BoW/4WoB: C or E optotypes had 4 possible orientations
8BoW/8WoB: C or E optotypes had 8 possible orientations

Sent from my iPad
Check out our iPhone Apps at http://iphone.kybervision.com

While you could use this feature to backup the acuity measurements, we recommend using the more powerful “Database Backup” option instead. With this option, the acuity data is attached to an email as a backup file with the date, time and originating device indicated in the subject line. The attached file has an “.vaxl” extension which indicates it has been created with the “Visual Acuity XL” app:

On reception of this email on a computer, you can save the attached file for archiving purpose. On reception of this email on another iPad, you can import the data back to “Visual Acuity XL” by taping the icon of the “vaxl” file and selecting the associated “Open” option:

When opening an “vaxl” file, the “Visual Acuity XL” app will launch and ask what to do with the data contained in the imported file. The available options are:

- “Overwrite” to replace the current data with the imported one (beware that the previous data will be lost so be careful!),

- “Append” to add the imported data to the current one (beware that patients with the same name may then appear in the patients list and may require that you manually “clean” this list),

- “Merge” to complete the current data with the imported one: patients with same name, gender and age (year and month) are merged so missing data like condition and contact information will be filled in and the respective acuity history be appended to the previous one if differing in the assessment date and time.

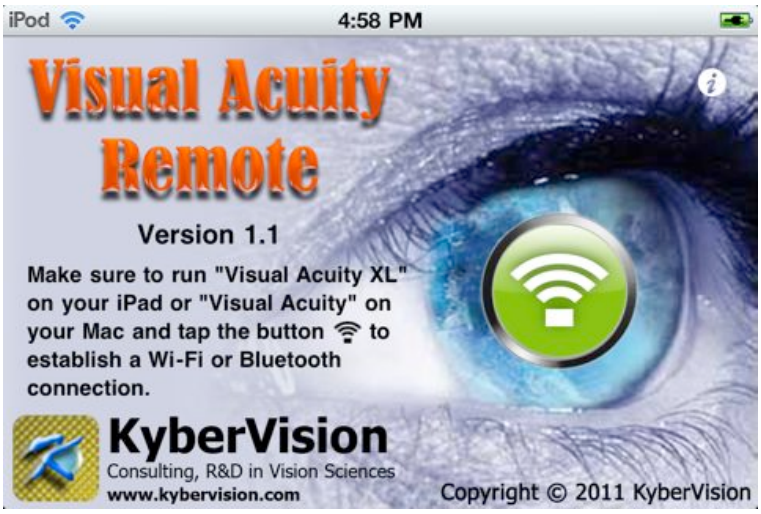
Visual Acuity Remote

The **Visual Acuity Remote** app runs on iPad, iPhone or iPod touch with Bluetooth or WiFi capabilities and it is used to remotely control the **Visual Acuity XL** app that runs on the iPad. Although the use of this app is optional, it provides a convenient access to the acuity test settings without having to physically access the iPad display. It also allows subject's responses to be entered while standing a distance away from the iPad or during self-administration of the test. Either the subject or the experimenter can use it.

Getting Started

Tap the "VARemote" icon on your other iOS device to start the remote app and follow these steps when using the remote (see also the Remote Mode section in the **Visual Acuity XL** chapter):

1. Establish a Bluetooth or WiFi connection between the device and the iPad,
2. Selecting the user role (experimenter or patient),
3. Start a test,
4. Run the test until it ends and save the score to the iPad, or abort the test,
5. Go to the step 2 to change the test or step 3 to start a new test.

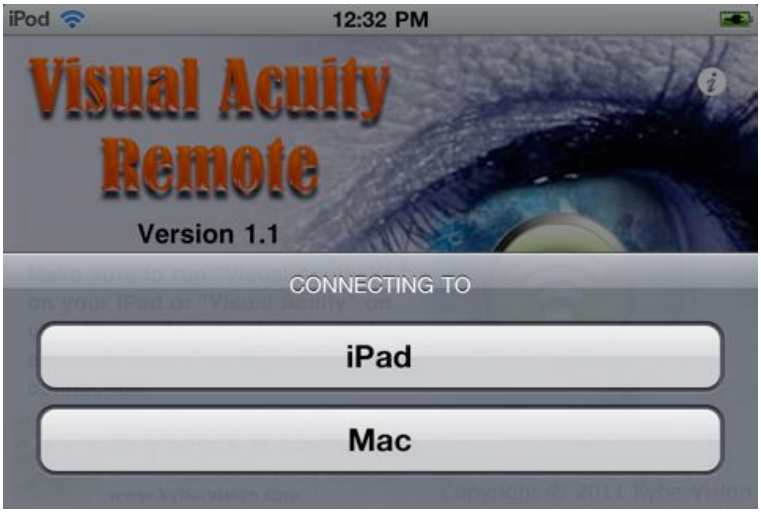


Establishing a connection between the remote control and the iPad

Here are the steps to follow to establish a working connection between the iOS device and the iPad:

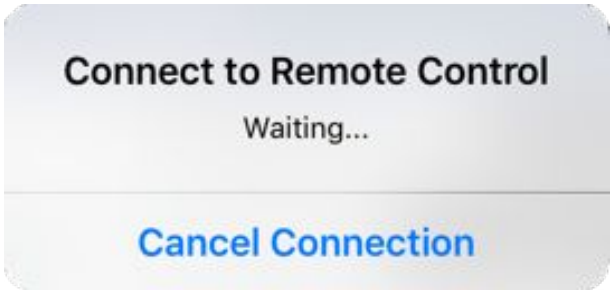
1. Make sure that both have Bluetooth enabled or are connected to the same WiFi network (to create a local WiFi network see the FAQ),

