SickKids®
THE HOSPITAL FOR SICK CHILDREN

Visual Electrophysiology Unit Services

Department of Ophthalmology and Vision Sciences

UPDATE 2020

This document is intended to provide an update on the clinical visual electrophysiology procedures offered at SickKids. Please see the DOVS Referrals page for instructions and forms. All testing procedures adhere to the standards put in place by the International Society of Clinical Electrophysiology of Vision. For a more in-depth explanation of these procedures please visit www.iscev.org

Created by: *Jeff Locke OC(C), COMT, MSc*
Anupreet Tumber MSc, COA
Ajoy Vincent MD, MBBS, MS,

Full-Field Electroretinogram (ffERG)

Purpose:

The full-field ERG is a widely used diagnostic test of mass retinal function. An electrode placed on or near the cornea measures the electrical response of the photoreceptors and inner retina as the eye is stimulated with various intensity, durations, and colours of light stimuli. The ERG is sensitive in detection of retinal dysfunction when approximately 40% or more of the retinal is affected and sometimes before any physical changes are noted on examination.

When to Request:

- Abnormal fundus examination, such as:
  - retinal schisis
  - foveal changes
  - macular atrophy
  - retinal pigmentary changes
  - and more ...
- Poor vision or visual behavior, despite corrected refractive error;
- High refractive error
- Nystagmus
- Patient notes the following symptoms:
  - Nyctalopia
  - Photophobia
  - trouble adjusting to lighting conditions
  - changes in visual fields
- Family history of any retinal dysfunction

When referring your Patients:

Age (years)	Testing Conditions
0 – 5	Under sedation or general anesthesia; when referring please ensure ASA information is provided
5 – 8	Are typically not compliant for full protocol, but should be assessed by our team (i.e., may be able to perform shorter protocol and/or monocular testing)
9 +	Routinely tested under normal testing conditions through full protocol.

Generally, any child compliant with drops is able to fulfill most ERG testing requirements

Indications for General Anesthesia (5+ years) include, but are not limited to:

- Delayed milestones
- Intellectual disabilities
- Severe physical limitations
- Behavioural limitations

**These patients will require assessment in clinic, to determine if general anesthesia is necessary, unless strongly indicated in your clinical assessment*

Key information for your patients:

Standard ERG testing takes approximately 40 minutes, involves dilation, performing the test while seated in a small dark-room. Electrode fibers used for testing rest across the eye while gold-cup electrodes are positioned at the forehead and temples. The patient is seated with their chin situated on a rest and their head against a bowl for the testing period, during which their eyes are stimulated with flashes of light (see figure 1).

ERG testing under sedation or general anesthesia involves dilation and performing the test while the patient is supine. Contact lens electrodes are placed on the eyes with a gel-lubricant while gold-cup electrodes are positioned at the forehead and temples. The bowl of the ERG-system is positioned above the patient's head and the eyes are stimulated with flashes of light. (see figure 2).

Multi-focal Electroretinogram (mfERG)

Purpose:

The Multi-focal ERG provides a topographic measure of central retinal activity. Typically 61 or 103 local ERGs are recorded from the cone-driven retina under light adapted conditions with full pupil dilation. This technique allows for analysis of localized retinal function (see figure 3).

When to Request:

- Suspected hydroxychloroquine (or other drug) toxicity
- Patterned dystrophies
- Suspected maculopathy *
- Abnormal macular findings/pigmentation *
- Normal full-field ERG results *
- Unexplained central vision loss*

*Can also be tested using PERG

When referring your Patients:

The following requirements must be met:

- 10+ years old (older cooperative children, teens, adults)
- Successful completion of a full-filed ERG in the VEU at HSC within a 2 year period.
- Ability to fixate centrally (i.e., no eccentric fixation or nystagmus)
- Excellent cooperation, specifically focus/concentration *
- Attentiveness/Alert

Patients that do not meet these criteria cannot perform a mfERG, please note:

- This test cannot be conducted under general anesthesia or sedation
- This test must be completed in full and cannot be shortened or modified

Key information for your patients:

Standard mfERG testing takes approximately 15 minutes, involves dilation and performing the test while alert and focusing using a bright LDC monitor. Electrode fibers used for testing rest across the eye while gold-cup electrodes are positioned at the forehead and temples. The patient remains seated with their chin situated on a rest, fixating on the center of a large pattern (see figure 4), whilst not blinking for 30 second intervals until the test is thoroughly completed. Cooperation, fixation, and blinks impact the length of the test period and the reliability of the results.

