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Better performance with two eyes than with one in stereo-blind subjects' judgments of motion in depth

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ABSTRACT

Visual tasks that involve judging distance or depth obviously benefit from considering retinal disparities and ocular convergence, but various simple visual thresholds are also lower when looking with two eyes. This is also true for stereo-blind subjects. One benefit of using two eyes is that looking with two eyes provides two chances of making the critical distinction. From the literature it would appear that using two eyes might only be an advantage for low contrast stimuli and simple tasks. We here demonstrate that stereo-blind subjects can benefit from using two eyes when making judgments about clearly visible complex stimuli. The task was to judge the direction of rotation of a simulated transparent cylinder. Stereo-blind subjects performed better when looking with two eyes than when looking with their preferred eye. It did not matter for their performance whether the images in their two eyes were correlated or not. Various control experiments ascertained that they judged the direction of rotation from the images in each eye separately and then combined these judgments, rather than relying on differences between the images in the two eyes. These findings raise doubts about the validity of using monocular vision as a control for quantitative studies of the use of binocular disparity.

1. Introduction

People perform various simple visual tasks that do not require specifically binocular information better when they look with two eyes than when they look with only one eye (reviewed in Blake & Fox (1973) and Blake, Sloane, and Fox (1981)). The extent to which binocular performance is better with two eyes is consistent with combining the independent probabilities of detecting the presence of the target in the two eyes (*probability summation*; Andrews, 1967; Blake & Fox, 1973). This binocular advantage has been reported to disappear as the task becomes more complex (Frisén & Lindblom, 1988), as the stimuli are presented longer (Bearse & Freeman, 1994), and as contrast is increased (Banton & Levi, 1991; Bearse & Freeman, 1994; Legge, 1984). Stereo-blind people with good vision in both eyes also benefit from using both eyes for detecting short flashes of near-threshold luminance, although the benefit is smaller than that for people with normal binocular vision (Westendorf, Langston, Chambers, & Allegretti, 1978). Benefits are even found in people with strabismic amblyopia, if the asymmetry between the eyes is compensated for with neutral density filters (Baker, Meese, Mansouri, & Hess, 2007). However, temporal modulation sensitivity is no better when looking with two eyes in the stereo-blind, whereas it is better when looking with two eyes in people with normal vision (Levi, Pass, & Manny, 1982).

In the present study we examine whether people benefit from looking with both eyes when deducing a transparent object's shape and three-dimensional motion from the complex motion of clearly visible dots on a screen. People with normal binocular vision obviously do, because the binocular disparities provide reliable depth information. But do stereo-blind subjects also benefit from looking with both eyes? Since we found that they do, we set out to determine whether they were using additional binocular information or whether they were simply combining two monocular judgments statistically. The stereo-blind subjects performed at chance level in a test of static stereopsis with the same disparities, and performed no worse for stimuli with uncorrelated images in the two eyes than for stimuli with correlated ones, so we can exclude the possibility that they were using residual disparity-based cues (Hess, Mansouri, Thompson, & Gheorghiu, 2009). It is also unlikely that they were using differences in velocity between the two eyes (Brooks, 2002; Nefs, O'Hare & Harris, 2010; Rokers, Cormack, & Huk, 2008) because the rotating object was transparent so dots were moving in opposite directions within each region. Nevertheless, to make completely sure that they were not using some truly binocular cue we examined how varying the correspondence between the motion in the two eyes in various ways influenced performance. Since one subject systematically performed better binocularly than predicted from his monocular performance, we subjected him to a final experiment in which we compared his

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normal binocular performance with his performance when both eyes saw the same image (so that binocular information specified that all motion was within a single plane). Taken together, the results show that stereo-blind subjects benefit from using two eyes despite not using truly binocular information.

