48.2: Slant Perception as a Function of Size-Disparity and Image-Motion

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Abstract

Slant perception was studied under viewing conditions that combined horizontal-size, vertical-size, and overall-size binocular disparities with motion and static image conditions. For both motion and static conditions, results indicated similar effects of size disparity on perceived slants of disparity and zero-disparity stimuli. Implications for binocular head mounted display (HMD) systems are considered.

Introduction

Magnification of an image to one eye only produces size-disparities (SD) between the two eyes. Ogle (1938) reported that an image with *horizontal* SD is perceived as slanted farther away on the magnified side. He also showed that an image with *vertical* SD is perceived as slanted nearer on the magnified side. He termed this latter phenomenon an induced effect.

Kaneko and Howard (1996) showed that when a central horizontal- or overall- (i.e., equal horizontal and vertical) SD field is viewed with a surrounding zero-disparity-stimulus (ZDS), the perceived slant of the central display is enhanced. In contrast, for vertical-SD, the presence of a surrounding ZDS reduced the perceived slant. They conjectured that horizontal-SD may be processed locally, but vertical-SD are integrated globally. This hypothesis was elaborated by Pierce and Howard (1997) who concluded that the perceived slant of an SD surface shown with superimposed ZDS is assessed at each location in terms of the difference between local horizontal-SD and vertical-SD averaged over a large region.

Hadani and Vardi (1987) and Vardi and Hadani (1989) reported that under certain conditions motion can interfer with perception of depth in a vertical squarewave random dot stereogram. The present experiment investigates the effects of motion on slant perception under horizontal-, vertical- and overall-SD stimulus conditions (see Figure 1). In particular, we investigate how previously reported interactions between SD stimulus and ZDS are affected by motion. Implications for binocular head mounted display (HMD) systems are considered.

Methods

Participants. Three males with normal non-corrected vision were paid to participate in this study.

Stimuli & Apparatus. Images were displayed on two computer monitors mounted in a mirror haploscope. Each stereo-pair was a computer-generated pattern of randomly distributed elements consisting of open squares, crosses and lines, drawn in red to reduce phosphor smear, and subtending 53°H x 43°V. Subjects reported *perceived slant* by adjusting an unseen tactile disk.

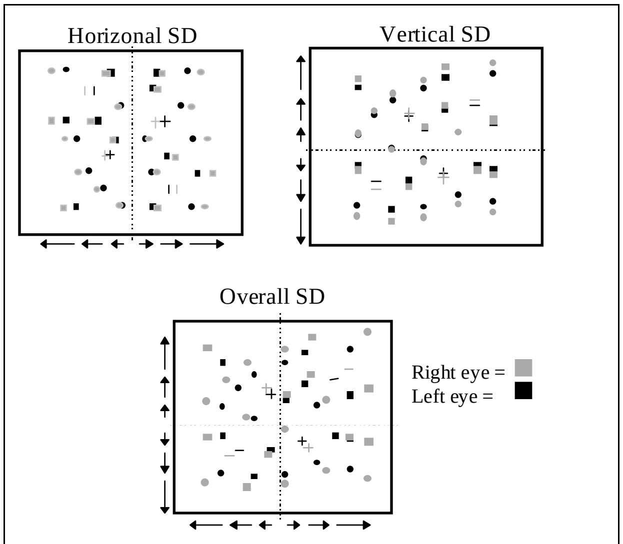

Figure 1. Schematic of Disparity Conditions
In each figure the black dots represent the image presented to the left eye, and the gray dots represent the linearly transformed image to the right eye.

Three types of SDs were presented: horizontal, vertical and overall. Four SD-magnitudes were used: 2%, 4%, 6% and 8% with a control level of 0%. The SD stimulus was presented (a) in isolation, (b) with a central 15° horizontal line-ZDS, or (c) with a pattern-ZDS containing the same texture elements, but interleaved between those in the SD pattern. Three motion settings were used: no-motion, and downward- or across-motion at 4° per second velocity. The SD stimuli and the pattern-ZDS both moved together; the line-ZDS did not move.

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Procedure. A block of trials consisted of {[4 disparity levels (2%, 4%, 6%, 8%)] X [2 disparity directions (positive, negative)] X [3 superimposed ZDS (none, line, pattern)] + [1 control (zero-disparity trial)]} X [3 disparity types (horizontal size, vertical size, overall size)] X [3 motion types (no motion, vertical, and horizontal)] for a total of 225 test trials. Each was randomly presented in a Latin square design.

Participants were given verbal instructions to observe the central area of the display. Observers matched the response disk to the perceived slant of the SD pattern first, then to the perceived slant of ZDS.

