The Work & Wisdom of Dr. Frederick W. Brock

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Frederick W. Brock understood strabismus better than any other individual, yet most vision care professionals have never heard of his work. If they do recognize his name, it is probably in association with the Brock string. That is how I first heard of Dr. Brock. I was a 48-year-old patient in optometric vision therapy who had been esotropic since early infancy. Although I had undergone three childhood surgeries, I continued to alternately fixate, was stereoblind, and had a poor sense of the visual periphery. All of this changed as a result of vision therapy provided by my optometrist, Dr. Theresa Ruggiero. Fascinated by the power of the Brock string and other vision therapy tools, I wanted to learn more about Dr. Brock but discovered that many of his publications were difficult to obtain. He had, for example, published his visual training manuals in serial form in the *Optometric Weekly* of the 1940's and 50's.[a, 1-6] I took trips into Manhattan to the library of SUNY's College of Optometry where I would engage in marathon Xeroxing sessions of Dr. Brock's papers.

In 2006, my stereovision story titled "Stereo Sue," was first published by Dr. Oliver Sacks in *The New Yorker*.[7] A week later, an interview with me aired on NPR's *Morning Edition*.[8] Among the many letters and emails in response to that program was a letter to Dr. Ruggiero from a man named Bruce Alvarez. He wrote that he was happy to hear mention of the Brock string during the radio program since his wife's grandfather was Frederick Brock. I contacted Mr. Alvarez and, through him, spoke by phone with Dr. Brock's daughter, Dolores (Dee) Brock Partridge. From Mrs. Partridge, I learned that Dr. Brock was born in Switzerland in 1899 and came to the United States in 1921 to attend the Columbia School of Optometry. Dr. Brock loved kids and loved to help people with their vision. He tuned up the vision of young men who wanted to join the service in World War II. When a French teacher's son needed vision therapy, he provided the training in return for extra tutoring lessons for Dee. At the end of our phone conversation, Mrs. Partridge added that she was about to move into a smaller home. She had a notebook of all her father's papers and wondered if I would be willing to take them.

All of the papers that Mrs. Partridge gave me were already present in the library of SUNY's College of Optometry - with one exception. There was an unpublished, type-written manuscript entitled "Lecture Notes on Strabismus" by Frederick W. Brock, and this document summarized Dr. Brock's most important observations and insights.[9] With Mrs. Partridge's permission, I have now published the notes on my website.[b] A synopsis of this manuscript, along with my own thoughts are provided in the following paragraphs.

Frederick Brock began his lecture notes with a list of his basic principles identified as "organismic laws," and, from time to time, referred to people in general as "the organism." These terms sound odd to modern ears, but they derive from Brock's studies of the work of neurologist, Kurt Goldstein, author of the classic book, *The Organism*.[10] Like Goldstein, Brock took a holistic approach to patient care and taught that a patient's symptoms can often be understood as coping mechanisms for his or her condition.

As Brock describes on pages 12 and 13 in his notes, strabismus may be as much an adaptation to, as it is a cause of, a poor ability to fuse. For accurate spatial orientation, an individual should receive similar, fusable images from the macula of each eye. Dissimilar, non-fusible images produce diplopia and visual confusion, requiring suppression of the macular image of one eye. If it is not possible to obtain fusion, then "a determined effort may be made to throw the two eyes into greater disalignment so that the non-macular image of the fixation object becomes so poorly defined (because of its peripheral location in the turned eye) that it can be easily suppressed."

I was very struck by Brock's explanation of strabismus especially when I learned how I used my eyes for reading prior to optometric vision therapy.[11] While fixating the words with one eye, I turned the other by 25 prism diopters. Hence, letters foveated by the fixating eye cast their image on the blind spot of the turned eye. Unconsciously, I had found a way to eliminate conflicting input from the non-fixating eye.

It is the nature of the posture that determines the nature of the responses.