2. Methods

We asked subjects to judge the direction of rotation of a transparent simulated horizontal cylinder defined by limited lifetime dots. The cylinder rotated around its major axis (a screenshot of the stimulus is provided in Fig. 1). The cylinder was presented in perspective projection, so that subtle details of the dots' motion revealed the direction in which the cylinder was rotating. The dots themselves were clearly visible. The cylinder's distance and diameter were such that the curvature of the dots' paths across the screen was just detectable. When looking with both eyes, people with normal binocular vision could easily tell which dots were on the front of the cylinder on the basis of retinal disparity, but the stereo-blind subjects obviously could not do so. We compared binocular performance with monocular performance, and with the binocular performance that one would expect from combining two independent monocular performances (probability summation). To investigate the possibility that stereo-blind subjects performed better when using two eyes by relying on binocular information that we had assumed that they were unable to use, we compared conditions with correlated and uncorrelated patterns of dots in the two eyes, compared conditions with additional synchronous and asynchronous changes to the images in the two eyes, and determined performance for static binocular disparities (subjects had to indicate whether a target was on the front or on the back of the cylinder).

2.1. Subjects

We tested three stereo-blind subjects (S1–S3; stereo-acuity below the range of the StereoFly™ test) and seven subjects with normal binocular vision (stereo-acuity better than 80″). We selected stereo-blind subjects who reported to have similar acuity in both eyes. When tested at a viewing distance of 70 cm (the distance used in our experiment) S1 and S3 had a visual acuity of at least 1 in both eyes. S2 had a visual acuity of at least 1 in his left eye, but a visual acuity of 0.15 in his right eye (he sees well with both eyes, but only at near distances with his left eye and at far distances with his right eye; he does not wear spectacles or contact lenses). All three stereo-blind subjects had been patched as children. All subjects took part in the first experiment. Only the stereo-blind subjects took part in the second experiment. Only one stereo-blind subject performed the third, control experiment (for reasons that will become evident).

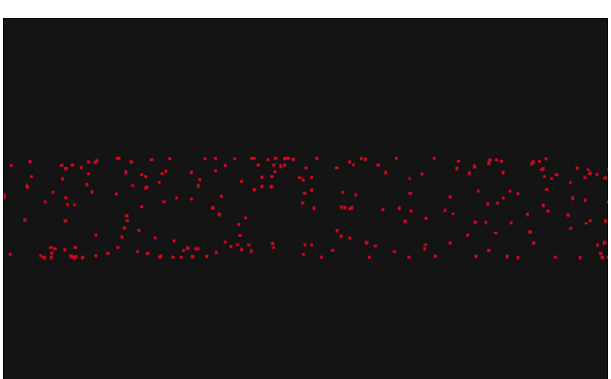

Fig. 1. One (monocular) frame of the transparent virtual cylinder.

2.2. Apparatus

The stimuli were presented on a Sony Trinitron CRT monitor (1096 × 686 pixels, 47.3 × 30.0 cm, 37° × 24°). Subjects sat 70 cm from the monitor, wearing Crystal Eyes liquid crystal shutter spectacles that successively blocked each eye in synchrony with the refresh rate of the monitor (160 Hz), so that different images could be shown to the left and right eye in rapid alternation. All images were red because the shutter spectacles have least cross talk at long wavelengths (transmitting more than 50 times as much light when open than when shut). A new image was presented to each eye every 12.5 ms (80 Hz). The individual's inter-ocular distance was taken into account when creating the images. We simulated the cylinder at screen distance (70 cm), so that not only the ocular convergence required to fixate the cylinder and the retinal images were appropriate, but also the accommodation.

2.3. Stimuli

The basic stimulus consisted of a cylinder defined by 275 red limited lifetime dots on a black background. The simulated cylinder had a diameter of 8 cm and extended horizontally across the entire screen. The dots always had a diameter of 4 pixels, so that the near and the far side of the cylinder could not be recognized on the basis of dot size. The cylinder rotated around its own major axis (corresponding with a horizontal line through the screen center) at 20°/s for 2 s, and then disappeared. During the 2 s, the dots were asynchronously replaced every 250 ms, with new dots appearing at random positions on the cylinder's surface. Since the dots were simulated to be on the surface of the cylinder, their positions on the screen were slightly different for the two eyes. In the three experiments we compared performance for various variations of this basic stimulus. When describing the different conditions we will only mention the deviations from the basic stimulus.

