UTAS

Multifocal Software

User's Manual

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CE 2797

Rx only

Part No. 96-014-EN

EN - http://www.lkc.com/IFUs Printable instructions for use (IFU) in multiple languages are stored on the UTAS computer as PDF files in the IFU folder on the computer desktop screen, or go to www.lkc.com/IFUs

DE - Druckbare Nutzungsanweisungen (IFU) in mehreren Sprachen werden auf dem UTAS-Computer als PDF-Dateien im IFU Ordner auf Ihrem Desktop gespeichert. Alternativ können Sie www.lkc.com/IFUs besuchen.

ES - En el ordenador UTAS hay almacenadas como archivos PDF instrucciones imprimibles de uso en varios idiomas, en la carpeta IFU del escritorio del ordenador, o acceda a www.lkc.com/IFUs

FR - Des instructions d'utilisation à imprimer (IFU) dans plusieurs langues sont stockées sur l'ordinateur UTAS sous forme de fichiers PDF dans le dossier IFU présent sur le bureau. Vous pouvez également les obtenir sur www.lkc.com/IFUs

IT - Le istruzioni per l'uso stampabili (IFU) in più lingue sono archiviate sul computer UTAS come file PDF nella cartella IFU sul desktop. In alternativa, sono reperibili all'indirizzo www.lkc.com/IFUs

PL - Instrukcje obsługi (IFU) do druku w wielu językach przechowywane są na komputerze UTAS jako pliki PDF w folderze IFU na pulpicie komputera lub na stronie www.lkc.com/IFUs

European regulatory Data

Instructions for USE (IFUs) in other languages may be found at www.lkc.com/IFUs
To request a printed copy of this manual please send an email to support@lkc.com and include the following information:

1) Company name
2) Your Name
3) Mailing address
4) The Serial Number of your device
5) The part number of the manual you need
   To find the correct part number, open the pdf file in the IFU in the language you want and find the part number, the part number will appear on either the front or back of the IFU. The manual part number will look something like 96-123-AB.

Your manual will be shipped to you within 7 days.

Reference 96-020 UTAS Hardware Manual for complete regulatory information.

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LKC PRODUCT LIFETIME POLICY

UTAS is the Trade Name for this device and all associated software. The lifetime of a UTAS is 5 years from the original shipment date of the UTAS. LKC will service any UTAS that is within its lifetime.

SOFTWARE LICENSE

The UTAS software is a copyrighted product of LKC Technologies, Inc. and is included with the UTAS under the following license agreement:

The software may be used in conjunction with the UTAS only. The purchaser of the UTAS may make copies of the software for convenience of use, provided the LKC copyright notice is preserved with each copy. This license specifically prohibits the use of this software with devices that does not include an LKC Technologies, Inc. UTAS Interface Unit. Additional copies of the software may be purchased to produce reports of UTAS data using a stand-alone computer system.

Table of Contents

Intended Purpose and Intended Users

UTAS is an electrophysiology device used as a diagnostic and disease management aid in visual pathway dysfunctions or ophthalmic disorders.

UTAS performs electroretinogram (ERG), electro-oculogram (EOG), visual evoked potential (VEP), multi-focal ERG/VEP, and the measurement of psychophysical responses of the visual system, including dark adaptometry.

This software is offered for sale only to qualified Health Professionals. The improper use of this software may cause injury to the patient.

Clinical Benefit

Assist health care professionals with diagnosis and management of ophthalmic or visual pathway dysfunction/disease or to ensure drug safety.

Intended Target Groups

There are no specific intended target groups.

Indications for use

UTAS is indicated for use in the measurement of visual electrophysiological potentials, including electroretinogram (ERG) and visual evoked potential (VEP). UTAS is also indicated for use in the measurement of psychophysical responses of the visual system, including dark adaptometry. UTAS is intended as an aid in diagnosis and disease management in visual pathway dysfunctions or ophthalmic disorders (e.g., diabetic retinopathy, glaucoma).

Multifocal software specific tests

The LKC Technologies Multifocal software performs the multifocal ERG and VEP tests as well as Pattern ERG and VEP to aid in the diagnosis and disease management of visual pathway dysfunctions or ophthalmic disorders.

The LKC Technologies Multifocal software is only intended to use used with runs on LKC's UTAS device. The software will only run on computers using a Windows 10 or higher operating system and having very specific video control hardware. LKC only supports UTAS computers that have been supplied by LKC specifically for this software. Reference 96-020 UTAS Hardware User Manual for details on UTAS hardware and regulatory information.

Precautions for Software Installation

Software Installation

WARNING: The installation of any software on the UTAS Windows computer that is not provided directly by LKC can cause the UTAS device to stop functioning or crash unexpectedly.

The LKC UTAS is a precision standalone medical device. The computer provided with your device has been specifically manufactured and configured for a specific purpose.

The warranty on your UTAS does not cover problems caused by installation of non-approved software on the computer. The UTAS is a medical device that uses a Windows-based computer. Installation of additional software on the UTAS computer may result in improper operation of the UTAS. It is the customer's responsibility to assure that any additional software installed on the UTAS computer does not affect the performance of their UTAS device. LKC is not liable or responsible for improper operation of the UTAS caused by customer-installed software.

Therefore, LKC strongly recommends that the UTAS be used as a standalone medical device. LKC also strongly recommends that:

The user does not change any user privileges or software settings.

No non-LKC approved software products be installed on the UTAS.

Furthermore, the supplied Multifocal software is not standalone and is only intended for use with the UTAS.

Microsoft Office (Word, Excel, PowerPoint, Access, etc.) has been tested with our software and does not interfere. It is therefore safe to install Microsoft Office on the PC of the UTAS to generate reports and analyze data. It is recommended that any Office applications be closed when running the Multifocal software.

UTAS Setup

Arranging the hardware

In most cases, your hardware will be installed and arranged by LKC Technologies Biomedical Engineers. In those cases where it is not, you will need to follow these guidelines.

The multifocal Monitor should be placed behind the chinrest base. The distance from the display to the patient's eyes determines the angular field of view for the multifocal stimulus. The distance from the screen to the center of the forehead rest should match the dimension given on the label on the front of the monitor).

The height of the chinrest should be adjusted so that a normal subject's eyes are approximately level with the fixation "X" at the center of the screen. To accommodate 99% of the population, the chinrest need only be adjusted by ± 1" from the nominal location. This small adjustment is usually unnecessary as the patient can look slightly up or down to fixate properly.

The fixation camera is mounted on the top edge of the monitor, centered right to left. The tilt of the camera should be adjusted to give a good view of the eyes of a subject whose chin is on the chinrest.

Software installation

In most cases, your software will be installed by LKC Technologies Biomedical Engineers. In those cases where it is not, follow these directions:

- Run (double click) the *MFERGSETUP.EXE* file.
- Follow the prompts to install the software.

After the software is installed, run the multifocal software. A box will appear asking you for a software key. This software key must be generated by LKC Technologies personnel and is specific to your computer. mfERG and mfVEP have two different software keys. If you order both parts of the software, you will require two keys. To send the necessary information to LKC so that keys can be generated:

Wait until the request for the number is on the screen then press the PrtScr key on your keyboard. This will copy a bitmap image of the screen to the Windows Clipboard.

Open WordPad (From the Start Menu, click All Programs -> Accessories -> WordPad) and paste the clipboard into the document.

Save the document and send it to LKC.

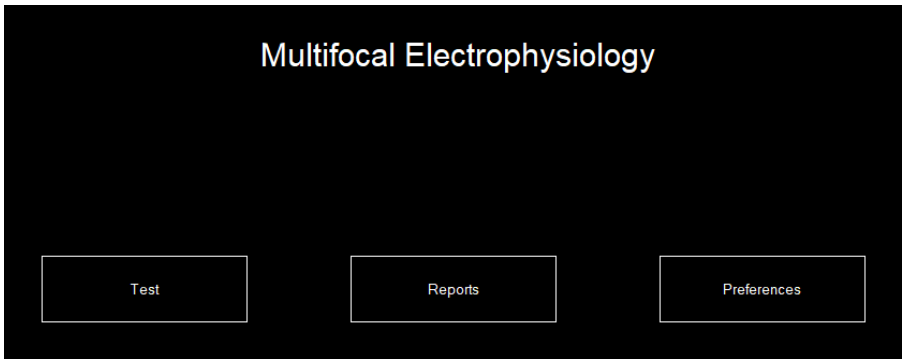
When the multifocal key(s) is sent to you, they will be called *MFERG.KEY* and *MFVEP.KEY*. Copy this file into the C:\DataMFERG directory to enable your software. If you have any questions, please call or email the LKC Customer Support Hotline.

Upgrading to MFERG or MFVEP

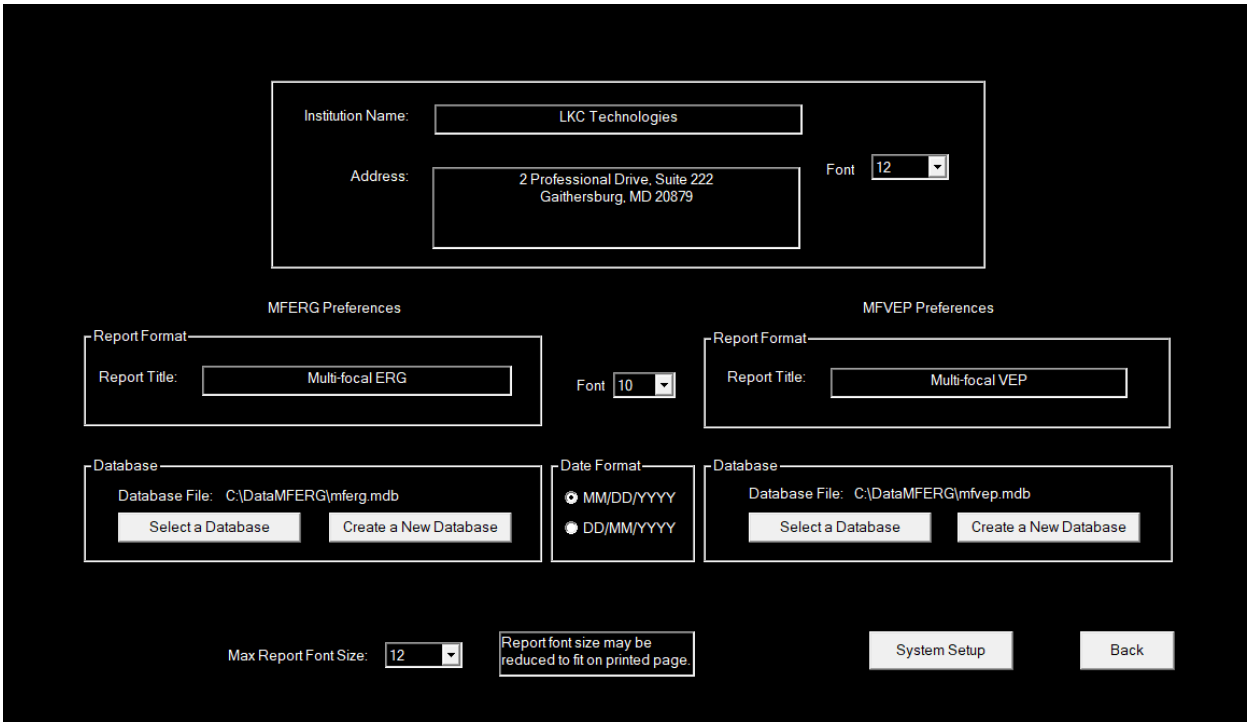
If you already have a license key for either MFERG or MFVEP and would like to upgrade to a full MFERG + MFVEP configuration, go to the Preference page and note your UTAS's Computer ID. Email this ID# to support@lkc.com with a request for a MFERG or MFVEP license key (cost might apply).

Software Configuration - Preferences

Double click on the mfERG icon on your desktop.



Go to the Preferences screen



Enter your practice information in the uppermost boxes. This header will be printed out on every page of the report.

You can enter different titles for MFERG and MFVEP reports that will appear on the printed reports.

Select a Database

Clicking this button allows you to change the default database. When you click the button, a screen will appear listing the names of all of the available mfERG databases. Double click on the one you wish to select or click it once and then click **OK**. The name of the default database appears to the right of the button.

Create a New Database

Clicking this button will cause you to be prompted for the name of a new database. You will not be allowed to create a database if one of the same name already exists. When you create a new database, it is automatically selected as the default database.

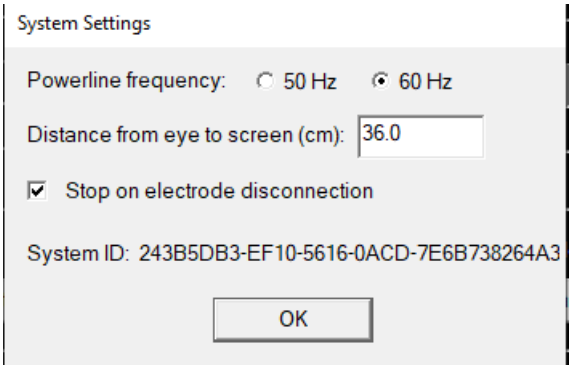
Different Databases are used to store MFERG and MFVEP data.

All multifocal databases are stored within the C:\DataMFERG folder

You must not store data from mfERG Version 2.0.0 or later in a database that contains mfERG records from a previous version of mfERG. The records are not compatible.

UTAS Setup

Clicking the system setup button will allow users to change specific settings for the software:



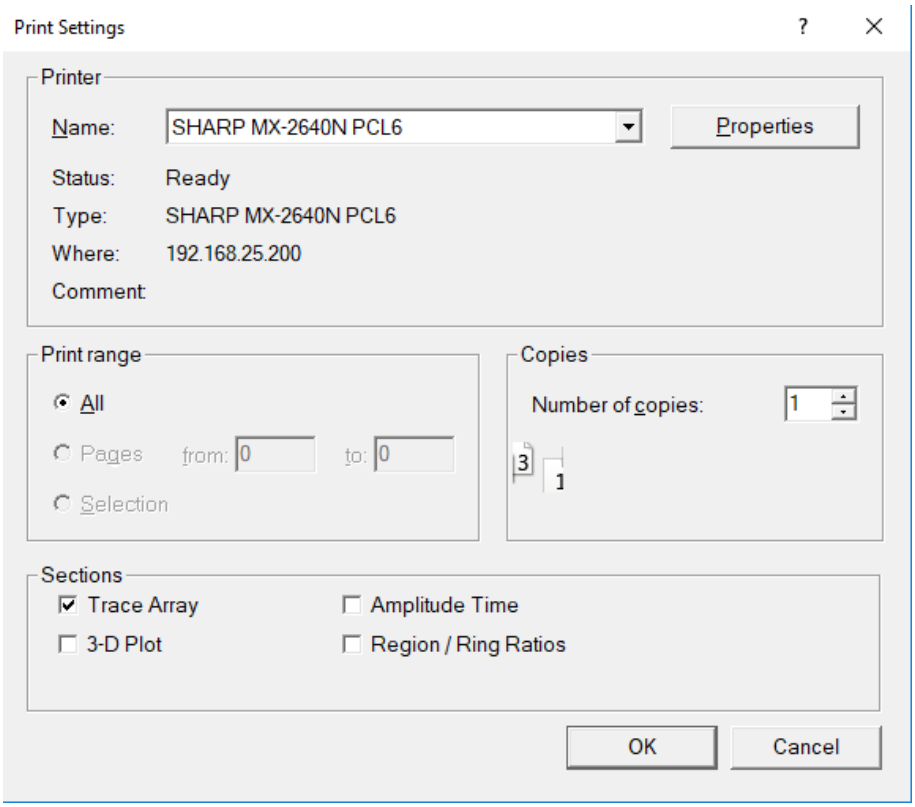
- The user may select the main powerline frequency for the device to set as the default for filtering
- The user may adjust the distance from the eye to the monitor based on the monitor size and field of view
- The user may select whether to enable the electrode disconnect option during testing. Disabling the electrode disconnect option will cause the device to ignore electrode disconnection events.

Exporting Data

To print or export data or graphics in any of the analysis views, click on one of the buttons in the lower left of the screen.

After clicking the **Print** button, an options screen will appear (see below) allowing the selection of the printer and the desired analysis views. All selected views will be printed on the same page. You may print one, several, or all analysis views on a single page.

After clicking the **Export Data** or **Export Graphic** button, a pop-up menu will appear allowing the exported data/graphic to be sent to the clipboard or saved directly into a .txt file (for data), or .png, .jpg, or .bmp file (for graphics).



Backing Up Data

LKC recommends to back up existing databases in order to ensure patient data is not lost unexpectedly. Therefore, it is good practice to frequently back up the data. How often depends on how much data is willing to be lost. To backup a database, go to the local C Drive. Under the local C drive, find the DataMFERG folder. Locate the desired database file ending in file type .mdb. Copy the database and save it to an external drive or server for backup. It is recommended that databases be backed up to a different filesystem than the original database.

