Static Standard Automated Perimetry (SAP, alternatively called white-on-white perimetry), which uses a white Goldmann size III stimulus presented on a white background, is by far the most commonly used type of perimetric test today. It is the standard of care to detect and follow glaucoma. The white stimulus stimulates nearly all types of retinal ganglion cells and as a result the test has a large dynamic range. Nevertheless, it would be desirable to have a more sensitive test than SAP for early detection of irreversible vision loss in diseases such as glaucoma.

Furthermore, the following shortcomings are associated with SAP using a size III stimulus: 1) there is large variability in patient responses in areas of significant vision impairment or low vision and 2) there is a marked floor effect in areas of significant vision impairment or low vision.

Other forms of perimetry have been developed to allow for earlier detection and to overcome the shortcomings of SAP. Non-conventional perimetry includes function-specific perimetric tests that use stimuli which target specific pathways and visual functions (e.g., flicker) and also white-on-white perimetry performed with the larger size V stimulus, which provides a useful alternative for testing in areas of vision impairment or low vision.
FIGURE 10-1 Function-specific perimetry has been developed to reduce the redundancy within the visual system with the goal of detecting visual field loss earlier. The idea is based on the hypothesis that white light universally stimulates nearly all retinal ganglion cell types. The loss of a few retinal cells should therefore be easily compensated by the remaining cells, as the example with the SAP stimulus (top) illustrates. The white stimulus stimulates many retinal cells and even when several are dysfunctional, the white stimulus (white circle) is still seen. In function-specific perimetry, only one cell type is predominantly stimulated. In the example with the Pulsar stimulus (bottom), there is no remaining functional magnocellular cell that can be stimulated by the Pulsar stimulus. As a result, the stimulus is not seen.
other neighboring cells may still detect the SAP stimulus. This presumably makes the SAP test less sensitive to early visual field loss. To give a simple analogy, it is as though one person out of the 20 who promised to help you move calls in sick on moving day. The other 19 helpers can effectively carry on the task and the impact of the one missing person is not felt too strongly.

In contrast, function-specific perimetry targets only a subset of retinal ganglion cells. It is assumed that if a few cells in this subset are adversely affected by pathology such as glaucoma, there are a smaller number of cells that are able to detect the function-specific stimulus, making the test more sensitive to early visual field loss. Using the previous analogy, this would translate into having one person out of only two cancel on moving day. There is only one person to help with the move and the task becomes much more difficult.

The function-specific stimuli currently available have all been developed for early glaucoma detection, but have also been used for other diseases.

**USE OF FUNCTION-SPECIFIC PERIMETRY IN CLINICAL PRACTICE**

While many studies have reported that function-specific perimetry detects glaucomatous vision loss earlier than SAP, other studies have found no such effect. As a result, experts have not yet reached a consensus on whether function-specific perimetry provides added value in comparison to SAP.

When making a decision about whether or not to use function-specific perimetry, it is essential to keep in mind that the quantitative results cannot be directly compared with white-on-white perimetry. While SAP is the recommended standard, one may choose either SAP or one of the function-specific perimetry tests as a default test for disease detection. If time allows, one might choose to perform an additional test, particularly in situations of uncertainty (i.e., to confirm suspected but unconfirmed visual field loss as shown in the example in FIG 10-2).

While there are distinct normative databases for each function-specific stimulus as well as for SAP, it is essential to consider that function-specific perimetry has a smaller dynamic range than SAP. Therefore, while normal subjects may show comparable responses on all tests, patients with more advanced disease are likely to show visual field defects that appear more severe on function-specific perimetry due to the smaller dynamic range.

Consequently, function-specific perimetry cannot be used through all disease stages. If there is advanced disease, one should use SAP. If function-specific perimetry is chosen as a default for disease detection, switching to SAP is recommended for follow-up at some point. In order to avoid a lack of historic reference data, it may be best to switch to SAP early in the follow-up process.
FIGURE 10-2 The same patient with an early glaucomatous defect is tested twice, once with the SAP test (top) and once with the function-specific Pulsar stimulus (bottom). While SAP does not show a statistically significant defect in this patient, there is a clear defect visible when using function-specific Pulsar perimetry. Note that the locations with p < 5% for SAP are within the area in which the defect is present for function-specific perimetry.