Results

Perceived slant for horizontal size disparity

Figure 2 shows the adjusted slant means for the horizontal-size disparity conditions. Each panel's abscissa indicates the disparity magnitude in the disparity pattern. Positive values along the abscissa indicate that the right-eye image was larger. Negative values indicate that the left-eye image was larger. Mean slants are plotted along the ordinate. Values above and below the zero line indicate that the fused image was perceived as right-side away and left-side away respectively.

Mean slants of disparity stimuli were submitted to a four-way ANOVA with motion type, superimposed stimuli, disparity direction and disparity[1] magnitude serving as the within-participant variables. Although control trials are shown in Figure 2, they were excluded from the analysis. The participant-by-factor interaction served as the error term in computing the F-ratio.

The analysis revealed a significant interaction between superimposed stimuli and disparity magnitude, $\underline{F}(6,12) = 3.94$, $\underline{p} < .05$. Additionally, the main effect for disparity magnitude was significant, $\underline{F}(3,6) = 17.94$, $\underline{p} < .05$. This main effect is clearly shown in Figures 2a, 2b and 2d; the slant means of the disparity pattern approached theoretical values and increased as the disparity magnitude increased for all three motion conditions. Additionally, the interaction between superimposed stimuli and disparity magnitude can be explained by a larger effect of disparity magnitude when a pattern-ZDS was presented. This interaction is referred to as *depth enhancement* (Pierce & Howard, 1997).

A pattern of moving elements with horizontal-size disparities produced approximately the same perceived slant as a static pattern of the same disparities. The main effect of disparity magnitude was shown to be consistent across the three motion conditions. None of the remaining main effects or interactions were significant.

A four-way ANOVA was computed for ZDS slants. In general, the perceived slant of the ZDS was approximately 10° for all conditions. Figures 2c and 2e show that the line-ZDS and the pattern-ZDS produced negative slants when the disparity pattern is larger in the right eye, and positive slants when the disparity pattern is larger in the left eye. None of the remaining main effects or interactions were significant.

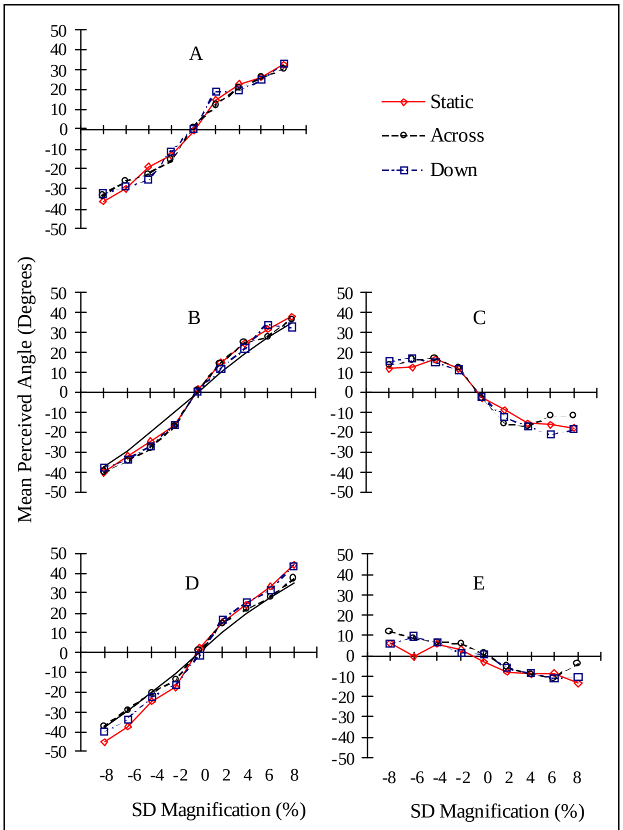

Figure 2. Horizontal Size Disparity
Perceived slant of: (a) SD stimulus by motion type, (b) SD stimulus with a superimposed line-ZDS by motion type, (c) line-ZDS with SD stimulus by motion type, (d) SD stimulus with a superimposed pattern-ZDS by motion type, and (e) pattern-ZDS with SD stimulus by motion type. Mean results for three participants.

Perceived slant for vertical size disparity

Figure 3 shows the response data for the vertical-size disparity conditions. A four-way ANOVA on disparity slant means revealed a significant interaction between superimposed stimuli and disparity magnitude, $\underline{F}(6,12) = 5.65$, $\underline{p} < .05$. Additionally, the main effects for superimposed stimuli and disparity magnitude were significant, $\underline{F}(2,4) = 10.19$, $\underline{p} < .05$ and $\underline{F}(3,6) = 4.22$, $\underline{p} = .063$ respectively.