Multifocal ERG

1.0 Introduction

1.1 What is a multifocal test?

Multifocal testing is a way of recording an electroretinogram (ERG) from many regions on the retina to get a map of retinal function. A multifocal test uses a computer display as a stimulator and divides it into a number of smaller test areas. Each test area is stimulated using an on-off sequence that differs in time from all the other test areas. Evoked responses are collected simultaneously from all stimulated areas, and the resulting data is processed after recording to extract the individual responses.

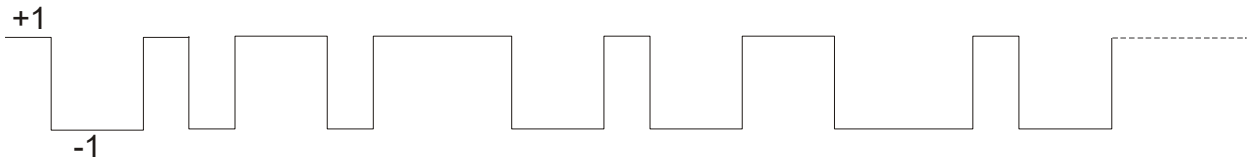
1.2 How does a multifocal ERG work?

In the mfERG, the screen that the patient views is divided into a number of hexagonal elements – from 19 to 241. Each hexagon will stimulate a small portion of the retina, and the mfERG will allow the response from that portion to be recorded separately from other portions of the retina. The amplitude of the response from healthy retina is proportional to the number of photoreceptors contained in the stimulated area. It is conventional to scale the mfERG hexagons so that approximately equal numbers of photoreceptors are stimulated by each hexagon in order for each hexagon to have a similar signal-to-noise ratio. This results in a pattern that has small hexagons in the central region, and larger hexagons with increasing distance from the fovea.

Multifocal ERGs are photopic (light-adapted) tests and provide information about the cone-based visual pathway. As with conventional ERGs, the signal recorded from the eye is primarily derived from cones, on- and off- bipolar cells, Müller and possibly ganglion cells. However, the mfERG is not just “a little ERG.” For a full discussion, see [Hood, 2000].

1.3 m-sequences and kernels

In theory, as long as each of the hexagons/sectors are flashed in a different order, it is possible to retrieve the response of each one. In practice, the best method of flashing the hexagons is to use a *pseudo-random binary sequence*. A pseudo-random binary sequence has 2 states, designated +1 and -1, and changes states in equally-spaced intervals. In each interval, the probability of the sequence being +1 or -1 is 50%. A typical sequence might look like this:



Each approximately ¼” in the above graph represents a single stimulus period (13.9 ms) on the screen; when the sequence value is +1, the hexagon/sector is flashed and when

the sequence value is -1 the hexagon/sector is not flashed. The flash duration is approximately 7 ms long. Each hexagon/sector has a different sequence of flashes.

Pseudo-random binary sequences eventually repeat themselves. A sequence that goes through all possible permutations of a group of contiguous states before repeating is called a "maximal sequence" or *m*-sequence. The *m*-sequences used in the 103 hexagon stimulus, for example, use permutations of a group of 15 or 16 contiguous states, and repeat after 32,768 or 65,536 elements. These are referred to as "long *m*-sequences."

To extract the signal for an individual hexagon from the recorded data is straightforward – simply add in all of the traces where the flash occurred (sequence value = +1) and subtract from that all the traces where the flash did not occur (sequence value = -1). The result is the response of the retina covered by this hexagon to a flash of light. This is also referred to as the *first order kernel* of the mfERG.

Using the maximal length pseudorandom binary sequence (*m*-sequence), it is also possible to study other effects. The *second order kernel* of the mfERG measures the effect of a prior flash on the response to the current flash, and thus is a measure of the adaptation of the retina (especially ganglion cell activity). The second order kernel is more difficult to record and interpret and is not generally used clinically.

1.4 Field of view

The field of view of the multifocal is determined by 2 factors – the size of the monitor screen and the distance from the monitor to the patient. The size of the patterns used in the LKC multifocal depends on the size of the screen, following our guidelines for viewing distances then the total field of view of 45° (±5°). For more information on calculating visual subtense of monitor-based stimuli, consult the ISCEV calibration guidelines. [CSC, 2003]

1.5 When is the mfERG useful?

The mfERG is primarily useful in detecting disorders of the central and mid-peripheral retina where there may be patches of retinal dysfunction. Disorders that the mfERG has been shown to be <u>especially</u> useful in include:

- Hydroxychloroquine (Plaquenil) retinopathy
- Diabetic retinopathy
- Early age-related macular degeneration
- White-dot syndromes such as MEWDS, AZOOR, and multifocal choroiditis
- Branch vein occlusion and Central retinal vein occlusion
- Stargardt disease
- Occult macular dystrophy / focal cone dystrophy
- Unexplained visual loss

1.6 When is the mfERG not useful?

Because the mfERG relies on careful patient fixation to obtain meaningful recordings, it is less useful in disorders where the patient has a large central scotoma. In disorders of this type, the patient will either 1) fixate with a preferred retinal locus other than the fovea or 2) erratically fixate. In either case, inaccurate or misleading mfERG results can be obtained. Disorders with large central scotomas include:

- Advanced age-related macular degeneration
- Significant diabetic macular edema
- Advanced Stargardt disease
- Advanced Retinitis Pigmentosa with macular deterioration

Other disorders that may also cause a patient to be unable to fixate sufficiently for mfERG testing include:

- Nystagmus
- Stroke
- Traumatic brain injury

2.0 Preparing for a mfERG recording

2.1 The patient

Before recording, the patient should be dilated with a short-duration mydriatic such as 1% tropicamide (*Mydriacyl* , *Mydral*, etc.). Allow at least 15 minutes for the drug to take effect. The patient should **not** be dark adapted for this test, but if they have been exposed to bright lights (such as from slit lamp, fundus photography, fluorescein angiography) allow at least 10 minutes before testing.

Because this test requires long periods of fixation without blinking (15 seconds at a time), we recommend that a local anesthetic be used both in the eye even if recording only from one eye. The anesthesia in the contralateral eye will make it easier for the patient to avoid blinking during the test.

2.2 Electrodes

Poor or unstable electrode contact is a major cause of poor quality mfERG recordings. We recommend that you pay special attention to proper electrode preparation, placement, and cleaning for mfERG recording.

2.2.1 Active Electrode

The best mfERG recordings will be obtained using bipolar contact lens electrodes such as the Burian-Allen electrode shown at right, or the Mayo bipolar electrode. If you use a bipolar electrode, plug the contact lens (white or red wire) into Channel 1 + and the speculum (black wire) into Channel 1 –. If recording binocularly plug the second electrode in a similar fashion in Channel 2. The Burian-Allen electrode is also available in a monopolar configuration; monopolar Burian-Allen electrodes require the use of a separate indifferent electrode (see section 2.2.2). Anesthetic should be used on the eye with this electrode.

You can obtain good mfERG recordings using the DTL electrode. The DTL Plus electrode (available from LKC Technologies) has 2 adhesive foam pads to hold the thread in place. Clean the nose near the nasal canthus and the skin near the temporal canthus with alcohol and allow it to dry. Place the smaller adhesive foam pad at the nasal canthus with the thread pointed towards the eye. While the patient looks up, drape the thread on the sclera above the lower lid, then attach the larger adhesive foam pad to the skin near the temporal canthus. When the patient looks straight ahead, the thread should be in contact with the cornea. Anesthesia is optional with this electrode.

ERG Jet electrodes can also be used as monopolar electrodes. These electrodes are contact-lens electrodes with a gold ring contact region. Anesthetic should be used on the eye with this electrode.

2.2.2 Indifferent Electrode

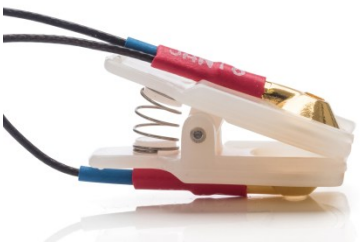
If you use a monopolar electrode, place the indifferent (reference) electrode near the temporal canthus of the eye from which you are recording, or alternately on the forehead. Either way, clean the site of the electrode with a prep pad or alcohol to remove skin oils, makeup, etc. before attaching the electrode.

If you use the temporal canthus use a gold cup (VEP) electrode with electrode cream (not gel) and place it as close to the temporal canthus as possible. (If you used a DTL Plus electrode, put the DTL on first as the adhesive foam pad must be located precisely. Then place the indifferent electrode.) Connect the active electrodes to Channel 1 + (and 2 + if recording from two eyes) and the indifferent electrode into Channel 1 – (and 2 -).

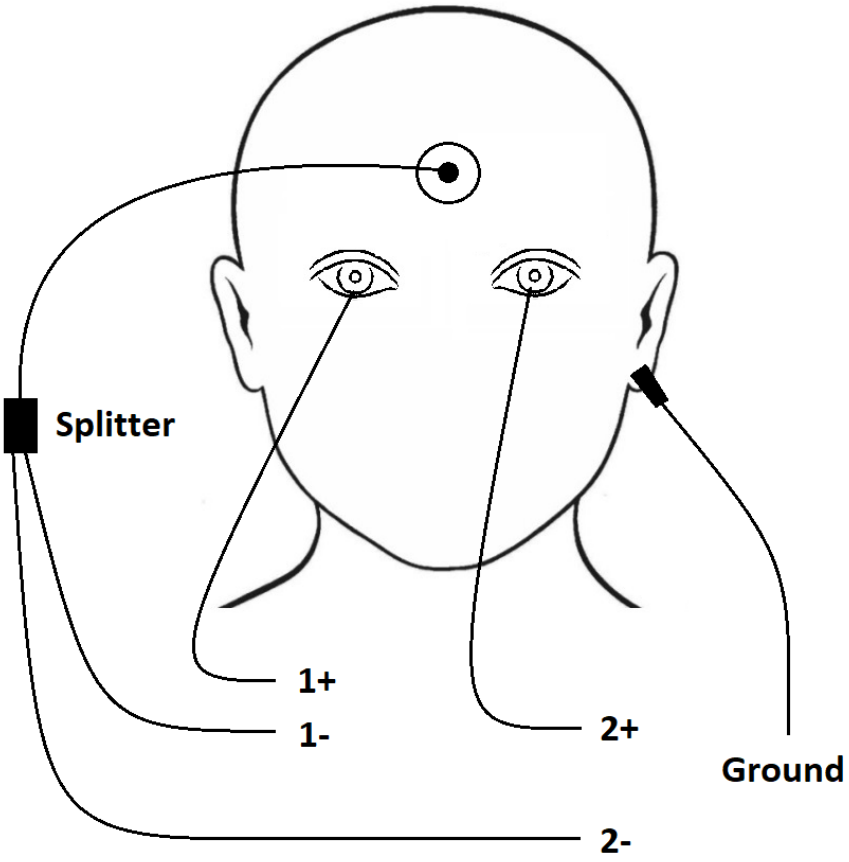
If you choose the forehead for your indifferent electrode, use an ECG electrode and a ground clip. Or you may use a gold cup (VEP) electrode with electrode cream.

2.2.3 Ground Electrode

An ear clip electrode makes an excellent ground. Clean one earlobe using alcohol and allow it to dry. Place Electrode Gel (not cream) into both cups of the electrode and place it onto the prepared earlobe. Connect this electrode to the Ground (G) input.

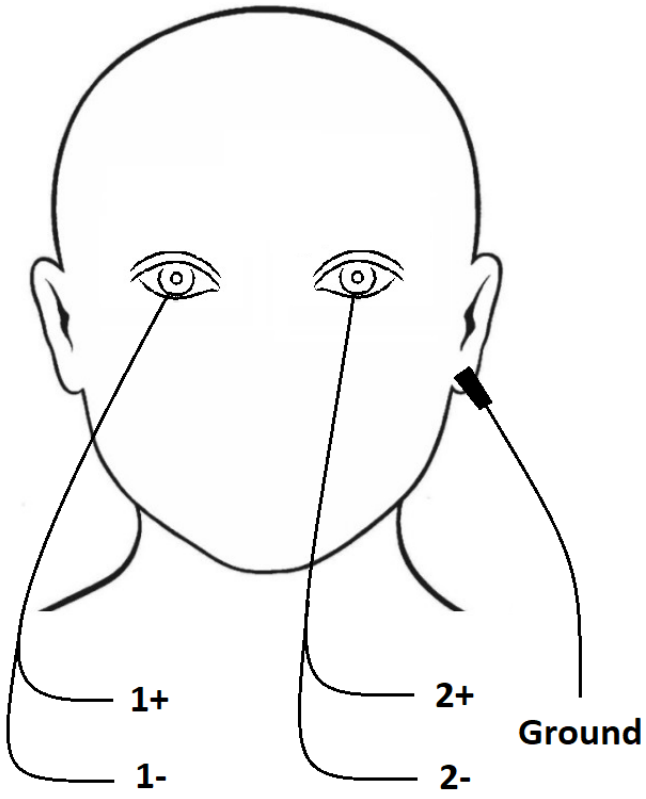


ERG Set-Up Using Mono-Polar Electrodes (i.e., ERG-Jet, DTL). Note that the Grounding electrode is an ear-clip filled with gel, the reference electrodes are gold cup electrodes filled with cream, and the positive or active electrode is shown here with a mono-polar corneal lens type of electrode (keep the same set-up for any other type of mono-polar ERG electrode).



Monopolar Electrode Placement (ERG-Jet, DTL...)

ERG/MFERG Set-Up Using Bipolar Electrodes (Burian-Allen). Note that the grounding electrode is an ear-clip filled with gel.



Bipolar Contact Lens Electrode Placement

2.3 Refraction

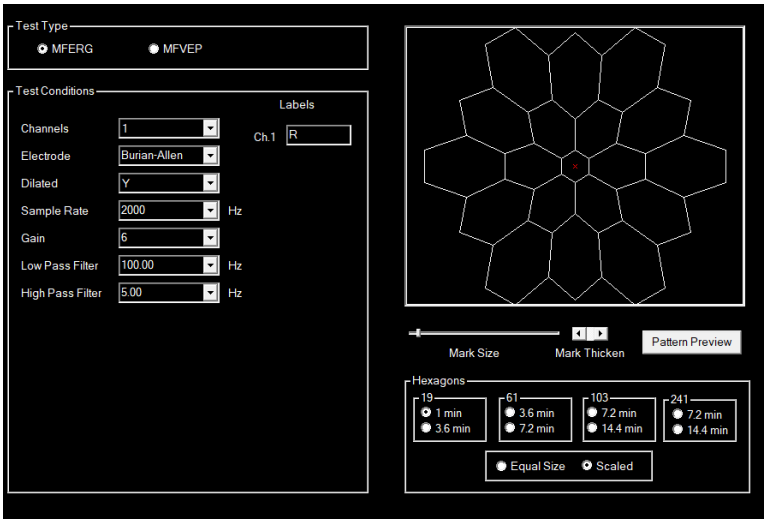
“There is some controversy about whether acuity is critical to the mfERG, at least within a range of ± 6D from emmetropia, so that some experts deem refraction unnecessary within these limits.” [Marmor, 2003]

If you elect to refract your patients before recording, we recommend that you include a +3 D (Diopter lens) add to compensate for the distance of the recording screen (~30 cm). Further, you should be aware that significant refractive correction will change the retinal size of the pattern elements and may limit your ability to compare results between patients.

2.4 Ambient lighting

The mfERG is a photopic test and should be conducted with the room lights on. The ideal light intensity for the room lights is one that produces illumination to the subject close to that of the average of the stimulus screen (100 cd/m^2). If the room lights are too bright, there may be reflections from the patient display that will interfere with the recording of the mfERG.

2.5 Issues with visually impaired patients



Patients with significant central visual impairment will have difficulty fixating on the screen. The usual fixation target is a small “X” in the middle of the central hexagon. This fixation target can be lengthened and thickened. The **Mark Size** control determines the length of the legs of the “X” while the **Mark Thicken** control determines the thickness of the legs.

Patients with poor central vision can sometimes fixate by centering the enlarged “X” in their remaining vision. This, however, is a move of desperation as it is unlikely that their fixation will remain stable enough for good mfERG recordings. In general, you should not change the fixation “X” from the default size, as it will obscure a greater proportion of the mfERG hexagons, leading to decreased response amplitude.