2. Tap the large green button on the iOS device and select the iPad option,

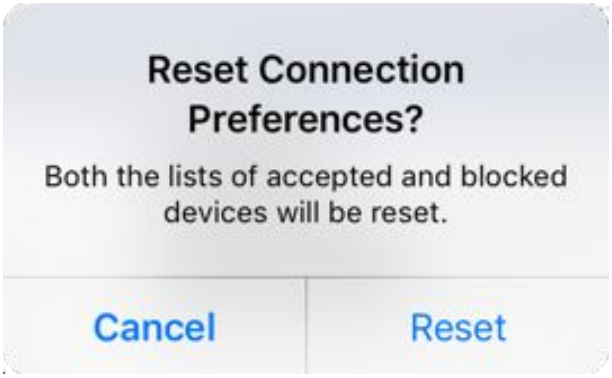


The iOS device will start looking for the iPad running the **Visual Acuity XL** app:

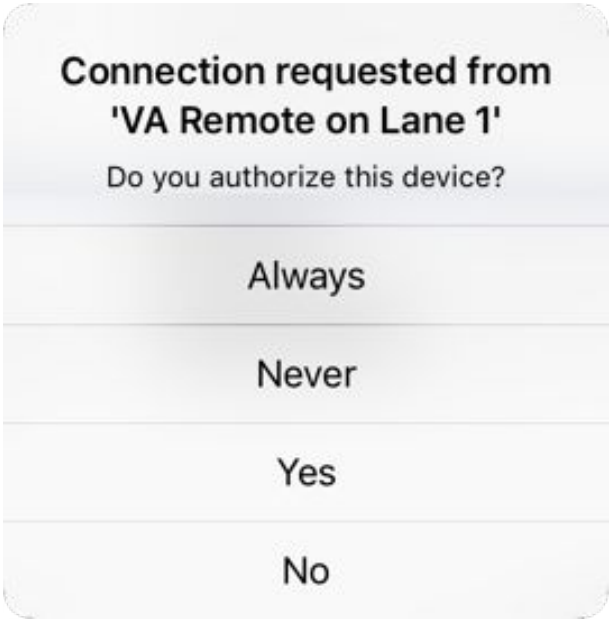
3. Launch the **Visual Acuity XL** app on the iPad if it does not run yet, and tap the connection button in the bottom toolbar to activate the remote capability. The iPad will start looking for an iOS device running the **VA Remote** app:



4. Once the **Visual Acuity XL** app detects a connecting device, it will ask whether to automatically connect to this device ("Always"), block it ("Never"), allow it ("Yes") or deny it for this session ("No"). This way it is possible to run multiple testing lanes in parallel by associating a remote device to each iPad running Visual Acuity XL. These connection preferences can be reset by simply pressing longer the connection button in the bottom toolbar.



❖ **Naming appropriately each remote device will help you remember the lane association (A device can be renamed from the Settings app in the 'General->About->Name' section).**



5. Once the 2 devices successfully connect after a few seconds, the following panel appears on the remote control screen and asks which role the user wants to act as. Tap the button that corresponds to the intended user role, experimenter or patient:

If establishing a connection takes too long, simply cancel the connecting process on both devices and repeat the process (Establishing a Bluetooth connection can be slow on the first attempt, however the subsequent connections should be much faster). If for some reasons, the communication between the devices stops working it is

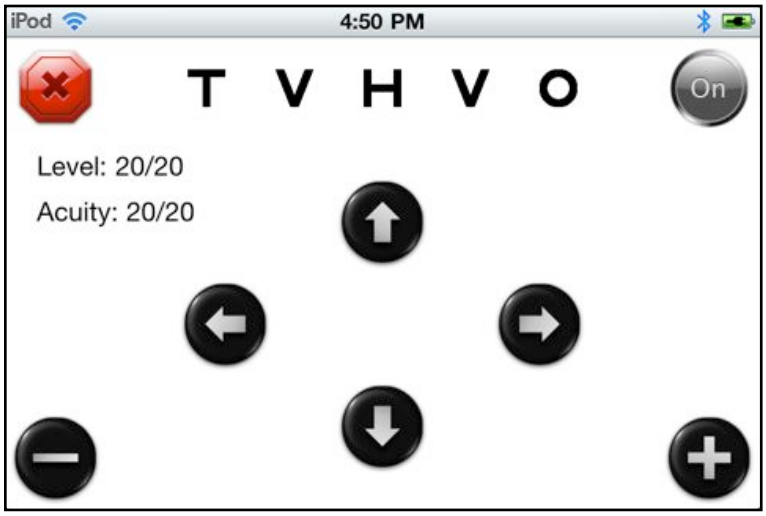
recommended to quit and relaunch both apps. Tap the “Done” button in the above panel or quitting the “VARemote” app to stop the connection (the iPad will automatically detect the disconnection). Note that since **Visual Acuity XL** supports multitasking under iOS 4.2, it is necessary to remove it from the list of background apps to actually quit it as illustrated below:

Playing the Experimenter role

In this mode, the Experimenter can manually browse through the chart lines presented on the iPad screen, have access to the acuity level and the currently presented optotypes, and validate the subject responses. The acuity score is automatically updated and is made available to the Experimenter who can decide to save or discard it. This mode is also useful for fast screening.

When selecting the Experimenter role, the user is presented with the above panel that provides control for the test settings: viewing distance (tap the viewing distance button to specify a value more precisely than the slider does), tested eye(s), whether the subject's vision is corrected, and the available optotype sets. The changes made through the remote are automatically synchronized with the iPad app. The user role can be changed by taping the red button to return to the previous panel.

Taping one of the optotypes starts a new measurement session on the iPad with the selected optotypes (note that the last selected optotypes become the default optotypes used in Subject mode, see Playing the Subject role below).



The above panel is then presented on the remote which provides the experimenter with the following controls and indications:

To stop the session and return to the previous panel,

To show and hide the controls on the iPad display,

To generate a new random chart with optotype size decreased or increased by 0.1 log unit,

To generate a new random chart with the same size,

To move the line indicator one line down or up in multiple lines charts. If the subject failed on the indicated line (e.g., 3 incorrect letters on the same line for the ETDRS method), the Experimenter is then presented with the option to save the score or continue (see below).

