Learning Effects and Artefacts in Automated Perimetry

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Rahul Saigal, B.Optom, M.Optom

Automated perimetry is the most reliable and widely used tool to monitor functional vision impairment caused by a host of ocular and neurological conditions. It has evolved rapidly over the past few decades, largely to the credit of Fankhauser,[1] Heijl and Krakau,[2] Flammer[3] and others. Artefacts of visual field tests are very common and may relate to instructions given to the patient, the set-up of the patient at the instrument, or the patient's ability to perform the test. Such errors can often simulate the types of field loss found in ocular pathologies, potentially leading to incorrect diagnosis and management. However, does the neglected factor really have a significant effect upon the results? Is it necessary to repeat the procedure again?

Learning Effects

Perimetry is a subjective psychophysical test that requires patient co-operation and a high degree of concentration. With practice and repeated attempts, patient performance improves with learning and experience.[4] This phenomenon is termed a 'learning effect' and is well documented.[5-7] Clinically this is demonstrated by a dramatic improvement in the second field test result compared with the first[8] and the magnitude of these improvements considerably decreases with increasing number of examinations. It is often recommended that a patient who is new to perimetry should undergo several test sessions to establish a baseline for subsequent comparisons, but it can often complicate the follow-up of patients over time and consequently determining the status of visual function as stable, declining or improving may become difficult.

Although the term learning effect is widely used in the literature, we do not know exactly what the patient is "learning". It could be a physiological phenomenon of the visual system adapting to the process, or it could be psychological affects that influence a patient's decision-making as to whether they saw a stimulus or not. The fact remains that the patient learns to respond consistently during the test; with experience, patients respond to more dim stimuli and to stimuli presented further away from the central fixation point.[9]

In clinical practice, three patterns of learning effect can be observed: (1) within a single examination of a given eye, (2) between eyes at the same visit, and (3) between subsequent examinations.[10] These learning effects depend on the test strategy employed (e.g. full threshold versus fastpac), the modality (SITA versus SWAP) and patient attention. Learning effects have been demonstrated in normal subjects,[11] patients with ocular hypertension[12] and glaucoma,[13] and they have been shown to be greater for peripheral rather than for central stimulus locations.[14]

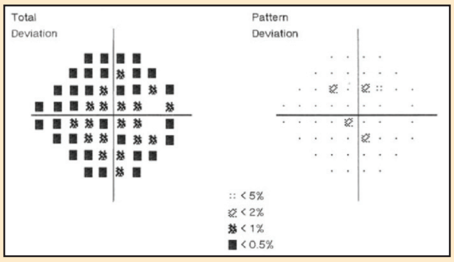

Figure 1
Visual fields affected by cataract. Total deviation (left) reveals overall depression in sensitivity whilst the absence of co-morbidity (e.g. glaucoma) should reveal no significant focal loss in the pattern deviation (right) (Courtesy of Dr Navneet Gupta, Clinical Editor, Optometry Today)

To minimize learning effects, it is advisable to conduct a practice test procedure in "demonstration" mode whereby the patient can begin the examination, but data is not collected by the perimeter. In addition, clear explanation of the complete test procedure should be given to the patient, so that they are aware of exactly what to do and what to expect.

Artefacts

Automation of the test reduces the need for constant observation and quality control of the procedure, but this does not mean a complete absence of an observer is acceptable. Indeed, this may explain the appearance of artefactual field test results. It is important to be aware of the possible causes of artefacts, particularly if no apparent cause of a defect was noted upon clinical examination. Assessment of the reliability indices is a good starting point, to assess whether the test was accurate. However, several factors can produce anomalous visual field plots without necessarily

