THE ARDEN GRATING TEST OF VISUAL FUNCTION

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Abstract

In the absence of detectable pathology, the optometrist must ascertain why a reading of % Snellen is not achieved. A new, inexpensive and simple test has been developed for this purpose, useful even with illiterates. An explanation of the test, some of its applications and drawbacks, plus comparison with other, currently used tests is presented.

Abrégé

Dans l'absence de signes pathologiques evidents, il est du devoir de l'optométriste de déterminer pourquoi un patient n'atteint pas un niveau visuel adéquat. Un nouveau test, peu couteux, simple et utile même avec les illettrés est maintenant disponible. Ce travail explique l'opération du test, certaines applications et ses inconvénients. Aussi comparaison est faite de ce test avec d'autres semblables couramment en usage.

For patients with visual acuities slightly less than 6/6 Snellen, optometrists rely on a battery of tests to distinguish other causes from uncorrected refractive error. Included are a fuller case history of symptoms, dark adaptometry, macular photostress test, the pinhole, polaroid filters, automatic refractor readouts, Amsler grids and thorough colour vision testing. In monocular instances, microstrabismus is ruled out. Even if there is accurate but overly slow or halting reading of the % lines, tests are done for visual field defects. All patients with reduced vision and especially in the absence of other clinical signs of abnormal function have disc colour and pupil responses carefully evaluated. Medications that the patient is using should be listed and their effects ascertained. Is the reduced acuity possibly associated with chronic marijuana smoking? The optico-kinetic response may be used as an objective test of vision. If available, the electro-retinogram (ERG) is a useful objective test for investigation of possible functional impairment.

What if the results of testing are unsatisfactory or inconclusive, the patient verbally reticent or suspected of malingering, the optic disc and fundus apparently normal, there is no other evidence of physiological or pathological damage, no medications are being taken, and there is no history of past visual impairment? Or suppose, on the other hand, that the patient complains of various visual problems, yet seemingly has adequate acuity? Is there a reliable, rapid and sensitive auxiliary diagnostic test that will help rule out the presence of ocular disease and neurological defects, and allow the optometrist to resolve the visual impairment by more traditional methods?

Just such a prognostic clinical test has been recently developed by Prof. G.B. Arden of the University of London's Institute of Ophthalmology. He named it "a simple grating test for contrast sensitivity". It is known as the Arden Grating Test (AGT), but can be found in the literature under its various research developmental names such as "contrast sensitivity function" (CSF), "a sine-wave grating test", "a test of spatial contrast discrimination", or most simply as "bar gratings". It is based on the fact that there are two main factors limiting the perception of fine detail: (a) the refractive status of the eye forming an image on the retina and (b) the ability of the visual pathway to resolve these details. The test measures the quality of the final image.

A gross comparison of the bar gratings' spatial frequency can be made to the white gap between the two black arms of the Landolt C ring. At some distance from the observer, the gap is no longer visible to a particular person at a definite distance away from it.

Sine-wave gratings can be generated on oscilloscope screens in various sizes, but for office use, one form of the test consists of a book containing seven printed plastic-coated paper plates of grating patterns, approximately 30 cm. square, providing a range of stimuli. Each plate shows a series of light and dark grey bars with no definite borders, which appear sinusoidally fuzzy (see Fig. 1). Their contrast varies continuously from top to bottom. As one looks down the page, one sees, if one has an intact, but not necessarily perfectly focussed optical system, an apparently uniform grey colour at the top, not recognisable as gratings; as one looks further down the page the eye is able to resolve definite bars. These become more pronounced and darker toward the bottom of the page. There

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is a difference in the (a) space and (b) contrast between the bars. This sinusoidal pattern type is based on experimental findings which reveal that there is a "normal" human perceptual threshold regarding contrast between closely spaced narrow bars, and this depends on the width between them. It was discovered that if the edges were not sharply defined, calculations could be made to relate the slope of the varying width of the bar to the observer's perception of it.