In *Experiment 1* there were four conditions: static, monocular, uncorrelated and correlated. In the correlated condition we used the basic stimulus described above (the name *correlated* refers to the fact that the same simulated dot positions were shown to both eyes). In the uncorrelated condition, we used stimuli with twice as many dots, but showed each dot to only one eye. This removes any (useful) depth information from binocular disparities. However since each eye obtains equivalent information to that in the correlated condition, if judgments for the two eyes are made independently and then combined, we will see similar performance in the two conditions. In the monocular condition, the dots for the images of one eye were simply not rendered. This condition provides us with an estimate of monocular performance, which we need for evaluating whether binocular performance is better than predicted from two independent monocular judgments. In the static condition, the cylinder did not rotate, and we placed a target dot with twice the diameter of the normal dots (8 pixels) at a random position on a horizontal line through the most distant or nearest part of the cylinder (within 10 cm of the screen center). This condition was included to evaluate subjects' ability to use static binocular disparities for almost identical stimuli to those used in the other conditions. Without motion, the distinction can only be made on the basis of binocular disparities.

Presenting uncorrelated dots to the two eyes eliminates all information based on binocular disparity. However it has been suggested that people can also use binocular information that does not require point by point matching between the eyes to perceive motion in depth. Differences in motion within corresponding parts of the images in the two eyes could be interpreted as motion in depth even if the structures that are moving cannot be precisely matched (e.g. Brooks, 2002; Rokers et al., 2008). This is not too surprising because our eyes do not necessarily see exactly the same parts of an approaching object, and if something is moving to the left on the retina of our left eye and to the right on the retina of our right eye, it is likely to be moving towards us. For our transparent rotating object matters are more complicated, because there are two surfaces at each position. Thus, the two surfaces first have to be segregated. They could theoretically be segregated on the basis of the direction of vertical motion, with local binocular differences in the velocity of lateral motion subsequently revealing the direction of motion in depth.

In *Experiment 2* we perturbed the stimuli in several ways to examine whether the stereo-blind subjects could be using some such binocular cue. There were monocular conditions (as in Experiment 1) and binocular conditions in which different dots were presented to the two eyes (as in the *uncorrelated* condition of Experiment 1). The first additional perturbation consisted of varying the speed at which the cylinder rotated. The speed oscillated sinusoidally (at 0.4 Hz) between 15°/s and 25°/s. In the binocular condition the oscillation was shifted by a quarter phase between the two eyes. Constantly varying the speed of rotation could make it more difficult to interpret the subtle differences in motion between the front and back of the cylinder in each eye. Varying the speed asynchronously in the two eyes could interfere with attempts to match corresponding parts of the two images.

The second perturbation of the second experiment consisted of translating the rotating cylinder back and forth along its major axis. Its lateral position oscillated sinusoidally (at 0.4 Hz) with a peak-to-peak amplitude of 1 cm. This perturbation does not affect any of the relative displacements within the image, but since the whole image is moving the pattern of motion of the individual dots is disrupted and it may be more difficult to detect critical subtle differences between the dots' paths. Thus, for instance, noticing that a dot that is moving downwards near the top left of the cylinder is moving slightly to the left (on the screen) would be enough to know that this dot is part of the front surface without any perturbation. Noticing this slightly leftward movement is no longer enough to determine which surface this dot belongs to if the cylinder is moving laterally.

The third perturbation consisted of stretching and compressing the rotating cylinder along its major axis. The cylinder expanded and contracted to between 110% and 90% of its original size at the same rate as we used for the translation. This perturbation obviously does influence the dots' relative displacements, although it does so in a systematic manner. Noticing that dots that are moving downwards near the top of the cylinder are moving slightly apart (on the screen) would be enough to know that these dots are part of the front surface, even if the cylinder is moving laterally. This is no longer true if the cylinder is expanding and contracting laterally as it rotates.