Level: <value> (<unit>) which indicates the acuity for the current line (the line pointed by the line indicator in multiple lines charts),

Acuity: <value> (<unit>) which indicates the current estimate of the subject acuity,

These optotypes displayed above the controls indicate the ones that the subject should recognize (i.e. those on the current line). Based on the subject response, the experimenter should tap each letter that is wrongly identified which is then shown in light grey. The acuity estimate is updated accordingly.

The Experimenter is presented with the option to save the score or continue after the subject fails a line: if saved, the score is recorded in the iPad database (see the Acuity History section). If not saved the test simply continues with the possibility to change the response for the last line.

If the test is interrupted by taping on the ‘Stop’ button, the user is asked whether to also save the current score or to abort only. If saved the score is recorded in the iPad database.

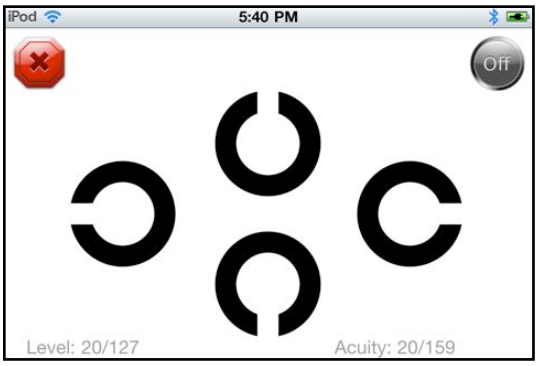
Playing the Subject role

The Subject mode should be used when the subject is allowed to directly enter their responses using the remote control device. Nevertheless, the Subject mode can also be used by the experimenter if the subject is unable to use the remote device or if the experimenter prefers to use this mode to enter the subject's responses himself. However, contrary to the Experimenter mode, the user cannot modify the test configuration in the Subject mode: these settings are shown but are locked (i.e. to modify them you need to return to the Experimenter mode).

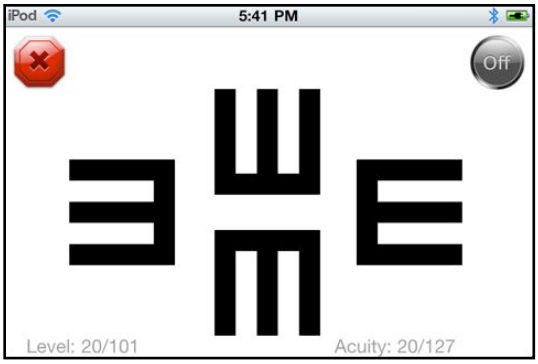
The optotypes set presented to the subject is specified above the "Start" button. These optotypes are those that have been last selected by the user in the Experimenter mode (see Playing the Experimenter role section). If none has been specified yet, then this is indicated and the "Start" button gets disabled as shown below:

To start the test, the subject should simply tap the "Start" button and enter their response for each letter of the presented line from left to right. The subject is presented with one of the following panels where each available optotype is represented by a large button:

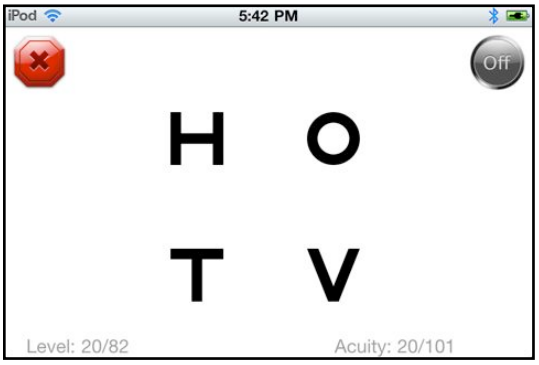
Landolt-C



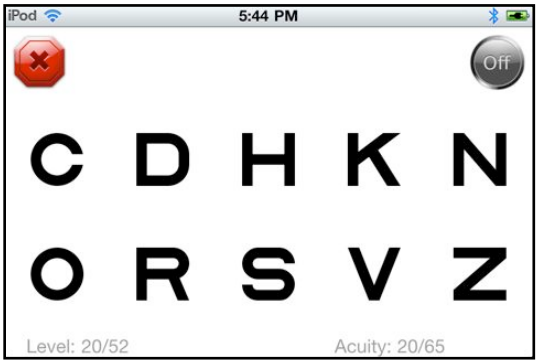
Tumbling ‘E’



