# Motion Sharpening Asymmetry and Stereoscopic Motion in Depth

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J. Ferrucci, P. Bex, and G. McCormack

New England College of Optometry


## Purpose

Physically blurred images moving in stereoscopic depth in 3D displays are neurally sharpened more than laterally moving equally blurred images with the same retinal image velocities[2]. We attributed this to higher contrast gain and saturation properties in stereoscopic motion neurons which symmetrically sharpen both target edges.

Our purposes in this study were threefold: (Expt. 1) – to verify and quantify asymmetric motion sharpening in our blurred bar motion stimuli. This hypothetical pre-binocular process sharpens the trailing edges of moving ocular images[1] (not leading edges) and could explain stronger stereoscopic motion sharpening. (Expt. 2) – to compare stereoscopic to lateral motion sharpening when asymmetric sharpening has been removed from images. (Expt. 3) – to replicate our previous study[2] of stereoscopic and lateral motion sharpening on this new study population.

## Methods

Subjects:

- 10 normally binocular subjects, ages 18 to 35 years old
  - 20/20 corrected visual acuity
  - Local stereopsis threshold < 30 sec of arc
  - Phoria, vergence, and health within normal limits

Apparatus:

- A LabView© program running on a Mac G4 sent stimulus parameters via a TCP/IP connection to MATLAB running on an Asus/Windows 7 PC. A PEST adaptive staircase procedure running in LabView established blur matches.
- MATLAB©/Psychtoolbox© software on the PC presented stimuli on a 3D monitor compatible with NVIDIA® 3D Active shutter glasses.
- The 3D monitor, 60Hz binocular frame rate, was viewed at 106.9cm
- Subject's head position was supported by a chinrest

Procedure:

- EXPERIMENT 1: Monocular Sharpening Asymmetry (Fig. 1A, 1B)
  - Blur stimuli appear above or below fixation at random
  - A static sharp bar discourages fixation/attention loss
  - Leading edge blur matched to trailing edge blur
  - Conditions:
    - Left vs Right directionality
    - Left vs Right eye presentation
    - Fast (2° /sec) vs Slow (0.5° /sec) velocity
- EXPERIMENT 2: Edge-Matched Stereo Sharpening (Fig. 1C)
  - Subjects compared the blur of a moving bar whose monocular edges were perceptually matched, to the blur of a static comparison bar
  - Conditions
    - Near (approaching) vs. Far (receding) stereoscopic motion
    - Conjugate Lateral binocular motion (leftward vs rightward)
    - Fast (2° /sec) vs Slow (0.5° /sec) velocity
- EXPERIMENT 3: Edge-Unmatched Stereo Sharpening (Fig. 1D)
  - Parameters like Expt. 2 except that the edges of the monocular images comprising the moving blur stimulus were physically matched[2], not perceptually matched.

