Improving screening for amblyopia in children

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Large trials in Israel and Sweden have demonstrated a very favorable cost-benefit ratio in screening children for amblyopia. Song, Levi, and Pelli (in prep.) have shown that the foveal vision of strabismic amblyopes is well-modeled by the crowding of normal peripheral vision. That finding on adults indicates that two improvements to existing charts would greatly increase their diagnostic sensitivity to strabismic amblyopia in children, with no loss of specificity. First, the flankers should be letter-like, not bars (Fig. 1). Second, the flankers should be closer to the target letter, i.e. more tightly spaced (Fig. 2). Atkinson's Cambridge Crowding Cards are exemplary in this regard, having the tightest spacing of all available tests. These principles are demonstrated in Figs. 1 and 2.

Figure 1. Flankers should be target-like. The clinical literature on screening for amblyopia has often implicitly assumed that "contour interaction" (overlap masking) and crowding are the same thing, but they are not, as this figure demonstrates. In the normal fovea, where flanked acuity is limited by overlap masking, surrounding the target with nearly contiguous bars ("contours") or letters has the same effect, which you may witness by comparing these three eye charts. All three targets in each row have the same size, dropping by a factor of $\sqrt{2}$ from row to row. The left column has letter flankers, the middle column has bar flankers, and the right column is unflanked. The conclusions of this demo depend only on comparing charts, side by side, from any viewing distance. If you wish, you can allay any fear that the printer or display resolution might be limiting you by increasing your viewing distance to one or more meters.

As a normal observer, looking directly at each target, you will find that both kinds of flanker are effective, raising threshold one row above that for unflanked acuity (right column), and that the letters and bars are equally effective. That is, for a given gap between target and flanker, you have the same flanked acuity (same row) with letter and bar flankers. This is overlap masking.

Simulating a strabismic amblyope, please fix your gaze on a + and peripherally view the target (to right or left). Provided the spacing is not very loose, the strabismic amblyope (real or simulated) is limited by crowding. Unlike overlap masking, crowding depends on the center-to-center spacing, not the gap, and is very sensitive to the degree of similarity of target and flanker. The letter flankers are much more effective than the bars, because they are more similar to the target, even though, having the same gap, they are farther away, center-to-center. Thus, in existing tests, replacing bar flankers by more-target-like flankers will worsen the flanked acuity of the strabismic amblyopes without affecting the flanked acuity of normals. This will increase the separation of the two populations, increasing the power of the test.