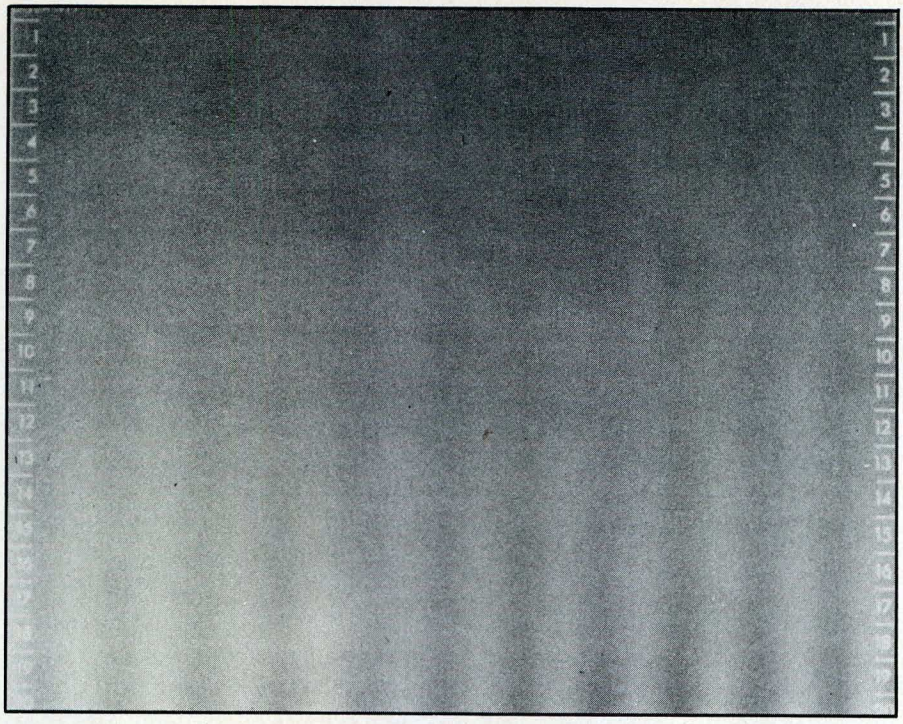

Fig. 1 Example of an Arden Grating Test Plate. (Supplied by Dr. G. Woo, U. of Waterloo.)

History

Westheimer, in 1959, found that in the presence of an eye with intact optics, the neurological integrity of the visual pathways from retina to brain could be quantitatively assessed. In 1968, Campbell and Robson were publishing the results of their work in measuring what is essentially the resolving power of this visual pathway. They proved that the results of the sinusoidal profiles were influenced by neither the chromatic aberration of the eye nor fluctuations in accommodation. Furthermore, they showed that fixation on any part of the grating pattern is not necessary. Campbell discovered that the visual system does not function as a whole, but as a number of independent detector mechanisms, each tuned to a different and narrow band of frequencies of grating patterns. Retinal ganglion cells, for instance, have a different contrast sensitivity function than the overall human contrast sensitivity function. Other parts of the visual system are sensitive to different visual signals of this type. Each mechanism responds maximally to some particular frequency and not at all to others. It should be emphasized that the results are not a distribution comparable to a visual field plot.

In the visual cortex of mammals, it had earlier been found that there were single cells uniquely sensitive to the shape, position and movement of a stimulus. Maffei and Fiorentini studied the responses of neurons to grating bars, at various levels in the visual system. The information gathered along the visual pathway is synthesized, and as a result components can theoretically be identified. Tolhurst was the first to believe that edge detector units existed in the visual system, as distinct from line (bar) detectors, and that they interact by inhibiting each other. They consist of many channels, each responsive within a narrow limit. Moreover, there are two separate classes of channels in reference to both stationary and moving patterns, each with its own independent role in perception. There has been physical corroboration of his hypothesis.

Weisstein and Bisaha have demonstrated that the human visual system presented with a series of bars does not rely on a simple detection of form, but that different nerve populations react to various sizes and orientations of bars. Concurrent experiments with the visual evoked response (VER) showed that borders were of great importance in vision.

Method

When the test is being administered the patient should wear the prescribed distance correction and be monocularly occluded and seated at a table. The patient is assured to have clear ocular media and steady fixation. If accommodation is decreased to the point of influencing the sharpness of the retinal image, a near correction should be incorporated. Ask the patient to read some of the side numbers if in doubt. Plate #1, the screening plate, is employed as the first stimulus. It is used mainly to ascertain adequate acuity, as very large losses are precluded from testing. The AGT is relevant only insofar as the patterns can be imaged on the retina. If they are not, the patient sees no stripes on the plate. Attention is called to the top and bottom of the page. Can the patient identify an intermediate value bearing a specific relationship to them? Can he/she make an attempt? How does the page seem to look?

