ORIGINAL ARTICLE

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Viewing Side-by-Side Stereo Images

Stereo Imaging

Ophthalmic imaging has a strong history of utilizing stereo techniques to document three-dimensional findings of the eye and ocular adnexa. The use of this technique in ophthalmology dates back as far as 1909, but it wasn't until the 1960's that stereo fundus photography became widely employed after Lee Allen described a practical technique for sequential stereo fundus photography in 1964.[1] The Donaldson simultaneous stereo camera was introduced that same year and stereo imaging soon became the standard in fundus photography.[2]

Stereo imaging simulates the clinical view observed during examination by slit lamp biomicroscopy and indirect ophthalmoscopy. The visual sense of depth and realism provided by stereo images make them particularly useful for identifying the anatomic location of ocular pathologies. The ability to study stereo images at length may be an advantage over the fleeting view observed during ophthalmoscopy, especially in light-sensitive or uncooperative patients. The cornea induced parallax described by Allen leads to a hyper-stereoscopic effect that enhances the depth relationships between ocular structures in stereo fundus photographs. Similarly, the separation between binocular objectives in the slit lamp biomicroscope exaggerates the stereo effect at such close working distances. Despite these advantages, stereo imaging is underutilized in current clinical practice. The more recent advent of cross sectional imaging with ultrasound or optical coherence tomography has led to a decline in routine use of stereo photography, but it still plays a strong role in clinical practice and remains a standard for many clinical trials investigating treatments for retinal diseases.

Stereo imaging relies on the visual phenomenon of stereopsis – the ability of the brain to construct a visual sense of depth from the two separate images generated by the left and right eye. The lateral distance between eyes (approximately 60-65 mm) induces parallax, or an apparent change in the appearance of a subject from the change in observational position. Stereo imaging simulates the effect of stereopsis by taking two photographs from slightly different lateral vantage points and then presenting them individually to the corresponding eye.

Free Viewing

Free-viewing side-by-side stereo images by fusing them without the aid of auxiliary lenses or prisms can be challenging. It requires separating accommodation from convergence, which is a skill that takes some practice.[3,4] Normally, our eyes converge and accommodate at the same time when viewing at near. In free-viewing, both stereo images are visible to both eyes, so the viewer also needs to learn to ignore the extra image. Parallel free-viewing presents the images in the normal left to right orientation and is limited to stereo pairs in which the image centers are spaced 65mm or less apart. Cross-eyed free-viewing switches the images so the left eye image appears on the right and the right stereo image on the left. This requires the viewer to cross their eyes until the images overlap and appear in stereo. The forced convergence enables larger image pairs to be fused. The images presented in the *Journal of Ophthalmic Photography* (*JOP*) are presented in the normal left-right orientation and can be viewed in stereo by relaxing convergence at near. Cross-eyed free-viewing of these image pairs will result in a reverse stereo effect.

To free-view the image pairs in this publication, center your gaze between the two images and relax your normal convergence. Think in terms of trying to deliver the left image to the left fovea and the right image to the right fovea. When done correctly, you will see three images: left & right blurred images, and a central overlapped image that should appear in focus. If you hold the printed pairs very close so that they are directly in front of each eye (and out of focus) and slowly back away, you should eventually see the central image in stereo. When free-viewing stereo images on a computer monitor, adjust the viewing magnification so that the distance between the center of the two images measures approximately 65 mm.

Stereo Viewers

There are a variety of optical stereo viewers available for viewing digital images on a computer monitor or printed page. Optical viewers may utilize lenses, prisms or mirrors to deliver the separate stereo images simultaneously but independently to each eye, allowing the brain to fuse the pair and recreate a three-dimensional image (Figure 1). In addition to the optical components, viewers may include a field mask to prevent cross-viewing between eyes. A number of optical viewers have been adapted or designed specifically for viewing ophthalmic stereo pairs.[5-7]