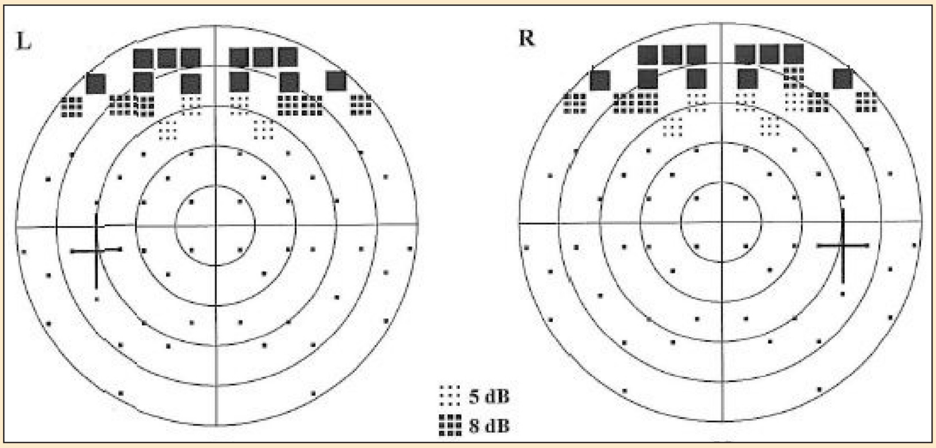

Figure 2
A superior visual field defect artefact caused by drooping upper eye lids (Courtesy of Dr Navneet Gupta, Clinical Editor, Optometry Today)

affecting the reliability indices.

Pupil size and anomalies

An examiner should be aware that pupil diameter can vary with factors such as ocular medication (e.g. miotics), neuro-ophthalmic disease, and age-related miosis. Pupil size can affect retinal illumination and influence visual field sensitivity; a constricted pupil dims both the intensity of the stimulus and that of the background. It may depress central and peripheral threshold sensitivities and increase the variability of threshold measure.[15] One study found that miosis causes significant worsening of the mean deviation (MD) and pattern standard deviation (PSD) indices and a decrease in short-term fluctuations.[16] In such cases, mydriatic drops could be instilled prior to the examination. Mydriasis has less influence on the visual field and it may only reduce peripheral threshold sensitivity.[17,18] If this is done, all subsequent tests need to be conducted with a dilated pupil in order to maintain standard test conditions. If a patient has previously suffered ocular trauma, then artefactual field defects can arise due to displaced or irregular pupil, which may mimic glaucomatous visual field loss.[19]

Media Opacities

Clinically, any opacity of the ocular media reduces the brightness of test stimuli and background equally, and therefore has no effect other than overall depression of retinal sensitivity; this is reflected in changes to the total deviation plot and global indices,[20] but no significant changes to the pattern deviation plot as this filters out the depression to identify focal losses (unless concurrent disease such as glaucoma is present) (Figure 1).[21] In order to conduct the test, more light should be used and/or larger stimulus sizes. When concurrently present with glaucoma, media opacities can cause considerable difficulties when attempting to plot the progression of visual loss. In such cases, the entire aspect of a patient's ocular status should be considered, and worsening visual fields should be attributed to the correct condition (e.g. cataract will affect the whole field but increased focal losses are suggestive of change due to glaucoma).[22] After cataract extraction, eyes with glaucoma may display improvement of foveal sensitivity and visual field scores.[23]

Eyelid and facial features

The presence of ptosis or a tendency for the upper lid to droop (e.g. dermatochalasis) may produce a superior artefactual visual field defect (Figure 2);[24] absolute loss (thresholds of 0db) is certainly indicative of this possibility,[25] especially if bilateral, whilst occurrence in the second eye is suggestive of fatigue (see later).

Prominent facial features such as a large nose can also create defects that mimic inferior nasal steps, whilst an overhanging brow and deep set eyes can lead to superior peripheral artefactual field defects.[26] These defects can be minimized by correct alignment and placement of the patient on the machine, or by taping of the upper lid; in both cases, the examiner should record that such a defect was caused by an anatomical structure so that they cannot be mistaken for a true defect.