We compared monocular and binocular performance for the perturbed stimuli, but the most important comparison was that between two variants of the stimuli with translation and expansion. In synchronous conditions, the translation or expansion was in phase for the two eyes. In asynchronous conditions, the translation or expansion was in anti-phase for the two eyes. If judgments are made independently for the two eyes then this should not matter, but if the motion in the two eyes is somehow compared, then adding asynchronous motion should make performance worse.

One of our subjects appeared to perform better with two eyes than one would expect from probability summation considering his monocular performance. In *Experiment 3* we conducted a critical test of whether he was using truly binocular information (relative disparities or inter-ocular velocity differences). We repeated the correlated condition of Experiment 1, but interleaved trials for this basic stimulus with trials in which both eyes saw the same image: the image that would be appropriate for a position between the two eyes. This final condition contains no truly binocular information about the direction of rotation.

2.4. Task

Except in the static condition, subjects had to indicate in which direction the dots were moving on the near half of the cylinder. They pressed the upward arrow key if they thought that these dots moved upwards, and the downward arrow key if they thought that these dots moved downward. In the static condition, subjects had to indicate whether the larger dot was on the near or far side. If they thought that the target dot was located on the front of the cylinder, they pressed the downward arrow key. If they thought that it was located on the back of the cylinder they pressed the upward arrow key. No feedback was given. There was no restriction on eye movements.

2.5. Procedure

Except in Experiment 3, the conditions were tested in separate blocks of trials. Within each block, subjects were presented with 50 trials per direction of movement, in random order. In the static condition there were 50 trials in which the dot was located on the front of the cylinder, and 50 trials in which the dot was located at the back of the cylinder. In the binocular conditions of Experiment 2 and in Experiment 3 subjects each performed two blocks of trials. In the monocular conditions subjects used their preferred eye. The three experiments were conducted in the indicated order; within the first two experiments the blocks of trials were performed in a semi-random order.

2.6. Analysis

For each subject and condition we determined the fraction of correct responses and the associated 95% confidence intervals. Plotting these values makes it easy to see whether the fractions of correct responses differ significantly between the conditions. We used the fractions of correct responses in the monocular conditions (P_m) to predict a fraction of correct responses for the binocular conditions (P_b) on the basis of probability summation, assuming that performance for the other eye would have been identical and considering this as a binary detection task. Considering that we used a two-alternative forced choice task, the response on half the trials in which the direction is not detected will be correct, so the fraction of monocular trials in which the direction was *not* detected is twice the fraction of errors: $2(1 - P_m)$. For two independent attempts (by the two eyes) the anticipated fraction of trials in which the direction is *not* detected on both attempts is $(2(1 - P_m))^2$. Since on half of these trials the response will nevertheless be correct, we expect the fraction of errors to be $2(1 - P_m)^2$, and thus the fraction of correct responses $P_b = 1 - 2(1 - P_m)^2$. We indicate the predicted values of P_b in the figures, but one must keep in mind that since these predictions depend on the measured values found for the monocular conditions (P_m) they also contain uncertainty.

3. Results

3.1. Experiment 1

In the static condition (gray bars in Fig. 2A), the three stereo-blind subjects performed at chance level, confirming that they cannot use binocular disparities. The control subjects performed

