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Self-reported Magic Eye™ stereogram skill predicts stereoacuity

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Abstract

Autostereograms—commonly known as Magic Eye™ stereograms (MESs)—are two-dimensional images that support stereoscopic depth perception given an appropriate crossing or uncrossing of the eyes. We find that self-reported MES skill is highly predictive of stereoacuity as measured by a standard clinical test ($r_{142} = 0.45$, $p < 0.0001$; TNO test). Indeed, in our sample of 194 individuals, those who report poor MES skill have a five-fold increased risk of stereo impairment. Those who report poor MES skill also require on average five times greater binocular disparity to perceive stereoscopic depth than those who report good MES skill. Reported MES skill thus carries significant information about stereoacuity.

With surprising regularity, the first question either of the authors is asked when someone learns they study stereoscopic vision is: “I am good/bad at Magic Eye displays ... what does that imply about my vision?”. The ubiquitousness of this question is a testament to the joy of stereoscopic experience, the ingenuity of both Bela Julesz who invented random-dot stereograms and Christopher Tyler who invented random-dot autostereograms (Julesz 1960; Tyler 1983; Tyler and Clarke 1990), and the innovative spirit of the founders of Magic Eye™, Inc., who transformed the autostereogram into a popular art form.

My (JBW's) stock response to this question—especially when someone reports ‘bad’ Magic Eye stereogram (MES) performance—has been to assure the asker that MES skill has been tied neither to stereoscopic ability nor to any other aspect of binocular function, intelligence, or physical coordination. Moreover, since MESs require an unnatural dissociation of the normally automatic coordination between eye focusing (accommodation) and eye alignment (vergence), it is easy to imagine individuals with finely tuned binocular systems and excellent stereopsis having difficulty with MESs. In fact, one might expect that those best able to view MESs would do so by virtue of rather sloppy binocular systems exhibiting subpar stereopsis.

We present evidence against such expectations. Not only does reported MES skill positively predict performance on a standard clinical measure of stereoacuity (TNO test, 13th edition, Lameris Ootech BV, The Netherlands); in our study it does so to a greater degree than all ten other questions previously shown to predict stereoacuity combined (Coren and Hakstian 1996).

The scatterplot in figure 1a shows reported MES skill plotted against stereoacuity, with dot areas proportional to number of persons at each point (total number = 194). Those with higher stereoacuity clearly report being more skilled at MES ($r_{142} = 0.45$, $p < 0.0001$; ordinal scales assumed and ‘don't know’ answers excluded; note that poorer stereoacuities correspond to higher numbers).

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The same data are presented in a different form in the bar graph in figure 1b. Cumulative percentages of those persons having stereoacuities equal to or poorer than those indicated on the x -axis are shown, broken down by reported MES skill. Poor stereoacuity is substantially more prevalent among those reporting poor than among those reporting good MES skill, with those reporting average skill in between. For example, a full 50% of those reporting poor skill, but only 6.5% reporting good and 16% reporting average skill, have stereoacuity at or poorer than 240 s arc.

As implied by figure 1, those reporting good, average, and poor MES skill have quite different stereoacuities, averaging 35, 66, and 173 s arc, respectively (assuming a linear log-scale bounded at 10.6 and 679 s arc; $p < 0.0001$ for Kruskal – Wallis test, which is a one-way ANOVA performed on ranked data; and $p < 0.02$ for all three Turkey – Kramer corrected paired-comparisons). Those reporting poor skill thus required on average almost five times greater binocular disparity than those reporting good skill to detect otherwise equivalent stereoscopic displays.

Could reported MES skill be used as a simple screen for stereo impairment? It is important that a screening question be answerable by most individuals. We found that almost three-quarters of individuals are willing to report their MES skill ($50/194 = 74.2\%$) when allowed the option “don't know”. Those who answered “don't know” did not differ from the rest in either age or stereoacuity ($ps > 0.50$). We examined the ability of reported MES skill to pinpoint stereo-impaired individuals, identified as those with zero items correct on the TNO test (stereoacuity > 480 s arc in figure 1). Indeed, as can be seen in table 1, those reporting poor MES skill had a five-fold greater risk of stereo impairment than those reporting good or average skill 41.7% versus 8.3%, respectively relative risk = 5.0, 95% confidence interval 2.4–10.4). Furthermore, more than four-fifths of those with stereo vision report being average or good at MES (82.5% specificity), while nearly two-thirds of those lacking stereo vision report being poor at MES (62.5% sensitivity). This simple question about MES skill therefore demonstrates potential as a clinical screening tool for stereo impairment.

