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Letters-in-Noise: A visual test chart that "bypasses" the optics.

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Abstract: A new chart, consisting of letters in noise, is sensitive to some neural deficits, but is unaffected by all optical deficits.

The typical patient for cataract surgery is elderly. Since cataracts are not life threatening, the decision to operate depends on a cost-benefit analysis. The costs are the monetary costs of the operation and the relatively small risks of the operation. The benefit is improved vision, but that depends on the heath of the visual system, which can be difficult to assess in the presence of the obscuring cataract.

The Letters-in-Noise chart has 3° letters at 100% contrast on a background of visual noise which becomes stronger and stronger from line to line, until it becomes impossible to read the letters. We say this chart measures *letter efficiency* because it is possible to compute the statistical efficiency of the observer: the higher the efficiency, the more noise is tolerated. This test is designed to "bypass" the visual optics. It does this by virtue of the fact that the legibility of the letters is determined by the *ratio* of letter contrast to noise contrast. Optical attenuation of contrast affects both letters and noise equally, without changing the ratio. Pilot data confirm this expectation: letter efficiency is immune to optical deficit. (There is a limit to this, for which the chart has a built-in test.) We hope that letter efficiency will be useful for the clinical diagnosis of neural deficit, hopefully even in the presence of dense cataract.

The Letters-in-Noise chart has letters on a noise background, with more and more noise on each line, until the letters become unreadable. Each line contains six letters. The subject is considered to have read the line if he or she gets 4 out of the 6 letters right.

We have collected pilot data on a prototype Letters-in-Noise chart. This chart has 1.5° letters at the 1 m test distance. (We intend to use 3° letters in future tests.) We have tested 69 eyes of the patients visiting an ophthalmic private practice and the Retina Clinic at the Dept. of Ophthalmology at the SUNY Health Sciences Center at Syracuse.

(The raw data appear at the end of this section.) The patients' mean age is 48 years, with a standard deviation of 25 years and a range of 8 to 103 years. The median acuity is 20/30. Performance on the Letters-in-Noise chart is scored as "*letter efficiency*," which is the log signal-to-noise ratio corresponding to the lowest (i.e. noisiest) line correctly read. The median efficiency score was 0.9. On the basis of the medical diagnosis we classified each eye as having neural (i.e. non optical) deficit or not. The table below summarizes the results:

	Quantiles			
	10%	**median**	**90%**	**N**
Acuity of all eyes	20/200	20/30	20/20	69
Acuity of eyes without neural deficit	20/60	20/22	20/20	41
Acuity of eyes with neural deficit	20/286	20/50	20/20	28
Letter efficiency of all eyes	0.75	0.9	0.9	69
Letter efficiency of eyes without neural deficit	0.9	0.9	0.9	41
Letter efficiency of eyes with neural deficit	0.75	0.9	0.9	28