2.6 Fixation monitoring

A camera is provided to allow you to monitor the patient during multifocal testing. The camera is mounted to the top edge of the stimulator monitor. The image from the camera is displayed on the operator screen of the computer. This camera allows you to see if:

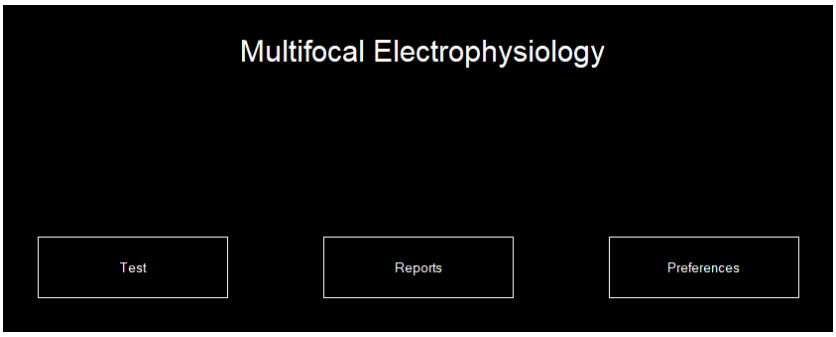
- the patient is blinking or moving their eyes,

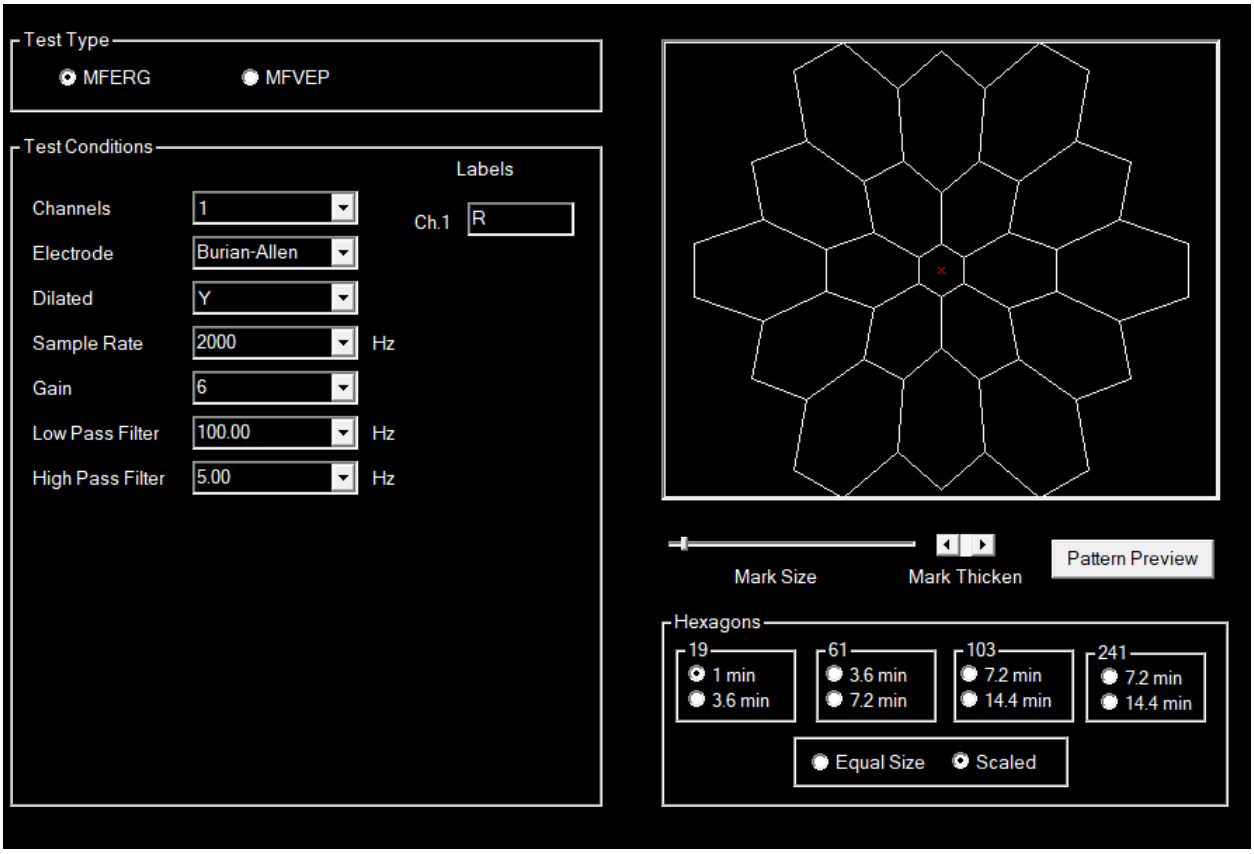
- an electrode has fallen out, or
- the patient is grossly off-fixating.

The camera does not allow you to determine if the patient is slightly off-fixating as in the case of a patient with a central scotoma using an alternate preferred retinal locus. Nothing short of a retinal camera will let you determine if the central hexagon is falling directly on the fovea.

3.0 Running the Test

Open Multifocal software and select *Test*.



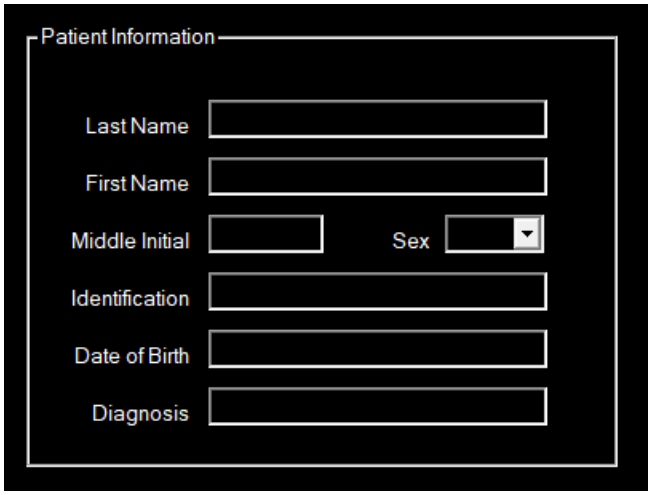


3.1 Test Type

Select MFERG, if the option does not appear this means you do not have a MFERG license. Refer to the UTAS setup section of this manual to upgrade.

3.2 Patient Information

Last Name or Identification and Date of Birth are required in order to start a test.



3.3 Channels and Labels

Channel number: all UTASs can record monocularly or binocularly. The software automatically defaults to the right eye in channel 1 and left eye in channel 2.

If you are only recording from 1 eye/1 channel at a time, always use channel 1.

3.4 Pattern Selection

There are three elements to consider in selecting an mfERG test:

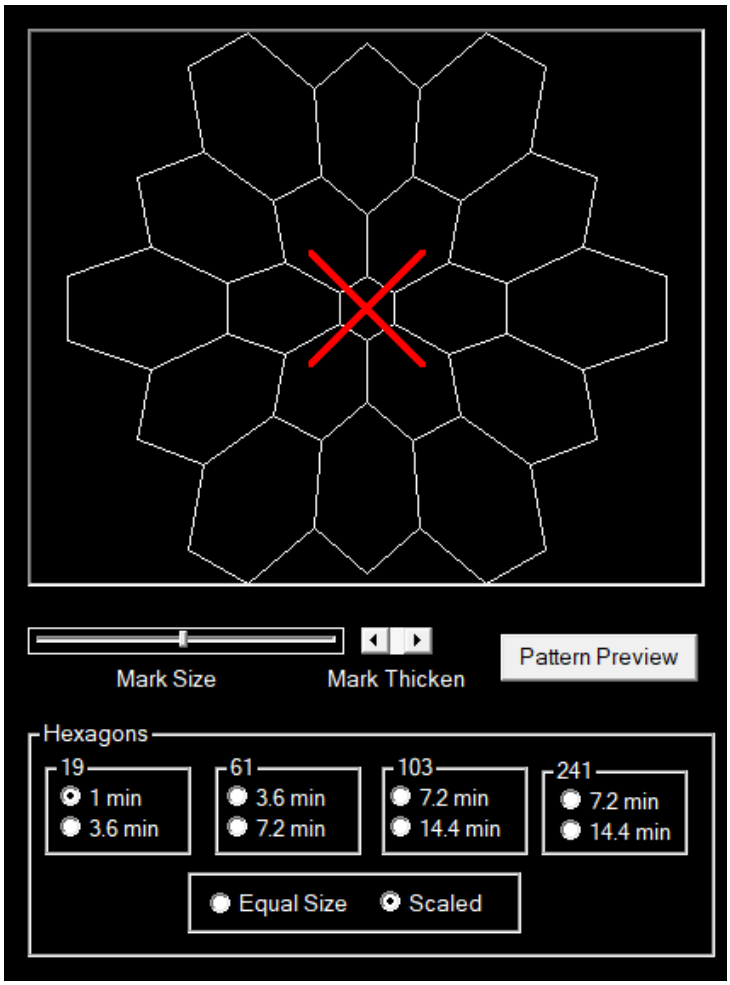
- Number of hexagons
- Scaling of hexagons
- Length of *m*-sequence

The mfERG software provides you with several choices of number of hexagons and length of *m*-sequence to meet your clinical needs.

Number of Hexagons

The larger the number of hexagons from which you record, the smaller the signal from each hexagon will be. Since the noise generated during the recording is independent of

hexagon size, larger hexagons (which produce higher signals) give better signal-to-noise ratio, and thus allow shorter recording times from a patient. Thus, in general, you should record using the smallest number of hexagons that will allow you to resolve the disorder. We find that 61 hexagons provide a good compromise for many disorders.



Scaling of Hexagons

If you are recording from human eyes, we recommend using the scaled hexagons. The scaling of the hexagons with eccentricity is such that each hexagon stimulates approximately the same number of cones, leading to approximately equal amplitude responses in each hexagon.

If you are recording from animals, we recommend using hexagons of equal size. mfERGs using equal sized hexagons are more easily interpreted when fixation is uncertain. Further, many animal species have cone density profiles that are significantly different from those of humans.

m-sequences

Longer *m*-sequences allow more averaging of data, and thus provide quieter recordings. When using noisier electrodes, such as DTL electrodes, a longer m-sequence should be used. In general, the noise decreases by the square root of the recording time, so recording for 4x as long will reduce the noise to approximately ½ of its original value. LKC classifies *m*-sequences by the approximate length of time it takes to complete a recording. (Since we present stimuli at the rate of 72 Hz, there are 72 x 60 = 4320 stimuli per minute.)

Recording Time	Length of m-sequence
1 min	4 096 (12 bit)
4 min	16 384 (14 bit)
8 min	32 768 (15 bit)
15 min	65 536 (16 bit)

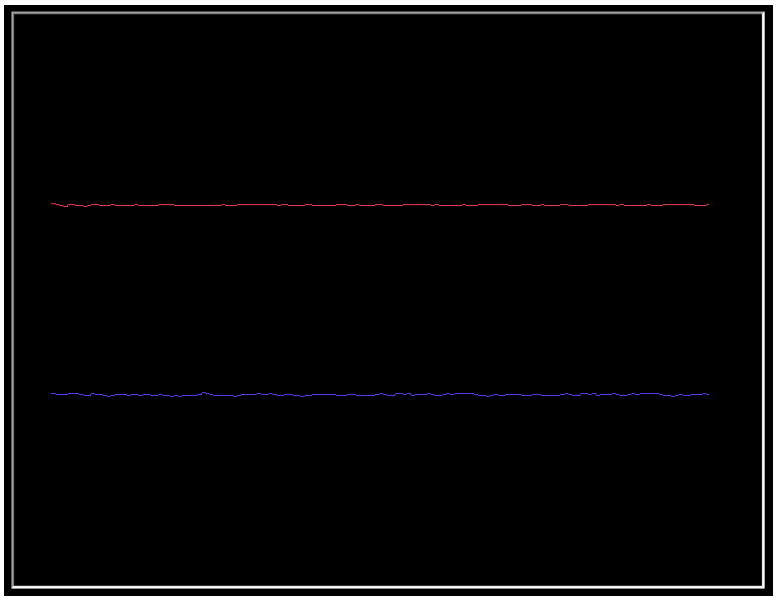
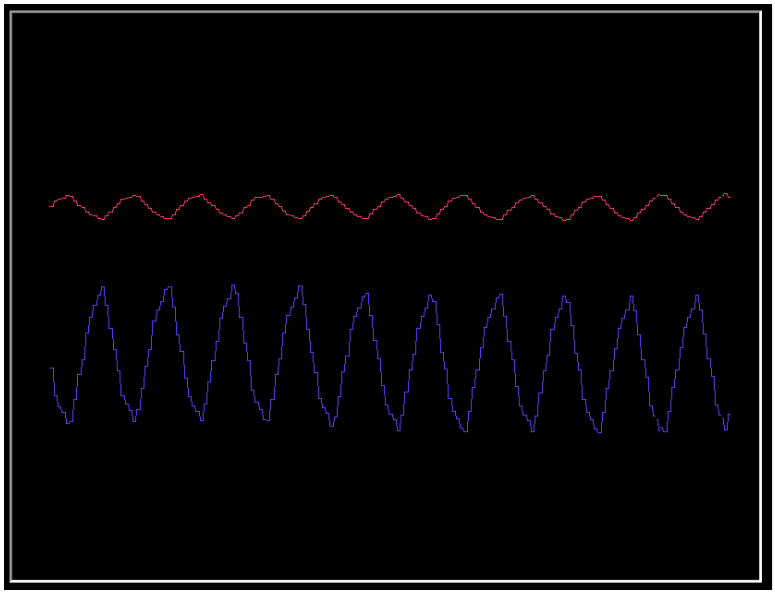
The recommended recording times for different electrodes are:

Hexagons	Recording with Burian-Allen Electrodes	Recording with DTL Electrodes or ERG Jet
19	1 min	4 min
61	4 min	8 min
103	8 min	15 min
241	8 min recorded twice and averaged	15 minutes recorded 4 times and averaged

3.5 Recording Data

Baseline

After the electrodes are placed on the patient and connected to the amplifier or patient cable, you should run the baseline to assure that the connections are all functioning properly and that the patient is able to hold steady fixation. Have the patient put their chin into the chinrest and adjust the height of the forehead rest if necessary. Then have the patient look directly at the red fixation "X" on the screen. Click **Baseline**. The UTAS will begin to collect data without presenting a stimulus and will allow you to observe the patient's baseline data. Examples of good and poor baseline tracings are shown below.

Good baseline	
Bad baseline This baseline has excessive mains (50/60 Hz) noise. It is most likely caused by a bad electrode connection, although there are other possible explanations for the noise. The analysis includes removal of power line interference so complete elimination of power line interference isn't required.	

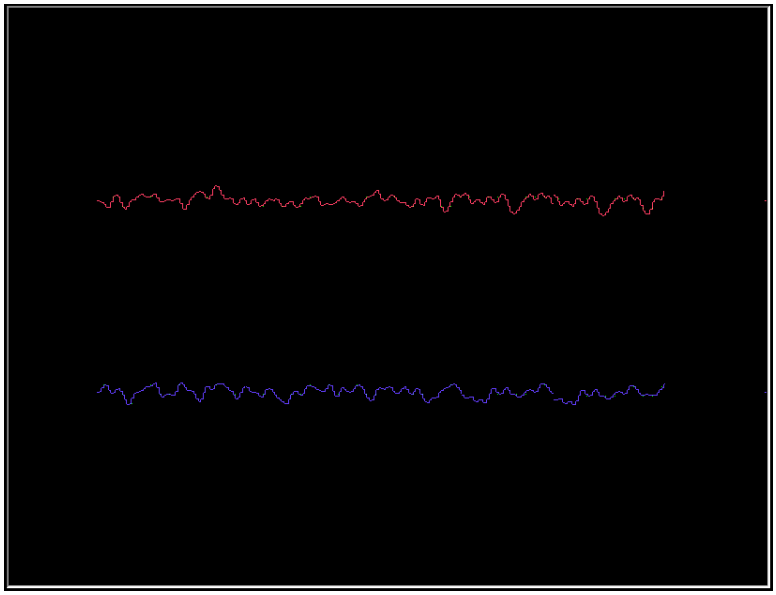
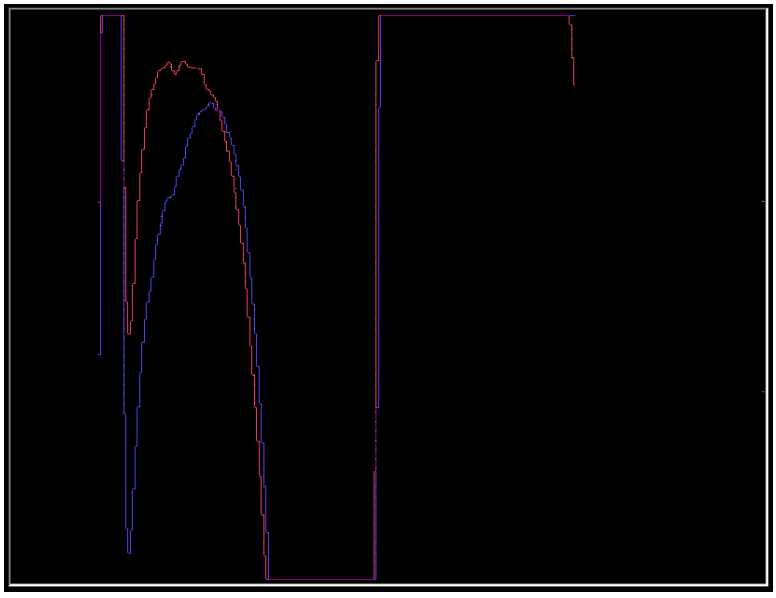
3.6 Record

The LKC mfERG software breaks recordings up into a series of **segments**. During each segment, the patient must fixate on the fixation target without blinking. After each segment, the patient can blink or rest before continuing. Longer *m*-sequences have more segments.