Plates # 2 to # 7 provide a quantitative estimation of visual performance. To maintain constant viewing distance, the patient should be instructed to sit with elbow on the table and with chin on fist; the low vision patient may have to move closer to the grating. The optometrist moves a covering card slowly from the top area downward, until the patient responds, indicating that the bars can be seen. The procedure then is to go to the next plate, where

the "normal" threshold for bars to be distinguished is different (see FIG. 2).

The optometrist can either record the results from a limited duration of one presentation for each target or an average of two or more readings for each target. There should be no appreciable interval between presentation of targets. The score, or position where the grating first becomes visible, is read off the arbitrary side scale, marked 1 to 20 on each plate. The other eye is then tested. The end result is compared to a known normal score. A normal viewer sees gratings beginning somewhere in the mid-third of each page. The upper and lower limits are not clearly defined. There is a range through which patients are uncertain as to whether they actually see a grating. Scores of each page are added for a final score, but no page can exceed a normal score in itself. There are also limits as to allowable differences between the eyes.

In summary, there is a maximum score for each plate, a range indicating probable abnormality, another range indicating definite abnormality and an asymmetry of results between the eyes indicating abnormality.

Most eyes with pathological conditions see AGT patterns, but with a delayed response compared to normal eyes. The same delays are apparent if the patient's acuity is even slightly altered. Refractive errors depress sensitivity uniformly for all frequencies except the lowest, which are unaffected.

Standardized instructions to the patient should be employed in order to facilitate comparisons. Repeated testing makes the patient more sensitive to detail. Campbell and Green's research suggests that rather rapid observations are preferable to prolonged viewing of one target plate. Inter-stimulus intervals ought likewise to be controlled. The test can be done in daylight or any usual office light, as long as the illumination level is uniform and at least at the patient's perceptibility threshold without being excessively above it. The surrounding lighting or room luminance should approximate the luminance on the target area, so as not to affect resolving power for the particular target at the standardized viewing distance. Any change in these parameters will affect the results.

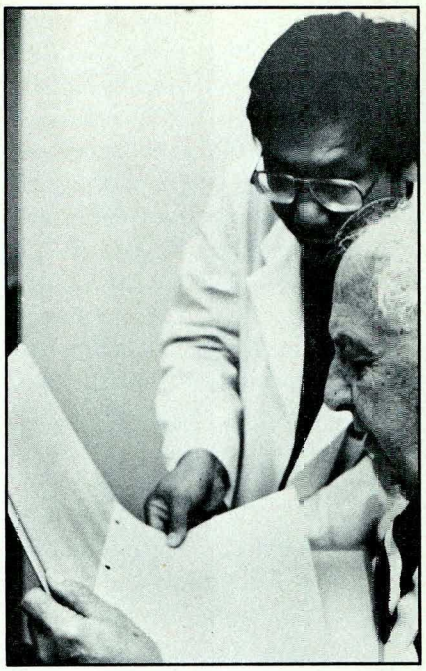

***Fig. 2** One method of using the Arden Grating Test; monocular patient. (Supplied by Dr. G. Woo, U. of Waterloo)*

Patients aged 8 to 70 have responded well to the AGT. Children and retardates have trouble with verbalization, so appropriate terminology and/or pointing can be utilized to elicit a response. In cases of complete communication breakdown, use only objective tests, as there definitely must be communication between the examiner and patient. Illiterates obviously do well in it.

Four to six minutes per patient are required to explain, complete and score the test. Repetitions can be made if necessary. As mentioned previously, a control ought to be used regarding the time allowed to perceive gratings. Research by Weisstein and Bisaha (23) suggests that observation time should be adequate because there is a reduction in contrast for a new grating stimulus presented after a previous grating has just been exposed to the eye. There is evidence that neurons sensitive to size and orientation lose sensitivity after prolonged stimulation.