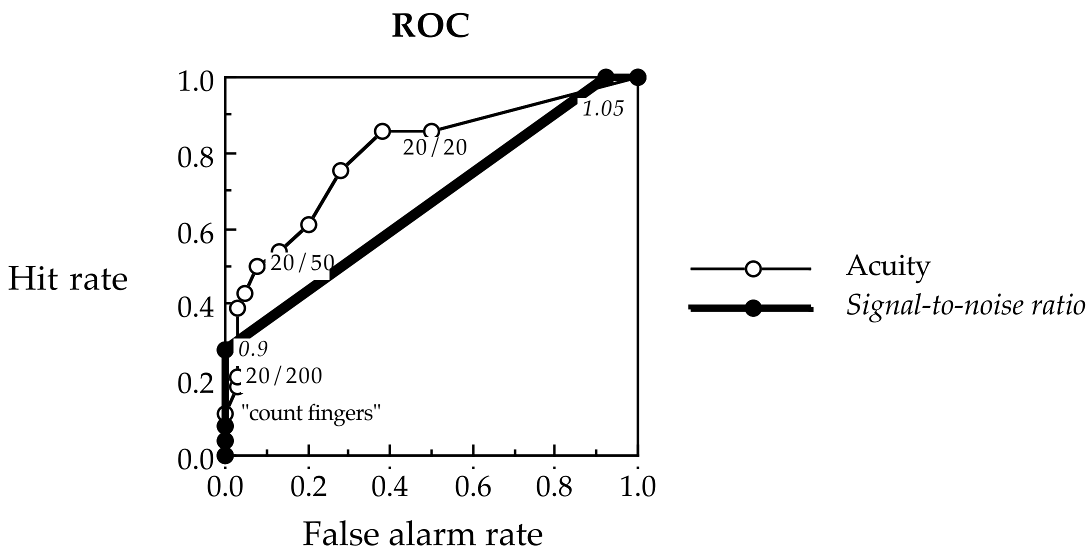
The 41 eyes *without* neural deficit had a median acuity of 20/22. Thirty seven of the 41 had the same, "normal," letter efficiency (the 0.9 line), three eyes read one *more* line, and one eye (with a dense cataract) could not read the top line of the chart, which is a prerequisite for testing. Thus *all* of the eyes without neural deficit which could be tested had normal or better letter efficiency, even though this group included a wide range of acuities.

The 28 eyes *with* neural deficit had a median acuity of 20/50. Seventeen had normal letter efficiency. Seven had below-normal letter efficiency (diagnoses: age-related maculopathy, macular hole, glaucoma, glaucoma, glaucoma, age-related maculopathy, strabismic amblyopia). Four eyes (all with macular degeneration) could not read the top line, so they could not be tested. Thus 7 out of 24 or 29% of the eyes with neural deficit that could be tested had below-normal letter efficiency.

The accuracy of acuity and letter efficiency as detectors of neural deficit is best evaluated by plotting an ROC curve (Swets and Pickett, 1982), as shown below.

The ROC curve shows that, in its present form, the Letters-in-Noise chart is not as accurate as acuity in detecting neural deficit for *intermediate hit and false alarm rates*. However, at extreme hit and false alarm rates the Letters-in-Noise chart is *more* accurate than acuity. All the points for efficiency have zero false alarms or 100% hits. For example a hit rate of 29% with a zero false alarm rate corresponds to a detectability d' of infinity. The acceptable false alarm rate depends on the application. For screening tests it is generally essential to have a very low false alarm rate, to minimize the cost of unnecessary referrals.

The ROC curve reveals that the Letters-in-Noise chart needs at least one intermediate line between the 0.9 line (which flunked 29% of the neural deficits and none of the non-neural deficits), and the 1.05 line (which flunked 100% of the neural deficits and 92% of the non-neural deficits). We can't know in advance where in the ROC space the criterion corresponding to an intermediate Letters-in-Noise line would land, except that on general considerations we may expect it to land above and to the left of the line connecting the criteria corresponding to the 0.9 and 1.05 lines. If the points for the Letters-in-Noise chart fall along a bi-normal curve—which is by far the most common result in many applications of ROC curves (Swets and Pickett, 1982)—then the new intermediate test line would produce an ROC point well above and to the left of the ROC curve for acuity, i.e. with much higher detective accuracy than acuity.