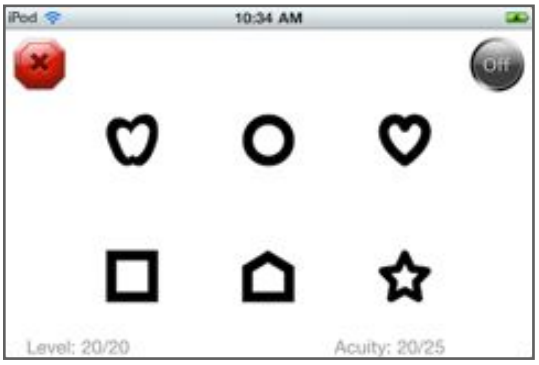
HOTV



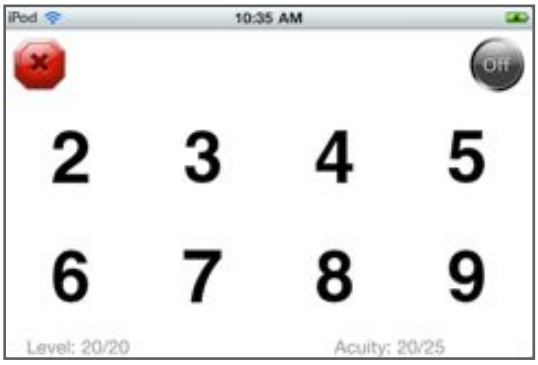
Sloan



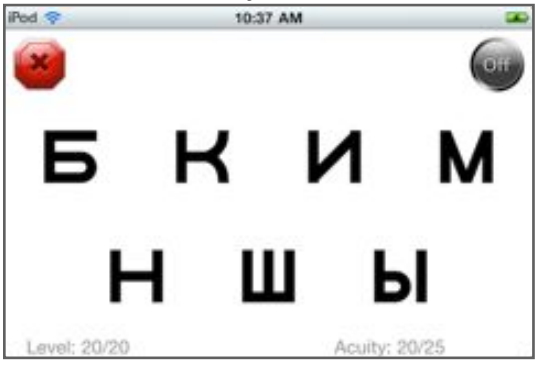
Kid



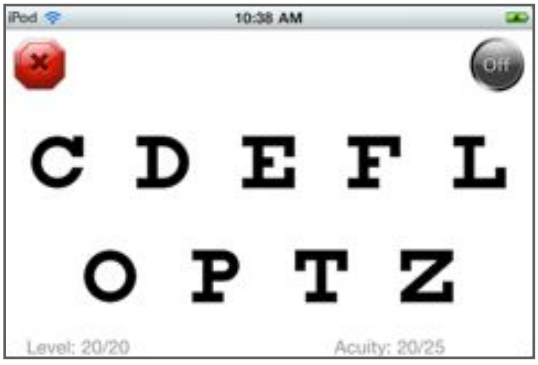
Numbers

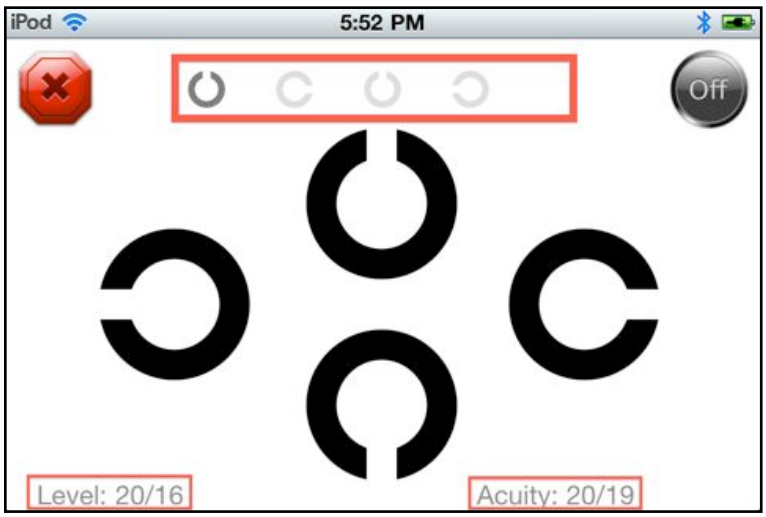


Cyrillic



Snellen





In addition of the large optotype buttons used by the subject to indicate their response, each of these panels provide the user with the following controls and indications:

 To abort the session and return to the previous panel,

 To show and hide the controls on the iPad display,

Level: <value> (<unit>) which indicates the acuity for the current line (the line pointed by the line indicator in multiple lines charts),

Acuity: <value> (<unit>) which indicates the current estimate of the subject acuity,

 These optotypes displayed above the controls indicate the responses already made by the subject for the current line. The light grey optotypes are those that the subject failed to recognized while the darker grey ones are those the subject successfully identified. The acuity estimate is updated accordingly, and the next line is automatically presented if the current line is successful.

On test completion (i.e. once the termination criterion has been reached), the user is presented with a message indicating the final score and with the option to record it in the iPad database (see the Acuity History section) or to abort the test.


iPod
2:36 PM
V T O T H
Off
Measurement Done!
Score: 20/42
At least 1 wrong responses on the same line!
Abort
Save
Level: 20/40
Acuity: 20/42

Frequently Asked Questions (F.A.Q.)

Q: *The iPad and the iOS remote control cannot connect! What's wrong?*

R: Make sure you have updated both "Visual Acuity XL" and "Visual Acuity Remote" to the latest versions from the App Store (Visual Acuity XL v1.5 and Visual Acuity Remote v1.3). Verify that either the Bluetooth or WiFi capability (**but not both**) is enabled on each device in the "General" section of the Settings app (WiFi is inside the "Network" option). Once enabled the WiFi  or the Bluetooth  indicators is shown in the top-left and top-right corners of the status bar, respectively.

Q: *I cannot use my iOS device as a remote control because there is no WiFi network to connect to! Is there a solution?*

R: If no WiFi network is available then use Bluetooth to connect the remote control to your iPad. You could also create your own WiFi local network using a recent Macintosh computer which can either share its wired internet connection through WiFi (see the "Internet Sharing" option in "**Sharing**" System Preferences) or create its own local *Ad Hoc Wireless network* (see the "Create Network..." option in the **Airport menu** ). Both of these solutions would allow the WiFi connection of the 2 iOS devices on your own local WiFi network. For more information check the following links:

- Turn your Mac into a WiFi hotspot using OS X's internet sharing
- How to Set Up an Ad Hoc Wireless Network

Q: *Has this Visual Acuity solution been validated by independent vision care professionals?*

R: Several research laboratories around the world are currently evaluating this solution compared to other chart-based or computer-based solutions. Find below references to some of these works. We will add more when made publicly available:

Jacobs Robert, Black Joanna, Tran An, Chen Lu, Geraint Phillips, Thompson Ben (University of Auckland) "***An iPad for an eye test?***" *89th Annual Meeting of the American Academy of Optometry*, Boston, October 2011.

JM Black, RJ Jacobs, G Phillips, L Chen, E Tan, A Tran, B Thompson (2013) "**An assessment of the iPad as a testing platform for distance visual acuity in adults**", BMJ Open [Link]

Conor P. Malone, Colm McCourt, Nawal T. Al Daqqaq, Conor Murphy (Royal Victoria Eye and Ear Hospital, Dublin, Ireland) "***Evaluation of Tablet Computers in the Assessment of Visual Acuity: Can iPads™ Replace the Snellen Chart?***" *ARVO 2014 Annual Meeting Abstracts*, Orlando, May 2014.

