Essay

Stereo Views

Susan R. Barry, PhD

Associate Professor of Biological Sciences, Mount Holyoke College

Just how important is binocular vision and stereopsis? This is a question I could not have answered five years ago. At that time, I had very little binocularity and very poor if any stereopsis. At the age of 48, however, with a pair of prism glasses and optometric vision therapy provided by Dr. Theresa Ruggiero, I gained binocularity and stereopsis. Stereopsis is a quale, a subjective, sensory experience like seeing red. I could not imagine what it was like to see empty space as palpable space before I gained stereopsis. How, then, could I have known the importance of stereopsis in day-to-day life if I could not even imagine what seeing with stereopsis was like?

Conversely, if you are a normal binocular viewer, someone who has had good binocular skills and stereopsis all your life, can you imagine your life without it? My answer would be no. An individual with normal stereopsis cannot experience the worldview of a person who has always lacked stereopsis. Even if the binocular viewer closes one eye, the brain will use a lifetime of former stereovision experiences to recreate the missing information. A binocular viewer will see the world as more depth- filled with one eye than a stereoblind individual with see the world with two eyes. I became convinced of this idea when I noticed that paintings drawn in perspective appear more depth-filled to me now that I have gained moderate stereopsis. This is true whether I look at the picture with one or two eyes. The painting is basically two-dimensional. However, monocular cues, such as perspective, that were used by the painter to create a sense of depth now suggest to my brain a greater sense of space and volume than I had previously seen.

I never understood what my family saw in the special effects in Star Wars movies until my vision changed. In the last Star Wars movie however, I was astonished by the sense of space and volume evoked by the movie scenes. Scenes of spaceships flying through the universe were fantastic. My new appreciation for the movie did not result because cinematography had improved significantly since the previous Star Wars movies. Instead, I was seeing the movie in a whole new way. Skilled Star Wars cinematographers had used monocular depth cues and motion to create scenes on the flat, two-dimensional movie screen that suggested a dramatic three-dimensional sense of volume and space. Before my vision transformed, I could not experience this sense of space while watching the movie because I had never experienced this sense of space in real life. This greater sense of space derives from my new and recent stereovision experiences.

I was diagnosed with alternating esotropia and left hypertropia in infancy. I had three eye muscle surgeries at ages 2, 3, and 7 in 1956, 1957, and 1961. The operations, performed by a highly respected ophthalmic surgeon, aligned my eyes cosmetically but not functionally. I was an expert alternator and suppressor and had no idea that there was anything wrong with my vision until I entered my junior year in college. At that time, I took a neurophysiology course and learned about Hubel and Wiesel's experiments on strabismic kittens.[1] I

Correspondence regarding this essay can be emailed to sbarry@mtholyoke.edu or sent to Dr. Susan R. Barry, Mount Holyoke College, 50 College Street, South Hadley, Massachusetts 01075. All statements are the author's personal opinion and may not reflect the opinions of the College of Optometrists in Vision Development, Optometry and Vision Development or any institution or organization to which they may be affiliated.

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will never forget sitting in the classroom that fall day and learning about ocular dominance columns and the presumed lack of binocularity in these wall-eyed cats. It certainly woke me up from the usual half attentive, automatic note-taking state that I had perfected from hours of sitting through lectures. After class, I went to the library and struggled through the scientific papers. I did my term paper project on Hubel and Wiesel's research. I tried every stereovision test that I could find and flunked them all. After a brief period of concern, however, I let the whole issue drop. After all, theories on critical periods suggested that I could never gain or regain stereovision. I was doing OK –I was slightly near-sighted but had normal acuity in both eyes with glasses, and I looked normal. No one knew (and I rarely told anyone) that I had this visual deficit. Moreover, my ophthalmologist told me that stereovision was not that important, just a little fine turning for the visual system. He made such statements as "You don't need binocular vision because you don't have binocular vision," a statement whose logic escapes me to this day.

If I did think about binocular vision, it was in regards to particular, discrete tasks. Maybe, I would be a less hesitant driver if I used both eyes together or perhaps I could operate an electric sewing machine. (I only passed sewing class in junior high school because my father, an artist, seeing my distress and total incompetence, went out and bought a sewing machine and did my sewing projects for me.) It did not occur to me that the difficulty I had learning to read, the fact that I was placed in a special needs class for third and fourth grade, or my uncanny propensity for getting lost were related to my vision. After all, one does not need to see in depth to read a book or a map. I just must be a bit slow.