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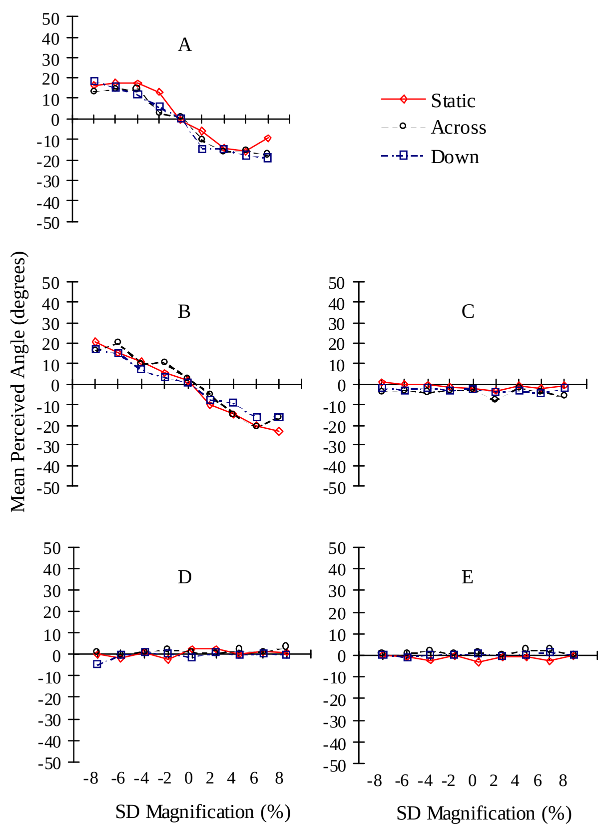

Figure 3. Vertical Size Disparity
Perceived slant of: (a) SD stimulus by motion type, (b) SD stimulus with a superimposed line-ZDS by motion type, (c) line-ZDS with SD stimulus by motion type, (d) SD stimulus with a superimposed pattern-ZDS by motion type, and (e) pattern-ZDS with SD stimulus by motion type. Mean results for three participants.

The effect of disparity magnitude, shown in Figures 3a and 3b, indicates that slant means increased as the disparity magnitude increased when the SD was presented alone or with a line-ZDS. This differs from the effect of disparity magnitude shown in the horizontal-size conditions. Figures 3a and 3b show that when the right-eye image was larger, a negative slant was perceived; by contrast, when the left-eye image was larger, a positive slant was perceived. This is characteristic of Ogle's (1938) *induced effect*. This induced effect was suppressed when pattern-ZDS was presented (see Figure 3d). For this latter condition, the angle means of the vertical-disparity pattern remained at 0° as disparity magnitude increased.

In the vertical-size disparity condition, motion was found to interact with superimposed stimuli, $F(4,8) = 7.21$, $p < .05$. Figure 3b shows that with a line-ZDS, larger slant responses were made to a static disparity pattern than to a downward moving disparity pattern. Although this interaction is statistically significant, the differences in angle means are small. None of the remaining main effects or interactions were significant.

Slant means for the superimposed ZDS were analyzed in a four-way ANOVA. The analysis showed no significant interactions or main effects. The slant means for the line-ZDS and the pattern-ZDS, shown in Figures 3c and 3e respectively, were not statistically different from 0°.

Perceived slant for overall size disparity

Figure 4 shows the adjusted slant means for the overall-size disparity conditions. A four-way ANOVA on disparity slant means revealed a significant interaction between disparity magnitude and superimposed stimuli, $F(6,12) = 6.01$, $p < .05$. Additionally, the analysis showed significant main effects for disparity magnitude and superimposed stimuli, $F(3,6) = 58.68$, $p < .05$ and $F(2,4) = 10.27$, $p < .05$. In general, the angle means of the disparity pattern increased as the disparity magnitude increased. The slant means followed the predicted slant of the horizontal-size component of disparity. In other words, when the right-eye image was larger (i.e., positive size disparity), positive slant was perceived whereas, negative slant was perceived when the left-eye image was larger. In addition, the angle means for the disparity pattern was largest when a pattern-ZDS was superimposed. Thus, the effect of the disparity magnitude was enhanced by the presence of a ZDS. This depth enhancement effect was previously reported by Pierce and Howard (1997).

A pattern of moving elements with overall-size disparities produced the same perceived inclination as a pattern of static elements with the same disparities. Therefore, the depth enhancement effect was shown to be robust in regards to the different motion conditions. None of the other main effects or interactions were significant.