"It is the nature of the posture which determines the nature of the responses... while the eyes are in a strabismic posture, the individual thinks strabismically, but the minute his eyes are in a normal posture he ceases to think strabismically and thinks the way we do."[9] Hence, the ability to interpret stereoscopically does not have to be taught. What has to be taught is the

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ability to posture binocularly, to aim the two eyes simultaneously at the same point in space. This concept summarizes the major theme of Brock's lecture notes and also captures one of the many epiphanies I experienced while going through optometric vision therapy. I remember in vivid detail the vision therapy session where I first attempted to fuse a near then a far bead on the Brock string. I felt for the first time my eyes working together and, later that day, experienced my first stereo views. By moving my eyes into a position for fusion, by making what Brock called a "fusion effort," I ceased to "think strabismically" and saw the world for the first time in stereo depth.

The relationship between our eye posture and our interpretation of the visual scene guided Brock in the design of all his training protocols. He divided eye posture into three basic variations: binocular posture in which one looks at a single fixation object simultaneously with both eyes; monocular posture in which only one eye fixates the target, and finally ambiocular posture (known more commonly as anomalous correspondence.) With monocular posture, the individual uses only the input from the fixating eye to interpret the visual target. In contrast, an individual using ambiocular posture can look in two directions at once and interpret the macular images of both eyes simultaneously. This adaptation develops over time in those individuals who initially posture monocularly and then learn to make use of the macular image of the turned eye. Ambiocular or strabismic seeing provides a sophisticated, visual interpretation of the world. However, normal binocular vision is achieved only when the eyes are in normal binocular posture. Brock maintained that visual training for all strabismics, including suppressors, amblyopes, alternators, and ambioculars, must involve the establishment of binocular posture.

Binocular vision requires a binocular sensory field that assumes, in turn, the existence of fovea-to-fovea correspondence. Brock was adamant in insisting that corresponding retinal regions consist of the two foveas and areas equidistant from and on the same side of each fovea. No other areas are acceptable as corresponding retinal regions. An individual with ambiocular vision does not fuse the images from corresponding regions and does not therefore enjoy a binocular sensory field. Instead, two separate sensory fields exist, one for each eye, and the resulting "ambiocular" field percept results from a summation of the right and left percepts. In contrast, a binocular sensory field percept is neither the percept from the right or left eye but *differs qualitatively from both*. This is a very important insight, one missed by many vision scientists, and one that took me entirely by surprise. When I first was able to position my eyes for fusion, the resulting percept, a sense of palpable pockets of space between objects, was entirely novel. It provided me with a new quale.

How did Brock discover the relationship between eye posture and visual interpretation? Certainly, he learned a great deal from his work with strabismic patients, but a second source for his insights appears on page 30 of the lecture notes. Brock describes how he often experienced diplopia when looking at a traffic light due to an intermittent divergent position of his eyes. It was, he wrote, "a simple matter to fuse [the two images], but this results in *appreciable difference in the general appearance of the landscape*"[9] (italics mine). Thus, Brock experienced for himself the change in visual interpretation that is brought about by a change in eye position.

There is a natural tendency toward completion of a contemplated act and to accomplish it with the least expenditure of energy.

Brock described his visual condition as "retinal slip," or a moderate tropia of the eyes. Under these conditions, the two foveas are no longer aligned, stereoacuity is compromised, but peripheral fusion may still be possible. Brock did not believe that his awareness of diplopia led to reestablishment of bi-fixation. Indeed, he wrote that the diplopic view of the traffic light was a pleasant experience! However, if the driving situation demanded more accurate spatial localization, his eyes moved into binocular posture.

The same was true for many of Brock's patients. "Nearly all strabismics" Brock stated, "have occasional moments when they maintain binocular vision. The only reason this is not generally known is that most of us have never taken the trouble to discover the fact." Many patients, particularly those with exotropia, posture binocularly but only if this effort is necessary for successful completion of a task. As Brock discussed in his "organismic laws," we tend to complete an act by using the least amount of energy possible. If a person with exotropia can accomplish his goal without making the effort to posture binocularly, then he will not expend the energy to do so. Vision therapy must be designed, therefore, to make binocular posture so automatic that it is adopted at all times.