Pattern Electroretinogram (PERG):

Purpose:

The pattern ERG is a retinal bio-potential evoked by a temporally modulated patterned stimulus (checkerboard or grating) of a constant mean luminance. The PERG arises largely in the ganglion cells, driven by the macular photoreceptors and corresponding retinal cells (see figure 6). Since the PERG is a local response from the area covered by the retinal stimulus image, it is a sensitive indicator of dysfunction within the macular region; it reflects the integrity of the optics, photoreceptors, bipolar cells and retinal ganglion cells.

When to request:

- Suspected hydroxychloroquine (or other drug) toxicity
- Suspected ganglion cell dysfunction*
- Suspected maculopathy
- Abnormal macular findings/pigmentation
- Normal full-field ERG results
- Unexplained central vision loss
- Patient was unable to perform a mfERG

*Please also have patients complete a pattern reversal VEP

When referring your Patients:

The following requirements must be met:

- 8+ years old (cooperative children, teens, adults)
- Ability to fixate (i.e., no nystagmus)
- Cooperation, specifically focus/concentration
- Attentiveness/Alert
- Most recent prescription glasses, if worn

Note: patients who are able to comply with full-field ERG testing are typically able to perform an PERG

Patients that do not meet these criteria cannot perform a PERG, please note:

- This test cannot be conducted under general anesthesia or sedation

Key information for your patients:

Standard PERG testing takes approximately 20 minutes, requires performing the test while alert and focusing on a CRT monitor at a distance with optimal visual correction. Electrode fibers used for testing rest accross the eye while gold-cup electrodes are positioned at the forehead and temples. The patient remains seated, relaxed and still (with minimal to no movement) while fixating on the center a checkerboard pattern (see figure 5). Patients are encouraged to blink minimally and remain alert until the test is thoroughly completed. Cooperation, fixation and blink impacts the length of the test period and the reliability of results.

Dark Adaptometry: Scotopic Full-Field Stimulus (FST) Testing

Purpose:

The full-field stimulus threshold (FST) is an alternative way of measuring the dark-adapted light sensitivity of a patient. It determines the luminance threshold for the detection of a diffuse stimulus flash and does not require fixation during the test. The FST represents the global sensitivity for the remaining most sensitive parts of the retina. It can be used as a useful functional test for patients with non-detectable ERG's or unreliable visual fields.

The FST test is currently being used to monitor disease progression in multiple natural history studies and is being used to document improvement in clinical trials in inherited retinal dystrophies.

When to request:

- Patient with severe vision loss (i.e., light perception) due to retinal dystrophies
- Non-detectable full-field ERG results but require long-term longitudinal follow-up

When referring your Patients:

The following requirements must be met:

- Non-detectable full-field ERG previously performed in the VEU at SickKids
- Cooperation, specifically in terms of concentration
- Attentiveness/Alert

Patients that do not meet these criteria cannot perform an FST, please note:

- This test cannot be conducted under general anesthesia or sedation

Key information for your patients:

FST testing takes approximately 90 minutes, requires dilation, an extended period of dark adaptation, and conscious responses to the perception of light stimuli. Patients must remains seated in a completely dark room with eyes covered during a 45 minute dark adaption period prior to testing. The patient will then place their chin on a rest and with their head against a bowl for the testing period, where they must enter a response using a button box to indicate whether they can or cannot perceive a variety of flash intensities (see figure 7).