As I approached my mid-forties, however, my vision became more troublesome. When I looked in the distance, objects appeared to jitter. It was hard to read road signs while driving because I could not keep my gaze fixed on the signs. Driving for more than twenty minutes at a time was fatiguing. I could not always tell whether someone in the distance was walking toward or away from me. I could not comfortably watch my children's performances from the middle of the high school auditorium. The children's faces and other details were all a blur. I consulted a respected local ophthalmologist who told me that my acuity was 20/20 in each eye with glasses so any problems with my vision must be psychological. I accepted his advice for a few years until a chance remark and incident at work made me realize that I should attend to my vision problems.

I am a professor of biology and neurobiology at Mount Holyoke College and lecture in the classroom almost daily. I was teaching an 80-person introductory biology class with one of my sharp-eyed colleagues. She asked me why I never acknowledged the students who raised their hands in the back of the 100-seat lecture hall. I told her that I did not notice students back there with questions. I could see the students if I looked. I just was not in the habit of looking in the distance. My colleague and I then came up with a plan. She would position herself in the back of the lecture hall, and when a student raised her hand, my colleague would stand up and wave her arms wildly until I noticed. Then she would gesture in an exaggerated manner toward the student. The students may have noticed these crazy antics, but they were too polite to say anything.

As I thought about this problem, I realized that I was confining my visual exploration of the world to within fifteen feet of my person. No wonder I was constantly getting lost and constantly surprised and unnerved by what seemed to suddenly appear before me. I decided to find an eye doctor who would focus on my day-to-day, functional vision, not just my visual acuity. Thanks to the advice of a local optometrist, I found Theresa Ruggiero, OD, FCOVD.

Dr. Ruggiero explained that my unstable gaze, my jittery view of distant objects, was due to rapid alternating fixation and binocular rivalry. She discovered a vertical disparity between my two eyes ranging from 3 to 5.5 diopters depending upon viewing distance. She placed a prism in my right eyeglass lens that aligned the visual field of my right eye more closely with that of my left and then started me on a program of optometric vision therapy. It was after a long session with the Brock string that I had my first stereo experience. As I left the vision therapy office, I got into my car, sat down in the driver's seat, and noticed that the steering wheel appeared to float in front of the dashboard. There was this space between the steering wheel and the dashboard. I told myself that the indirect light from the setting sun was playing tricks on me. However, the next day, after performing my therapy exercises, I got into the car and noticed that the rear view mirror popped out in front of the windshield.

I continued home and office vision therapy for a year and a half and practiced the exercises at least five times per week. With every jump in my ability to do the exercises, i.e. to free fuse stereo pairs, to perform the Brock string task at different bead distances, to master the amblyoscope for different

degrees of convergence or divergence, for every jump in these abilities came a correlated improvement in my everyday vision. This would always come as a surprise to me. I would happen to glance at something and think, "that object looks so well-defined and so solid; the air must be particularly clear today." Then I would realize that the object or the air around it had not changed. What had changed was my perception.

These experiences taught me that binocular and stereovision do not impact only specific tasks such as driving. Binocular and stereovision change the whole way one experiences the world and the way one places oneself in one's three-dimensional surroundings. I now look in the distance and am less liable to get lost. I enjoy strolling through busy streets, an activity I used to avoid because too many people and cars seemed to suddenly come up at me. With my newfound binocularity, borders, edges, and outlines of objects are far crisper. Brick walls and stone fences appear far more detailed and textured. I still cannot get over the clarity of my vision. Other individuals who recently gained stereovision tell me the same thing. And then there is that sense of depth, objects popping out and receding inward, that sense of space as palpable, and that sense of myself within that space. This sense of space and volume constantly surprises me and has given me moments of pure joy.

When my vision first began to transform, I found it hard to explain these perceptual changes to people with normal binocular vision. They did not see anything novel or unusual in my descriptions of objects popping out, tree leaves hovering in their own 3D space, or brick walls looking more textured. In December of 2004, however, I wrote a letter to the well-known author and neurologist, Oliver Sacks, M.D. To my great surprise and delight, he wrote back right away and visited me and Dr. Ruggiero at my home and her office. After a year-and-a-half of further correspondence, Dr. Sacks wrote a story about stereovision and my experiences titled "Stereo Sue" that appeared in the June 19, 2006 issue of the *New Yorker* magazine.[2] Moreover, Robert Krulwich of National Public Radio put together a program about my experiences on *Morning Edition* that aired June 26, 2006. This program was titled, "Going Binocular: Susan's First Snowfall."[3] Within four days of the Morning Edition piece, I had received over eighty e-mails specifically from strabismics and strabismic amblyopes looking for ways to improve their vision. (My e-mail address had not been made public so that these individuals had to do some web searching to find it.) For me, this was a week filled with both excitement and sadness. I was struck by the yearning in the emails for better vision. A 50-year-old man wrote that the radio story had moved him to tears. One woman wrote that she had to pull her car over to the side of the road to finish listening to the radio story, and another wrote that the story made her whole body quiver. I was fascinated by accounts from several strabismics saying that once, perhaps in the dark during a 3D movie, they had seen in depth and wondered what it would be like to see that way all the time. However, all the individuals echoed the same mantra. They had been told by their eye doctors that they could never gain binocularity and stereopsis. This depth-filled way of seeing the world would never be possible for them.