Fatigue effects

Patient fatigue manifests as either an increase in the threshold or an increase in fluctuation and is usually due to difficulty in maintaining attention. This becomes more pronounced as the examination time increases,[27] when the second eye is examined,[28] in areas adjacent to visual field loss,[29] with increasing eccentricity,[30] and age.[31] Learning and fatigue effects change with the frequency of follow-up examinations and they seem to have an inverse relation during visual fields examination. If there is more fatigue then the resultant artefact resembles a

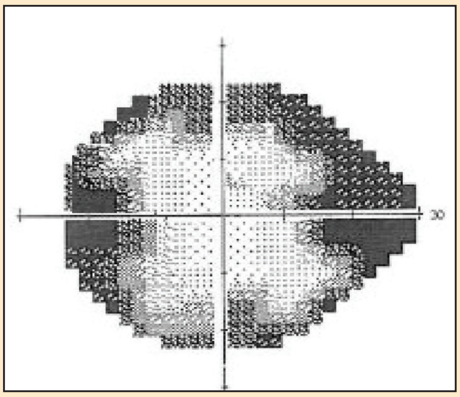

Figure 3
"Clover leaf" visual field plot resulting from patient fatigue (see text for details) (Courtesy of Dr Navneet Gupta, Clinical Editor, Optometry Today)

'clover leaf pattern' in which the patient performs well at the beginning of the test but becomes inattentive with time and fails to respond to the stimuli.[32] It is characterized by normal or near-normal central field with a dark periphery (Figure 3) and it may also be associated with a high false negative rate. If there are greater learning effects, the resultant artefact resembles a 'four-dot pattern' in which the patient does not respond to initial stimuli but then responds well to later stimuli; such effects should disappear upon repeat testing.[33] In order to reduce fatigue effects in particular, the practitioner can use a faster test strategy (e.g. fastpac or SITA-Fast) as opposed to a full threshold programme,[34] provide verbal encouragement, and allow for rest periods during the test.

Head position

The patient's head should be upright and not tilted to the side or backwards (Figure 4). The head must also be placed against the headrest, in order to prevent an artefactual altitudinal defect from forming (as a result of the patient not being able to see stimuli presented in the inferior visual field). If the head is turned temporally, the nose may present a considerable obstacle, even to a central 30° plot (Figure 5). If the head is tilted, the blind spot may be elevated; the chin should therefore be firmly resting on the chin rest so that the head position can be altered before and during the examination, ensuring accurate placement of the light stimuli. During the test, the observer should monitor the head and chin position and ensure that the correct position has not been altered.

Refractive errors

Uncorrected or improper refractive correction could cause the projected stimulus to be out of focus on the retina and therefore not only reduce luminance but also increase the amount of blur.[35] This can result in an artefact whereby the threshold is artificially abnormal. The effect appears to be more marked for smaller targets and less marked with increasing eccentricity.[36]

Figure 4

Poor head positioning for visual fields testing. The patient's head position is tilted too far back. The forehead should rest against the forehead rest (Courtesy of Dr Navneet Gupta, Clinical Editor, Optometry Today)

Figure 5

Poor head positioning for visual fields testing. A temporal head turn can induce a central defect artefact (Courtesy of Dr Navneet Gupta, Clinical Editor, Optometry Today)

Threshold sensitivity can significantly alter in hyperopic[37,38] and myopic patients,[39] regardless of the method of correction. High myopic errors can create areas of retinal blur that appear as a vertical wedge–type defect and may be confused with glaucomatous field loss; therefore it is worth reviewing the global indices, as the mean sensitivity, average defect and fluctuation can be abnormal.[40,41] A rule of thumb would be to correct refractive error even as low as 1.00D. However, practitioners need to be aware of astigmatic errors too. Using the mean sphere will result in significant cylindrical defocus being induced when astigmatism is greater than 1.00D. Therefore, all cylinders greater than 1.00D should be corrected for visual fields testing. Many patients undergoing a visual field examination will be presbyopic and therefore the correction should include an adjustment for near vision; the Humphrey visual field analyzer uses age-matched data to aid in determining the appropriate correction.[42] In order to prevent artefacts caused by refractive error, patients should be asked at each examination if they have received new spectacles or contact lenses and whether any ocular surgery has been conducted since the last visual field exam. It is always useful to repeat the refraction and measure the current spectacle correction with a lensmeter to assess whether there is a difference.