Electro-oculogram (EOG):

Purpose:

The clinical EOG assesses function of the outer retina and retinal pigment epithelium (RPE) during dark and light adaption. The EOG measures changes in the electrical potential across the RPE at successive periods of dark and light adaptation (see figure 8). The light response is affected in diffuse disorders of the RPE and in some photoreceptor layer disorders of the retina including inflammation.

When to request:

- Suspected dysfunction of RPE layer
- Suspected inflammatory disorder (i.e., AZOOR)
- Vitelliform-related disorders in children or adults
- Chorio-retinal atrophy noted
- Pattern retinal dystrophy

When referring your Patients:

The following requirements must be met:

- 10+ years old (cooperative children, teens, adults)
- Successful completion of a full-filed ERG in the VEU at HSC
- Ability to fixate centrally (i.e., no nystagmus or central vision loss)
- Ability to adduct and abduct
- Orthophoria
- Cooperation, specifically focus/concentration
- Attentiveness/Alert

Patients that do not meet these criteria cannot perform a EOG, please note:

- This test cannot be conducted under general anesthesia or sedation

Key information for your patients:

EOG testing takes approximately 45 minutes and requires dilation prior to testing. Patients are required to perform 10 second saccades, every minute under dark- and light- adapted conditions. Gold cup electrodes are positioned at the lateral orbital rim and adjacent to the inner canthus by the nose (see figure 9). The patient remains seated with their chin situated on a rest and their head against a bowl for the testing period. Patients are required to keep their head still and perform 10-second saccades at 1 minute intervals, which is specified by sound and light stimuli. 15 saccades are performed in the dark, and followed by 15 saccades in the light.

Visually Evoked Potential (VEP)

Purpose:

Visually Evoked Potentials (VEPs) are recorded from the scalp, overlaying the primary visual cortex, in response to specific pattern and flash stimuli. VEPs depend on the functional integrity of central vision at any level of the visual pathway including the anterior, posterior, and vitreous chamber of the eye, the retina, optic nerve, optic radiations, and occipital cortex. There 4 types of VEP protocols currently offered.

VEP procedures offered include:

- Flash VEP (simple VEP)
- Pattern reversal VEP (Threshold VEP)
- Low-contrast onset/offset VEP (Threshold VEP)
- Multichannel VEP (mcVEP)

See below for more information on each of these procedures

Suitable VEP Procedures by Age

Age (years)	Type of VEP
0 – 2	(flash) VEPs and Multi-Channel VEPs
5 – 8	flash/mcVEP and pattern onset/offset VEPs
8 +	all VEP protocols

** Patients that are asleep or very uncooperative during any VEP cannot yield a reliable result. No VEP can be performed under general anesthesia or sedation*

Flash VEP (Simple VEP):

Purpose:

The flash VEP distinguishes if there is *any* gross visual potential, at the primary visual cortex only to light.

When to Request:

- Poor vision, including:
  - Suspected cortical visual impairment
  - Suspected delayed visual maturation
- When there is poor optics
- Patient has very poor cooperation
- To confirm the absence of light perception
- Suspected demyelination process
- Suspected compressive lesion of optic pathway

When referring your patients:

The Flash VEP can be used on any patients and is most suitable for:

- Infants
- Individuals with very poor cooperation, including:
  - physical limitations
  - delayed milestones
  - intellectual disabilities

The following requirements must be met:

- Attentiveness/Alert
- Absence of light-induced seizures

Patients that are asleep during a flash VEP cannot yield reliable result

- This test cannot be conducted under general anesthesia or sedation

Key information for your patients:

The flash VEP involves the patient attending to a series of bright flash stimuli elicited every half-second (see figure 10). Gold cup electrodes are positioned at the center of the forehead, top of the head, and just above the inion at the back of the head, and held together with self-adhering gauze. The patient sits comfortably while attending to the flash stimuli with both eyes and/or either eye. The test is also typically performed in the absence of any flashes for a baseline measurement. Movement, sleepiness, and crying can all have an impact on the reliability of the results.