When Brock first met a patient with strabismus, he spent a great deal of time looking for "a point of attack," a distance range in space where the patient postured binocularly. Once this was found, the patient was presented with tasks just outside this viewing range. These tasks could not be completed if the patient remained in a strabismic posture. Instead, the individual had to make a real effort to move his or her eyes into a binocular posture. Only then would the patient make a shift in thinking and arrive at a new visual interpretation. Since most of Brock's patients demonstrated binocular posture at a distance within arm's reach, Brock gradually expanded their binocular range by presenting them with stereo targets projected onto a screen placed further and further away. Like many of his other training tools, he built this projection device himself; he called it a "Brock stereomotivator" (BSM). Thus, Brock attempted to obtain binocular posture right at the onset of training and then strengthened this ability to the point that it became automatic under virtually all circumstances.

Since the patient must make a fusion effort to see with normal binocular vision, passive interventions that compensate for the eye turn, including surgery and prisms, do not generally result in stereovision. Moreover, attempts at training individuals to see binocularly when their eyes are in their strabismic posture are least likely to succeed. Thus, one should not attempt to train a patient to fuse images that are presented through an amblyoscope at the patient's strabismic angle. Binocular vision should always be associated with proper binocular posture.

After years of working with patients with an ambiocular way of seeing, Brock concluded that ambiocular vision or anomalous correspondence did not have to be "broken down." If one could get the patient with ambiocular vision to move his eyes into normal binocular posture, then a normal binocular interpretation of the visual world would ensue. He tells a story of one young woman with exotropia who saw ambiocularly. She came to see him because she needed glasses, not to treat her exotropia. Brock was curious about her vision, however, and asked her to perform some tests with the BSM. He placed two small visual targets, each consisting of a letter enclosed in a little box, on the screen so that one letter was in line with her right axis of gaze and the other in line with her left. He then projected onto the screen a pair of red/green anaglyphic rings that surrounded an image of a rabbit. While wearing red/green lenses, his patient kept her eyes on the letters (i.e., in their exotropic position) and reported that she saw one ring that was half red and half green as is expected for ambiocular vision.

When he moved (or motivated) one ring to the right and the other to the left, the patient initially reported a sideways movement of the ring but did not see the ring leave the plane of the screen. Suddenly, however, her view changed, and she saw the ring float closer to her or recede behind the screen. She even reported SILO. Brock was shocked because this percept should not be obtained if her eyes were in a strabismic posture. He wondered if his years of testing and theorizing had all been in vain. He wrote, "I had hardly the strength to change my location to view the patient. It was with both a decided surprise and relief to find that her eyes no longer seemed in their former exotropic position but appeared to be directed to the center of the screen. My question "Where are you looking?" seemed to come as a surprise to her, because after a moment's hesitation she exclaimed rather dazedly that she felt she was looking at the rabbit rather than the two letters." The transition from ambiocular to binocular posture had given her a qualitatively new view of the world.

Training conditions should be made to simulate natural surroundings as nearly as possible.

Visual training, Brock reminds us, should be designed to bring about a better adjustment of the individual to his natural surroundings. This principle emerges naturally from his holistic approach to patient care. However, this concept is often ignored. For example, patients are asked to work with simple images seen through stereoscopes. We assume that simple images are easier to interpret, a strategy based on a general trend in science to break down complex phenomena into their simpler parts. But there is a danger in trying to understand by oversimplification. For example, Claude Worth described three degrees of fusion: simultaneous perception (first degree), flat fusion (second degree) and stereopsis (third degree).[12] Since this sequence seems to progress from the simple to the more complex, some visual training programs may be designed around training first, then second, then third degree fusion. However, this sequence may have nothing to do with the way our vision normally develops. We are exposed to the three dimensional quality of the world from birth, and our other senses, such as touch, tell us that the world is in 3-D. When we ask a patient to look into a stereoscope that presents a bird to one eye and a cage to the other, we are asking them to perform flat fusion and see the bird in the cage. This never happens in real life. We do not see a bird with one eye and a cage with the other and then make the judgment that the bird is in the cage! Flat fusion is actually a harder and less natural process than stereopsis.