Configuring your iPad & iPhone/iPod touch

Both the iPad and remote control need to be properly configured before running any visual acuity test. Here are a few important recommendations to follow before carrying out a test to ensure a smooth process:

Power Adapter vs Battery

If the iPad and remote control are not plugged to an electrical outlet or a computer system while running the acuity testing, make sure that their batteries are fully charged beforehand (the battery level is indicated in the top right hand corner). While the iPad provides up to 10 hours of battery life, the use of the Bluetooth connection can significantly reduce this time. Keep handy the USB cable for charging through an electrical outlet or a computer system or an iPad 10W USB Power Adapter that lets you charge your iPad directly through an electrical outlet. A 6-foot-long power cord is available to allow you to charge it from an even greater distance.

Settings

It is important to make sure that there is no system setting on your iPad device that may interfere with the testing process. We recommend that you open the "Settings" app and check the following properties:

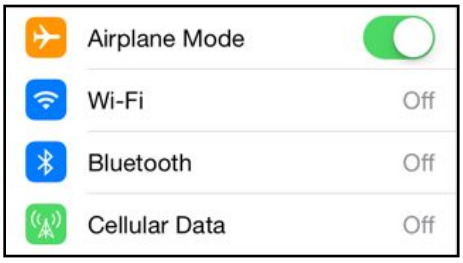
- in the "Display & Brightness" section:

  - "Auto-Brightness" set to OFF
  - Brightness level set to an appropriate level (see below)

- in the "Notifications" section:

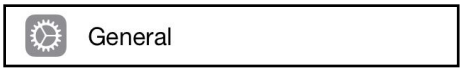
  - all "Notifications" set to OFF

- in the "Network" section:



  - “WiFi” set to OFF
  - "Bluetooth" set to OFF
  - "Cellular Data" set to OFF
  - or simply “Airplane Mode” set to ON

- in the "General" section:

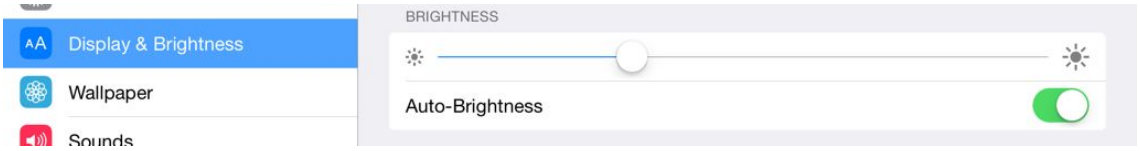


  - "Auto-Lock" set to NEVER

Lightning Conditions & Brightness

Visual acuity testing should be conducted under standardized lighting conditions. The test light level recommended by the National Academy of Sciences and by the American National Standards Institute for ETDRS is a minimum luminance of 85 cd/m^2. This level corresponds to about 25% of the maximum brightness level provided by the iPad display (measured maximum brightness is about 375 to 400 cd/m^2). This testing brightness can be specified either:

- by moving the slider in the "Display & Brightness" section of the "Settings" app to about 3 cm from the left extremity should provide about 85 cd/m^2. If unsure about the correct brightness, simply max out the iPad brightness to ensure optimal viewing conditions.



- or using the Luminance option available from the settings section ⚙: it can be indicated independently of the system brightness (see above) and directly in term of cd/m^2.

The iPad should be also placed at a well illuminated location that does not bring reflections in iPad screen (because of the very glossy nature of the iPad screen, it is recommended to install an antiglare screen protector if reflections occur in the experimental environment). Keep handy some cleaning cloth for the iPad display and remote control screens as they can get easily covered with finger prints and smudges.

Landscape vs Portrait Mode

The iPad can be either used in Landscape or Portrait mode: the portrait mode allows the presentation of more acuity lines on the same display while the landscape mode allows the presentation of more optotypes per line for larger optotype size (up to 5). For iPad mini, the NEOD phoropter mount may be particularly useful to easy gliding and fastening along any test distance on a phoropter rod.

Airplay Mirroring Setup

Visual Acuity XL supports TV-Out to display optotypes and charts on an external monitor or TV. The external display can be directly connected to the iPad using one of the adapters provided by Apple (referred as *Video Mirroring*, see Apple support note: "iOS: About Apple AV Adapter compatibility") or wirelessly through an Apple TV on the same Wi-Fi network (referred as *Airplay Mirroring*, see Apple support note: "Apple TV: How to use AirPlay Mirroring").

Here are step-by-step instructions to make **Visual Acuity XL** display calibrated optotypes on an external display through *Airplay Mirroring* with an Apple TV:

1) ***Before*** running **Visual Acuity XL**, make sure that your Apple TV can mirror your iPad:

   - Connect your iPad and your Apple TV to the same Wi-Fi network.
   - Double-click the Home button on your iPad to display your recently used apps.
   - Swipe the recently used apps twice from left to right until you see the AirPlay icon.
   - Tap the AirPlay icon to display a list of available AirPlay devices.

At this stage you should see the following screen on your iPad. If you don't, then refer to Apple support "Apple TV: How to use AirPlay Mirroring" to troubleshoot the problem.