Correcting a lens artefact

The placement of a trial lens in a visual fields machine's lens holder, for the correction of refractive error, can itself induce artefactual defects. A lens that is off-centre can restrict the visual field on the same side and induce prismatic effect as governed by Prentice's rule. This effect becomes more pronounced with higher lens powers. For example, a -6.00D lens displaced by 2cm will induce 12Δ. This effect could shift the visual field and potentially mask small central or paracentral scotomas. If a lens holder is misaligned, a portion of the peripheral points may be depressed, possibly leading to a defect mimicking a nasal step.[43]

A lens placed too far from the eye can produce a rim defect (Figure 6), with the appearance of ring-type peripheral scotoma. The effective power of the lens can also be altered, especially if it is greater than ±4.00D, thus inducing defocus blur, which can affect the thresholds.[44] Therefore, the lens should be placed as close as possible to the eye without obstructing lid movement or touching the eyelashes. Monitoring throughout the examination is essential, as the patient may move away from the correct position during the examination.

When correcting refractive error, full aperture lenses must be used since reduced aperture lenses can simulate tunnel vision and induce peripheral ring scotomas. It is appropriate to use a patient's own spectacle correction, but only if it is a single vision lens and with a depth that will not induce rim artefacts. The use of bifocal lenses should be avoided as optical defocus will be induced by the distance portion and prismatic jump will be induced by the segment, resulting in blind spots and displacement of stimuli.[45] Varifocal lenses can induce both spherical and cylindrical defocus because of their inherent optical design.

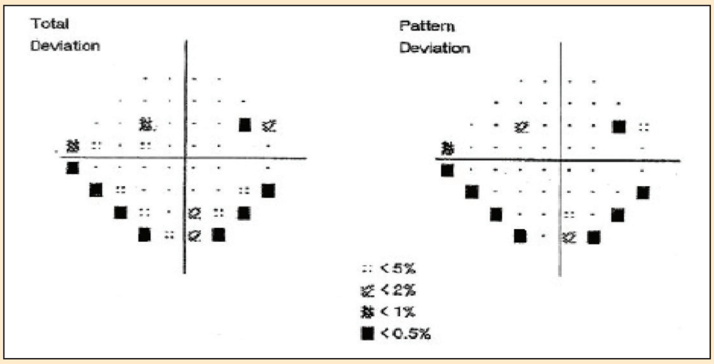

Figure 6

Lower rim artefact induced by poor lens alignment during visual field testing (Courtesy of Dr Navneet Gupta, Clinical Editor, Optometry Today)

Trigger-Happy field

Some patients, particularly if they are anxious, will be eager to see most or even all of the stimuli during a test. As such, they will press the response button as often as possible, resulting in large numbers of false positive errors. The resultant "trigger-happy" field is characterized by patches of abnormally light white areas in the greyscale plot due to abnormally high thresholds.[46] The only solution to this problem is to re-instruct the patient regarding the correct procedure to follow, and to re-assure them that not seeing any lights during the test is actually a normal part of the process.

Hysterical visual loss and malingering

Hysteria and malingering are examples of 'functional visual field loss' despite an otherwise structurally normal visual pathway. They should be suspected when the field defect does not match a presumed diagnosis or if it is not physiologically possible. Such visual fields plots are best assessed using kinetic techniques (e.g. Goldmann bowl perimeter) and typically yield a constricted visual field or spiral defects (Figure 7),[47] where the field size reduces on each presentation along each radius tested. When either the next eye is tested or the same eye is repeated, a severely contracted or tubular field is found. Another significant sign is that there is no change in the size of defect when tested at different distances.[48]

When functional disorders are investigated with automated static perimetry, it is very difficult to differentiate them from genuine organic loss. Fixation loss and reliability indices are often elevated, but they may not differ greatly from an organic visual field defect.

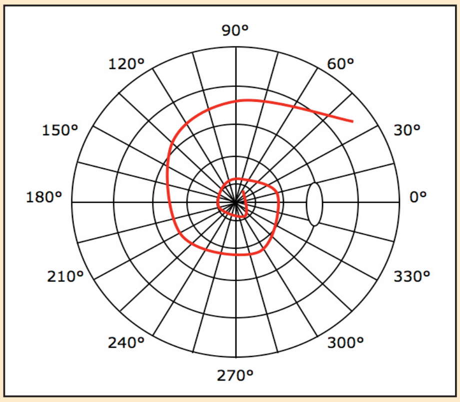

Figure 7

Functional visual field loss as assessed by kinetic perimetry. Such "spiral" defects are typical in "hysterical" reactions or "malingering" patients, and are psychological in origin (Courtesy of Dr Navneet Gupta, Clinical Editor, Optometry Today)