Viewers can be divided into two main types, those which correspond to images spaced at the normal eye spacing of 65mm and those that can accommodate larger images that extend beyond 65 mm.[8] The original Wheatstone design works well for large image pairs. Wheatstone viewers (like the Screen-Vu or Screenscope) consist of a pair of angled front surface mirrors for each eye. The publication size of the stereo pairs in the print version of the *JOP* is too small for using these viewers, but they are excellent for viewing large side-by-side stereo images on a computer monitor. An adjustment lever will enable the observer to angle the mirrors to fuse image pairs of different sizes. Zoom the onscreen view so that the stereo pair fills a significant portion of the monitor (typically 200-400% depending on monitor size and resolution settings), and then position the viewer between the two images. Close your left eye and adjust the right side mirror so that the right image is centered. Then open your left eye and you should begin to see the stereo effect as the images are now optically superimposed.

Brewster-type stereoscopes (lenticular or semi-lenticular) use lenses to separate convergence from accommodation to facilitate stereopsis of small image pairs. These are the viewers most commonly used for viewing backlit 35 mm film based stereo pairs (Donaldson, Larson, etc) on a light box. Lenses range from +4 to +12 diopters. Viewers such as the Donaldson have a fixed-height opaque base and aren't useful for viewing the printed *JOP* as designed, but can be inverted to avoid shadowing. Lenticular viewers with a folding or removable base can be used without blocking necessary ambient light needed to view the printed images. This design has been manufactured and sold under various names (Abrams, Luminos, Gordon, Sokkia) in 2X and 4X models. The 2X version is better for viewing the printed *JOP* images and they can also be held in front of a monitor for viewing small image pairs as long as the zoom level keeps image centers no wider than 65 mm apart.

If no stereo viewers are readily available in the eye clinic, a temporary viewer can be assembled with a pair of trial lenses (+4 to +8) in a trial frame. Magnification increases and viewing distance gets shorter as lens power is increased, with +6 lenses representing a good compromise.

Loreo Lite 3D Viewer

The Loreo Lite 3D Viewers included with the print version of this issue of the *JOP* can be used for the printed journal or onscreen viewing. The Loreo viewer employs a pair of base out prisms which prevents convergence when viewing at the normal viewing distance (12-20 cm). Holding the printed journal upright will usually prevent shadows from interfering with the view. Onscreen viewing allows the observer to zoom to an optimal range for these viewers. Depending on the physical size and resolution of a monitor, screen zoom settings from 100 to 250% work well for the Loreo viewer. Once the image centers are more than 10 cm apart the stereo effect is lost. These simple viewers provide a surprisingly good view of both the printed and onscreen versions of the journal.

Summary

The routine use of stereo imaging in ophthalmology has declined in recent years. Contributing factors may include the shift to digital imaging, the lack of stereo presentation in ophthalmic education, and the introduction of OCT. Despite this decline, stereo imaging remains a valuable diagnostic tool in ophthalmology. Lee Allen, founding member and first President of the Ophthalmic Photographers' Society, once stated that stereo images "preserve valuable information about elevations, depressions, relative depths and, equally important, about character of lesions and conditions of tissues which is not at all present in regular photographs".[9] These

Figure 1*:* Stereo viewer types, left to right: Wheatstone-type (mirror), Brewster-type (lenticular), Loreo Lite (base-out prisms).

observations still hold true today and there continue to be many advocates for stereo imaging in our field.[10,11] New stereo televisions and monitors are becoming popular with consumers and may provide a practical means of viewing stereo ophthalmic images. As these high quality viewing technologies become commonplace, we are likely to see a renewed interest in capturing and displaying ophthalmic images in stereo.

The award winning stereo images presented in the *JOP* are a tribute to the value and tradition of stereo imaging in ophthalmology.

Stereo Resources

Stereo Viewers:

ASC Scientific
http://www.ascscientific.com/stereos.html

Berezin Stereo Photography Products
http://www.berezin.com/3d/viewers1.htm

Online Stereo Publications:

Stereoscopic Displays & Applications Virtual Library
www.stereoscopic.org/library/index.html

Stereoscopy.com Library
http://www.stereoscopy.com/library/index.html

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