To use *AirPlay Mirroring*, select the name of your Apple TV, then toggle the ON/OFF slider to ON as illustrated below:

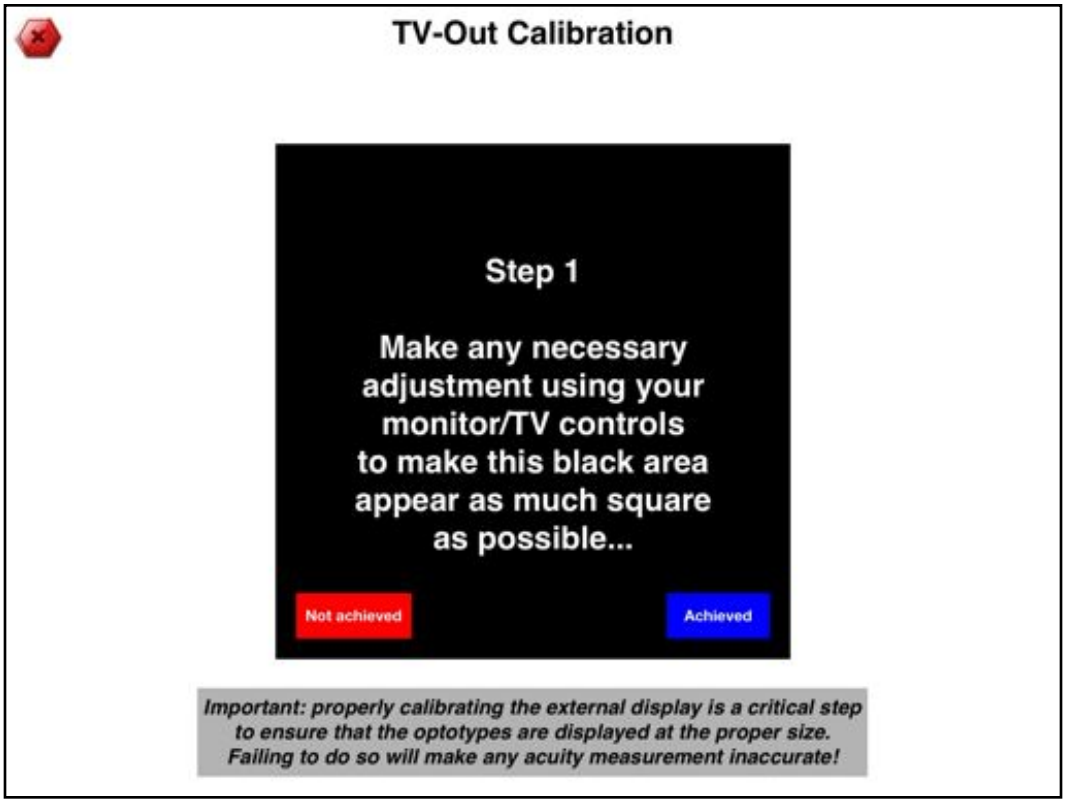
At this stage the Apple TV should mirror the exact same screen on the monitor attached to it. If it does not, then refer again to Apple support note "Apple TV: How to use AirPlay Mirroring" to troubleshoot the problem.

2) Run and setup **Visual Acuity XL**:

- After launching, Visual Acuity XL should automatically detect the presence of an external display and ask you whether to turn TV-Out on, as illustrated below:

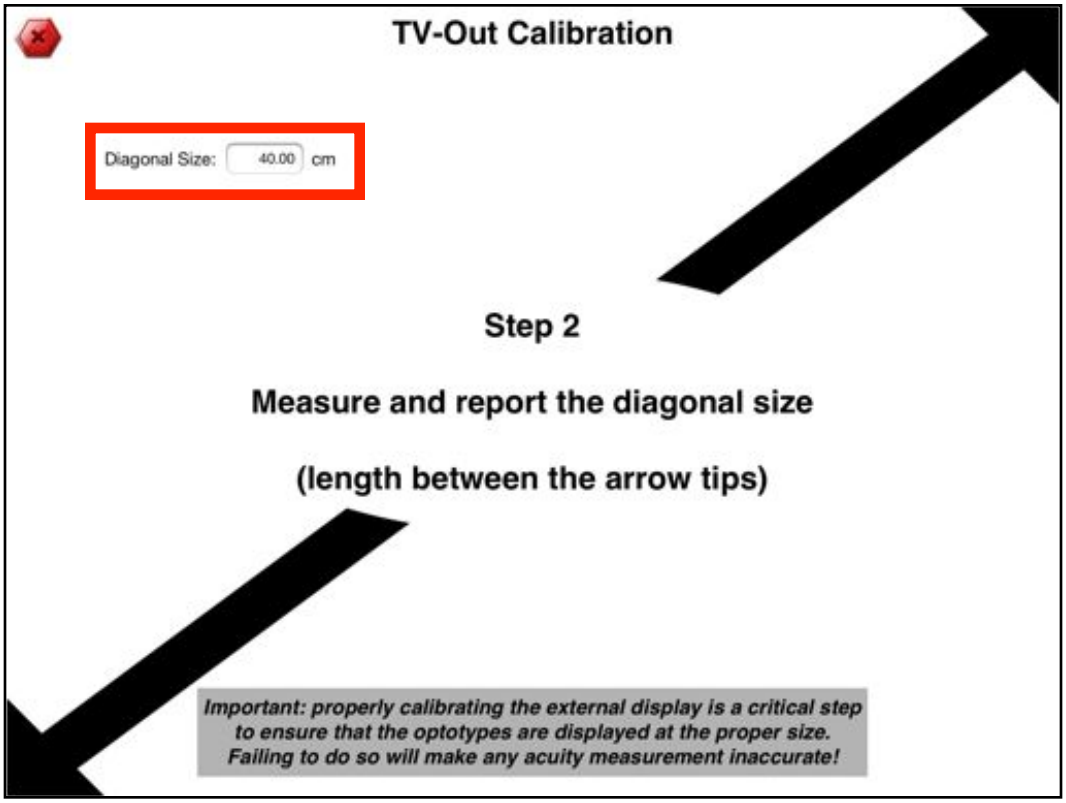
- Tap YES to turn on the TV-Out mode. As illustrated below, **Visual Acuity XL** should then display a list of compatible resolutions. If your monitor and your Apple TV are properly configured, this list should include the optimal resolution “1280 x 720”:

- Select the “1280 x 720” resolution, and **Visual Acuity XL** should then switch to the ***TV-Out Calibration*** panel (phase 1) as illustrated below:



The external display may sometimes distort the geometry of the iPad image by changing its aspect ratio. It is important to correct for this distortion because the pixels that compose the optotypes have to remain square. This can be typically done by specifying a 4:3 ratio (similar to the 1024x768 iPad resolution) using the configuration menu available on your TV set or by adjusting the buttons (e.g.  ) on the front of your monitor so the large black square presented on the iPad screen also appears exactly square on the external display.