There is no discomfort involved in the AGT. As can be seen, very little equipment is required, and that not expensive. However, much depends on the examiner maintaining a constant speed in moving the cover card. Results vary slightly, but consistently with the practitioner using the technique. In any case, results from normal eyes are very different from abnormal eyes. The result is reproducible for a given individual. When inattention is a problem, there is a uniform overall reduction in CSF. Real problem cases show greater losses selectively in high, middle or low ranges. This means, also, that individuals with high threshold criteria behave in a similar manner.

The AGT has an advantage over visual field plots (although it does not replace them) in that it does not require constantly maintained fixation, nor does it demand a relatively still patient. It is also not absolutely necessary to have fully aided acuity such as reading glasses, which can restrict measurements with visual field testing techniques.

Assessing Results

Not only do normal eyes respond differently from abnormal ones, but for some conditions, notably glaucoma, the degree of loss of sensitivity to the bars relates directly to the severity of the condition. In borderline cases, diminished tresholds in contrast can be compared to diminished tresholds in, for example, adaptometer results.

A small decrease in contrast sensitivity occurs with age, but not nearly as much as in abnormal eyes. Pupil size is almost a negligible factor unless there is very much dilation, as with drugs. The resulting spherical aberration gives a mild decrease in retinal resolving power.

Using the test, some patients with acuity of % will be found to exhibit some degree of abnormality as indicated by the departure from normal contrast sensitivity. In retrobulbar neuritis, there may be no trouble

perceiving the outlines of letters on the visual acuity chart at the % level, but patients may say they look misty or flat. When the condition is more advanced, the decrement in contrast is more disturbing than the small loss of acuity. Once the condition has been diagnosed, recovery can be monitored by again employing the CSF. The extent of return to the normal condition becomes apparent when the results show stability.

Scotomas may be absent on field studies, but abnormal responses on the AGT can provide an indication of patchy punctate retinal dysfunction. VER patterns can corroborate such losses.

In probable or possible multiple sclerosis patients with no apparent acuity loss (ie, % Snellen), evidence of pathology can be detected by the CSF. These people can see fine, high-contrast detail, like black letters on a white chart; coarse details without a contrasting background seem to them to be "washed out". They know they have a visual problem but the usual clinical procedures, such as ophthalmoscopy and colour vision analyses may not pick it up. It is a particularly disressing problem problem to the congenitally colour-blind, who are unable to rely on colour differences to distinguish objects. The AGT will often show surprising loss of visual contrast, although the type of results measured to date are not specific to multiple sclerosis.

As a rapid screening device the AGT is useful for detection of visual degradation in early lens changes, hypertensive arterial disease and intracranial lesions. With cataracts, CSF's are different with different patients and the clarity of the media limits use of the test. We know, however, that the acute cataract specific to diabetes gives deteriorating sight before any actual lens opacities are seen. The test can be used to monitor the progress of a cataract.

Subjects with occipito-parietal and occipital lesions can have symptoms out of proportion to their mild loss of visual acuity as tested on the maximum contrast Snellen chart. Larger targets of lower contrast however, cannot be detected. They can have difficulty reading or episodic blurring of vision. They complain of headaches. They may pass many tests for revealing retinal pathology; yet CSF testing may show marked departures from the norm. Some patients lose sensitivity in the high frequencies and some in the middle ranges. Tumors have been found in different parts of the brain for patients with different CSF data. Again, this suggest a possibility of future channelling of diagnoses.

The AGT detects abnormalities due to retinal damage like eclipse burns, but not retinitis pigmentosa, because only cones are involved in viewing the plates. When the macula and fovea do become involved in RP, then defects in contrast sensitivity will occur.

Some amblyopes do well on this test, and others do not. Hess and Howell have, on the basis of the CSF, postulated two types of amblyopia. One class of strabismic amblyopes cannot detect the high frequencies and another class has a depressed function for all frequencies, including the low. The normal fixing eye of these strabismics was found to correlate perfectly with non-strabismic "normal" eyes. The researchers examined both central and eccentric fixators in their study. They found they could detect the degree of amblyopia in all affected eyes, but consistently found two classes of amblyopes. Their explanation is, that there exists one form of a mild amblyopia (type I), over which is superimposed a more severe progressive loss (type II). The implications of this for visual training specialists is, that the AGT can (a) confirm the accuracy of the diagnosis, and (b) it will predict whether the visual function is amenable to restoration. For very young children, the VER recording is preferred, especially as it can also monitor acuity changes during occlusion therapy.