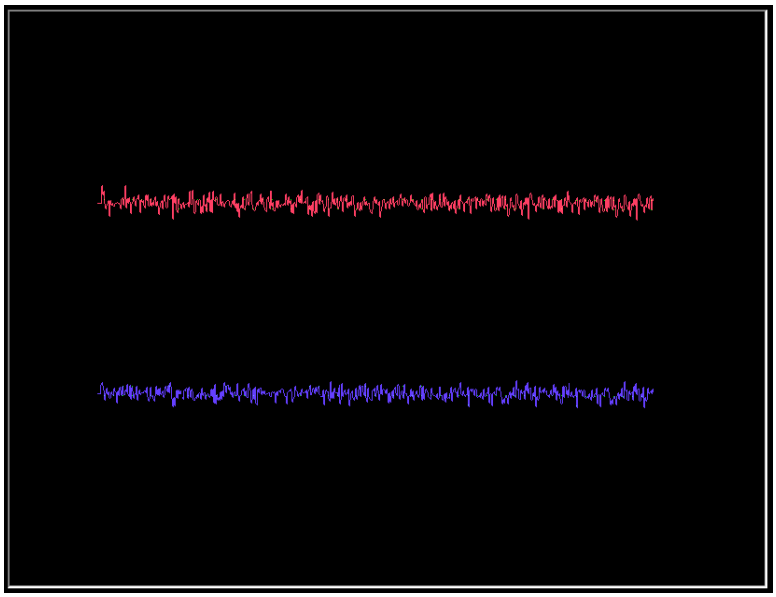
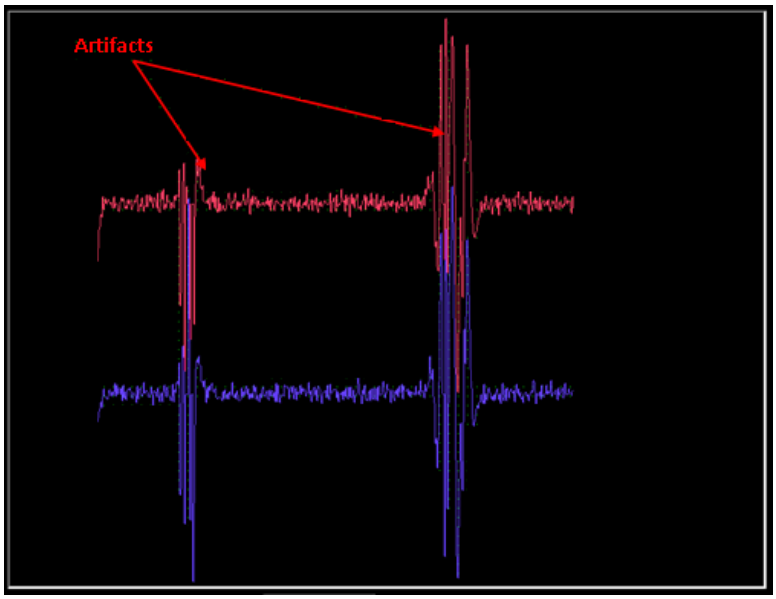
Each segment consists of a number of **steps**. Each step is one stimulus presentation, so there are 72 steps per second. There are 1024 steps per segment, so a segment is 1024 / 72 = 14 seconds in length, plus another fraction of a second for synchronization and blending of the segments together. The progress of each segment is displayed on the screen as a fraction of the total number of steps in the segment, for example 257/1024. The progress of the segment is updated each 16 steps.

During the recording, a window will display the data from each 16 steps. You should carefully watch the displayed data to make sure that no eye movements or other artifacts contaminate the recording. Examples of good and bad tracings are shown below. In general, if the recorded data appear to go outside the window, the artifact is unacceptably large and that segment should be re-recorded.

While recording a segment, **Interrupt** may be used if the patient blinked or moved and you need to repeat the current segment.

This is a good recording trace during acquisition.	
This is an example of a blink artifact during recording. If too many blink artifacts occur, the segment should be interrupted (click the **Interrupt** button) and repeated (click the **Repeat** button).	

At the end of the segment, initial processing to eliminate artifacts is performed and the segment is displayed. At this point, the segment can be repeated or you can continue with the **Next Segment**.

This is a good recording. The response of the eye to the mfERG signal is visible (small wavelets), there are no large eye movements, and all of the data is within the bounds of the display and is relatively consistent in amplitude.	
This is a segment containing two large eye movements. The eye movement has larger amplitude than the rest of the waveform. Blink artifacts will be removed by the processing algorithms. However, if the % artifacts displayed above the graph is greater than a few percent, the segment should be re-recorded. In this case select **Repase Segment** to re-record.	

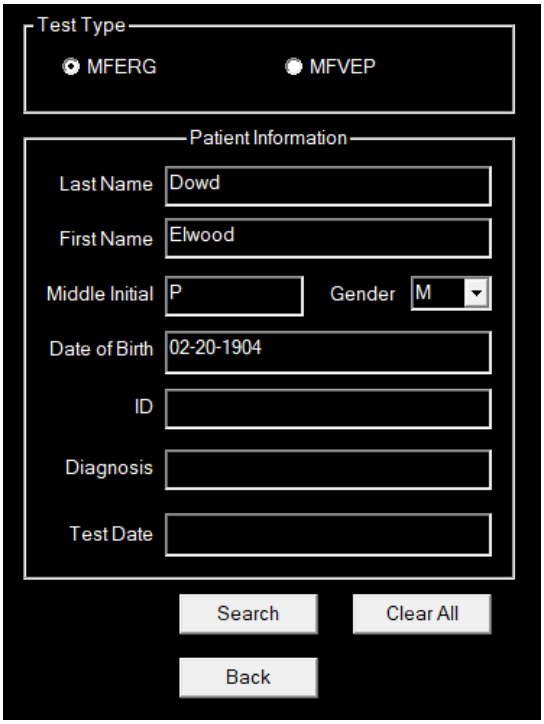
Keep recording until all segments are done. Then click on **Save Test** to store the data.

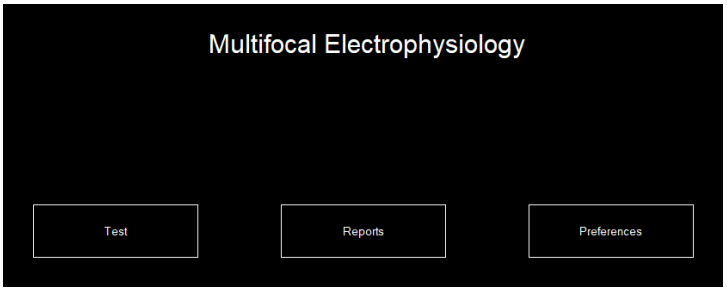
Once the data has been stored the **Analysis** screen is displayed.

4.0 MFERG Data Analysis and Report

mfERG results may be influenced by the exact stimulator used, therefore the manufacturer and model of the stimulator should be included in reports to help compare mfERG data to results from a UTAS using a different stimulator type.

4.1 Finding a patient's data





Start Multifocal Software and go to **Reports**.

Select MFERG in Test Type

Then enter your search parameters (example to the right)

Clicking **Search** displays all mfERG recordings with the matching parameters.

Clear All will clear all the patient information fields

Click **Back** to go to Main Menu

Select up to 4 recordings from the list. Recordings will have to be the same **Test Type** and **Test Length** in order to be retrieved together.

Select by left clicking with the mouse.

Index	Name	BirthDate	TestDate	TestType	TestLength	Label/Eye
0	test	01/01/2011	09/23/2019	19	1 min	R
1	test	01/01/2011	09/23/2019	19	1 min	R
2	Doe, John	03/01/1970	09/23/2019	19	1 min	R
3	Doe, John	03/01/1970	09/23/2019	19	1 min	L
4	Doe, John	03/01/1970	09/23/2019	61	3.6 min	R
5	Doe, John	03/01/1970	09/23/2019	61	3.6 min	L
6	Doe, John	03/01/1970	09/23/2019	103	7.2 min	R
7	Doe, John	03/01/1970	09/23/2019	103	7.2 min	L
8	mf-557	08/08/1999	10/30/2019	19	1 min	R
9	JS	09/06/1990	10/31/2019	61	7.2 min	R
10	JS	09/06/1990	10/31/2019	61	7.2 min	L
11	mf570	08/08/1999	11/18/2019	19	1 min	R
12	mf553	08/08/1999	11/18/2019	19	1 min	Right
13	mf553	08/08/1999	11/18/2019	19	1 min	Left

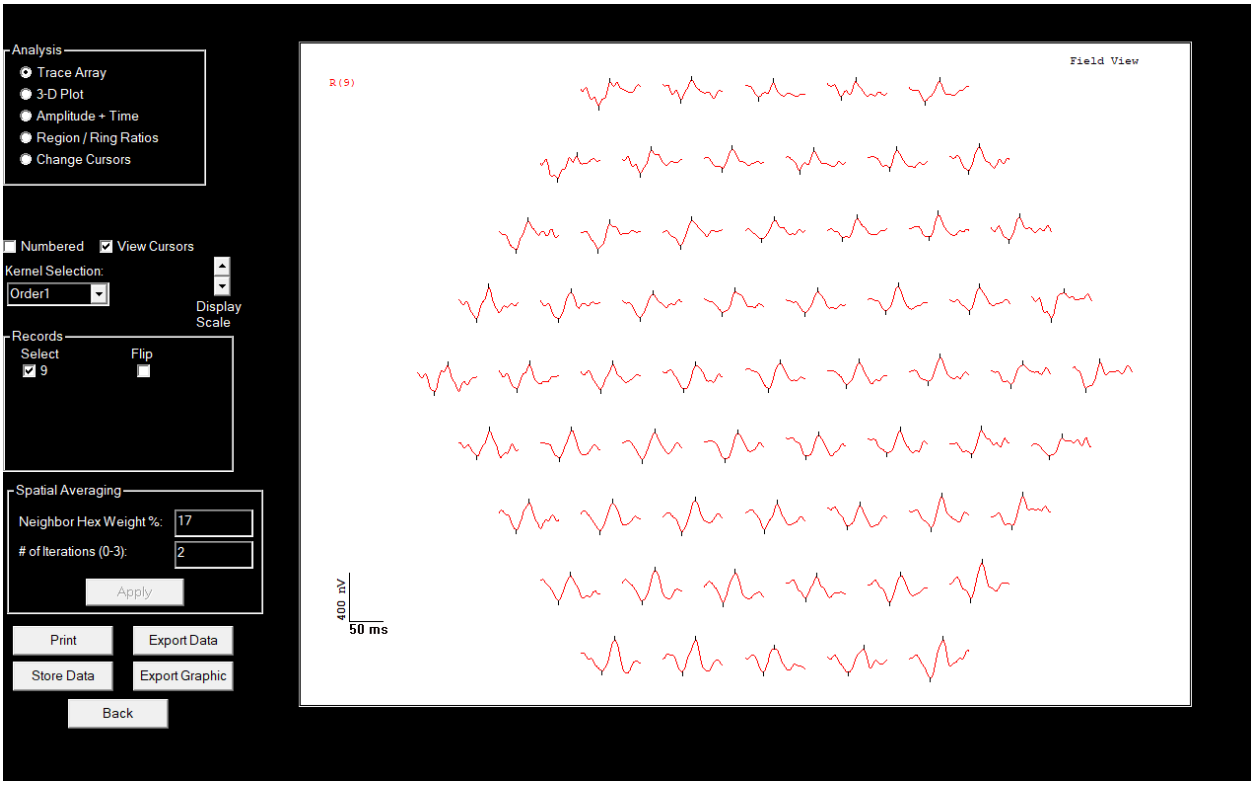
Click on ***Next*** to go to the Analysis page

4.2 Analysis of Data

For all mfERG analysis the 1st order kernel is the default selection.

Trace Array

The **Trace Array** view shows the individual mfERG waveforms for each hexagon. This is the most important view of your data, as it shows whether artifacts are present and best lets you interpret the mfERG waveforms. You should always print the Trace Waveform view as part of a report. Trace arrays are presented in field view: the right-most waveform results from the right-most hexagon on the display (unless **Flip** is checked), and the top row of waveforms results from the top row of hexagons on the display.



You can adjust the magnification of the waveforms on the screen by using the **Display Scale** slider. Clicking on the up arrow will enlarges the waveforms. The scale at the bottom left of the screen will change so that the correct waveform amplitude is displayed.

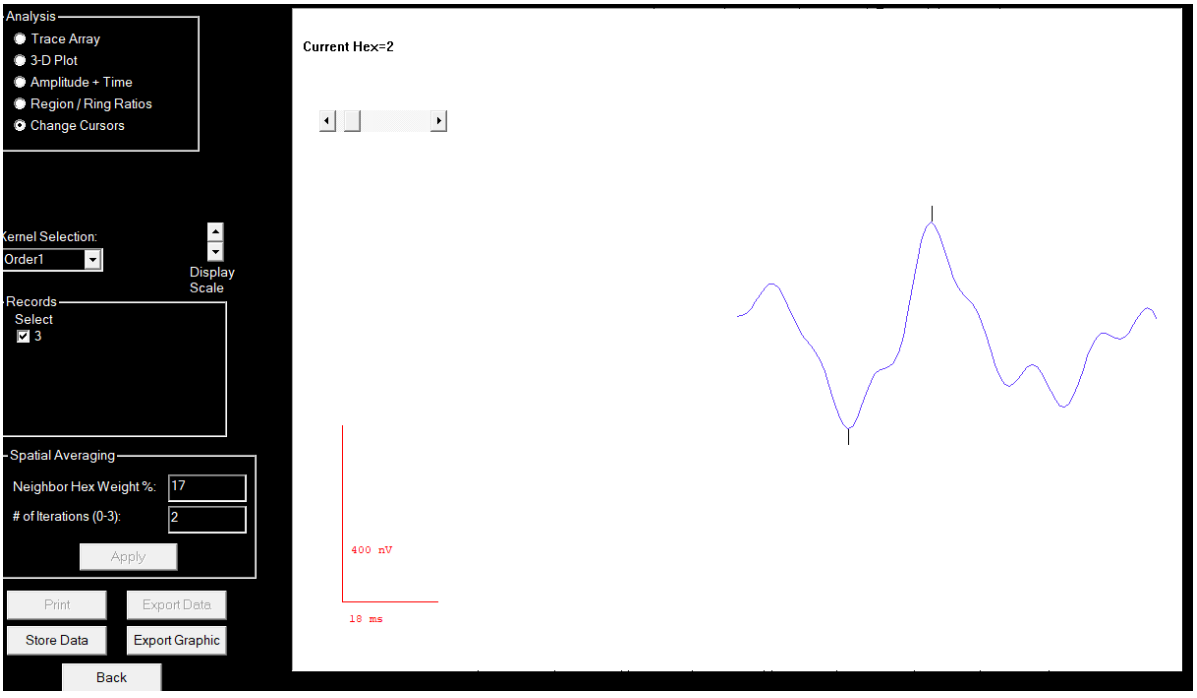
- **Numbered** Turns on the sequential numbering of the individual traces.
- **View Cursors** Shows the marks placed by the software for N_1 and P_1 (defaults as checked)
- **Flip** Mirrors the waveforms about a vertical line. It makes a right eye appear as a left eye or vice-versa. It can be useful in overlapping Right and Left eyes.

In this screen, you should look at the placement of cursors on the waveforms (the **View Cursors** box must be checked to see the cursors). If there are hexagons for which the cursors appear to be placed incorrectly, you can adjust them using **Change Cursors** under **analysis** in upper left corner of the screen, described below.

If you have several records selected, you can enable or disable displaying of individual waveforms by checking the **Select** box next to them.

Checking the **Average** box will display the average of all selected waveforms.

Change Cursors



Cursors are automatically placed on the waveforms using a template stretching routine. [Hood 1998]. While this technique will almost always place the cursors for N_1 and P_1 in the correct location, you should review the placement of cursors on the waveform. If you feel they need to be adjusted, this can be done in the **Change Cursors** screen. If you click the **Change Cursors** radio button, the screen at right will be displayed.

You can view the response from each hexagon by clicking on the slider at the top left of the screen. If you disagree with the cursor position, you can use the mouse to adjust placement of the cursors on N_1 and P_1.

Click below the waveform to place the cursor for N_1

Click above the waveform to place the cursor for P_1

When you have corrected any cursor placement errors, you are ready to continue analyzing your waveforms. Note adjustments to the cursor positions are not stored with the waveform.