- Once you have corrected for the geometry distortion, tap the "***Achieved***" button. The external display should then show the 2nd phase of the **TV-Out Calibration**:



As indicated, measure and report the diagonal size of the external display (between the 2 arrow tips) by editing the "***Diagonal Size***" textfield highlighted in red above.

- Tap the red button in the top-left corner to return to the main panel when you are done. **Visual Acuity XL** should be now ready to show calibrated charts on the external display.

Make sure to perform the display calibration in the orientation mode you intend to use for measuring visual acuity: changing the device orientation to portrait or landscape after the initial calibration will affect the pixel geometry and would require a new calibration.

Make sure to carefully follow all the above instructions, and setting up **Visual Acuity XL** to use *Airplay Mirroring* should be a smooth process! If you wonder why this setup looks so complicated, then remember that measuring visual acuity requires optotypes at a given acuity level to be presented with the right size at the specified vision distance. Determining precisely the resolution and physical size of the external display is a critical step to achieve this!

Adequacy of the iPad for Visual Acuity Testing

iPad Display Specifications

- Technology: LED-backlit IPS LCD
- Aspect ratio: 4:3
- Glossy screen

iPad 1 & iPad 2:

- Resolution: 1024 x 768
- Diagonal: 9.7" (24.6 cm)
- Pixel density: 132 ppi (5.2 ppmm)
- Min Luminance: ~ 0.5 cd/m^2
- Max luminance: ~ 375 cd/m^2
- Max contrast ratio: ~ 750:1
- **Adequacy: very poor (too low pixel density)**

iPad 9.7" with Retina Display:

- Resolution: 2048 x 1536
- Diagonal: 9.7" (24.6 cm)
- Pixel density: 264 ppi (10.4 ppmm)
- Min Luminance: ~ 0.5 cd/m^2
- Max luminance: ~ 300-500 cd/m^2
- Max contrast ratio: ~ 700-1000:1
- **Adequacy: acceptable**

iPad 10.5" with Retina Display:

- Resolution: 2224 x 1668
- Diagonal: 10.5" (27.0 cm)
- Pixel density: 264 ppi (10.4 ppmm)
- Min Luminance: ~ 0.5 cd/m^2
- Max luminance: ~ 600 cd/m^2
- Max contrast ratio: ~ 700-1500:1
- **Adequacy: acceptable (low reflection)**

iPad 12.9" with Retina Display:

- Resolution: 2732 x 2048
- Diagonal: 12.9" (33.0 cm)
- Pixel density: 264 ppi (10.4 ppmm)

- Min Luminance: ~ 0.25-0.5 cd/m^2
- Max luminance: ~ 400-600 cd/m^2
- Max contrast ratio: ~ 700-1500:1
- **Adequacy: acceptable (low reflection)**

iPad mini (released in 2012):

- Resolution: 1024 x 768
- Diagonal: 7.9" (20 cm)
- Pixel density: 163 ppi (6.4 ppmm)
- Min Luminance: ~ 0.5 cd/m^2
- Max luminance: ~ 400 cd/m^2
- Max contrast ratio: ~ 800:1
- **Adequacy: poor**

iPad mini 2/3 with Retina display:

- Resolution: 2048 x 1536
- Diagonal: 7.9" (20 cm)
- Pixel density: 326 ppi (12.8 ppmm)
- Min Luminance: ~ 0.5 cd/m^2
- Max luminance: ~ 400 cd/m^2
- Max contrast ratio: ~ 800:1
- **Adequacy: good**

iPad mini 4 with Retina display (released in 2015):

- Resolution: 2048 x 1536
- Diagonal: 7.9" (20 cm)
- Pixel density: 326 ppi (12.8 ppmm)
- Min Luminance: ~ 0.5 cd/m^2
- Max luminance: ~ 450 cd/m^2
- Max contrast ratio: ~ 900:1
- **Adequacy: very good (low reflection)**

Specifications for visual acuity testing

- Recommended minimum luminance: 85 cd/m^2
  (see the Luminance and Configuring your devices sections)

- The table below provides some comparison between the different iPad devices and should help you select the best iPad device for your specific requirements:

Devices Comparison	iPad 1 & 2 (132 ppi)	iPad mini (163 ppi)	iPad 9.7”, 10.5” & 12.9” (264 ppi)	iPad mini with Retina display (326 ppi)
Minimum distance for 20/20	26.5" / 67 cm	22” / 55 cm	13" / 33 cm	11" / 27 cm
Minimum distance for 20/10 (60 cpd)	53" / 135 cm	43” / 110 cm	26.5" / 67 cm	22" / 55 cm
Best acuity at reading distance (14-16” / 36-41 cm)	20/32 to 20/37	20/30 to 20/26	20/18 to 20/16	20/15 to 20/13
Best acuity at 39” / 1m	20/13	20/11	20/7	20/5

Pros & Cons

The iPad screen is a very high quality LCD display, with a high brightness and a high contrast ratio, well suited for acuity testing. Pixel density for the iPad 1 and 2 (132 ppi) is adequate for measuring far visual acuity only (20/10 measurable at a distance of 53") and pixel density for larger iPad with a Retina Display (264 ppi) is adequate for also measuring near visual acuity (20/10 measurable at a distance of 25"). The iPad mini with Retina Display provides the best performance as its pixel density (326 ppi) is adequate for measuring near visual acuity at typical reading distance (20/10 measurable at a distance of 55 cm or 22").