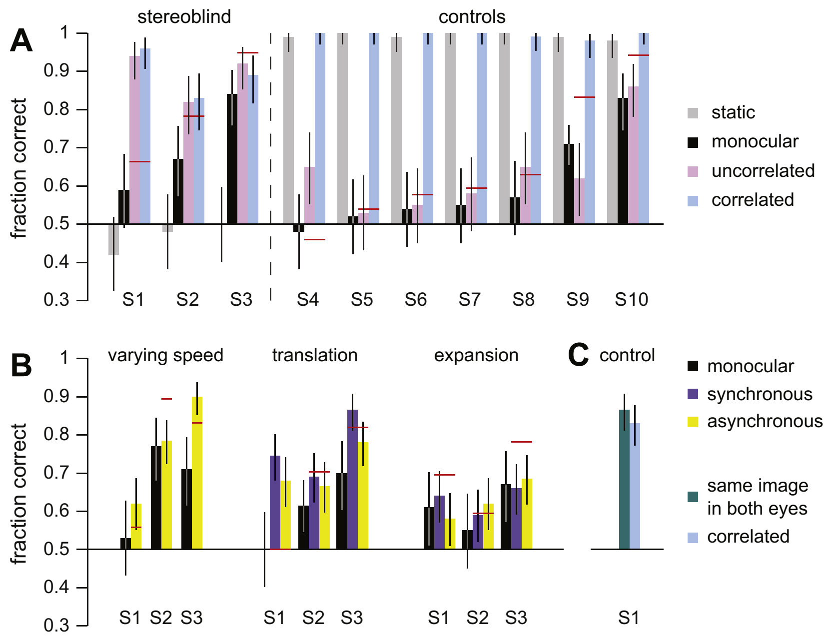

Fig. 2. Individual subjects' performance in Experiments 1, 2 and 3 (A, B and C respectively). Error bars represent 95% confidence intervals. Red horizontal lines are predictions for binocular performance based on probability summation and the monocular data of one eye.

almost perfectly. In the monocular conditions (black bars), some subjects performed well above chance level, whereas others did not. This was so both for the stereo-blind subjects and for the controls. In Fig. 2A the subjects within each group are ordered according to their performance in this condition. The stereo-blind subjects performed better with two eyes than with one (compare pink[1] and blue bars with black bars; note that the error bars are 95% confidence intervals, so the only comparison for which we cannot be confident that performance was better with two eyes is that between the monocular and correlated conditions for S3). The stereo-blind subjects performed equally well when the dots were correlated as when they were not correlated in the two eyes (compare pink with blue bars). One of the stereo-blind subjects (S1) performed better with two eyes than was to be expected on the basis of his monocular performance and probability summation (pink and blue bars well above red line). All the controls performed better with two eyes than was to be expected from probability summation if the dots were correlated in the two eyes (in which case their performance was almost perfect; blue bars), but not if the dots were not (for uncorrelated dots performance was not systematically better than when only one eye saw the dots).

3.2. Experiment 2

We can conclude from Experiment 1 that the stereo-blind subjects benefit from using two eyes (compare monocular and binocular conditions), and that this benefit is not based on binocular disparities (compare correlated and uncorrelated conditions). In Experiment 2 we examine whether the stereo-blind subjects could be using binocular information that does not require precise matching of the points in the two eyes. To do so, we varied the cylinder's rate of rotation, shifted it laterally as it rotated, or stretched and compressed it as it rotated. The subjects' monocular performance when the cylinder did not rotate at a constant velocity, and when it moved or expanded laterally, was generally lower than without the additional perturbations, but it was nevertheless sometimes reliably better than chance (black bars in Fig. 2B). Moreover, there were still quite a few conditions in which performance with two eyes was better than with one. Importantly, performance for synchronous transformations in both eyes was not much better than for asynchronous transformations in the two eyes, so performance is unlikely to rely on a comparison between the motions in the two eyes.

3.3. Experiment 3

Although two of the stereo-blind subjects' binocular performance was more or less what one would expect considering their monocular performance and the improvement that one could obtain through probability summation, one of the stereo-blind subjects (S1) performed better than was to be expected when viewing with both eyes in Experiment 1 and in the translation conditions of Experiment 2. When presented with interleaved trials with either the correct perspective or the perspective from the same position for both eyes, the subject performed equally well for both kinds of stimuli (Fig. 2C), indicating that the improved performance when using both eyes did not rely on truly binocular information. The improvement also could not have depended on the summation of the images before extracting the rotation because it was robust with respect to various transformations. Perhaps the blank image that was presented to one eye somehow disturbed his performance in the monocular conditions.