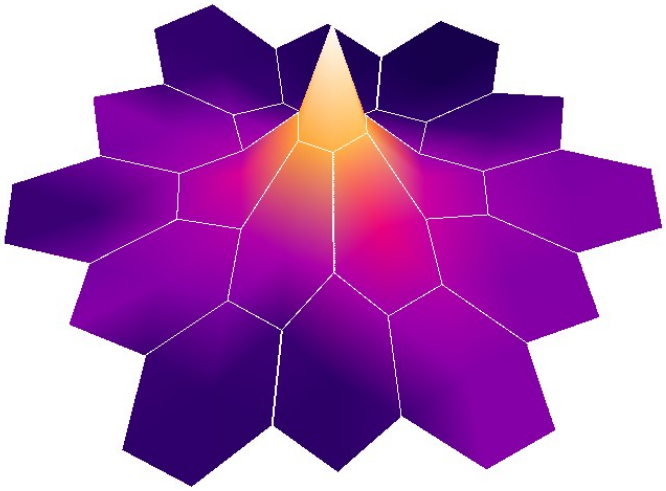
If several waveforms were selected and averaged **Change Cursors** will allow you to change the cursor placement on the average of selected waveforms.

Amplitude and Time

If you would like to see the numerical values of the individual hexagon amplitudes and implicit times, click the **Amplitude and Time** analysis. The screen will show you the waveform amplitude ($P_1 - N_1$) as a voltage and the implicit time of P_1 in milliseconds. This is indicated by the legend in the lower left of the graphing area. You can turn off the numbering of the hexagons by unchecking the **Numbered** box.

If several waveforms were selected and averaged this view will display the amplitude and time of the cursors of the averaged waveform.

3D Plot

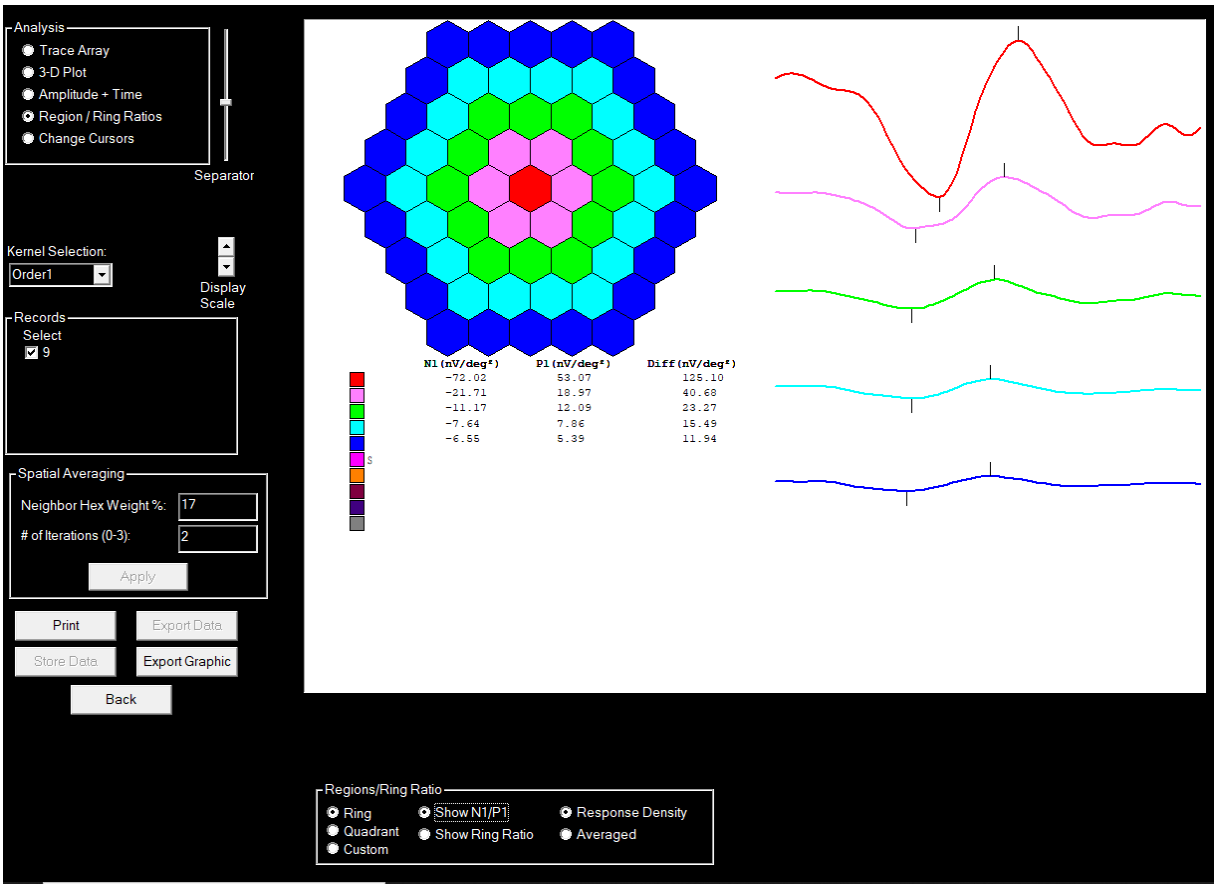


The 3D plot is arguably the most misused of the mfERG data displays, In the 3D plot, the data is represented in nV/deg^2. That is the value of the mfERG for a hexagon is divided by the area of the hexagon (in square degrees of visual angle). Since the cone density is greatest in the fovea, the 3D plot should show a spike in amplitude at the fovea. However, Dr. Don Hood of Columbia University has shown that a convincingly normal 3D plot can be generated by placing the electrodes in a beaker of saline. This is true because the noise in each hexagon is constant, thus the scaled 3D plot has a near-normal appearance. Thus, it is important to view the trace waveforms before attempting to interpret the 3D plot.

You can change the appearance of the 3D plot by tilting either of the 2 planes using the sliders immediately to the right and immediately below the graph area.

Averaging Regions

In some disorders, the mfERG is affected in some regional pattern. For example, in Plaquenil toxicity, mfERG amplitudes are affected in pericentral rings. In these instances, it may make sense to group regions of the mfERG for analysis. See [Lyons 2007] for a good example of this. When you first click on the **Region/Ring Ratio** button, you will be presented with a screen where all of the hexagons are averaged into a single response.



The mfERG software provides you with the ability to create your own regions, and with two common default regional groups.

Creating your own regions

To create a region of your own design, first you must click on **Custom** in the **Regions/Ring Ratio** box. And then select one of the colored boxes at the lower left of the screen. A small letter 'S' should appear next to the box, indicating that it is selected. Click on the hexagons you wish to include in this region. Continue selecting groups and including hexagons until all of your groups are defined. Up to 10 groups can be defined.

Pre-defined regions

The most common regions for analysis of mfERG data are rings and quadrants.

If you select **Select ring regions** the software will automatically create ring regions as shown in the picture at the top of the page. See example for a 19 hexagon mfERG ring region above.

If you select **Quadrant** regions the software will automatically divide the hexagons into quadrants. Some hexagons may be included in more than one quadrant; this will be shown on the graph if so.

Measuring

Once your regions are defined, you can measure them by selecting **Show N1/P1** from the menu. The software will automatically place cursors on the averaged waveforms for each region and will determine the amplitude and latency of N_1, P_1, and P_1-N_1. These will be displayed in the graph area. You may manually adjust the placement of these cursors by clicking on the box matching the color of the wave you are interested in adjusting (an "S" will appear next to the selected box to show that it has been selected), then clicking and dragging the cursors to the desired position. The amplitude and latency values will automatically update as you make changes.

If Ring was selected as a **Region Selection**, then you can also select **Show Ring Ratio** as a measurement.

Ring Analysis Units

There are two choices of units to display the waveforms, either **Response Density** which gives you the ring averages scaled with the size of the hexagon in nV/deg^2 or **Averaged** which is the simple average of all the hexagons of the same color in nV.

MFERG Recording Quick Guide

1. Prior to beginning testing, the patient should be fully dilated (see manual on patient refraction).
2. On the computer, close all other applications and start the multifocal software.
3. Select MFERG as test type. Enter all applicable patient information and channel information (select 2 channels if recording binocularly). At a minimum, Last Name or Identification and Date of Birth must be specified.
4. Choose the desired pattern (19 hexagon – 1 min, 61 - 4 min, 103 hexagons – 8 min, 241 hexagons – record 8 minutes twice).
5. While in a moderately light room attach electrodes as per mfERG setup diagram. Be sure to anesthetize the eyes with a local anesthetic and fill the contact lens with Goniosol or another 2% methylcellulose. Place electrodes according to drawing. **NOTE: IF ONLY RECORDING FROM 1 EYE ALWAYS USE CHANNEL 1 TO RECORD** Anesthetize contralateral eye if only recording from one eye to reduce blinking.
6. Place patient on the chin rest 14” from the pattern monitor. Adjust fixation camera if needed.
7. Start **Pattern Preview**, then adjust the mark size so that the patient can fixate (change size or thickness).
8. Click on **Next** to go to the recording screen. Click on **Baseline** to check the noise level. The baseline should be relatively noise free.
9. Once you have a relatively flat baseline, select the **Record** button. This will start recording the first segment.
10. If the recording segment was blink free, go to the next segment by clicking **Next Segment** (if you want to redo this segment click on **Repeat Segment**).
11. Go through all of the segments (4 segments for 19 hexagons, 16 for 61 hexagons and 32 segments for 103 hexagons…). At the end of all segments store the data by clicking the **Save Test** button.
12. The **Analysis** screen is displayed. Evaluate the results and repeat recording if necessary.
13. If you are recording from the 241 hexagons pattern you will need to record twice for each eye and average later.
14. Remove electrodes from the patient.
15. See LKC user manual for data analysis.

MFERG Report Quick Guide

1. On the computer, start multifocal software and go to reports
2. Select MFERG in test type
3. Type in last name of patient or ID number and click **Search**
4. Select recording(s)
5. Select the recording you'd like to print out (e.g., 19 Hexagons Right Eye). In the case of 241 hexagons you should have recorded twice – select the two recordings and average them.
6. Review cursor placement in the **Trace Array view**, move cursors if needed in the **Move Cursor** view
7. Print the desired views

MFERG Interpretation Guide

Introduction

There are a number of ways in which the multifocal ERG can be viewed and analyzed. Here are broad guidelines for understanding and interpreting mfERG data.

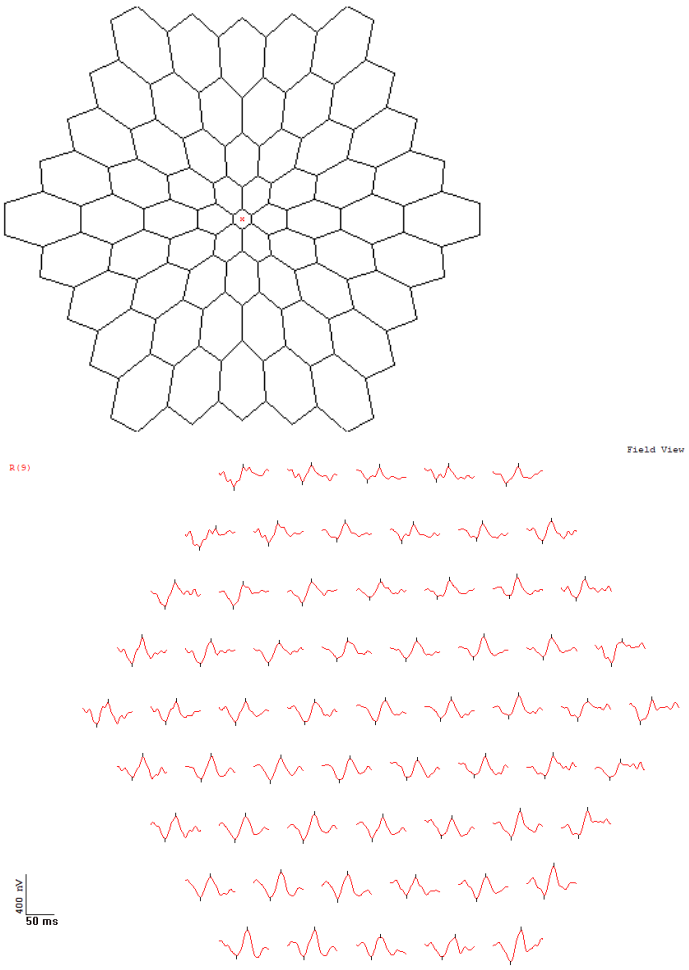
Trace Arrays

> "The trace array is the basic mfERG display and should always be included in the report of clinical results."
>
> — ISCEV mfERG Guideline [2]

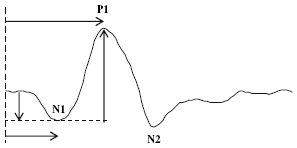
The Trace Array is the most useful way to visualize and understand the multifocal ERG. You should always begin your analysis of an mfERG by looking at the Trace Array.

What does a good recording look like?

The Trace Array is the display of the individual multifocal ERG wavelets arranged in the same manner as the stimulus presentation. The hexagons in the multifocal stimulus are scaled so that in normal subjects the mfERG response is approximately the same amplitude in each hexagon. The scaled stimulus array and a typical 61 hexagon trace array from a normal subject are shown below.

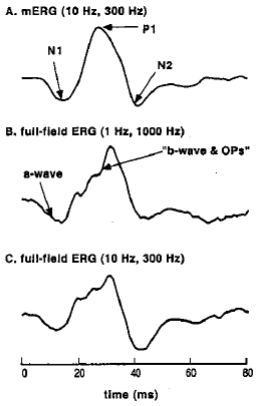


Each multifocal wavelet has 3 primary features, an initial negative deflection (N_1), followed by a positive deflection (P_1), followed by another negative deflection (N_2). An example is shown at right (Picture taken from [2]).

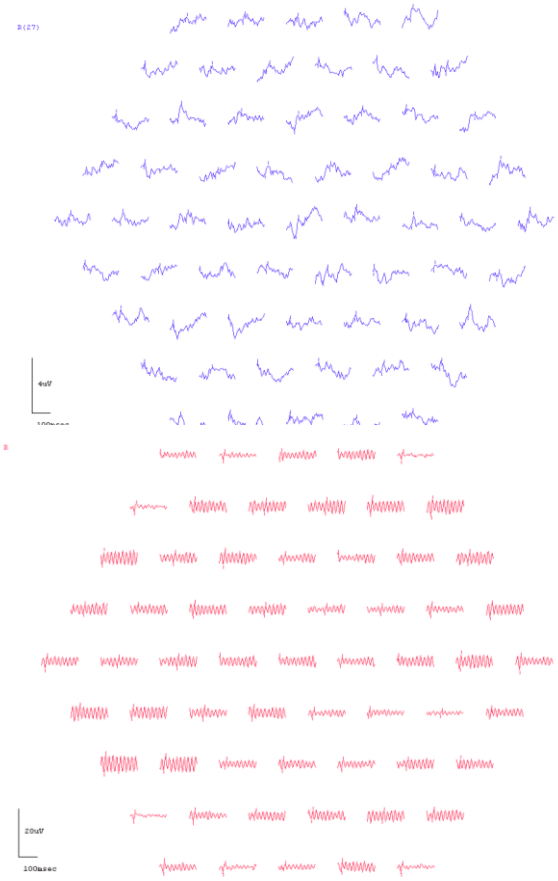


The multifocal ERG response to each hexagon can be thought of as a "mini photopic ERG." The components of the mfERG tracing are not exactly the same as those of a ganzfeld photopic ERG, but they are very similar. N_1 is comprised of the same components as the a-wave of the ganzfeld ERG and P_1 is comprised of the same components as the b-wave and OPs of the ganzfeld ERG. See [1] on page 42 for more details. A comparison to the components of the standard photopic ERG is shown at right (Picture taken from [1]). The top tracing shows a multifocal ERG tracing. The bottom 2 tracings show a photopic ganzfeld ERG with normal amplifier and filter settings and with amplifier and filter settings that match the recording conditions of the mfERG. Note that the P_1 component appears earlier in the mfERG than does the b-wave in the ganzfeld ERG.

The most useful diagnostic measure of the individual mfERG tracing is the amplitude of P_1, measured from N_1. This is referred to as the "N_1-P_1 amplitude." The N_1-P_1 amplitude is typically expressed in nanovolts (1 nV = 0.001 μV). In some instances, the N_1-P_1 amplitude is normalized by the area of the stimulating hexagon in square degrees; this is referred to as the "response density" and is expressed in nanovolts per square degree (nV/deg^2). Another diagnostic measure that is sometimes used is the P_1 implicit time – the time to the peak of P_1. The features of N_2 are not of clinical significance.