Where there is photophobia precluding prolonged ophthalmoscopic examination, the AGT can be used as an auxiliary procedure.

For some abnormalities uncovered by CSF, there may be a profile of typical responses, resulting from selective loss of sensitivity. This provides potential for future clinical applications. Not only could loss of function be ascertained, but an indication of type of abnormality involved. However, the main use of the test would be on selected, previously carefully refracted patients.

In addition to its uses in ocular abnormalities, this technique has been recently found to ascertain small or large changes in visual acuity. This suggests testing of various devices on both low vision and contact lens patients. The gratings used are not the coarse ones mentioned above, but those of a finer and more sophisticated variety. Changes in refractive power of the eye show up in the higher rather than lower spatial frequencies. Green and Campbell, in 1965, realized that by measuring the contrast at which a subject can just detect the presence of a sinusoidal grating pattern, it should be possible to assess the effects of focus on the visual system. They showed that increasing amounts of myopia reduce sensitivity to the higher spatial frequencies.

Rotating or tilting the gratings allows also for meridional refraction, and hence aid in correction of astigmatism. At defined distance, angular subtense, lighting conditions and the inclusion of the patient's limit of resolution in the targets, readings are possible through various optical appliances. As usual, the patient's task is to detect the presence of a grating. The best possible correction and the range through which there is no noticeable change are noted. Paralyzing the accommodation appears to have no effect on the results when compared to the normally functioning accommodation. Results are accurate to 0.50 D. Clinical applications of the method are currently being studied, but there are, as yet, unresolved drawbacks.

The test is extremely useful for patients who have had episodes of transient blurring of vision. It will detect abnormalities which the VER

misses, besides doing it more simply and cheaply. If used along with the VER, it can indicate reasons for VER delay. However, if subjective testing is not possible, and there is access to the entirely objective VER testing equipment, this latter would then be the preferred tool of diagnosis and prognosis. Both instruments assess central acuity. In such cases, electro-retinograms should be obtained first, to ensure a normally functioning retina before looking for lesions higher in the visual pathway.

Summary

An aid is available for distinguishing some patients whose unexplained visual loss cannot be helped by glasses, from those who have the potential for improved vision. The AGT is superior to tests of acuity in cases of minimal reduction in acuity and early visual disturbances, because contrast sensitivity may be impaired even though acuity is normal. The VER has, up to now, been the most sensitive way to determine optic neuritis and detect abnormalities in glaucoma before any field loss has occurred. For brain and central nervous system conditions, especially inflammatory processes, the AGT is a more sensitive index of loss of function than any other test currently used. Even so, it is not a substitute for visual field screening. It is a valuable diagnostic tool for revealing clinically silent lesions in the optic pathways, albeit subjective and not objective like the VER. Both tests judge abnormality by delayed responses. The VER is a much more elaborate test, slower, not easily available and not as quantifiable as the AGT. It can, nevertheless, distinguish visual impairment due to refractive errors from those caused by retinal and optic nerve disease. In recent times, the VER has moved from bar gratings to the more sensitive checkerboard patterns to ascertain the degree of focus of the retinal image. It provides a definite,purely objective, quantitative analysis of blur within ±1.00 diopter, and improvements are constantly being made. However, as an in-office technique, it is, as yet, impractical, having many limitations. The AGT is not to be considered a replacement for it.

Furthermore, if in doubt, ultrasonographic scans and, where available, the new but extremely expensive hospital-based radiological technique of computerized tonography can be used, where the AGT or electrodiagnostic screening results are abnormal.

The AGT is a useful, easily understood test for young children and mentally disturbed patients.

When monitoring eyes during treatment of pathological conditions, the AGT can be used for intermittent follow-up testing to record the progress of changes in visual function. Also, it is a better test of visual competency and return to normality than visual acuity, because in everyday life, few objects are encountered at 100% contrast.

Finally, the AGT can be used as a simple, rapid screening tool on large populations such as in school surveys.

Even if the AGT has no direct impact on present modes of practise, the foregoing review indicates its potential.

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