## Methods – Figures

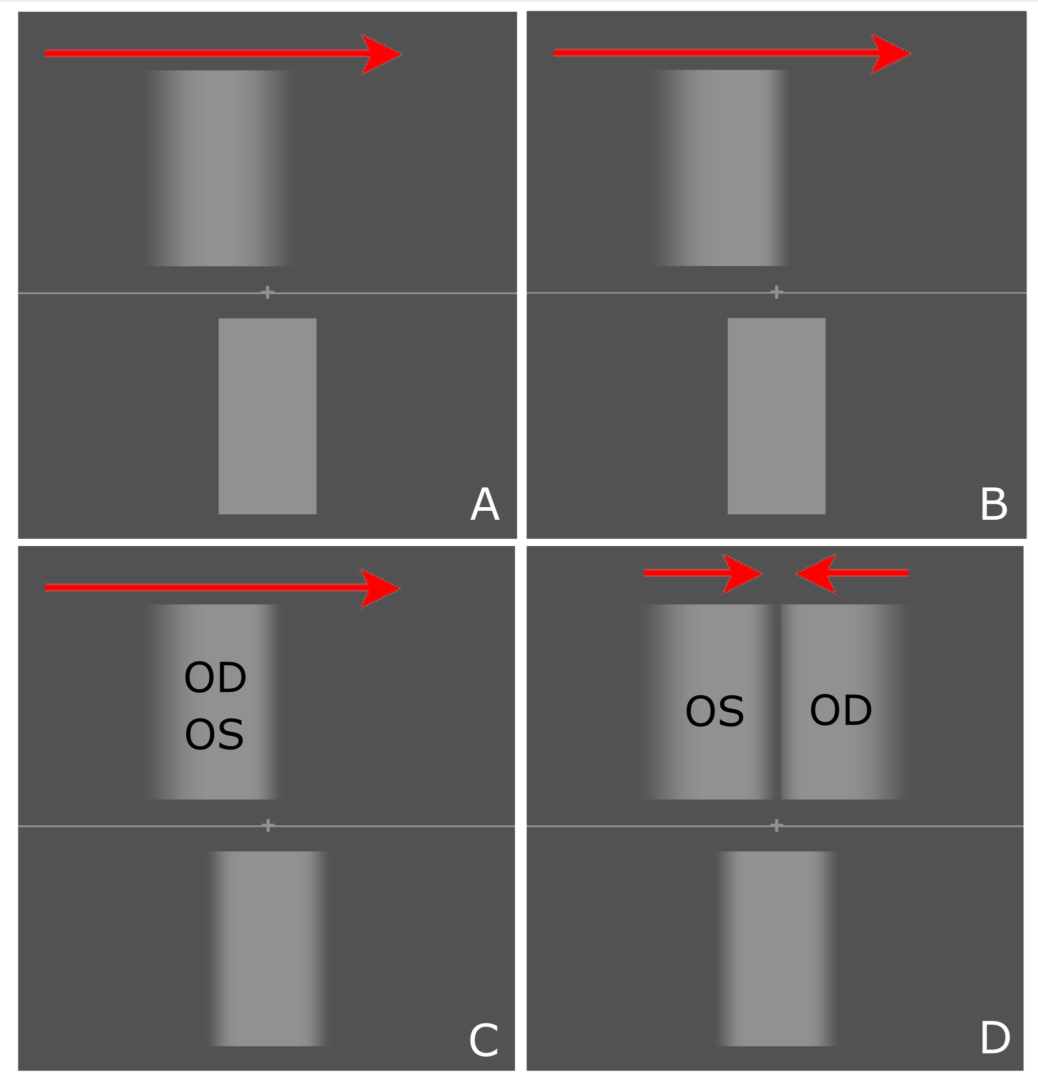


*Figure 1A.* Expt.1: A 60 minarc wide monocular bar is moving rightward (red arrow) with 42 minarc physically-matched leading and trailing edge blurs. The bar moves symmetrically about fixation. *Figure 1B.* Expt.1: The leading edge blur of the monocular bar is adjusted to match the perceived trailing edge blur by PEST. This leading edge adjustment measures monocular sharpening asymmetry. The sharp lower bar is not involved in the judgments. *Figure 1C.* (Expt.2): A conjugate motion trial. Both eyes view identical edge-matched motion stimuli in which the leading (right) edges are physically sharper. The perceived blur of the moving upper bar is measured by comparison to the blur of the static lower bar. *Figure 1D.* (Expt.2): A stereo near motion trial. The leading edges of the nasally-moving monocular images have been sharpened to match the trailing edges. The perceived blur of the stereoscopically moving fused upper bar is measured by comparison to the blur of the static lower bar.