PULSAR PERIMETRY

The Pulsar stimulus is a function-specific stimulus that tests both flicker sensitivity and contrast sensitivity. It has been developed specifically for early glaucoma detection and has been shown to be both sensitive and specific in the detection of early glaucoma. It is a very patient-friendly perimetric test.

The stimulus used in Pulsar perimetry consists of a ring pattern with a diameter of 5° of visual angle, which is more than 10 times larger in radius and 100 times larger in area than the white size III stimulus used in SAP. The Pulsar stimulus consists of phase and counter-phase images. This means that light rings on the phase image are displayed as dark rings on the counter-phase image. The two images alternate at a frequency of 10 Hz over 500 ms. If flicker sensitivity is reduced, the visual system cannot detect the change between the phase and counter-phase images. As a result, the phase and counter-phase images are perceived as a single image. Because the average intensity of the rings of the phase and counter-phase images are equal to the mean intensity of the background, the Pulsar stimulus blends with the background and is not visible anymore (FIG 10-3). However, if flicker-sensitivity is not affected, the visual system distinguishes between the phase and counter-phase images and the Pulsar stimulus is perceived like a pulsating ring pattern, similar to the ripple pattern generated if a water drop enters a smooth water surface.
The Pulsar test uses a very patient-friendly stimulus. It is easy to instruct the patients on how to perform the test (seen or not seen) and patients have more confidence about seeing the stimulus both because of its large size and perceived motion. As a result, Pulsar perimetry has low test-retest variability and a minimal learning effect. These features make it very suitable for screening purposes.

In addition, sensitivity thresholds can also be determined. Pulsar perimetry employs its own unit scale, the src scale, consisting of 36 distinct steps, with increased spatial resolution (sr) and contrast (c) with each step. The results of this threshold test are then displayed as any SAP result and all the visual field representations presented in Chapters 7-9 are available. Pulsar perimetry uses all representations available for SAP.
**FLICKER PERIMETRY**

Flicker perimetry is similar to Pulsar perimetry in that it stimulates flicker sensitive cells and has been created for early glaucoma detection. However, the stimulus design is fundamentally different from that of Pulsar perimetry. Flicker perimetry determines the critical fusion frequency (CFF), or in other words, the frequency at which the flicker appears to fuse into continuous steady light. In this test, a white stimulus of Goldmann size III with a stimulus intensity of 4,000 asb (i.e., the most intense stimulus that the perimeter can display) flickers over a period of 1 second and the patient is instructed to press the response button only when the stimulus seems to flicker (FIG 10-5). The flicker frequency ranges from very fast (approximately 50 cycles per second) to slow (i.e., 1-5 cycles per second). The CFF represents the sensitivity threshold of Flicker perimetry (FIG 10-6) and is expressed in Hertz (Hz).

**DESIGN OF THE FLICKER STIMULUS**

![Diagram](image)

**FIGURE 10-5** Flicker perimetry uses a flickering white stimulus (size III) of 4,000 asb on a white background that flickers at different temporal frequencies. The frequency is expressed in Hertz, a unit that defines how many times the stimulus is flickering per second. In the example above, the stimulus has a frequency of 4 Hz.

Flicker perimetry was shown to be both sensitive and specific in the detection of early glaucoma. One of its major additional advantages is that sensitivity thresholds are minimally influenced by media opacities stemming from pathologies such as cataracts or refractive errors, for example.
Flicker perimetry is more demanding of patients compared to Pulsar perimetry, because they must pay attention to both the presence of a stimulus and whether it is flickering or not. Thus, careful patient instruction and observation are even more essential in flicker perimetry than in other perimetry forms. Its use is therefore recommended only for patients who perform very well on perimetry. In these patients, it is a useful perimetric test. **BOX 10A** provides practical guidance on how to best perform flicker perimetry.
Short Wavelength Automated Perimetry (SWAP) is commonly referred to as blue-on-yellow perimetry, because it displays a large blue (short wavelength) stimulus of Goldmann size V on a bright yellow background with a luminance of 315 asb (100 cd/m²). The patient is asked to respond whenever a blue stimulus is visible.