Pattern reversal VEP (Threshold VEP):

Purpose:

Pattern reversal is the preferred stimulus for most clinical purposes. VEPs obtained are less variable in waveform and timing compared to VEPs obtained by other stimuli. This protocol is best suited when implicit timing and amplitude need critical evaluation

When to Request:

- Suspected optic nerve or ganglion cell dysfunction
- Suspected demyelination process
- Suspected compressive lesion of optic pathway

When referring your patients:

The following requirements must be met:

- Attentiveness/Alert
- Cooperation, specifically focus/concentration
- Ability to fixate (minimal to no nystagmus)
- Most recent prescription glasses, if worn

Key information for your patients:

The pattern reversal VEP involves the patient attending to an alternating checkerboard pattern stimulus (see figure 5). Gold cup electrodes are positioned at the center of the forehead, top of the head, and just above the inion at the back of the head and held together with self-adhering gauze. The patient sits comfortably at a fixed distance while attending to the stimulus with both eyes and either eye (i.e., one eye occluded). Ocular and physical movements and sleepiness can all have an impact on the reliability of the results.

Low-Contrast Pattern onset/offset VEP (Threshold VEP):

Purpose:

Adopted by the protocol established by McBain et al, 2007, short duration pattern onset/offset stimuli with various check size and contrast are used for a visual acuity assessment (Snellen equivalent; up to 20/20 vision).

When to Request:

- Suspected non-organic vision loss
- Suspected demyelination process
- Suspected compressive lesion of optic pathway
- Patients with nystagmus and suspected optic nerve dysfunction
- Poor cooperation with subjective visual acuity assessments

When referring your patients:

The following requirements must be met:

- Attentiveness/Alert
- Cooperation, specifically focus/concentration
- Most recent prescription glasses, if worn

Key information for your patients:

The pattern onset/offset VEP involves the patient attending to a checkerboard pattern stimulus (see figure 5) that alternates with a grey screen (i.e., absence of a pattern stimulus). Gold cup electrodes are positioned at the center of the forehead, top of the head, and just above the inion at the back of the head and held together with self-adhering gauze. The patient sits comfortably at a fixed distance while attending to the stimulus with either eye (i.e., one eye occluded). Loss of focus or sleepiness can have an impact on the reliability of the results.

Multi-Channel VEP (mcVEP):

Purpose:

Multi-Channel VEPs are used to compare the visual cortical responses of each hemisphere in patients with chiasmal misrouting or albinism. The amplitude and latencies of the cortical responses are evaluated for any asymmetry, to confirm cases of chiasmal misrouting.

When to Request:

- Question of ocular albinism/ oculocutaneous albinism

When referring your patients:

The following requirements must be met:

- Attentiveness/Alert
- Some cooperation, specifically focus/concentration

Key information for your patients:

Multi-Channel VEPs involve the patient attending to a flash (see figure 10) and/or pattern onset/offset stimulus (see figure 5) with either eye. Gold cup electrodes are positioned at the center of the forehead, top of the head, and just above the inion at the back of the head with the addition of 4 electrodes along the visual cortex (i.e., two over each hemisphere) and all held together with self-adhering gauze. The patient sits comfortably at a fixed distance while attending to the flash or pattern onset/offset stimulus with either eye (i.e., one eye occluded). Physical movements, sleepiness, and crying can all have an impact on the reliability of the results.