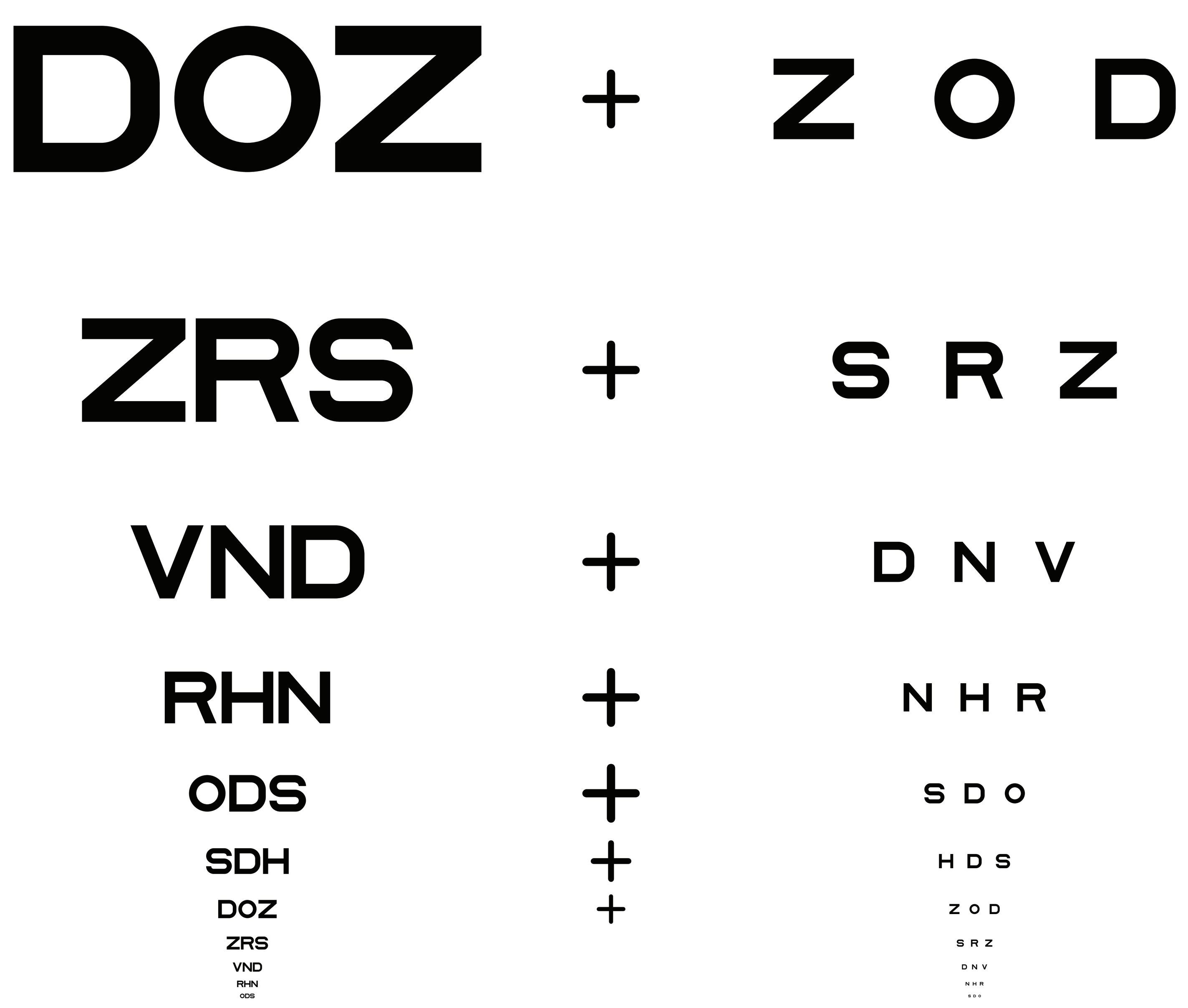

Figure 2. Spacing should be tight. Two charts with different spacing factors (=spacing/size): a tight 1.1× (which we recommend) and a loose 2× (which is typical of the commercially available tests). The spacing factor of the test imposes a floor on the measurement. Given an observer with acuity A and a chart with spacing factor s, the measured spacing threshold cannot go below sA. This is of little concern when using a 2× chart to test a strabismic amblyope (for whom $S > 1.87A$). However, it is a problem for normal foveal vision, for which one finds the informative $S = 1.4A$ when spacing is tight (1.1×)—strongly suggesting overlap masking—and the much less informative $S = 2A$ when spacing is a loose 2×—which is hitting the acuity limit of the target, unaffected by the relatively distant flankers. All commercially available letter-flanked acuity tests have a spacing factor of 1.5× or 2×. The reader, presumed normal, may test this on her own eye, foveally—as a normal—and peripherally—modeling a strabismic amblyope. Each column has a different spacing factor: 1.1× on the left and 2× on the right. Each row has a different spacing. The columns are aligned so that both targets in each row have the same center-to-center spacing of target to flanker. The whole triplet shrinks by a factor of $\sqrt{2}$ from row to row.

Normal fovea. Test yourself. Look directly at each target, the middle letter of each triplet.* Notice that, viewing directly, you read one more row (smaller spacing) with the tighter spacing (left column). On the left you are limited by overlap masking by the flankers (threshold spacing $1.4A$). On the right, the flankers have no effect and you are limited by acuity (threshold spacing $2A$, since the spacing factor is 2×).

Periphery as a model for strabismic amblyopia. Viewing from any distance, fixate the central + in the top row. While still fixating, try to identify the target to the left and the target to the right. If you succeed, then proceed to the next row down, until you fail. Notice that, as a strabismic amblyope, limited by crowding, you have the same spacing threshold with both charts (left and right). Thus, tightening the spacing (from 2× to 1.1×) reduces threshold spacing in the normal, but does not affect threshold spacing of the strabismic amblyope, which increases the separation of the two populations, which increases the power of the test. Note that, for any given test, spacing and size are related by the test's spacing factor, so it is a matter of taste whether to report threshold spacing or flanked acuity. The power of the test is the same.

* If you are concerned that you might be limited by the resolution of the printer (or display), you may wish to increase your viewing distance to several meters. However, in fact, the point demonstrated here is independent of the source of the acuity-limiting blur. No matter whether the limiting blur arises in the chart, the retinal image, or the neural representation, the more-tightly spaced chart is better at detecting strabismic amblyopia.

D. G. Pelli, S. Song, D. M. Levi (2011) Improving the screening of children for amblyopia. Vision Sciences Society, Naples, Florida, May 6-11, 2011. http://psych.nyu.edu/pelli/posters.html