A four-way ANOVA on the slant means of superimposed ZDS showed an interaction between the disparity magnitude and superimposed stimuli, $F(3,6) = 14.99$, $p < .05$. Additionally, the analysis revealed significant main effects for disparity magnitude and superimposed stimuli, $F(3,6) = 6.87$, $p < .05$ and $F(1,2) = 15.95$, $p = .057$. Figure 4c shows that the angle means of the line-ZDS increased as the disparity magnitude increased. The line-ZDS produced negative slant perceptions for larger right-eye images and positive slants for larger left-eye images. This effect of a disparity image on the perceived slant of a superimposed ZDS is referred to as a *depth contrast effect* (Pierce & Howard, 1997). However, Figure 4e shows that the mean perceived angle of the pattern-ZDS remained near 0° as the disparity magnitude in the disparity pattern

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increased. None of the remaining main effects or interactions were significant.

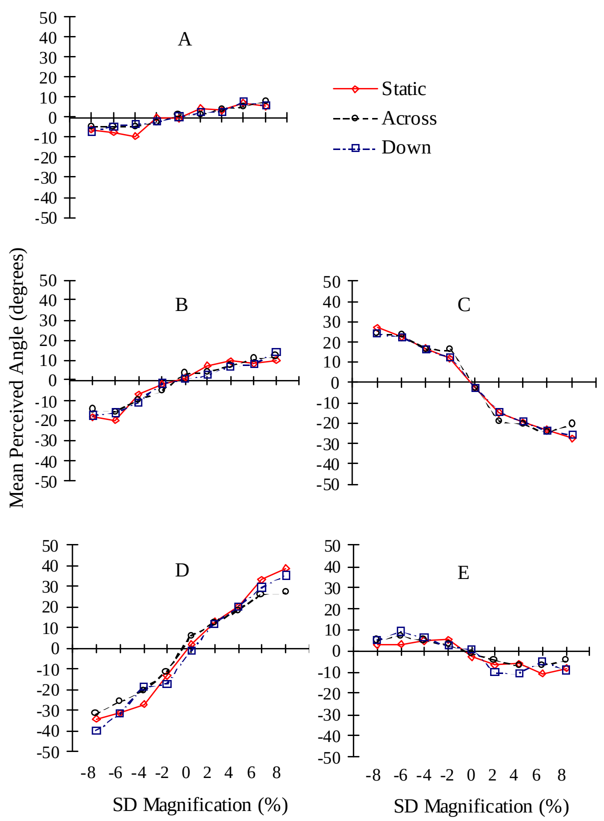

Figure 4. Overall Size Disparity
Perceived slant of: (a) SD stimulus by motion type, (b) SD stimulus with a superimposed line-ZDS by motion type, (c) line-ZDS with SD stimulus by motion type, (d) SD stimulus with a superimposed pattern-ZDS by motion type, and (e) pattern-ZDS with SD stimulus by motion type. Mean results for three participants.

Discussion

We have studied the effects of size disparity on stereoscopic slant perception in order to determine whether previously reported results could be extended to viewing conditions approximating those of a real-world application such as flight simulation. Unlike previous efforts which used static images only, we included motion conditions which have shown in prior studies to impair stereoscopic depth perception. Our results indicate that size disparity affects slant perception of disparity and ZDS similarly in both static and moving displays. The use of HMD systems in pilot training and in flight has heightened the need to further understand the impact of intended disparities (e.g., stereographic 3D effects) and unintended disparities (e.g., misalignment of optical elements, distortion of the display device) in such systems.

It is important to consider the effects of size disparities both in the imagery presented in HMDs as well as imagery seen through the display. However, our results suggest that designers of HMDs need not be concerned with potentially complex interactions between the perceived slant of imagery containing size disparities and the changing motion of that imagery.

[1] The dependent variable in these analyses was a measure of slant angle adjusted for the direction of the size disparity. The absolute value of disparity size was used in these analyses. Disparity direction (positive vs. negative) was treated as a separate factor.

References

Hadani, I. & Vardi, N. (1987). Stereopsis impairment in apparently moving random dot patterns. *Perception and Psychophysics*, 42, 158-165.

Kaneko, H. & Howard, I. P. (1996). Relative size disparities and the perception of surface slant. *Vision Research*, 36(13), 1919-1930.

Ogle, K. N. (1938). Induced size effect I: A new phenomenon in binocular space-perception associated with the relative sizes of the images of the two eyes. *AMA Arch. of Ophthalmology*, 20, 604-623.

Pierce, B. & Howard, I. P. (1997). Type of size disparity and the perception of surface slant. *Perception*, 26(12), 1503-1518.

Vardi, N., & Hadani, I. (1989). Stereo impairment during smooth pursuit eye tracking. *Brain Behavior Evolution*, 33, 99-103.

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