## Methods (continued)

- Sharpening was quantified by the reduction of leading edge blur that matched the 42' trailing edge blur in Expt.1, or by the overall reduction of comparison target blur that matched the overall blur of the moving target in Expts. 2 & 3.
- A Data Desk© Repeated Measures algorithm did mixed ANOVAs:
  - EXPERIMENT 1:
    - Between-subject independent factors: Subject, Motion Direction, Eye
    - Within-subject dependent variable: Sharpening at target velocities of 0.5°/sec and 2.0°/sec
  - EXPERIMENTS 2, 3:
    - Between-subject independent factors: Subject, Motion direction
    - Within-subject dependent variable: Sharpening at target velocities of 0.5°/sec and 2.0°/sec

## Results

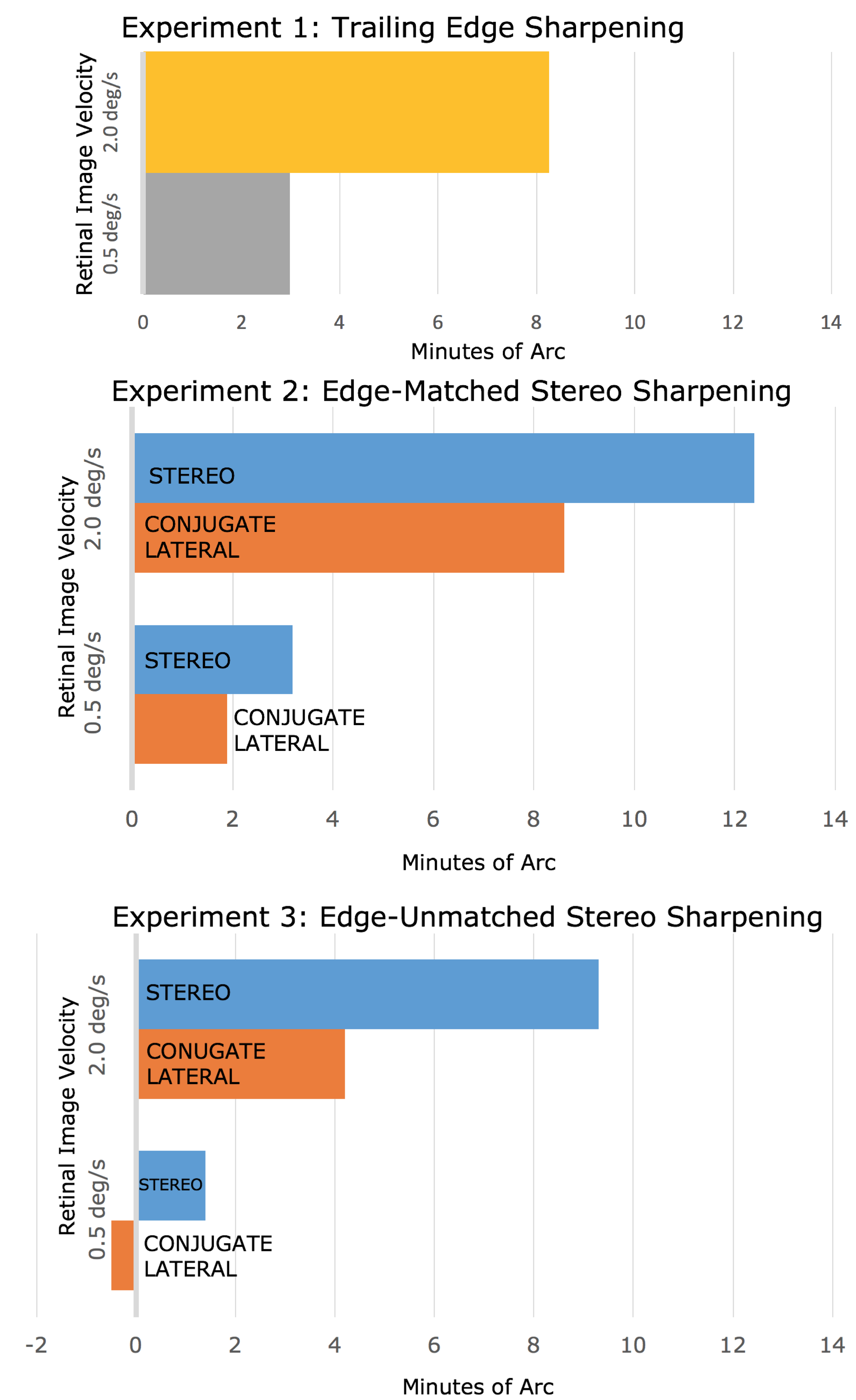


*Figure 2. Expt.1(top):* Amount of sharpening of the leading edge (in min. of arc) that matched the 42' blur of the trailing edge at velocities of 0.5° /sec (gray) and 2° /sec (yellow).
*Expt.2 (middle): :* Amount of sharpening of the static comparison target that matched the sharpness of the stereo motion target (blue) or conjugate lateral motion target (orange) as a function of target velocities of 0.5° /sec and 2° /sec. The ocular image edges were perceptually-matched in each case.
*Expt.3 (Bottom):* Same as Expt.2 but with the edges of the ocular images of the moving binocular target physically matched, but not perceptually matched.

## Results

- **Experiment 1 – Monocular Sharpening Asymmetry**
  - Overall, the effect of target velocity on sharpening was highly significant ($F=92.5$, $p\leq 0.0001$), showing that asymmetric sharpening occurred in this experiment.
  - The eye and direction factors were not significant
  - Asymmetric motion sharpening magnitude differed between subjects ($F=3.13$, $p = 0.0028$)
- **Experiment 2 – Edge-Matched Stereo Sharpening**
  - Motion sharpening was greater for stereo motion than lateral motion ($F=6.68$, $p=0.036$)
  - There was no significant effect of direction of motion (near vs. far or left vs. right) on match blur so these effects were collapsed for subsequent analysis of stereo vs. lateral motion.