Color Vision Assessment:

Purpose:

Color vision is the capability of discriminating between light sources on the basis of wavelength, even when those sources are equally bright. The ability to discriminate color may be altered in some retinal or optic nerve conditions. The degree of the color defect can vary based on pathology, inheritance, sex, and duration of the condition. In the VEU, we offer the following colour vision asessments:

Hardy Rand Rittler Plates (HRR):

See figure 11

- Capable of detecting protan, deutan and tritan defects
- Permits assessment of the degree of the defect
- May be tested on younger children who can identify shapes

D15 tests

In a D15 assessment, a reference cap is left in the box while all other colour discs are removed and mixed. Patients are requested to place the best-matching disc next to the reference disc, and continue to match coloured discs to the previous one placed in the box until all discs are in place. The arrangement of these discs are scored and crossing that align with a specific axis can indicate the presence of protan, deutan, and tritan defects (see figure 12)

Farnsworth D15:

See figure 13

- A modification of Farnsworth-Munsell 100Hue test
- Dichotomous test used for classification into: normal/mild color deficient or medium/strong deficient
- Available in large test plates for patients with low vision

Lanthony D15:

See figure 14

- Similar to Farnsworth D15 but has less saturated colors
- Appropriate for detection of mild color vision abnormalities

Mollon-Reffin ‘Minimal’ Color Vision test:

See figure 15

- Examines the patient’s chromatic discrimination along three significant axes of color
- Identifies and classifies dichromatic types of color defects
- Alternative to D15 testing
- Children (>3) typically do well with test

References:

Back, M., Brigell, M.G., Hawlina, M., Holder, G.E., Johnson, M.A., McCulloch, D.L., Meigen, T., Viswanathan, S. (2012). ISCEV standard for clinical pattern electroretinography. Doc Ophtalmol, 126, 1-7

Hood, D.C., Back, M., Brigell, M., Keating, D., Kondo, M, Lyons, J.S., Marmore, M.F., et al. (2011). ISCEV standard for clinical multifocal electroretinography (mfERG). *Doc Ophthalmol, 124:* 1-13.

Marmor, M.F., Brigell, M.G., McCulloch, D.L., Westall, C.A., Bach, M. (2010). ISCEV standard for clinical electro-oculography. *Doc Ophthalmol, 122*, 1-7

McBain, V.A., Robson, A.G., Hogg, C.R., & Holder, G.E. (2007). Assessment of patients with suspected non-organic visual loss using pattern appearance visual evoked potentials. *Graefe's Arch Clin Exp Ophthalmol, 245*, 502-510.

McCulloch, D.L., Marmore, M.F., Brigell, M.G., Hamilton, R., Holder, G.E., Tzekov, R., & Bach, M. (2015). ISCEV standard for full field clinical electroretinography. *Doc Ophthalmol, 130:* 1-12.

Odom, J.V., Bach, M., Brigell, M., Holder, G.E., McCulloch, D.L., & Tormene, A.P., & Vaegan. (2009). ISCEV standard for clinical visual evoked potentials. *Doc Ophthalmol 120*, 111-119.

Images

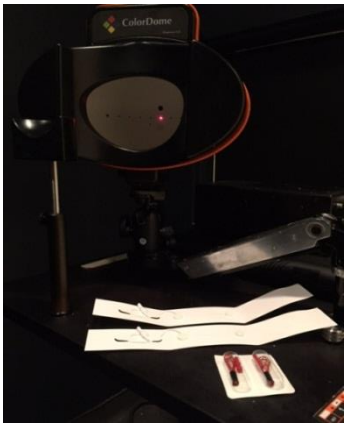

Figure 1. Clinical ERG system. Performed on patients seated upright, in a dark room.

Figure 2. Portable ERG system. Performed under sedation or general anesthesia on patients who are supine.