SWAP is designed to elicit a response from the blue-sensitive pathway (S-cones for “short” wavelength cones and the koniocellular cells in the lateral geniculate body that receive input from blue-sensitive retinal ganglion cells) while the intense yellow background is used to suppress (i.e., adapt or fatigue) the relative sensitivity of both the green (M-cones for “middle” wavelength cones) and the red cones (L-cones for “long” wavelength cones). Sensitivity thresholds are determined by increasing the luminance (i.e., light intensity) of the blue stimuli from less visible to more visible and are expressed in dB (FIG 10-7). Nevertheless, the numerical dB values are not directly comparable to those obtained with SAP.

Like other types of function-specific perimetry, SWAP has also been shown to be useful for early glaucoma detection. Unlike flicker perimetry, it is influenced by media opacities and blur.

The task of performing SWAP is easy to understand for the patients (seen or unseen). Nevertheless, this test is challenging for patients because the intensity of the yellow background makes it difficult to perceive the blue stimuli. This results in increased test-retest variability. In addition, the patient’s eye needs to adapt to the very intense background for several minutes before starting the test in order to avoid false results. This light adaptation is time-consuming and makes SWAP an overall longer test to perform than SAP.

However, given a patient who is able to perform the test reliably, SWAP is a useful perimetric test. BOX 10B provides practical guidance on how to best administer a SWAP test.
STIMULUS V FOR PATIENTS WITH LOW VISION

There is a limit to the visibility of the standard size III white perimetric stimulus in patients with significantly impaired sensitivity. This is because there are no longer enough intact cells to elicit a response to a stimulus even though the patient has some vision remaining (FIG 10-9). In order to overcome this floor effect and to increase the dynamic range in regions of poor vision, the Goldmann stimulus V can be used. When this stimulus, which is 16 times larger in area than the size III stimulus (FIG 10-8), is displayed for a longer period of time (i.e., 200 ms), it provides a useful alternative perimetric stimulus for patients with severe visual field loss.

GOLDFMANN STIMULUS SIZE III VS V FOR LOW VISION

Because the larger stimulus V reaches more intact cells, it can elicit a response when the smaller stimulus III no longer can, as illustrated in the example shown in FIGURE 10-9.

HOW TO ADMINISTER A RELIABLE SWAP TEST

Most points highlighted in Chapter 3 on how to run a reliable visual field test also apply to SWAP perimetry. However, particular attention needs to be given to some specific points.

For SWAP, allow the patient’s eye to adapt to the very intense background for several minutes before starting the test in order to avoid untrustworthy results. Patients should be instructed to press the response button when they see a blue light presented anywhere in the bowl. The examiner should let the patient know that the color of the stimulus may appear to be slightly different from blue, as some patients report seeing the stimulus as bluish or purplish.

SWAP is a more challenging test to perform than SAP. The examiner should closely monitor the patients as they are taking the test, to identify any need to rest. Particular attention should also be paid to reliability indices to ensure that patients are performing the test to the best of their ability. It is often helpful to provide a brief demonstration test to familiarize the patient with the test procedure.
In addition to the increased dynamic range, the larger and thus more visible stimulus size V has also been shown to have significantly lower test-retest variability compared to stimulus size III.19–21 This is thought to be due to a larger stimulus being easier to see, which is essential in low-vision patients who struggle much more with perimetric testing than patients with normal visual fields.

Besides using stimulus size V for low-vision patients, use of the low-vision strategy, which starts with the most intense stimulus available (as illustrated in FIG 6-3), is also recommended. This approach saves valuable testing time and is easier for patients to complete. For more information on the low-vision strategy, see Chapter 6.

Because stimulus sizes III and V are not directly comparable, switching to stimulus V is only recommended for patients for whom testing with stimulus III no longer renders useful clinical results, either due to the floor effect or the large variability of stimulus III.
REFERENCES


