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Reply to J. H. Verbaken: Contrast Sensitivity Function as a Screening Test

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We welcome Verbaken's response[1] to our critique[2] of the contrast sensitivity function (CSF) as a screening test. Although his comments pertain more generally to the clinical value of the CSF, his answers to our four questions are certainly germane to screening. He concludes that:

> "A mass of research has answered in part the questions raised by Legge and Rubin."

While it is incontestable that there exist data pertinent to our questions, we believe that definitive answers are not yet available.

Verbaken places considerable weight on data collected with the Arden grating test (AGT).[3] The AGT was the first test to be used widely for clinical measurement of contrast sensitivity. Its value as a screening test has been cast into doubt.[4] Moreover, the AGT relies on a psychophysical procedure that is susceptible to criterion bias on the part of the observer. For these and other reasons, the AGT has, for the most part, been superseded by more objective techniques. We are unsatisfied by answers to our questions that depend solely on results gathered with the AGT.

Question 1

How accurately does the CSF distinguish subjects with abnormal vision from those with normal vision, either on its own or in conjunction with conventional test measures?

In response, Verbaken cites the AGT study of Weatherhead.[5] In this study, patients were prescreened by "general practitioners in their rooms." Those with AGT scores greater than 78 were referred to the eye clinic and constituted the sample studied by Weatherhead. The sample is biased strongly toward individuals with high AGT scores. The data presented by Weatherhead are based on subsequent AGT measures taken in the clinic under standardized conditions. It is not clear how to evaluate the effects of the sampling bias on the estimated sensitivity of the test. If the population distributions of normal and abnormal AGT scores are approximately Gaussian, the effect of the biased sampling would be to increase the false positive rate more than the hit rate, hence producing a reduced estimate of accuracy. It is possible, therefore, that Weatherhead's sampling scheme resulted in an underestimate of the screening accuracy of the AGT. However, in comparing the screening accuracy of Snellen acuity and the AGT, Weatherhead forthrightly observes that the differences he found required highly standardized conditions, careful refractions, and that patients were "considerably encouraged" to obtain their best AGT and Snellen scores. Presumably, the "encouragement" reflected an attempt to instill some roughly equivalent response criterion in all patients who performed the AGT. With regard to these precautions, Weatherhead says:

> "Since most screeners will have neither the time nor the facilities to do this, there is likely to be a difference between their results and those reported here. . . . This means that in testing by the general practitioner, the AGT would yield more false positives and this would tend to counteract any slight difference between the AGT and the Snellen test for screening purposes. Hence, there is little to be gained from its use here."

Weatherhead says that the AGT may be useful as a supplementary test in an eye clinic where viewing conditions can be controlled and refractive state can be managed.

Neither Weatherhead nor Verbaken have considered whether screening accuracy can be improved by the addition of the CSF to conventional screening tests. Their focus is on the comparison of the CSF with conventional acuity. More likely, both types of test would be used

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and we would like to know if this increases the overall accuracy of the screening.

Question 2

How do we score a CSF? What criteria do we use to separate normal from abnormal CSF's?

By definition, a CSF consists of measurements at several spatial frequencies. How are the results to be combined, and what criteria should be set to separate normal from abnormal performance? Verbaken cites the combination rule used to score the AGT, but the value of the AGT as a screening test has been called into question.[4] The dB criterion used by Bodis-Wollner[6] refers to sensitivity differences at a single spatial frequency and does not deal with the combination of results across frequencies. With the exception of the AGT, there are no clear rules to guide the clinician in the interpretation of CSF's. A major problem standing in the way of such rules is the lack of large-scale normative data collected in a context broadly representative of visual screening.

Question 3

How many measurements of contrast sensitivity are necessary to make the test accurate enough to be of use in screening? At what spatial frequencies should these measurements be taken?

Verbaken reminds us that the AGT consists of measurements at 6 spatial frequencies, 0.2 to 6.4 c/deg, in 1-octave steps and that Ginsburg's VCTS 6500 uses 6 spatial frequencies ranging from 1 to 24 c/deg. He reviews some of the limitations of these tests, but offers no justification for the range or number of spatial frequencies. One theory-based view of this question holds that there should be a separate measurement for each independent "channel." Because we do not yet have a broad consensus on the number and distribution of such channels, theory-based design of a test seems problematic. Such a test would require measurements not only across a range of spatial frequencies, but across a range of orientations as well (inasmuch as channels are generally thought to be both spatial-frequency and orientation-specific). An alternative view is that most eye diseases affect contrast sensitivity across a wide range of spatial frequencies. According to this view, depressed sensitivity at 1 spatial frequency will be correlated with depressed sensitivity at a nearby spatial frequency. The challenge is to design a test of contrast sensitivity that captures most of the information with a minimal number of measurements. A promising direction is provided by Verbaken and Johnston[7] in which just two measurements—acuity and "edge" contrast sensitivity—are used as a clinical summary. Similarly, Pelli et al.[8] have recently analyzed CSF's from a sample of normal and low vision subjects and have suggested that entire CSF's may be specified by just two numbers such as peak contrast sensitivity and the cutoff spatial frequency.

Question 4

How robust are measurements of contrast sensitivity to the types of unavoidable variability in testing conditions typical of screening contexts? What sort of repeat reliability is expected of the CSF?

Verbaken cites the study of Verbaken and Johnston,[7] which included repeated measurement of contrast sensitivity for luminance edges. They found a test-retest correlation of 0.69 for a sample of 144 eyes. This means that a little less than one-half of the variance ($0.69^2 = 0.476$) in the repeated test scores could be accounted for by original test scores. It is not clear whether the remaining variability was due to changes within the subjects or in the test procedure or conditions. This study together with the study of Higgins et al.[9] give us some idea of the retest reliability of clinical CSF's.

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