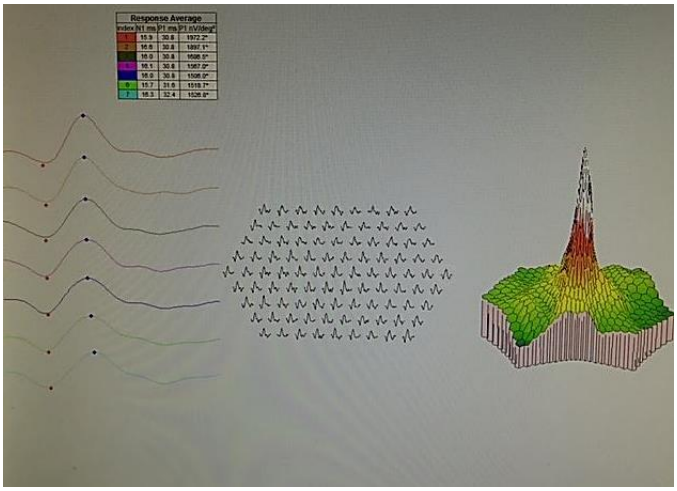

Figure 3. Multifocal Recording. An array of traces is extrapolated provided fixation is maintained throughout the test. Data can be used to indicate smaller areas, patterns, or rings of dystrophy within 30 degrees of the fovea.

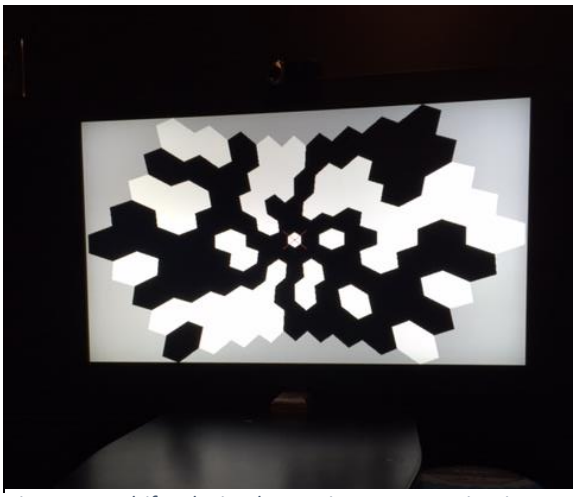

Figure 4. Multifocal stimulus. Patients must maintain focus at the center of the screen, without blinking for 30s at a time.

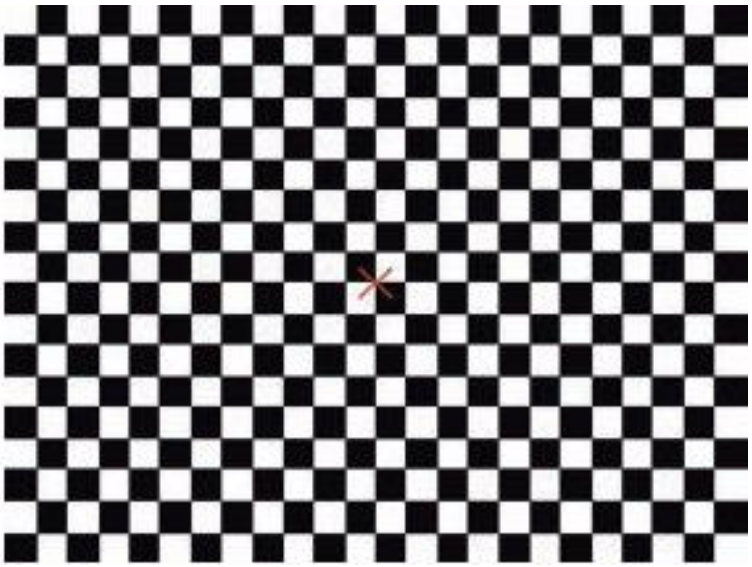

Figure 5. Pattern Stimulus. Patients are required to fixate at the center of the stimulus, typically marked with a red fixation spot.

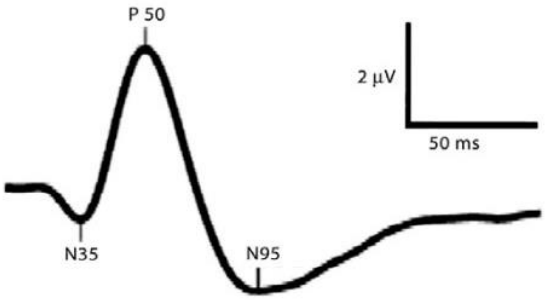

Figure 6. Sample of a typical PERG response.