A familiar image, seen every day, no matter how complex, appears more real to us than a very simple form. When training a patient to see stereoscopically, Brock provided conditions that best resembled everyday seeing for that individual. With his stereomotivator, Brock projected stereo targets onto a screen. Such a projection system allows the patient to look out into free space and permits a view of the visual periphery that is important for aligning the eyes. Moreover, fusion of images cast outside the fovea is more easily achievable by a strabismic than fusion of foveal images. In contrast, elimination of the visual periphery with the use of stereoscopes presents a viewing situation that is removed from reality and one that may be hard for a patient, new to stereoscopy, to interpret. While stereoscopes are useful instruments to enhance stereoscopic skills, Brock warned that they should not be used with patients who have not yet developed a binocular field percept or who are prone to regression to a strabismic posture.

On pages 21 and 22 of his lecture notes, Brock provides a striking example of his principles. He describes a young child who had been esotropic since birth. At age four, she began to develop alternating fixation, and Brock was concerned that this behavior would lead to ambiocular seeing. To prevent this, Brock prescribed plano lenses with binasal occluders that prevented the child from seeing with both maculas at the same time. In this way, she could not develop ambiocular vision or the ability to simultaneously interpret the spatial location of both macular images. At age seven, the child underwent an operation that cosmetically straightened the eyes although she continued to alternate fixation. After the surgery, Dr. Brock began vision training first by using his stereomotivator to project anaglyphic Brock rings onto a viewing screen. After some practice, the child fused the images of the ring and exclaimed that the ring seemed to come toward her or recede through the projection screen. Immediately after she experienced this stereoscopic percept, Dr. Brock projected a complex stereoscopic scene onto the screen. The scene was a water buffalo standing in water. Here is where Brock's attention to the individual patient is clearly evident. He chose this image because it most closely resembled a scene from the child's own life: she lived by a cow pasture with a lake. The child looked at the screen for a little while and then cried out to her father, "Say, daddy, that cow is real!" She was fooled into thinking that the virtual, three dimensional image of the animal was a real cow! Brock tested her stereoscopic ability further by asking her to place a flashlight beam only on images perceived at the depth of the screen. Though the child had never before seen in stereo, she performed this task accurately.

According to Kurt Goldstein, new visual experiences do not develop slowly by gradual extension of prior experiences but appear suddenly as complete entities.[10] The story of the little girl seeing the 3-D cow certainly supports this hypothesis. Brock goes on to say, "It is about time that we abandoned the concept that one-eyed seeing differs in any major particular from binocular seeing." In other words, even a one-eyed person understands and appreciates that the world is in 3-D. A cardboard cut-out of a person looks no more real to him than it does to a normal binocular viewer. Brock's young patient, when presented with the right training conditions, could see with stereopsis because this process augmented her lifelong, three-dimensional interpretation of the real world.

Like Brock's little patient, my first stereo view, the steering wheel of my car floating in front of the dashboard, came on quite suddenly and filled me with wonder. This novel percept emerged because my new stereoscopic view of the steering wheel and the surrounding space fit with my longstanding interpretation of the spatial layout of the inside of my car. While this experience provided me with an unforgettable and deeply rewarding experience, I actually saw something that I had always known to be true.

Yet, I would expand on Brock's statement above. A stereoscopic view of the world, as Goldstein probably would have predicted, does come on quite suddenly, but it is deepened by further visual training. When I first fused the images in the Quoits Vectogram, I was able to see a single image of the rope circle and even appreciate SILO, but my sense of depth was shallow. The rope circle appeared only a very small distance in front or behind the vectogram sheets. To calibrate my new stereoscopic abilities, I suspended a string across my dining room so that the length of the string was aligned parallel to the floor and ceiling at my eye level. Thus, when I walked into the dining room, I came face-to-face with one end of the suspended string. I could look down the length of the string and determine at what distance I aimed my eyes by where the string images crossed. Then I held the Quoits Vectogram in front of the string and positioned the fused image of the Quoits to appear around the suspended string. I moved the sheets in the base-in direction, and noted the float of the fused Quoits image. The Quoits image should appear at the distance in space where I was aiming my eyes, that is, at the crossing point of the string images. I took a dowel and probed the space in front of me to locate the virtual, fused image. It took several weeks for me to see the fused Quoits image at the distance in space where the string images crossed, but when I was able to do this, I appreciated a much greater sense of stereoscopic depth.

