STEREOACUITY AT DISTANCE AND NEAR

Bonita B.P.Wong[2], MSc,
Russell L.Woods[1], MCOptom, PhD, and
Eli Peli[1,2], OD, MSc
[1]*The Schepens Eye Research Institute and Harvard Medical School, Boston, MA*
[2]*New England College of Optometry, Boston, MA*

ABSTRACT

Purpose. Is there a difference in stereoacuity between distance and near? Previous studies produced conflicting results. We compared distance and near stereoacuities using identical presentation formats at the two distances. **Methods.** Stereoacuity was determined with the B-VAT Random Dot E (BVRDE) and Contour Circles (BVC) stereograms presented at 518 cm (distance-habitual) and at 40 cm (near-habitual) while subjects wore their habitual correction. To equate the accommodative and convergence demands at distance and near, testing was repeated at 40 cm with the addition of +2.50 DS lenses and base-in prisms (near-compensated) that aligned the eyes to the same position as for distance-habitual viewing. **Results.** The two stereotests showed similar findings. On average, stereoacuity was equal for distance-habitual and near-habitual viewing of the BVRDE and BVC stereotests. Near-compensated stereoacuity was worse than near-habitual and distance-habitual for both stereotests. **Conclusions.** Stereoacuity was the same at distance and near with normal viewing. The conflict between subject knowledge of target proximity and the optically-induced relaxation of accommodation and convergence might have caused poor near-compensated stereoacuity.

BACKGROUND

§ Stereoacuity depends on the design of the stereotest. In addition to binocular cues, some tests contain monocular cues (eg. linear perspective, shadows, parallax, and texture).
§ The relationship between stereoacuity and observation distance is not well-understood. Comparison of distance and near stereoacuities is only meaningful if the presentation formats are identical under the two conditions (Table 1).
§ Our goal is to determine if observation distance affects depth perception in stereograms.

Table 1 - Review of distance and near stereoacuities from previous studies.

	Ogle (1958)	Amigo (1963)	Brown et al (1965)	Lit & Finn (1976)	Zanoni et al (1991)	Yildirim et al (1998)	Kaye et al (1999)
Same stereoacuity at distance than near	√		√	√			√
Higher stereoacuity at distance than near		√			√		
Higher stereoacuity at near than distance					√	√	
Elimination of empirical factors to depth	√		√	√			
Same stereotest given at different distances	√	√	√	√			√
Type of stereotest(s)	HA	HA	HA	A	*Distance*: BVRDE,BVC *Near*: Titmus, TNO, Randot Circles	BVRDE, BVC Titmus, Randot Circles	

HA = haploscopic apparatus; A = alignment test; BVRDE = B-VAT random dot E; BVC = B-VAT Contour Circles.

METHODS

Apparatus

§ A computerized display system, a modified Mentor B-VAT II SG, allowed four alternative forced choice testing.
§ The targets shown on the standard Mentor monitor (Figure 1) and small monitor (Figure 2) were calibrated to subtend corresponding visual angles.

Distance Testing at 518 cm

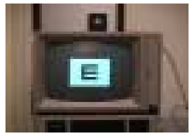

Figure 1. Standard Mentor Monitor (19.3 x 25.0 cm) (Mentor O & O, Norwell, MA)

Near Testing at 40 cm

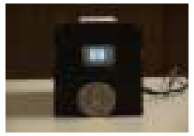

Figure 2. Small Monitor (1.4 x 2.0 cm) (Model 1M180P45, Thomas Electronics, NJ)

§ Identical presentation formats were used for distance and near testing.
§ Range of disparities in stereotests: 141 to 9 seconds of arc.
§ Four-alternative, forced-choice testing using a 1 up/1 down procedure.
§ Stereoacuity = 62.5% correct (Probit analysis). The Wilcoxon Signed Rank Test was used to determine statistical significance.

Random Dot Stereotest (BVRDE)

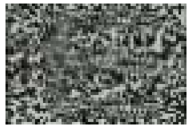

Figure 3. A 6/56 (20/188) Tumbling E in a random dot pattern with 71 second dot sizes. The task was to identify the orientation of the letter as up, down, right, or left.

Contour Circles Stereotest (BVC)

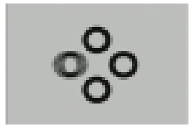

Figure 4. Four black 6/14 (20/47) circles on a white background. The task was to identify the circle that appears to be in front of the others (up, down, left or right).

Experimental Design

Stereotests were performed under 3 conditions →
- Distance-habitual at 518 cm (17 ft) (with habitual Rx)
- Near-habitual at 40 cm (16 in) (with habitual Rx)
- Near-compensated at 40 cm (16 in) (with +2.50 D lenses and BI prisms)

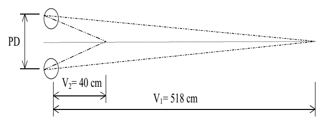

Figure 5. For the near-prism condition, the power of plus lenses to equate accommodation (Diopters = $1/V_2$) and base-in (BI) prisms to equate convergence demand (Prism = 100 tan $[2(\tan^{-1}(PD/2V_2) - \tan^{-1}(PD/2V_1))]$) were determined for each subject based on his/her interpupillary distance (PD).