4. Discussion

The stereo-blind subjects discriminated the direction of the rotation better with two eyes than with one. None of them performed better than chance for the static binocular version of the stimulus, so they did not simply have residual stereopsis under these conditions (in Hess et al., 2009, when *not* tested with neutral density filters, only subjects who exhibited static stereopsis could reliably detect motion in depth from dynamic random dot stimuli). Our stereo-blind subjects performed equally well in the correlated and uncorrelated conditions of Experiment 1 (Fig. 2A), so the better performance with two eyes does not depend on information that

[1] For interpretation of color in all figures, the reader is referred to the web version of this article.

requires point-to-point correspondence between the eyes. Varying the speeds asynchronously in the two eyes, or translating the images in opposite directions in the two eyes, did not remove the benefit of using two eyes (Fig. 2B), so the better performance cannot be based on using inter-ocular velocity differences either (Fernandez & Farell, 2006; Harris, Nefs, & Grafton, 2008; Rokers et al., 2008). Two of the subjects' performance was globally consistent with probability summation (S2 and S3). The third subject (S1) often performed even better with two eyes. Since he even did so when there was no binocular information in the stimulus that could help solve the task, we assume that his better performance when using both eyes was somehow related to the absence of information in one eye in the monocular conditions, rather than to specialized binocular mechanisms such as those underlying binocular depth perception.

We only tested each subject's preferred eye. Of course our predictions would have been more reliable if we had tested both eyes rather than assuming that performance with the non-preferred eye was identical to that of the preferred eye. We selected stereo-blind subjects who reported having good acuity in both eyes, but having sufficiently good acuity in both eyes (which may not be true for subject S2) does not guarantee that the relevant measures for our task are also similar. If there are differences between the subjects' eyes with respect to the visual features that are critical for this task, the subjects are unlikely to prefer to use their poorer eye, so our estimates based on probability summation may be a bit too high. The fact that performance was often better with two eyes than with one indicates that information from the other eye cannot be very much worse (see Baker et al., 2007). Thus simply assuming that performance with the other eye would have been similar for this task is probably justified.

We mentioned that the spectacles transmitted more than 50 times as much light when open than when shut. The upper limit of 2% transmission indicates the resolution of the Minolta LS-110 luminance meter that we used to quantify the cross talk (using the red gun of the screen as the light source). The true difference in transmission is probably much larger. When only presenting our rotating cylinder to one eye, and looking with the other eye, one cannot see anything if one looks straight ahead through the center of the shut spectacles. However, if one looks towards the edges something does become vaguely visible, especially if one turns one's head. Note that even if subjects are able to use such information, our conclusions will not change, because having additional information in the monocular conditions only makes it more surprising that binocular performance is better.

The subjects with normal binocular vision did not benefit as clearly from using both eyes when the images in the two eyes were uncorrelated, as did the stereo-blind subjects (Fig. 2A). This is probably because although the images were not correlated, subjects with normal binocular vision did pair some of the dots in the two eyes, which resulted in those dots being seen at random depths. These depths were in conflict with the grouping of dots on the surfaces on the basis of their motion and density. Thus the lack of a clear benefit of using two eyes (as found for the stereo-blind subjects) could be a result of the cue conflict between such informative monocular information and the random binocular disparities. We therefore consider the results of the stereo-blind subjects to be more reliable for evaluating the benefit of having two independent estimates based on monocular information.

Our findings have consequences for studies on cue combination involving monocular and binocular cues. In some such studies (e.g. Girshick & Banks, 2009; Hillis, Watt, Landy, & Banks, 2004; Knill & Saunders, 2003) stimuli are presented to one eye to isolate monocular cues. Stimuli that only contain disparity information about the attribute in question are used to isolate binocular cues. Binocular stimuli containing both kinds of cues are subsequently presented and performance is analyzed in relation to performance in the other two conditions. Often care is taken to ensure that the two kinds of cues are about equally effective (same variability in settings) so that one expects an improvement for the combined performance of up to $\sqrt{2}$. The present study shows that for some stimuli and tasks, simply looking with two eyes could give an improvement of similar magnitude, even if truly binocular information is not considered at all. On the other hand, Hillis et al. (2004) found similar thresholds for detecting differences in slant when looking with one or both eyes in circumstances in which binocular disparity was given nearly no weight, so one cannot be certain of obtaining such an improvement. Thus, until we can reliably predict when there will be no benefit in using both eyes, it is probably essential to check for benefits that are not related to the use of binocular disparities in all studies in which stimuli presented to one and to both eyes are compared in order to study how monocular cues and binocular disparities are combined.