Shortly after this accomplishment, I noted that my reflection no longer appeared in the plane of a mirror but at some distance behind it. A tree outside the window, framed by the window pane, no longer appeared in the plane of the window. This Christmas season, I experienced the most wonderful illusion. Christmas lights, that were strung across the inside walls of a restaurant, were reflected by the window onto the street outside. "Why are there lights floating in the middle of the street?" I wondered until I realized that these lights were a reflection of the indoor lights and appeared at a distance from the window on the outside equivalent to their distance from the window on the inside. I did not enjoy such illusions with my initial achievement of stereoscopy; the reflected lights would have appeared in the plane of the window. I required further practice and experience to be so fooled. Indeed, my adventures with stereoscopy have come full circle. While, initially, I needed conditions that mimicked the real world to bring out and fine-tune my stereoscopy, I can now use my new ability to see something that is not real!

Single Awareness in Binocular Vision

Stereovision is not an all-or-none phenomena. Brock noted that many individuals have a stereoscopic sense even though they may not develop high stereoacuity. In section IV of the lecture notes, Brock points out that only objects located in the fixation plane are fused. Yet, an object located in front or behind this plane is seen as single. This singleness does not result from suppression of one retinal image. Instead, the object appears to be in a somewhat intermediate position between the projection axes of the right and left eye. Moreover, it is located in depth with respect to the fixation plane, and this depth judgment is better than what would be achieved if looking through one eye only. Thus, the location of the object is still binocularly determined. "Single awareness," Brock wrote, "is then due to a closure by a process of abstraction."

This phenomenon has been called qualitative stereopsis by others.[13,14] It is an important, and usually overlooked, benefit of binocular vision. According to textbook definitions, stereopsis provides an increased sense of depth only for objects whose images are cast on Panum's fusional area, that is, those objects located on or close to the fixation plane. Having learned this definition and taught it to my students, I was astonished to discover, when I gained stereovision, that the whole world appeared in layers and layers of depth. I could appreciate the pockets of space between objects located outside Panum's fusional area. This global depth sense was provided by the ability to take in and merge information simultaneously from the overlapping visual fields of the two eyes. Many patients, particularly those with infantile esotropia, never develop precise foveal-to-foveal fixation and fusion, but the change in worldview provided by the acquisition of qualitative stereopsis and perifoveal fusion is profound.

Since the process of closure involved in single awareness provides a sense of depth, Brock did not favor vision training procedures that made patients aware of physiological diplopia under natural viewing conditions. Diplopia provides an imperfect closure. It is ironic then that one of the most powerful and popular techniques developed by Dr. Brock is the Brock string.[15] As Brock noted, however, the string method uses physiological diplopia to teach the patient where he is aiming his eyes, but it does not resemble a typical target seen under normal viewing situations.

Frederick Brock was clever in the tools he built and thorough in his analysis of individual case studies, but his real strength stemmed from his holistic approach. Brock tried to get behind his patients' eyes and think as they did. He drew an analogy here to his own life. Brock was born in Switzerland and spoke German until coming to the United States. Eventually, English became his preferred language. Concerning his adoption of English, he wrote, "The most difficult phase of the transition was that from thinking in German to thinking in English…It took a tremendous effort of will for me to make a total shift from German dominated thinking to English…For the cure of a strabismic a similar transition has to be made."

When Dolores Brock Partridge gave me Dr. Brock's papers, she also included his academic hood, a garment worn in graduation ceremonies. As a professor at Mount Holyoke College, I march twice a year, at convocation and graduation, in full academic regalia. Since I received my Ph.D. from Princeton University, I don my Princeton academic robe. But I put on Brock's hood. The colors of the hood clash with the black and orange of the robe, but that does not matter. If I am going to march in an academic procession, I want to honor a true scholar, Dr. Frederick W. Brock, whose humanity and work continue to inspire.

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Footnotes

a. Brock published over 100 papers, journals, manuals, monographs and lecture notes. Samples can be found in the References and Further Reading.

b Dr. Sue Barry's website: www.stereosue.com.

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