Figure 7. FST button box with ERG dome. Patients are required to indicate if they can perceive a flash of light while they are looking into the dome.

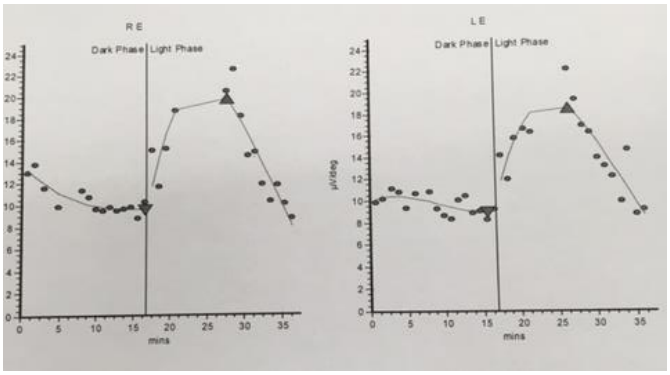

Figure 8. RPE dark- and light- adapted thresholds are measured as an indication of RPE function.

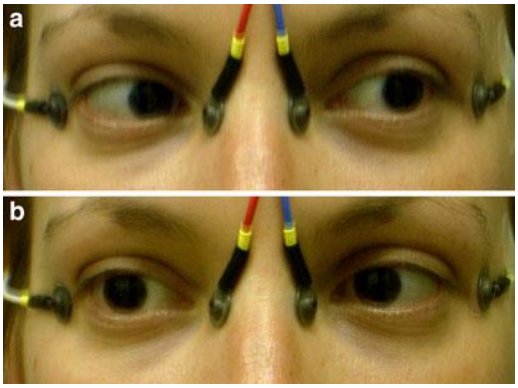

Figure 9. Electrodes are placed at the orbital rim. Patients are required to perform saccades throughout the test.

Figure 10. Flash stimulator. Patient is required to fixate on this light during flash VEPs.

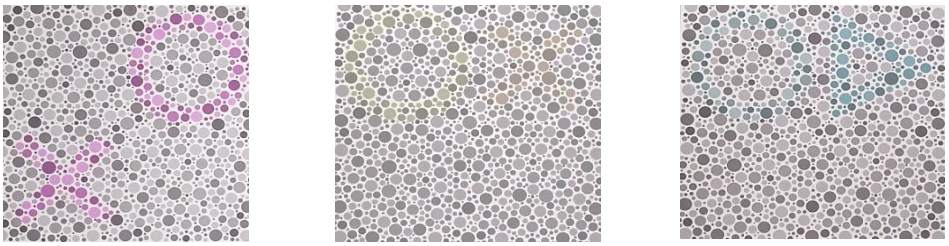

Figure 11. Sample of tests plates in the HRR. Patients are required to identify the shapes that stand-out against the background, and their colour.

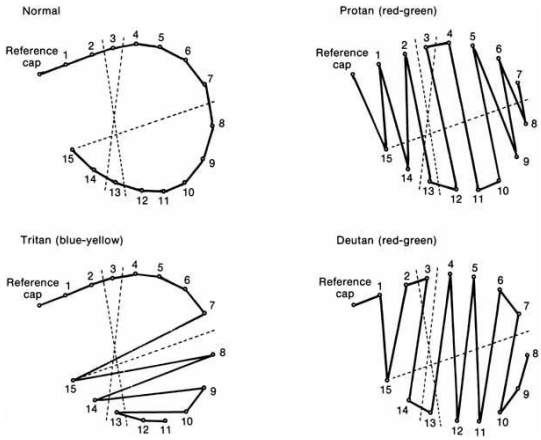

Figure 12. Sample of D15 scoring patterns in a normal patient, and patients with a protan, deutan, and tritan defect.

Figure 13. Farnsworth D15.

Figure 14. Lanthony D15.

Figure 15. Minimalist colour vision assessment.