Coren and Hakstian (1996) developed and validated the 10-question Stereopsis Screening Inventory (SSI) to detect reduced stereoacuity, choosing the 10 items best predictive of stereoacuity from an initial pool of 161. We compared the predictive power of the SSI to that of reported MES skill. Recall that in the three-quarters of individuals who answered other than “don't know”, reported MES skill correlates $r_{142} = 0.45$ with TNO-measured stereoacuity. In comparison, correlations between SSI and stereoacuity vary from 0.09 to 0.32 for individual SSI items, and are $r_{192} = 0.34$ for SSI gross score (gross score computed as suggested in Coren and Hakstian 1996). Reported MES skill therefore accounts for almost twice as much stereoacuity variance as the SSI (20.5% versus 11.7%) in those willing to report their MES skill.

Age has previously been shown to predict 30%–40% of variance in stereoacuity on standard tests, with stereoacuity declining consistently from ages 17 to 83 years (Garnham and Sloper 2006). We found a similar relationship between age and stereoacuity in our sample ($r_{192} = -0.55$, 30.7% variance explained). In a regression analysis, reported MES skill, SSI, and age each predicted unique variance in stereoacuity ($ps < 0.025$); however, the unique contribution of SSI was small relative to that of reported MES skill and age (2.2%, 11.0%, and 28.5%, respectively). The three regressed measures accounted together for 51.8% of stereoacuity variance, whereas reported MES skill and age alone accounted for 50.0% of variance. 48.0% of stereoacuity variance is accounted for by the simple summed z -scores of reported MES skill and age (reported MES skill mean = 1.07, SD = 0.75, coded as 0,1,2 = poor, average, good; age mean = 35.06 years, SD = 13.75 years).

Given that reported MES skill and age each account for substantial unique variation in stereoacuity, it is tempting to suppose that they tap into distinct stereoacuity-relevant mechanisms. We hypothesize that MES skill reflects the integrity of the early cortical neurons used to measure small binocular disparities. For MESs, this system would support locking in of eye alignment via sensory–motor fusion once the eyes approach desired alignment. For tests of stereoacuity, this system would enable the detection of fine stereoscopic depth differences. It has been shown that much of the reduction in stereoacuity with age can be accounted for by parallel reductions in contrast sensitivity (Greene and Madden 1987). We therefore follow those researchers in hypothesizing that the poorer stereoacuity we observe with age reflects reductions in contrast sensitivity. The SSI contains seven items related to (monocular) visual acuity and one each probing anisometropia (difference in acuity between the eyes), eye fatigue, and suppression. We therefore hypothesize that the SSI mainly reflects the integrity of mechanisms related to visual acuity. The degree of redundancy between age and SSI in predicting stereoacuity could result from the reduction in contrast sensitivity caused by refractive error.

We have shown that reported MES skill predicts stereoacuity to a substantial degree (20.5% of variance explained), and that combining this question with age provides a quick measure that predicts nearly 50% of variance in stereoacuity. Reported MES skill may prove useful in certain clinical or epidemiological situations for its ability to predict stereoacuity without the use of technical equipment, for example by phone, e-mail, or web-based survey.

Study details

Twin participants ($n = 194$, ages 18–60 years) were recruited at the annual Twins Days Festival in Twinsburg, OH. Twins show a higher prevalence of poor stereopsis than the general population (Harland and Coren 1996). Self-reported MES skill was obtained with the written question “My skill at ‘Magic Eye’ displays (aka stereograms) is ... Good/Average/Poor/Don't know”. While this question could logically have been answered on the basis of stereograms other than autostereograms, our informal impression was that this was rare. Stereoacuity was subsequently assessed with the TNO test for stereoscopic vision, which uses red–green anaglyph glasses and random-dot stereograms to present twelve four-alternative forced-choice stereoscopic displays, two each at six binocular disparities (480, 240, 120, 60, 30, and 15 s arc). All conclusions remain the same when analyses are performed on ranked data.

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Figure 1. Reported Magic Eye™ stereogram (MES) skill and stereoacuity. (a) Reported MES skill plotted against stereoacuity, with dot areas proportional to number of persons at each point (total number = 194). Least-squares line is shown, excluding “don't know” answers and treating data as ordinal. Better stereoacuties correspond to smaller x -axis numbers. (b) Cumulative percentages of those persons having stereoacuties equal to or poorer than those indicated on the x -axis, broken down by reported MES skill.

Table 1

Reported Magic Eye™ stereogram (MES) skill versus passing/failing TNO stereotest.

MES skill	TNO-pass	TNO-fail
Good/average	99	9
Poor	21	15