§ Twelve subjects were selected based on age, refractive status, and oculomotor function.

Table 2 — Subjects

AGE	18 to 35 years old
Refractive error	≤ -3.00 DS and -1.50 DC
VA	*Distance:* 20/20 or better *Near:* 20/20 or better
Habitual Rx	± 0.50 DS of best correction
Anisometropia	< 0.75 DS
Eye suppression	No eye suppression 2 lines above best VA
LATERAL PHORIA*	*Distance:* ≤ 3.0 Δ of ESO or 5.0 Δ EXO *Near:* ≤ 7.0 Δ ESO or 13.0 Δ EXO
VERTICAL PHORIA*	*Distance & Near*: ≤ 1.0 Δ
Horizontal fixation disparity	*Distance*:* ≤ 2 minarc *Near:* ≤ 10 minarc
Vertical fixation disparity*	*Distance:* ≤ 1 minarc *Near:* ≤ 1 minarc

* Values are considered to be in the normal range found in the general population (Peli, 1998).

Results

§ Measured stereoacuity was better with BVC than BVRDE.
§ Both BVRDE and BVC tests showed similar trends in distance and near stereoacuities.

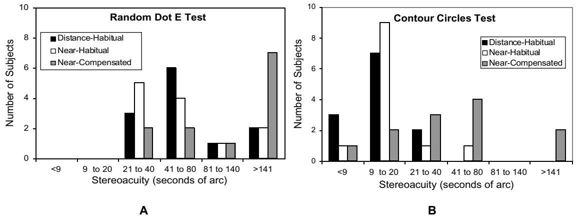

Figure 6. Distribution of stereoacuity for BVRDE (A) and BVC (B) under the three testing conditions of distance-habitual, near-habitual, and near-compensated (n=12).

Was there a difference between distance and near stereoacuities? **NO.**
Distance-habitual and near-habitual stereoacuities were equal (BVRDE, p=0.43 ; BVC, p= 0.79) (Figure 6).

Did relaxation of accommodation and convergence affect normal stereoacuity? **YES.**
Near-compensated stereoacuity was significantly worse than near-habitual (BVRDE, p=0.005; BVC, p=0.004) and distance-habitual stereoacuity (BVRDE, p=0.05; BVC, p=0.003) (Figure 6).

Did prisms induce distortions that reduced near-compensated stereoacuity? **NO.**
Near stereoacuity with yoked prisms was the same as without prism (near-habitual).

Was poor near stereoacuity associated with horizontal fixation disparity? **NO.**
There was no obvious relationship between stereoacuity and horizontal fixation disparity. However, Subjects RC and SU both had worse near stereoacuity than distance and showed a Type III fixation disparity curve (Figure 7).

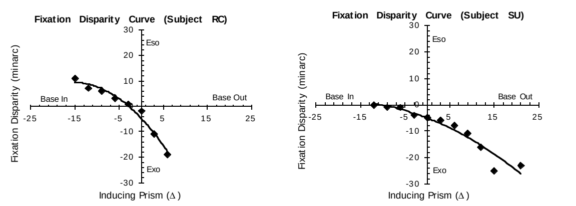

Figure 7. Horizontal fixation disparity curves for two subjects who demonstrated worse stereoacuity at near than distance for both BVRDE and BVC stereotests.

DISCUSSION

§ Distance and near stereoacuities were equal under normal viewing conditions. Near-compensated stereoacuity was worse than both near-habitual and distance-habitual.
§ The conflict between subject knowledge of target proximity and the optically-induced relaxation of accommodation and convergence might have caused poor near-compensated stereoacuity.
§ When using head-mounted displays (HMDs), there is a potential for a similar conflict between target proximity and accommodative convergence.

Acknowledgment
Supported in part by NASA grant NLC2-1039 and T. Becker Fund.

REFERENCES

Amigo, G. Variation of stereoscopic acuity with observation distance. *J. Opt. Soc. Am.* 53(5): 630-635, 1963.
Brown, J.P., K.N. Ogle, and L. Reiher. Stereoscopic acuity and observation distance. *Invest. Ophthalmol.* 4(5): 894-900, 1965.
Kaye, S.B., A. Siddiqui, and A. Ward. Monocular and binocular depth discrimination thresholds. *Opt. Vision. Sci.* 76(11): 770-782, 1999.
Ogle, K.N. Note on stereoscopic acuity and viewing distance. *J. Opt. Soc. Am.* 48(11): 794-798, 1958.
Peli, E. The visual effects of head-mounted display (HMD) are not distinguishable from those of desk-top computer display. *Vision Res.* 38(13): 2053-2066, 1998.
Yildirim, C., H.I. Altinsov, and E. Yakut. Distance stereoacuity norms for the Mentor B-VAT II-SG video acuity tester in young children and young adults. *J. Am. Assoc. Pediatric Ophthalmol. & Strabismus.* 2(1): 255-260, 1998.
Zanoni, D. and A.L. Rosenbaum. A new method for evaluating distance stereo acuity. *J. Pediatr. Ophthalmol. & Strabismus.* 28(5): 255-260, 1991.