I am certainly not alone in my acquisition of stereovision. Stories like mine can be found on such websites as visionstories.org. I have spoken with individuals with a variety of binocular disorders including alternating esotropia, strabismic amblyopia, and anisometropic amblyopia, all of whom gained stereovision in adult life. However, the email messages that I received after the radio program make it clear that this experience of gaining binocular vision in adult life is far less frequent than it should be. Why is the average person with a binocular disorder told that nothing can be done to allow them to see at the same time with two eyes? The reasons are variable and complex but I will list a few below.

1. One reason goes back to the paradox that I stated at the beginning of this editorial essay. How are we to gauge the importance of binocular vision and stereopsis if a stereoblind person cannot imagine the world with stereopsis and a normal binocular viewer cannot imagine the world without it? It is this difficulty, I believe, that has caused many eye doctors to downplay the importance of stereovision in everyday life.
2. In the 1960's, experiments done by Hubel, Wiesel and other neurophysiologists indicated that there is a critical period in early postnatal life for the development of certain visual skills including binocularity. However, data on critical periods derived mostly from experiments involving closure of one eye shortly after birth,[4,5] an experimental manipulation most comparable to the presence of congenital cataracts in one eye. This condition is certainly not the major cause of binocular loss in children.

   In mammals with normal binocular vision, most neurons in the visual cortex are binocular, i.e., respond to input from both eyes. However, in animals with infantile or experimentally-induced strabismus, most cortical

neurons became monocular, i.e. respond to one or the other eye but not both.[1] Although these results indicate that a strabismic animal may not develop stereopsis, no laboratory experiments have been done to reverse the strabismus in animals and look for effects on visual pathways. Dr. Hubel himself points this out in his latest book, *Brain and Visual Perception*.[6] He and Wiesel never actually proposed a specific critical period for effects of strabismus.

In any case, I am not convinced that strabismic recovery experiments on animals would have yielded relevant results. It may not be possible to re-align the eyes of a strabismic animal with enough precision for the animal to develop stereopsis. Less than half of the children who receive strabismic surgery, even in the first year of life, develop measurable stereovision, and only a very few develop fine stereopsis. Eye alignment may have to be very precise for the development of stereopsis in a strabismic, and even the best of surgeons may not be able to achieve this precision of alignment. Moreover, optometric vision therapy may be necessary to break interocular suppression and teach binocular fusion. It is probably impossible or at least extremely difficult to teach therapy exercises to a cat or even a monkey in order to thoroughly test for recovery of binocularity in experimental animals.

3. Optometric vision therapy requires dedication, time for practice, and sufficient financial resources. Unfortunately, most medical insurance plans do not cover optometric vision therapy, a situation that needs to change.
4. Many ophthalmologists and pediatricians are ignorant of and/or openly hostile to optometric vision therapy. Much of their attitude derives from professional rivalry and deep-seated but unwarranted prejudices. Ophthalmologists often state that no good clinical studies have been done to show the effectiveness of optometric vision therapy. I would encourage members of the COVD to initiate and participate in clinical studies demonstrating the critical role of optometric vision therapy in the care of individuals with binocular disorders. One such study done on convergence insufficiency was published in the Archives of Ophthalmology in 2005 and clearly showed that vision therapy was superior to all other treatments in ameliorating this condition.[7] I am confident that similar studies would drive home the importance of optometric vision therapy in treating strabismus, amblyopia, and anisometropia. Approximately ten percent of the population suffers from binocular disorders, and these individuals deserve better treatment than that currently offered by most ophthalmologists.
5. Since I am a 50-year-old, post-surgical alternating esotrope, my condition is considered difficult to treat. I am very thankful that Dr. Ruggiero offered me the therapy despite the fact that many would have given me poor chances of gaining binocularity. Thus, my success in gaining binocular vision and stereopsis is cause for optimism.

Optometrists should not be too quick to judge whether or not therapy will work especially if the patient is motivated to work at the therapy exercises. Judging from the emails that I have received following the Morning Edition piece, there are many patients out there who would work hard to gain better vision and just need the encouragement from their doctors.

I believe that members of the College of Optometrists in Vision Development play a crucial role in transforming the vision and, therefore, the lives of many of their patients who struggle with a wide range of visual disorders. I am one of those lucky patients and will do all that I can to broadcast the importance and enormous benefits of optometric vision therapy.

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Dr. Barry will be a speaker at the 2006 COVD Annual Meeting, Phoenix, AZ, October 24-28.