Acknowledgment

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References

Andrews, D. P. (1967). Perception of contour orientation in the central fovea. I: Short lines. *Vision Research, 7*, 975–997.

Baker, D. H., Meese, T. S., Mansouri, B., & Hess, R. F. (2007). Binocular summation of contrast remains intact in strabismic amblyopia. *Investigative Ophthalmology and Visual Science, 48*, 5332–5338.

Banton, T., & Levi, D. M. (1991). Binocular summation in vernier acuity. *Journal of the Optical Society of America A. Optics and Image Science, 8*, 673–680.

Bearse, M. A., Jr, & Freeman, R. D. (1994). Binocular summation in orientation discrimination depends on stimulus contrast and duration. *Vision Research, 34*, 19–29.

Blake, R., & Fox, R. (1973). The psychophysical inquiry into binocular summation. *Perception & Psychophysics, 14*, 161–185.

Blake, R., Sloane, M., & Fox, R. (1981). Further developments in binocular summation. *Perception & Psychophysics, 30*, 266–276.

Brooks, K. (2002). Interocular velocity difference contributes to stereo motion speed perception. *Journal of Vision, 2*(3), 218–231 [3].

Fernandez, J. M., & Farell, B. (2006). Motion in depth from interocular velocity differences revealed by differential motion aftereffect. *Vision Research, 46*, 1307–1317.

Frisen, L., & Lindblom, B. (1988). Binocular summation in humans: Evidence for a hierarchical model. *Journal of Physiology, 402*, 773–782.

Girshick, A. R., & Banks, M. S. (2009). Probabilistic combination of slant information: Weighted averaging and robustness as optimal percepts. *Journal of Vision, 9*(9), 1–20 [8].

Harris, J. M., Nefs, H. T., & Grafton, C. E. (2008). Binocular vision and motion-in-depth. *Spatial Vision, 21*, 531–547.

Hess, R. F., Mansouri, B., Thompson, B., & Gheorghiu, E. (2009). Latent stereopsis for motion in depth in strabismic amblyopia. *Investigative Ophthalmology and Visual Science, 50*, 5006–5016.

Hillis, J. M., Watt, S. J., Landy, M. S., & Banks, M. S. (2004). Slant from texture and disparity cues: Optimal cue combination. *Journal of Vision, 4*(12), 967–992.

Knill, D. C., & Saunders, J. A. (2003). Do humans optimally integrate stereo and texture information for judgments of surface slant? *Vision Research, 43*, 2539–2558.

Legge, G. E. (1984). Binocular contrast summation I. Detection and discrimination. *Vision Research, 24*, 373–383.

Levi, D. M., Pass, A. F., & Manny, R. E. (1982). Binocular interactions in normal and anomalous binocular vision: Effects of flicker. *British Journal of Ophthalmology, 66*, 57–63.

Nefs, H. T., O'Hare, L., & Harris, J. M. (2010). Two independent mechanisms for motion-in-depth perception: Evidence from individual differences. *Front Psychology, 1*, 155. doi:10.3389/fpsyg.2010.00155.

Rokers, B., Cormack, L. K., & Huk, A. C. (2008). Strong percepts of motion through depth without strong percepts of position in depth. *Journal of Vision, 8*(4), 1–10 [6].

Westendorf, D. H., Langston, A., Chambers, D., & Allegretti, C. (1978). Binocular detection by normal and stereo-blind observers. *Perception & Psychophysics, 24*, 209–214.