Stereoscopic acuity, observation distance and fixation disparity: a commentary on ‘Stereoscopic acuity and observation distance’ by Bradshaw and Glennerster (2006)

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In their paper, “Stereoscopic acuity and observation distance”, Bradshaw and Glennerster (2006) report that angular stereoscopic thresholds are significantly higher for targets viewed at a distance of 28.5 cm than at distances of 57 cm or farther. The authors propose that stereoscopic thresholds may be limited at near viewing distances by a minimum physical depth, based on a high-level combination of multiple depth cues, rather than by the angular disparity between the targets. Although the authors acknowledge (p. 33) that a “low level” factor such as eye movement jitter might account instead for the increase in stereoscopic thresholds at near distances, one potentially important explanatory factor was relatively unexplored. In particular, stereoscopic thresholds are elevated in the presence of vergence constant error (known also as fixation disparity, FD) and vergence variability (Cole and Boisvert, 1974; Saladin, 1995, 2005; Ukwade et al., 2003a, 2003b) which, together, produce a deviation of the mean binocular eye position from the fixation plane. Previously, we defined the vergence mean deviation as the time-averaged, unsigned pedestal disparity that results from the combination of vergence constant error and vergence variability (Ukwade et al., 2003a, 2003b). Several previous studies showed that pedestal disparities larger than approximately

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1 arc min lead to a systematic increase in the angular stereoscopic threshold (e.g. Siderov et al., 1999; Ukwade et al., 2003b; Westheimer, 1979).

The vergence demand increases with a decrease in the viewing distance. The greater the vergence demand, the greater the resulting vergence constant error and vergence variability (Jaschinski, 1997; Ogle et al., 1967; Ukwade et al., 2003a) and, consequently, the greater the expected increase in the stereoscopic threshold. An increase in the displacement of the stereoscopic target from the fixation plane as a result of vergence errors could therefore contribute substantially to the higher stereoscopic thresholds that Bradshaw and Glennerster (2006) found when the physical distance (Experiments 1 and 3) or the simulated distance (Experiment 2) of the test stimulus was nearer than 57 cm. We consider the quantitative relationships between viewing distance, vergence error, and stereoscopic acuity in the paragraphs below.

If we assume that the subjects in the study by Bradshaw and Glennerster (2006) had an average inter-pupillary distance of 6 cm, then the convergence demands for stereoscopic targets presented at 57 and 28.5 cm were approximately 10.5 and 21 prism diopters, respectively. From Fig. 11a in Jaschinski (1997), we see that this change in the vergence demand should, on average, produce a change from approximately 0.5 arc min of eso FD to approximately 2.5 arc min of exo FD. (An eso fixation disparity signifies that the visual axes cross in front of the target of regard and an exo fixation disparity indicates that the visual axes cross at a distance that is farther than the target.) Concurrently, Jaschinski’s data indicate that the variability of vergence eye position increases from approximately 2 arc min at 57 cm to 4 arc min at 28.5 cm (see Ukwade and Bedell, 1992 for qualitatively similar results). Based on these estimates of the FD and vergence variability, we calculated that decreasing the viewing distance from 57 to 28.5 cm should increase the vergence mean deviation from approximately 2 to 4 arc min (Ukwade et al., 2003b). Figure 6 of Ukwade et al. (2003b) shows that an increase in the vergence mean deviation from 2 to 4 min arc would be expected to elevate the stereoscopic threshold approximately 1.5 fold, which is consistent with the average ratios of 1.72 and 1.40 reported by Bradshaw and Glennerster for the stereoscopic thresholds at 28.5 vs. 57 cm in their Experiments 1 and 3.

Jaschinski (1997) also simulated changes in the viewing distance using prisms. For an increase in convergence of 10.5 prism diopters, Jaschinski’s data (1997; Fig. 11a) indicate a change in the average FD from approximately 0.25 arc min eso to nearly 4 arc min exo, and a change in the associated vergence variability from approximately 2.5 arc min to almost 4 arc min. The calculated vergence mean deviation increases from approximately 2 to 4 arc min, which again predicts that the stereoscopic threshold should increase by a factor of 1.5 (Ukwade et al., 2003b, Fig. 6). In Bradshaw and Glennerster’s (2006) second experiment, viewing at a near distance of 28.5 cm was simulated by rotation of the mirrors in their haploscope and the ratio of the stereoscopic thresholds at simulated distances of 28.5 vs. 57 cm was 1.27.