The amplitude of an ERG waveform is proportional to the area stimulated (measured in square degrees) and to the average photoreceptor density. In a ganzfeld ERG, the stimulated area of the eye (roughly 150° x 120°) is on the order of 20,000 deg^2, while a typical multifocal hexagon (for a 61-hexagon stimulus) is on the order of 100 deg^2. Thus, while the amplitude of a normal ganzfeld photopic ERG is on the order of 100 μV, the amplitude of a typical mfERG hexagon is on the order of ½ μV, or about 500 nV.



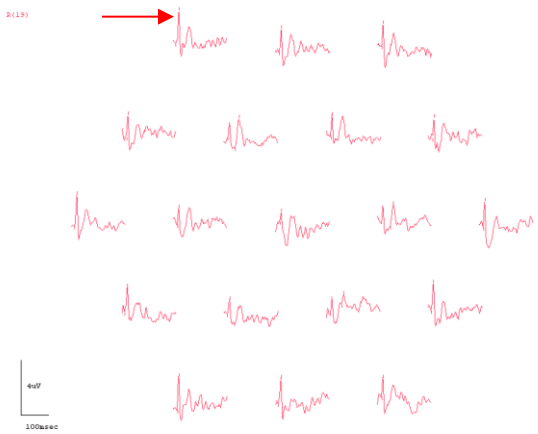
For those who are just getting started with mfERG, we strongly suggest recording a series of at least 10 normal controls. This will assure that 1) recording technique is correct and 2) you will be able to recognize a normal mfERG.

Sources of artifact in the mfERG.

***Eye movements*.** Probably the most common source of artifact in the mfERG is excessive eye movement, squinting and blinking. Because the muscle (EMG) signal from eye or lid movements can measure hundreds of μV, it can easily obscure the underlying multifocal signal. The primary identifying feature of this artifact is a sloping baseline with little or no recognizable mfERG waveform. The slope may be either positive or negative.

Mains noise. Mains noise results from power line interference being coupled into the electrodes being used to record the mfERG. The most common cause of mains noise contamination is poor electrode contact. Mains noise is readily recognized by its periodic sinusoidal appearance. An example of mains interference (recorded with 60 Hz power lines) is shown at right. There is no mfERG signal present in this recording; it is pure artifact. If your mfERG looks like this, it needs to be re-recorded.

Monitor artifact. The monitor used to record the mfERG generates a small amount of interference in synchrony with the stimulus presentation. This interference may be picked up by the electrodes and appear as part of the mfERG tracing. The usual cause of the interference is poor electrode contact or having the electrode wires too close to the monitor. The interference manifests as a spike (which may be positive-going or negative-going) at the beginning of the trace waveform. An example of monitor artifact is shown in many of the tracings in the recording at right.



What about the blind spot?

In mfERG recordings using the 19, 61, or 103 hexagon patterns, it is very possible that no stimulus hexagon will fall entirely within the optic disc. Additionally, small amounts of fixation instability may cause some stimulation of adjacent retina even if a hexagon largely falls within the optic disc. Thus, for the 19 and 61 hexagon patterns the blind spot will probably not be visible; for the 103 hexagon pattern the blind spot may or may not be visible. With a display of 241 elements, at least one hexagon should fall entirely within the optic disc if steady fixation is maintained, resulting in a visible blind spot on the mfERG trace array.

The effects of age on the mfERG

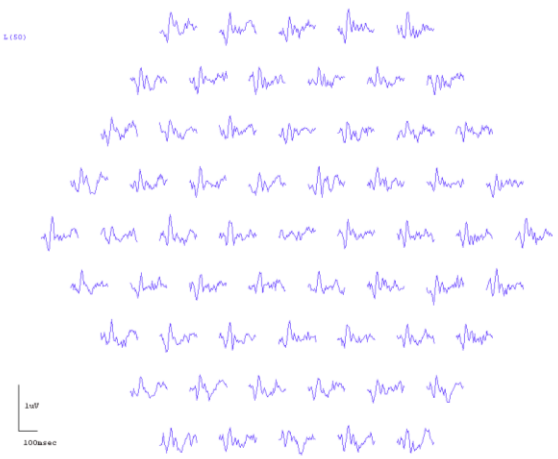
mfERG N_1-P_1 amplitude exhibits a linear decrease with age of approximately 0.9% per year from age 10 to 80, while P_1 implicit time increases at the rate of approximately 1.3% per year. [5] This change in age should be taken into consideration when looking at the numerical results for a particular patient.

The effects of retinal disorders on the mfERG

Because the mfERG measures the ERG locally, it is very useful in identifying sites of localized disease, or – in the case of diseases like Retinitis Pigmentosa – sites of localized remaining function. The main effect of most retinal disorders is to reduce the amplitude of P_1.

For most conditions in which the mfERG is useful, the trace array will show some areas of normal function and some areas of abnormal function. For example, a patient with early macular degeneration will usually show normal peripheral tracings and attenuated mfERG wavelets in the center of the trace array.

A simulated AMD tracing can be seen at right. The simulation was created by blocking the light from the central hexagon when recording from a normal eye.



Other disorders will manifest themselves in the trace array as areas of diminished $N_1 – P_1$ amplitude in the areas with functional impairment.

Sites and mechanisms of retinal damage and changes in the mfERG

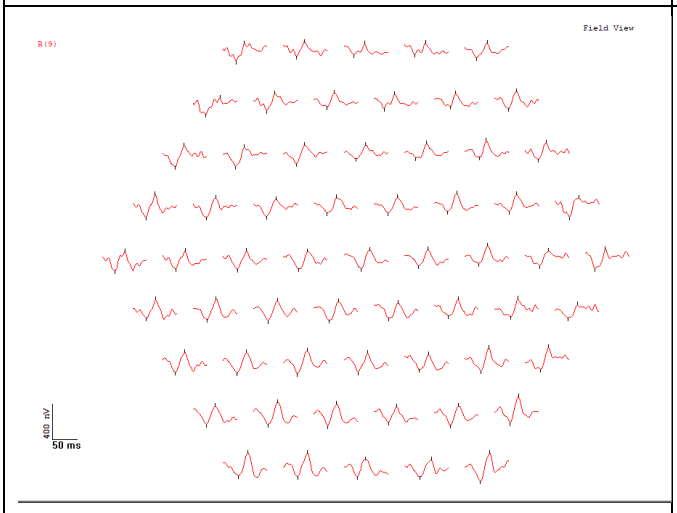
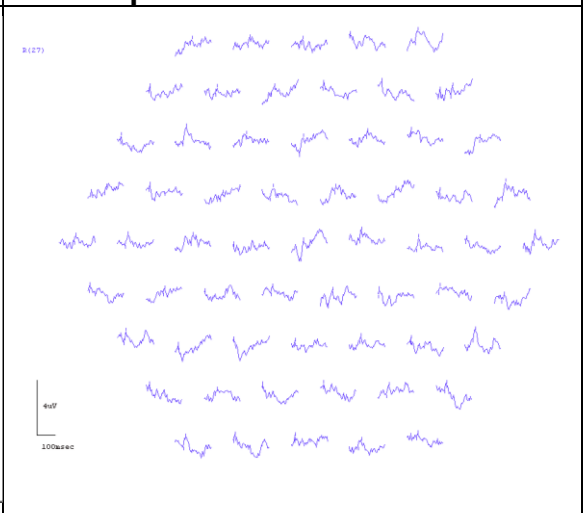
[Adapted from Reference 1]

Damage to	Mechanism	P_1 Amplitude	P_1 Time
Cone receptor	Outer segment damage	Smaller	Moderate delay
	Cell loss	Smaller	Normal
Outer plexiform layer	Altered synaptic transmission	Smaller or Larger	Large delay
On-Bipolar cells	Cell loss	Smaller	Moderate delay
Off-Bipolar cells	Cell loss	Larger	Slightly faster (?)
Inner plexiform layer	Altered synaptic transmission or cell loss	Approx. normal (shape changes)	Small delay
Ganglion cells	Cell loss	Approx. normal	Approx. normal

The 3D Plot

The 3D plot is an area plot of $P_1 - N_1$ amplitude scaled by the size of the hexagon. It is thus reported in nanovolts per square degree (nV/deg^2). In theory, this allows visualization of function in the foveal area. While the 3D plot provides a pretty picture, it is not generally useful for diagnosis.

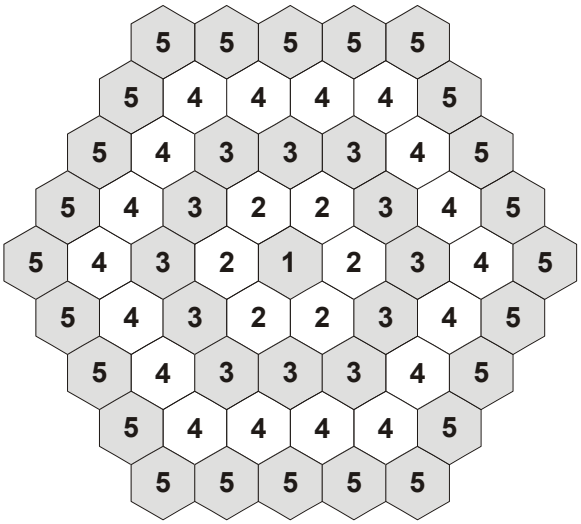
This cannot be stressed enough: **The 3D plot can be extremely deceptive in its appearance and should not, in general, be used for diagnosis**. Below are examples of a good mfERG and a completely uninterpretable mfERG and their corresponding 3D plots:

Normal mfERG	**Uninterpretable mfERG**
	
	

Note that the "garbage" mfERG on the right has a completely normal-looking 3D plot. One prominent mfERG researcher (Don Hood of Columbia University) has demonstrated that a normal-looking 3D plot results from placing the recording electrodes in a beaker of saline.

Ring Ratios

mfERG ring ratios are measurements of response density (in nV/deg^2) created by averaging rings concentric to the fixation point. They are most commonly used with the 61 hexagon mfERG, which is shown at right. (The scaling of the hexagons with cone density is not shown for clarity.) Ring ratios are created by taking the ratio of the response density of the central hexagon (Ring 1) to the average response density of a peripheral ring.



Ring ratios have several useful diagnostic properties: They do not vary with age, and their variability (coefficient of variation) is much less than that of the ring averages.

Ring ratios provide very sensitive and specific early detection of Plaquenil toxicity. [3] Elevated values of R_1:R_2 and/or R_1:R_3 indicate toxicity in patients who are taking Plaquenil. The ring ratios calculated by the mfERG software can be compared to the limits published in [3, 4].

Ring ratios are also useful in the detection of macular disease, where low values of R_1:R_4 may indicate a significantly diminished macular response relative to the periphery. Lower limits of normal for use in evaluation of macular disease can be found in [4].

Stimulus Source

The exact type of stimulator used on an mfERG can affect the amplitude and waveform of mfERGs making it essential to report the type of display and to specify the details of the manufacturer and model when reporting results that may be compared to UTASs with different stimulators.

References:

1. Hood, DC. Assessing retinal function with the multifocal technique. *Progr Retin Eye Res.* 19:607-46, 2000.
2. Hoffmann, M.B., Bach, M., Kondo, M. et al. ISCEV standard for clinical multifocal electroretinography (mfERG) (2021 update). Doc Ophthalmol 142, 5–16 (2021). https://doi.org/10.1007/s10633-020-09812-w
3. Lyons JS, Severns ML. Detection of early hydroxychloroquine retinal toxicity enhanced by ring ratio analysis of multifocal electroretinography. *Am J Ophthalmol* 143:801-9, 2007.
4. Lyons JS, Severns ML. Using multifocal ERG ring ratios to detect and follow Plaquenil retinal toxicity: a review. *Doc Ophthalmol* 118:29-36, 2009.
5. Tzekov RT, Gerth C, Werner JS. Scenescence of human multifocal electroretinogram components: a localized approach. *Graefe's Arch Clin Exp Ophthalmol* 242:549-60, 2004.

Multifocal VEP

1.0 Introduction

1.1 What is a multifocal test?

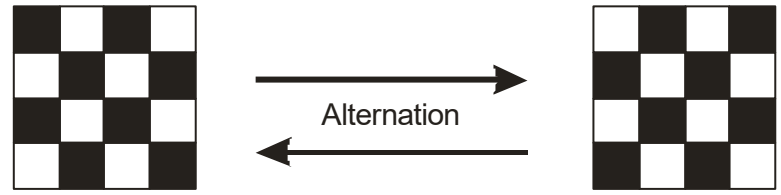
Multifocal testing is a way of recording a visually evoked potential (VEP) from many regions to get a map of visual function. A multifocal test uses a computer display screen as a stimulator and divides it into a number of smaller test areas. Each test area is stimulated using an on-off sequence that differs in time from all the other test areas. Evoked responses are collected simultaneously from all stimulated areas, and the resulting data is processed after recording to extract the individual responses.

1.2 How does a multifocal VEP work?

In the mfVEP, the screen that the patient views is divided into a number of sectors – from 4 to 60. Each section will stimulate a small portion of the retina and the information will be transferred to the visual cortex via the optic nerve. mfVEP will allow the response from that portion to be recorded separately from other portions of the visual cortex.

1.3 m-sequences and kernels

Please review the section on "m-sequences and kernels" in the mfERG section of this manual to understand the basics. Unlike the mfERG, the stimulus in the mfVEP is not usually a flashing stimulus. Instead, it is an alternation of the pattern in a particular sector.



A stimulus is elicited from the VEP pattern only when an alternation occurs, i.e., when the pattern is in one state during one frame and the other state during the subsequent frame. To extract the signal for an individual sector from the recorded data, one adds all of the traces where there was an alternation (sequence changed from +1 $\rightarrow$ -1 or from -1 $\rightarrow$ +1) and subtracts all of the traces where a change did not occur (sequence value +1 $\rightarrow$ +1 or -1 $\rightarrow$ -1). The result is the response of the visual system (from retina through optic nerve to primary visual cortex) to the alternating stimulus. This is referred to as the *second order kernel* of the mfVEP.

1.4 Field of view

The field of view of the multifocal stimulus is determined by 2 factors – the size of the monitor screen and the distance from the monitor to the patient. Position the monitor so that distance from the patient to the monitor matches the distance specified on the label on the front of the monitor. Following the viewing distance on the front of the monitor

results in a total field of view of 45° (±5°). For more information on calculating visual subtense of monitor-based stimuli, consult the ISCEV calibration guidelines. [CSC, 2003]

1.5 When is the mfVEP useful?

mfVEP provides an objective evaluation of the topographic visual function. For a normal subject, the mfVEP of left and right eyes are nearly identical. Any significant difference between two eyes indicates an abnormality. mfVEP has high spatial resolution in the foveal region.

Uses:

- Help to diagnose glaucoma.
- To confirm unreliable visual field test.
- Help to diagnose optic neuritis, MS, and compressive tumor in the visual pathway. The latency of the mfVEP will be altered by these conditions. Note that ischemic optic neuropathy (ION) is very similar to MS acute phase in terms of syndrome but produces no delay in VEP.
- To confirm functional visual field.

1.6 When is the mfVEP <u>not</u> useful?

The mfVEP requires both adequate fixation and proper focus for accurate recording. Any disorder that prevents adequate fixation (e.g., central scotoma) or adequate focus (e.g., dense cataract, or mydriasis)

<u>2 Preparing for a mfVEP recording</u>

2.1 The patient

- The patient should **not** be dark adapted for this test. If they have been exposed to very bright lights (such as from slit lamp, fundus photography, fluorescein angiography) allow at least 10 minutes before testing.
- The patient should **not** be dilated for this test.
- Good **near** refraction is important. The entire screen must be in focus, so presbyopic patients with multifocal lenses (including bifocals / trifocals) should be refracted using trial frames with a plus add to compensate for the screen distance (requiring approximately 3.5D plus add).

2.2 Electrodes

Poor or unstable electrode contact is a major cause of poor quality mfVEP recordings. We recommend that you pay special attention to proper electrode preparation, placement, and cleaning for mfVEP recording.

The recording electrodes are gold cup electrodes, as shown on the right. One of these electrodes is needed for each recording site (up to 3 channels). Another electrode for ground usually placed on the forehead or earlobe and one for reference usually placed at Cz.

Clean thoroughly to remove all skin oils and other debris that might impair a good contact and let alcohol dry off.

Using 2-to-1 or 3-to-1 splitters, jumper together the negative (**-)** positions ofthe forehead reference channel. . Plug the reference electrode (Cz) into the splitter.

Locate each recording electrode site. Part the hair to expose the scalp at the recording site, and scrub *vigorously* with an electrode prep pad. (If the patient's hair is long, bobby pins may help to hold the hair out of the way during this process.)