Conclusion

At the outset of this article the author raised some questions as to whether artefacts in visual field tests are significant and whether repeated measurements are necessary. The answer is obviously "yes" but it is also important to question whether or not the omission can be avoided in the first place. In glaucoma and other diseases that cause slow, progressive loss, such artefacts can hinder the practitioner because deterioration due to disease might be missed or over-exaggerated. As such, it is important for all members of staff who are involved with performing visual field tests to ensure that patients are correctly set-up on the machine, to allow a demonstration examination, and to give clear and proper instructions, with re-assurance and monitoring throughout the examination.

About the author

Rahul Saigal obtained his post-graduate degree in optometry (M.Optom) from School of Optometry, Bharati Vidyapeeth Deemed University, Pune, India. Thereafter he was a Lecturer in the School of Optometry. His main interest areas are paediatric optometry, occupational optometry, geriatric optometry and ocular pathology. He has an active interest in optometry education and web designing, and he maintains a student blog for educational purposes.

References

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1. When explaining ophthalmoscopy:
a) Ensure the consulting room lights are turned on
b) Tell the patient that all cases of diabetes are detected
c) Explain that other methods for health screening are just as important
d) Never show an accompanying fundus photo as it may alarm the patient

2. For a first time myope:
a) Always show a comparison of distance vision with and without the prescription
b) Advise on the ability to meet driving standards with and without the prescription
c) Ensure that advice on use of the prescription relates to the presenting symptoms
d) All of the above

3. When increasing the prescription for a hyperopic patient:
a)Only prescribe the change if headaches are present
b)Only prescribe the change if it is more than +0.50DS
c) Demonstrate the change using a near vision chart
d) Always prescribe half of the change found

4. If a patient is new to astigmatic correction:
a) Draw an optical diagram showing the effects of uncorrected astigmatism
b) Always prescribe half of the astigmatic correction found to help adaptation
c) Calculate the best sphere correction in preparation for contact lens fitting
d) Counsel them on the visual effects of cylinder in spectacle lenses

5. When prescribing for a first-time presbyope:
a) Offer ready-readers as an acceptable substitute to prescribed spectacles
b) Demonstrate the distance blurring effect of the near correction
c) Only consider prescribing if the patient is over 45 years of age
d) Inform the patient that their eyes will get worse with increased spectacle wear

6. When handing over a patient to a dispensing colleague:
a) Introduce them by name and explain your recommendations
b)Talk to the dispensing colleague privately, away from the patient
c) Let them browse and present to the dispensing colleague in their own time
d) Don't make dispensing recommendations until the dispensing colleague is available

Course code: C-17077 O/D

1. "Clover leaf" field defects are associated with:
a) High false-negative rate
b) High false-positive rate
c) Fatigue
d) Low false-negative rate

2. High false-positive errors:
a) Indicate that the incorrect refractive correction is being used
b) Produce white areas in the greyscale plot
c) Occur when a patient fails to respond to a previously seen stimulus
d) Decrease the sensitivity estimate in full threshold tests

3. When conducting a visual fields test:
a) Refractive errors over 1.00D should be corrected
b) Astigmatism should always be corrected if under 1.00D
c) There is no effect if the lens holder is misaligned
d) The head position should not be corrected if it strays

4. Which of the following does NOT cause a superior field defect?
a) Upper lid ptosis
b) Upper lid dermatochalasis
c) Inferior retinal detachment
d) A large nose

5. Which of the following statements about performing visual field tests is FALSE?
a) A four-dot artefact is the result of a learning effect
b) Defocus results in artificially high thresholds
c) Bifocal lenses can result in displacement of stimuli
d) A constricted pupil increases the variability of threshold measurement

6. Which of the following statements about performing visual field tests is TRUE?
a) Learning effects vary with the test strategy employed
b) Learning effects vary with the test stimulus location
c) Malingering is associated with paracentral scotoma
d) Monitoring a patient during the test is not required if it is automated