However, when following a logMar design, the main limitation is its resolution/size limited to 9 x 6 deg at the minimum distance of 53" and 4 x 3 deg at a distance of 10 ft for a 9.7” iPad: a maximum of 4 letters can be presented on the same line at a 20/200 acuity level at the minimum distance and only 1 letter at 10 ft. This is even more limited for the iPad mini due to its smaller 7.9” size. The larger and newer iPads 10.5” and 12.9” slightly improve the field of view.

Another potential problem is the screen glossiness: glossy screens are more susceptible to glare, reflecting light from windows and light bulbs. Moreover they tend to show fingerprints and smudges more readily, especially when they are off. On the contrary matte screens tend to handle glare better, due to a polarized coating over the glass that diffuses ambient light. A side effect of the matte finish is a slight blurring, reduced contrast and a narrower viewing angle. Newer generations of iPads are less affected as their display has an antireflective, oleophobic, fingerprint and scratch-resistant coating.

Useful Accessories

You may find the following accessories very useful to carry out the acuity testing using the iPad and the remote control. Make sure to get accessories that fit your devices (e.g. many accessories are not compatible between iPads because of differences in display size or connector)!

➡ *This list is indicative only and non-exhaustive, and we do not endorse any of these products in particular: similar products may be available from different manufacturers at different prices and some of these products may not be available anymore.*

Phoropter Mount

NEOD Mount specifically designed for the iPad mini to allow easy gliding and fastening along any test distance on a phoropter rod and is functional for both left or right sided exam room configuration.

Provider: http://www.neodinc.com
Price: US$125.00

Game Pad

The **Gamer Action** for iPhone 3G and 3GS, and iPod touch 2G and 3G provides a rubber grip texture that gives more comfort and control of the iPhone and iPod touch running the Visual Acuity Remote app. Note: This accessory is currently not compatible with iPhone 4/4S/5 and iPod touch 4/5G though you may find some cases that would make your device fit into this accessory (e.g., the dermaSHOT Silicone Case from **Incipio** for the iPod touch 4G provides the same form factor than the iPhone 3G).

Provider: http://www.boxwave.com/
Price: US$24.95

Stylus

The **mini Capacitive Stylus** for iPhone, iPod touch and iPad works on all capacitive touch screens and is perfect to prevent finger smudges left on your device display or for cold days when you don't want to remove your gloves. It is also conveniently designed to attach to your device via the 3.5mm headset jack.

Provider: http://www.boxwave.com
Price: US$19.95

Protection

The **ClearTouch Antiglare screen protector** provides in addition of scratches protection the perfect blend of antiglare and optical clarity with maximum screen readability under sunlight and various outdoor lighting conditions. This screen protector is particularly useful to minimize the reflections due to the glossy nature of the iPad display.

Provider: http://www.boxwave.com/
Price: US$24.95

One of the numerous skin cases available for the iPad. The **QuadGrip FlexiSkin** for the Apple iPad is an ultra low profile skin case designed for complete usability. Precision constructed with antistatic material, the QuadGrip FlexiSkin skin case provides reliable protection from unwanted dust and accidental bumps and adds extra grip ergonomically.

Provider: http://www.boxwave.com/
Price: US$22.95

Stand & Wall Mounting

The **BookArc tabletop stand** for iPad provides a choice of four different positions. In "work mode," iPad sits at an angle in both portrait and landscape positions, and provides access to the home button. In "storage mode" iPad sits upright in both portrait and landscape positions, perfect for charging and using your iPad as a stylish photo frame. No matter what position you're in, you always have access to the charging port.

Provider: http://www.twelvesouth.com/
Price: US$39.99

The **Pad Bracket** is a simple system for conveniently mounting your iPad to the wall. Your iPad will sit securely in both landscape and portrait orientation.

Provider: http://www.claywarestore.com/
Price: US$24.95

The **Wallee** is a seamless wall mounting & hard case system made specially for the iPad. No unsightly brackets, just a simple disk that mounts and blends seamlessly into any surface.

Provider: http://thewallee.com/
Price: US$50.00

Charging

The **iPad 10W USB Power Adapter** lets you charge your iPad directly through an electrical outlet and the 6-foot-long power cord allows you to charge it from an even greater distance.

Provider: http://store.apple.com/
Price: US$29.00

The **PowerDock Dual** lets you charge both your iPad and iPhone/iPod touch from a single charging dock.

Provider: http://www.griffintechnology.com/
Price: US$60.00

Connecting to External Display

The **Apple 30-pin VGA Adapter** mirrors exactly what you see on the iPad screen to an external display equipped with a VGA connector (TV, monitor or external projector). This adapter supports video mirroring on iPad 2 or iPad 3 and iPhone 4S; and video out (only) on iPad (1st generation), iPhone 4, or iPod touch 4th generation.

Provider: http://store.apple.com
Price: US$29.00

The **Lightning to VGA Adapter** mirrors exactly what you see on the iPad screen to an external display equipped with a VGA connector (TV, monitor or external projector). This adapter supports video mirroring on iPad 4 or iPad mini, iPhone 5 and iPod touch 5th generation.

Provider: http://store.apple.com
Price: US$49.00

The **Apple 30-pin Digital AV Adapter** mirrors exactly what you see on the iPad 2 or iPad 3 to a HDMI-compatible display (TV, monitor or external projector). This adapter also supports video out for iPhone 4/4S and iPod touch 4th generation.

Provider: http://store.apple.com
Price: US$39.00

The **Apple Lightning Digital AV Adapter** mirrors exactly what you see on the iPad 4 or iPad mini to a HDMI-compatible display (TV, monitor or external projector). This adapter also supports video out for iPhone 5 and iPod touch 5th generation.

Provider: http://store.apple.com
Price: US$49.00

The **Apple TV** allows you to play content from your iOS devices on your TV using AirPlay. The Apple TV also gives you access to the 1080p HD content — including movies, music and photos, and more — right on your widescreen TV. Apple TV requires one HDMI cable (sold separately).

Provider: http://store.apple.com
Price: US$99.00