- **Experiment 3 – Edge-Unmatched Stereo Sharpening**
  - Stereoscopic motion sharpening was greater than for conjugate lateral motion ($F=7.11$, $p=0.032$) and differed significantly between subjects.
- The relative strength of stereoscopic motion sharpening over lateral motion sharpening was not significantly different between experiments 2 & 3 ($F=1.2$, $p=0.31$).

## Conclusions

- **Experiment 1 – Monocular Sharpening Asymmetry**
  - Asymmetric motion sharpening occurs for large blurry stimuli of the type used in this experiment.
  - Marinovic et al., observed the strongest asymmetric sharpening when an image's trailing edge follows the leading edge by ~60ms[1]. They suggested that an active inhibitory mechanism like backward masking could explain this behavior. Our targets were much larger than theirs, and the trailing edges followed the leading edges by at least 500 msec, which seems too long for backward masking.
- **Experiment 2 – Edge-Matched Stereo Sharpening**
  - When asymmetric motion sharpening is neutralized, stereoscopic motion sharpening is still stronger than lateral motion sharpening. This finding is consistent with the suggestion by McCormack et al.[2] that sharpening is stronger in stereo motion neurons than lateral motion neurons.
- **Experiment 3 – Edge-Unmatched Stereo Sharpening**
  - Motion sharpening is stronger in stereoscopic motion-in-depth than in conjugate lateral motion, with or without edge-matched images.
  - Interestingly, the relative strength of stereoscopic motion sharpening is not significantly increased by the asymmetric sharpening process. This suggests there is a limitation in the amount an edge can be perceptually sharpened.

## References & Acknowledgment


1. Marinovic W, Arnold DH. An Illusory distortion of moving form driven by motion deblurring. Vision Res 2013, 88: 47-54.
2. McCormack, GL, Van Cura, J, Bex PJ Neural Sharpening of Images Moving in Stereoscopic Depth. Invest Ophthalmol & Vis Sci 2014; 54: ARVO E-abstract #3002



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