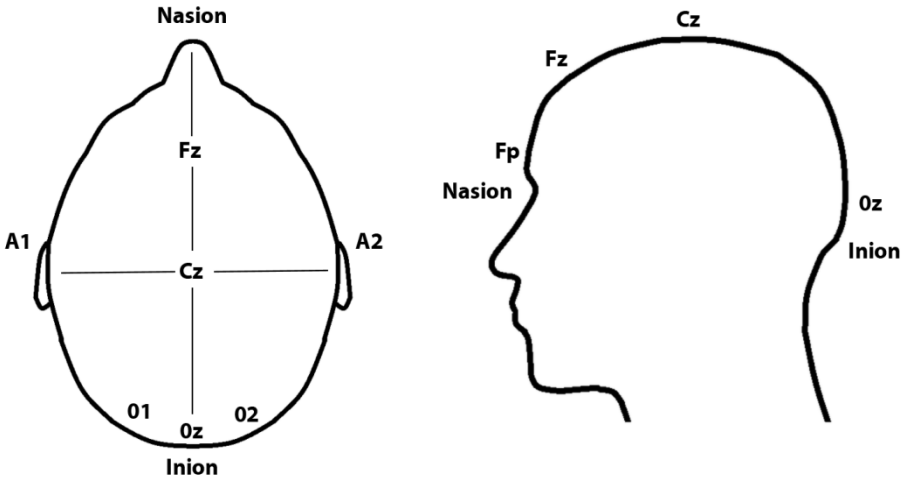
It is important to clean the scalp thoroughly to obtain a good electrode contact.

Using a generous dollop of electrode **cream** (not gel); paste the hair on each side of the part to the scalp. This is messy, but it's the best way to keep the scalp exposed. Once the hair is pasted down, put a generous portion of electrode cream in the cup of the electrode and press the electrode *firmly* into place. Cover the electrode with a 2 to 3 cm (1 to 1½ inch) square of tissue paper and press firmly again.

Repeat this procedure for each electrode. Plug the electrodes into the positive (+) side of the Amplifier unit, taking note of which electrode is plugged into which channel.

Suggested electrode placement (there are many possible electrode arrangement):

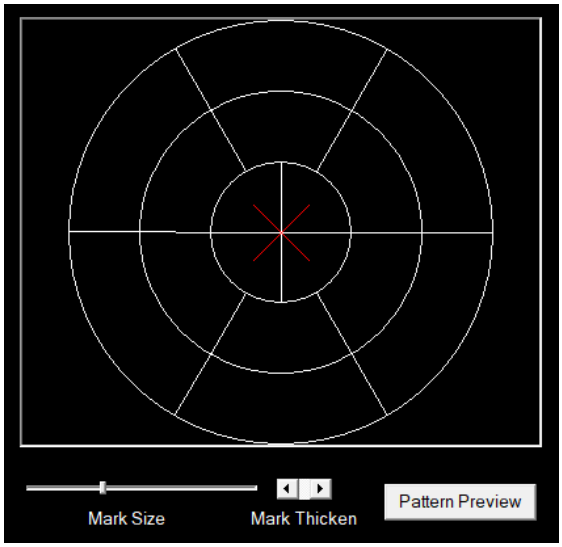
Electrode location	Amplifier connection
Ground at Fp or earlobe	Ground
Reference at Cz with a 1 to 3 splitter	1- 2- and 3-
Recording electrode #1 at Oz	1+
Recording electrode #2 one inch above Oz	2+
Recording electrode #3 one inch below Oz.	3+



2.3 Ambient lighting

The mfVEP should be conducted with the room lights on. The ideal light intensity for the room lights is one that produces illumination to the subject close to that of the average of the stimulus screen (100 cd/m^2) . If the room lights are too bright, there may be reflections from the patient display that will interfere with the recording of the mfVEP.

2.4 Issues with visually impaired patients



Patients with significant central visual impairment will have difficulty fixating on the screen. The usual fixation target is a small “X” in the center of the screen. This fixation target can be lengthened and thickened. The **Mark Size** control determines the length of the legs of the “X” while the **Mark Thicken** control determines the thickness of the legs.

Patients with poor central vision can sometimes fixate by centering the enlarged “X” in their remaining vision.

2.6 Fixation monitoring

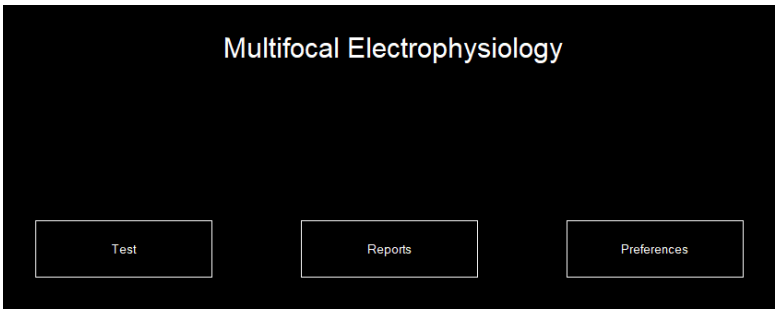
A camera is provided to allow you to monitor the patient during multifocal testing. The camera is mounted to the chin rest assembly below and in front of the pattern stimulator monitor. The image from the camera is displayed on the operator screen of the computer. This camera allows you to see if:

- the patient is closing their eyes,
- the patient is grossly off-fixating.

The camera does not allow you to determine if the patient is slightly off-fixating as in the case of a patient with a central scotoma using an alternate preferred retinal locus. Nothing short of a retinal camera will let you determine if the stimulus is centered on the fovea.

3.0 Running the Test

Open Multifocal software and select *Test*.

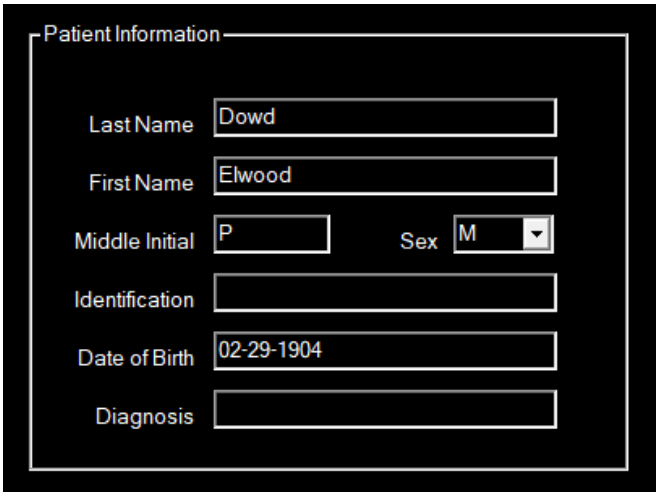


3.1 Test Type

Select MFVEP, if the option does not appear this means you do not have a mfVEP license. Refer to the UTAS setup section of this manual to learn on how to upgrade.

3.2 Patient Information

Last Name or Identification and Date of Birth are required in order to start a test.

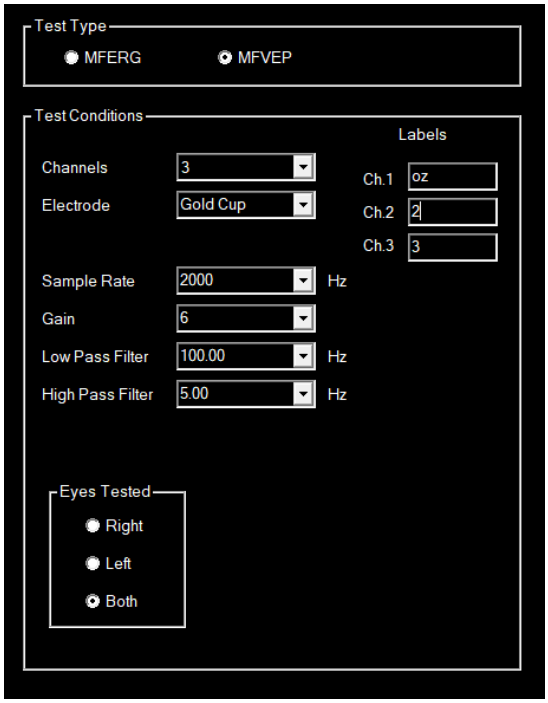


3.3 Channels and Labels

The more channels you record from the better the result.

Select the number of channels to record from and enter labels.

Select the eye or eyes to be tested. Patch any eyes not to be tested.



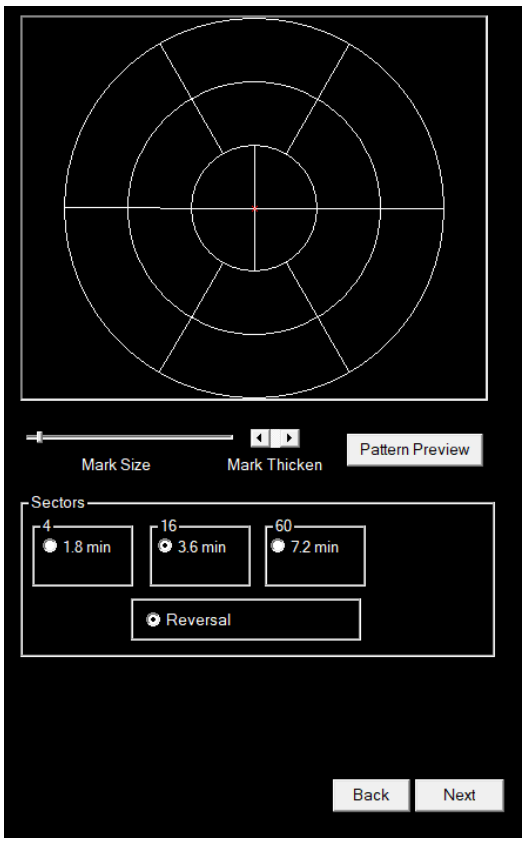
3.4 Pattern Selection

The mfVEP software provides you with several choices of number of ring segments (sectors) and length of *m*-sequence to meet your clinical needs.

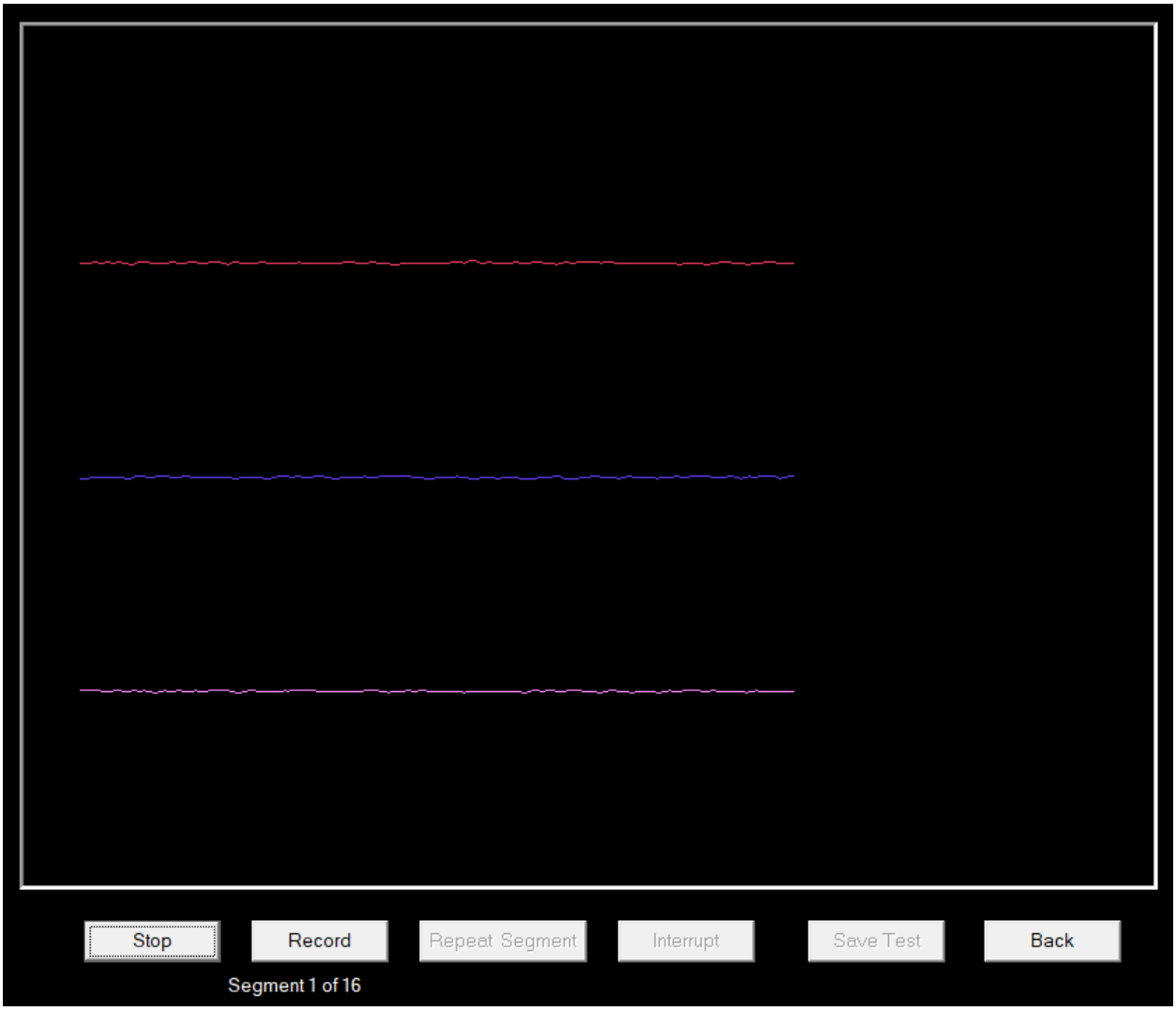
Number of Sectors

The larger the number of sectors from which you record, the smaller the signal from each sector will be. Since the noise generated during the recording is independent of sector size, larger sectors (which produce higher signals) give better signal-to-noise ratio, and thus allow shorter recording times from a patient.

The **Mark Size** control determines the length of the legs of the "X" while the **Mark Thicken** control determines the thickness of the legs.

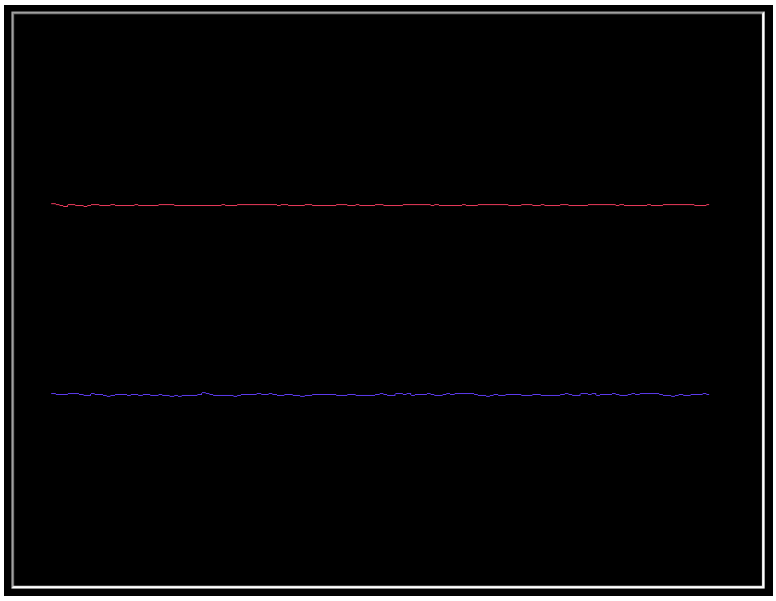
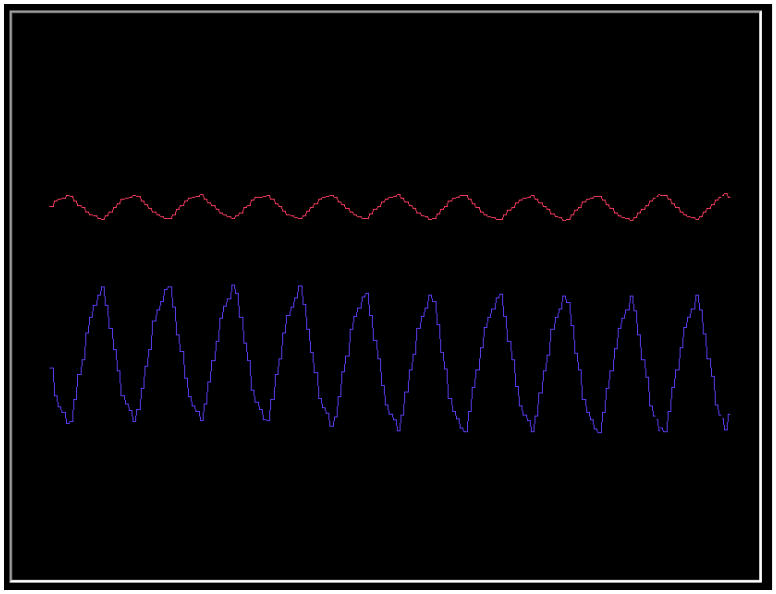


3.5 Recording Data



Baseline

After the electrodes are placed on the patient and connected to the amplifier or patient cable, you should run the baseline to assure that the connections are all functioning properly and that the patient is able to hold steady fixation. Have the patient put their chin into the chinrest and adjust the height of the forehead rest if necessary. Then have the patient look directly at the red fixation "X" on the screen. Click **Baseline**. The UTAS will begin to collect data without presenting a stimulus and will allow you to observe the patient's baseline data. Examples of good and poor baseline tracings are shown below.