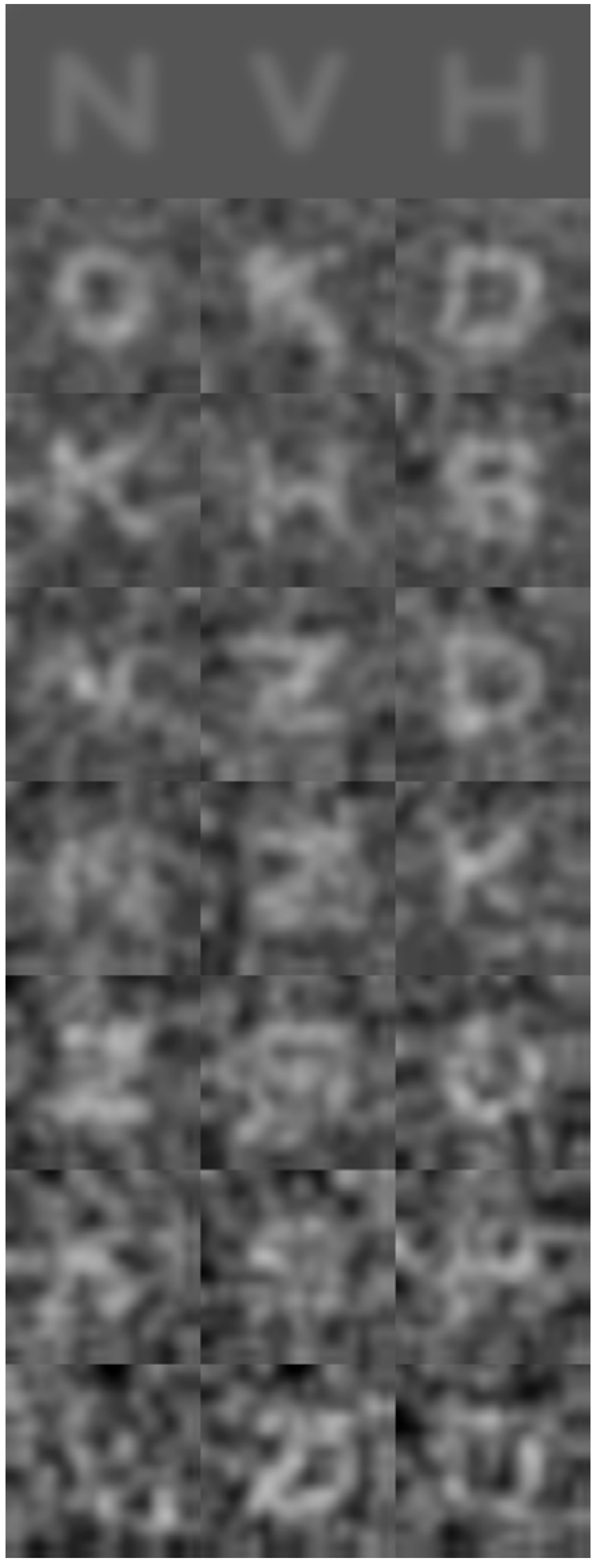
Receiver Operating Characteristic for detection of neural deficit by acuity (open symbols) and by the Letters-in-Noise chart which measures letter efficiency (closed symbols). The vertical scale is probability of a hit (the probability of correctly classifying an eye as having a neural deficit) and the horizontal scale is probability of a false alarm (the probability of falsely classifying an eye as having neural deficit). Each point corresponds to a certain criterion. For example, the 20/20 criterion classified every eye which failed to read the 20/20 acuity line as having neural deficit; this criterion had a hit rate of 86% and a false alarm rate of 50%. (See Swets and Pickett, 1982, for a discussion of the advantages of ROC analysis in evaluation of diagnostic systems.)

We are excited by these results from this prototype chart. If we consider the 0.9 line of the Letters-in-Noise chart as a detector of neural deficit, it exhibited no false alarms when tested on 41 eyes without neural deficit but which had a wide range of acuities, and correctly detected 29% of the eyes with neural deficit (excluding four that could not be tested).

Related work

Kersten, D., Hess, R. F., and Plant, G. (1988) Assessing contrast sensitivity behind cloudy media. *Clinical Vision Science 2(3).*

Swets, J. A., and Pickett, R. M. (1982) *Evaluation of Diagnostic Systems: Methods from Signal Detection Theory.* Academic Press.



The Letters-in-Noise chart. [Only the right half is shown. The left half, not shown, has different letters but is otherwise similar.]