Good baseline	
Bad baseline This baseline has excessive mains (50/60 Hz) noise. It is most likely caused by a bad electrode connection, although there are other possible explanations for the noise. The analysis includes removal of power line interference so complete elimination of power line interference isn't required.	

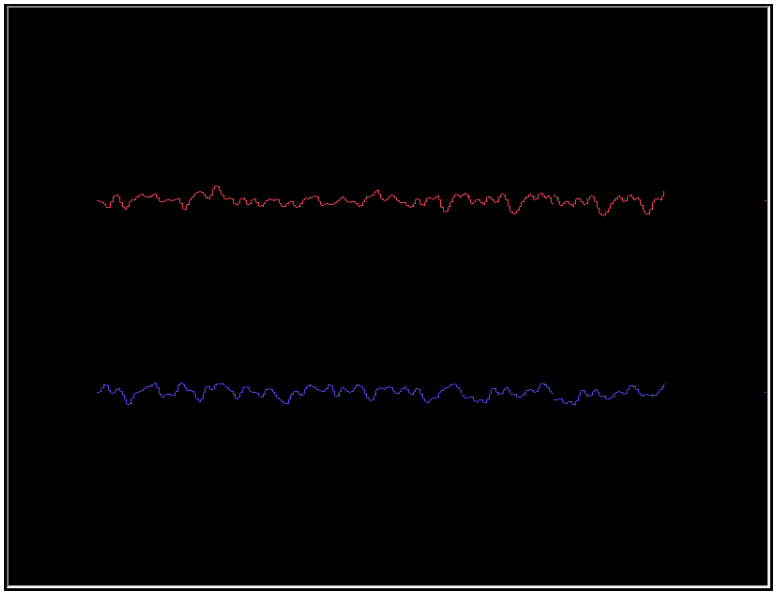
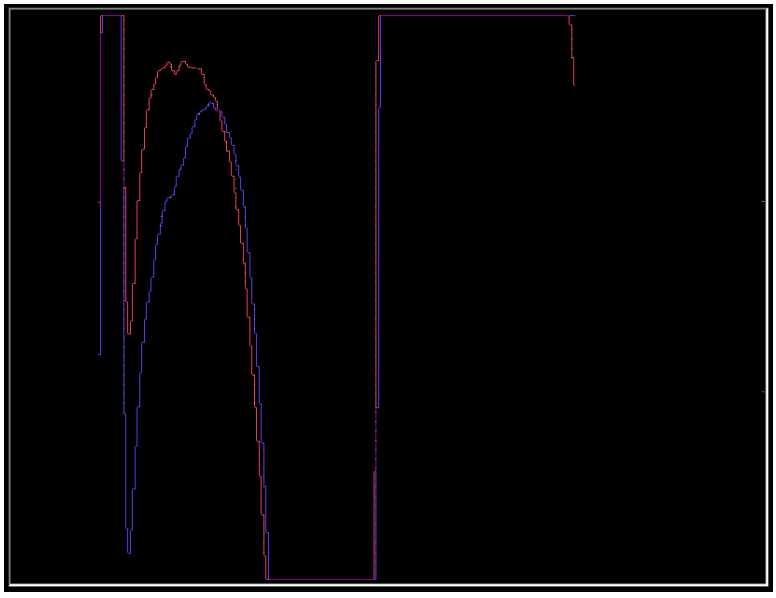
3.6 Record

The LKC mfERG software breaks recordings up into a series of **segments**. During each segment, the patient must fixate on the fixation target without blinking. After each segment, the patient can blink or rest before continuing. Longer *m*-sequences have more segments.

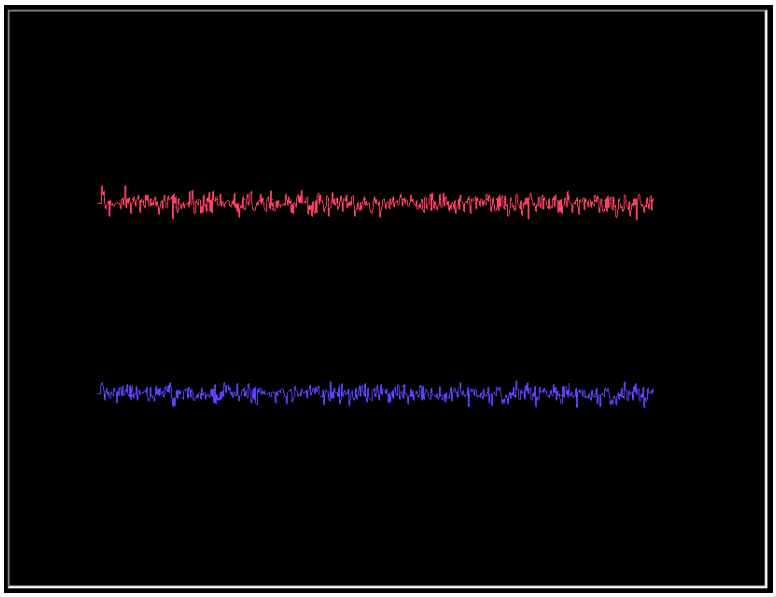
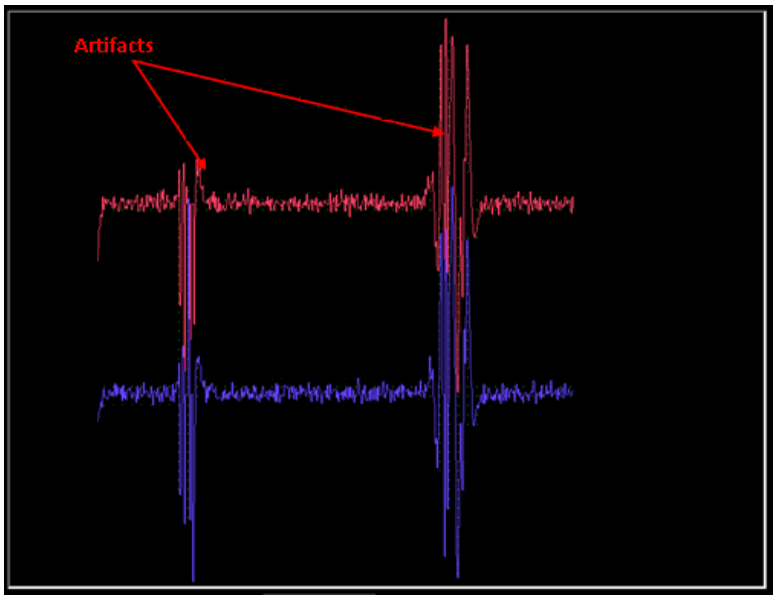
Each segment consists of a number of **steps**. Each step is one stimulus presentation, so there are 72 steps per second. There are 1024 steps per segment, so a segment is 1024 / 72 = 14 seconds in length, plus another fraction of a second for synchronization and blending of the segments together. The progress of each segment is displayed on the screen as a fraction of the total number of steps in the segment, for example 257/1024. The progress of the segment is updated each 16 steps.

During the recording, a window will display the data from each 16 steps. You should carefully watch the displayed data to make sure that no eye movements or other artifacts contaminate the recording. Examples of good and bad tracings are shown below. In general, if the recorded data appear to go outside the window, the artifact is unacceptably large and that segment should be re-recorded.

While recording a segment, **Interrupt** may be used if the patient blinked or moved and you need to repeat the current segment.

This is a good recording trace during acquisition.	
This is an example of a blink artifact or muscle twitch during recording. If too many blink artifacts occur, the segment should be interrupted (click the **Interrupt** button) and repeated (click the **Repeat** button).	

At the end of the segment, initial processing to eliminate artifacts is performed and the segment is displayed. At this point, the segment can be repeated or you can continue with the **Next Segment**.

This is a good recording. The response of the eye to the mfERG signal is visible (small wavelets), there are no large eye movements, and all of the data is within the bounds of the display and is relatively consistent in amplitude	
This is a segment containing two large eye movements. The eye movement has larger amplitude than the rest of the waveform. Blink artifacts will be removed by the processing algorithms. However, if the % artifacts displayed above the graph is greater than a few percent, the segment should be re-recorded. In this case select **Repeat Segment** to re-record.	

Keep recording until all segments are done. Then click on **Save Test** to store the data.

Once the data has been stored the **Analysis** screen is displayed.

In order to get a good quality MFVEP it is recommended to repeat the recording at least another 2 times, then average the results.

4.0 MFVEP Data Analysis and Report

Start Multifocal Software and go to **Reports**.

Clear All will clear all the patient information fields

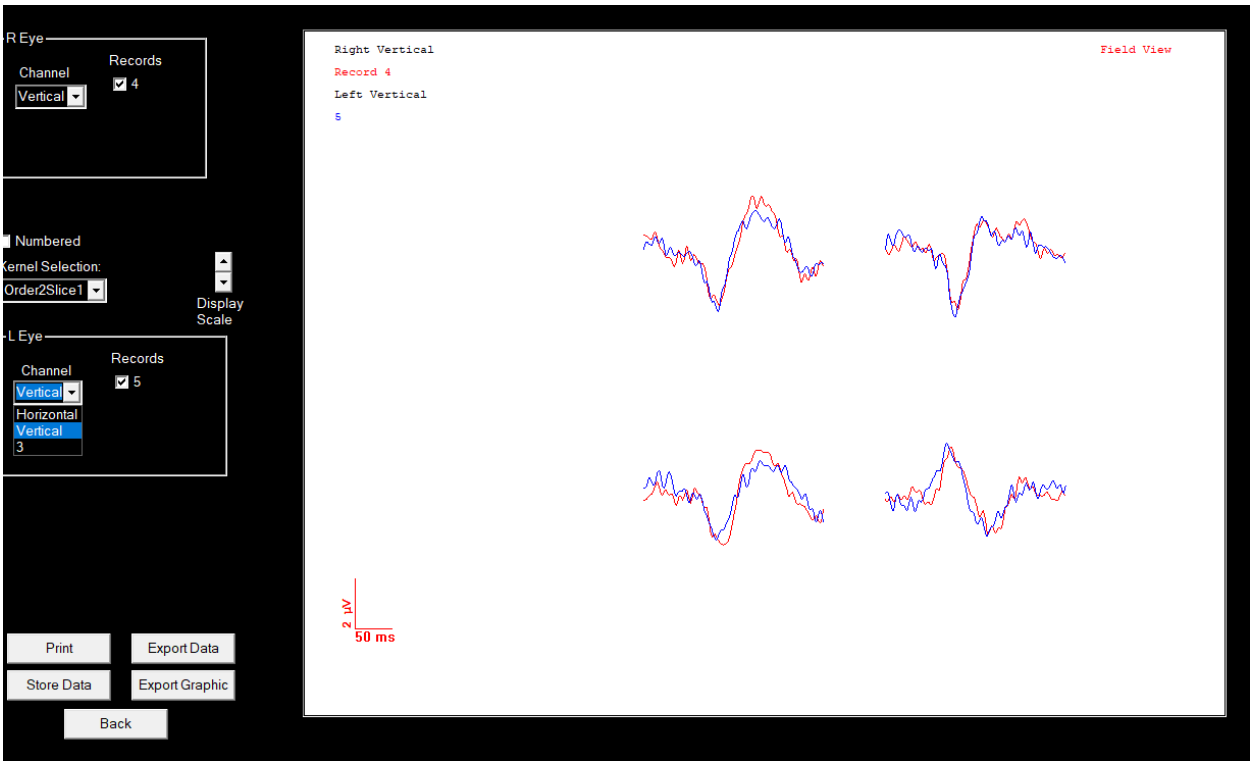
Click **Back** to go to Main Menu

Select **MFVEP** under **Test Type**, the database will then show all tests stored.

Type in the last name or ID of the patient you would like to create a report for and click on **Search**.

Select a total of up to 4 recordings. Right-eye recordings can be selected with left-eye recordings or both-eye recordings, left-eye recordings can be selected with right-eye recordings or both-eye recordings, but left-eye, right-eye, and both-eye recordings cannot be simultaneously analyzed. Recordings also have to be the same **Test Type** and **Test Length** in order to be retrieved together.

Select by left clicking with the mouse. Select **Next** and the analysis screen will be displayed



Ensure the appropriate records are checked to review the desired waveforms. Compare each channel and review the waveforms for any defects.

You can use the up and down arrow of the **Display Scale** to adjust the size of the waveform.

In order to change the channels use the drop down list in the R eye box. In this example we used 3 recording electrodes labeled at position Horizontal, Vertical, and 3.

Qualitatively, depressed or delayed responses represent abnormalities. Reviewing each channel will give you an insight in what areas of visual loss there are when compared to adjacent sectors, or separate channels.

The mfVEP responses can be used to determine spatially localized VEP responses. As the electrodes are placed over the occipital region, the recording allows for responses dominated by a component of the primary visual cortex. There are a number of applications this test has in the field of neuro-ophthalmology as an aid in diagnosis. This includes the following:

1. **Multiple Sclerosis, Glaucoma, Optic atrophies, ischemic optic neuropathies:** it has been shown that the mfVEP responses can be linearly correlated to local changes in behavioral measured sensitive tests, such as the Humphrey visual fields. This suggests that the mfVEP is a method of characterizing the loss of retinal ganglion cells. In some cases, the use of mfVEP can show abnormalities in localized areas prior to the visual field abnormalities. It can also be used on patients that have trouble with performing the HVF test.
2. **Non organic visual loss:** Similar to the conventional VEP, the mfVEP can be used to rule out functional visual loss. It also provides the advantage of producing a topographical representation of visual loss, which can then be correlated to the patient's visual fields.

Although the multifocal VEP has a variety of clinical applications, it is still being explored and developed in a clinical and research context.

Multifocal Troubleshooting Guide

Symptom	Suggested Actions
Inset screen with camera image is missing in recording window.	Make sure that the camera is plugged into a USB port Try re-starting the software – sometimes the camera does not register the first time.
I get a completely flat line when running baseline or record.	Unplug the USB connection from the UBA to the computer, then plug it back in.
Excessive 50 Hz / 60 Hz interference	An electrode may not be making good contact. Check reference and recording electrodes A wire may be broken inside the electrode.
Broken Burian-Allen electrode (broken lens or speculum)	Replace the electrode

Cleaning Between Patients

Cleaning the Forehead and Chin Rests

The patient will come into contact with the forehead rest and chin rest during testing. These should be cleaned and disinfected between uses to prevent the spread of skin infections.

The simplest method of cleaning and disinfecting the forehead rest and chin rest is to wipe them with a 70% isopropyl alcohol solution. Using a disinfecting wipe is a good way to do this. You may also clean the forehead rest and chin rest using a glutaraldehyde solution.

References

The publications below are referenced in the manual.

[CSC 2003] Calibration Standards Committee of ISCEV. Guidelines for calibration of stimulus and recording parameters used in clinical electrophysiology of vision. *Documenta Ophthalmologica* 107: 185–93, 2003.

[Hood 1998] Hood DC, Li J. A technique for measuring individual multifocal ERG records. In Yager D (ed.) *Non-invasive assessment of the visual system. Optical Society of America, Trends in Optics and Photonics* 11:33-41, 1998.

[Hood 2000] Hood DC. Assessing retinal function with the multifocal technique. *Prog Retinal Eye Res* 19:607-646, 2000.

[Hood 2002] Hood DC, Zhang X, Hong J, and Chen C. Quantifying the benefits of additional channels of multifocal VEP recording. *Documenta Ophthalmologica* 104:303-320, 2002.

[Hood 2002] Hood DC. The multifocal electroretinographic and visual evoked potential techniques. *Principles and practice of clinical electrophysiology of vision* 197-205, 2006.

[Hoffman 2021] Hoffmann, M.B., Bach, M., Kondo, M. *et al.* ISCEV standard for clinical multifocal electroretinography (mfERG) (2021 update). *Doc Ophthalmol* **142,** 5–16 (2021). https://doi.org/10.1007/s10633-020-09812-w

[Marmor 2003] Marmor M, et al. Guidelines for basic multifocal electroretinography (mfERG). *Doc Ophthalmol* 106:105-15, 2003.

[Lyons 2007] Lyons JS, Severns ML. Detection of early hydroxychloroquine toxicity enhanced by ring ration analysis of multifocal electroretinography. *Am J Ophthalmol* 143:801-9, 2007.

[Sutter 1986] Retinal area response mapping using simultaneous multi-area stimulation with binary sequences and objective response analysis. US Patent Number 4,846,567.

[Sutter 2001] Sutter EE. Imaging visual function with the multifocal m-sequence technique. *Vision Res* 41:1241-55, 2001.