BrienHolden Vision Institute

INTRODUCTION TO BINOCULAR VISION

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COURSE OVERVIEW

Vision is perhaps the most important of our senses. This is indicated by the fact that about 50% of the cerebral cortex is involved in visual processing. Vision provides us with a tremendous amount of information about the world around us. This tells us two important things about the objects we see:

- What they are, and
- Where they are.

Vision is based on the retinal image formed in each eye, and monocular vision alone provides us with much information that helps us identify and recognize objects — the 'what' part. Monocular vision also provides important data about visual direction, motion and depth perception — the 'where' part. Binocular vision — that is, vision that results from the combined input from two eyes — significantly enhances both of these aspects of vision, but its greatest contribution is in our perception of where objects are located. After this introduction, our study of binocular vision will be organized according to the following outline:

A. NORMAL BINOCULAR VISION	1. Visual direction 2. Binocular fusion - motor fusion 3. Binocular fusion - sensory fusion 4. Fixation disparity 5. Binocular summation 6. Ocular dominance 7. Depth perception & stereopsis
B. ANOMALOUS BINOCULAR VISION	1. Alternatives to normal sensory fusion a. Rivalry & suppression b. Aniseikonia 2. Developmental binocular anomalies a. Normal binocular development b. Anomalous development c. Amblyopia d. Strabismus e. Eccentric fixation f. Anomalous correspondence

IMPORTANCE OF BINOCULAR VISION	Why is the study of binocular vision important to clinical optometry? Clinical applications of this basic science include: • Managing patients with complaints of eyestrain, headaches, difficulty reading, etc. • Paediatric optometry • Vision therapy • Monovision and contact lenses Q. What is the purpose of binocular vision? A. Simply put, the purpose of binocular vision is to enhance the quality of vision that we have with each eye alone.
ADVANTAGES OF BINOCULAR VISION	A scientist once said, "with the exception of stereopsis, seeing with both eyes is marginally, if any, better than seeing with one—absolute threshold, differential threshold, and visual acuity being about the same." (Von Noorden GK. (1996) Binocular Vision and Ocular Motility - 5th edition. Mosby, St. Louis) What are the advantages of binocular vision? Are two eyes better than one? **Major benefits:** • Larger visual field: Without eye movements, the monocular field is about 150° wide. With both eyes, it's at least 180° wide. Note that there is considerable overlap of the two visual fields in the forward direction. Interactions from the two eyes can occur within this binocular portion of the visual field. (Steinman et al. Foundations of Binocular Vision. McGraw-Hill, New York, 2000.) • Stereopsis: Stereopsis is the highly accurate sense of depth perception that is unique to binocular vision, and is usually considered the most significant advantage gained by binocular vision. **Other benefits:** • Spare eye. If one eye is lost to injury or disease, we will still be able to see well with the other. • Binocular summation. Within the binocular visual field, certain aspects of vision are improved due to the combination of input from two sensors (two eyes) rather than one and the result is better sensitivity/easier detection of visual stimuli. Greater sensitivity makes things which are smaller, dimmer, quicker, etc. more detectible. The improvement may be small, but it definitely improves certain aspects of vision. These include visual acuity, light detection thresholds and seeing a camouflaged object. • , ,. **Other enhancements to visual performance.** Binocular vision also provides better space perception, hand-eye coordination, more efficient and comfortable reading, etc. Parents of children who have had their strabismus corrected, thereby changing from monocular to binocular vision, often report that their children's visual-motor skills such as hand-eye coordination are vastly improved. (von Noorden, p. 37-38)

DISADVANTAGES OF BINOCULAR VISION	Are two eyes always better than one? If so, would multiple eyes (such as spiders have) be better than two? Not necessarily. In fact, there are some disadvantages to binocular vision. The neurophysiology needed to support and fuse the input from two eyes is more complex than if we just had one eye. With greater complexity, there is more potential for problems. Binocular vision has its own unique set of problems that arise when part of the binocular system is not working correctly. Binocular visual anomalies are frequently the cause of symptoms such as eyestrain, headaches or difficulty reading. Many of these problems would not exist if we had only one eye. For example, binocular stress can be caused by: • Incorrect refractive balance • Dissimilar images between the two eyes due to anisometropia or retinal disease • Over or under convergence • Conflicts between accommodation and convergence In an extreme case, such as intractable diplopia, the only solution to a binocular problem may be to occlude one eye, that is, discontinue binocular vision. You could do this by prescribing an eye patch. This prevents binocular fusion and renders the patient monocular. In this case, the binocular system causes more trouble than benefit.
MISCONCEPTIONS ABOUT BINOCULAR VISION	• Some people incorrectly assume that the only advantage to binocular vision is stereopsis. As we discussed already, there are other advantages. • Some think that, without binocular vision, you have no depth perception. Actually, there are many important monocular cues that allow you to judge depth in the absence of binocular vision. In some cases, monocular depth perception is superior to binocular depth perception. • Some people think that stereoscopic depth perception helps them judge depth for distant objects; for example, a pilot landing an airplane, or for driving. Beyond a few meters, stereopsis contributes little to depth perception beyond what we already have from monocular depth cues.
BINOCULAR VISION, DEPTH PERCEPTION & THE CASE OF DELTA FLIGHT 554	In the early evening on October 19, 1996, Delta Airlines flight 554, from Atlanta to LaGuardia Airport in New York was approaching the runway in heavy rain and fog. Visibility was severely restricted, so the pilots were depending on instruments until the last few seconds of the final approach, when the runway and guide beacons became visible. The control tower had directed them to land on runway 13, which is built on a concrete causeway that extends into the bay, so they were approaching over water. A few seconds before they were to touch down, the pilot realized that he was too low, and in danger of flying into the wall at the end of the causeway. He raised the aircraft, but not quite enough to completely clear the wall. The landing gear was clipped off, and the aircraft skidded 3,000 feet down the runway on its belly. The crew conducted an emergency evacuation, and fortunately there were no deaths or serious injuries.

BINOCULAR VISION, DEPTH PERCEPTION & THE CASE OF DELTA FLIGHT 554

Figure 14.1 *Delta Flight 554 on the runway following the accident*

The National Transportation Safety Boards (NTSB) investigated the accident, and found that during the final seconds of the approach, the pilot and co-pilot thought the aircraft was higher than it actually was. Several factors contributed to this almost-fatal error:

- Unknown to the crew, the vertical speed indicator was providing information that was delayed by a few seconds. Also, when the pilot thought they were descending at 700 feet per second, they were actually descending at 1,200 feet per second.
- Whereas most other runway lights are regularly spaced at 200-foot intervals, the ones at LaGuardia Airport were spaced at 150 feet. This could have given the pilots the impression that they were higher than they actually were.

  In addition, the accident report described several visual illusions that may have contributed to the accident:

- "Featureless terrain illusion: An absence of ground features, as when landing over water, darkened areas, and terrain made by featureless snow, can create the illusion that the aircraft is higher than it actually is."
- "Atmospheric illusion: Rain on the windshield can create the illusion of greater height, and atmospheric haze creates the illusion of being at a greater distance from the runway."

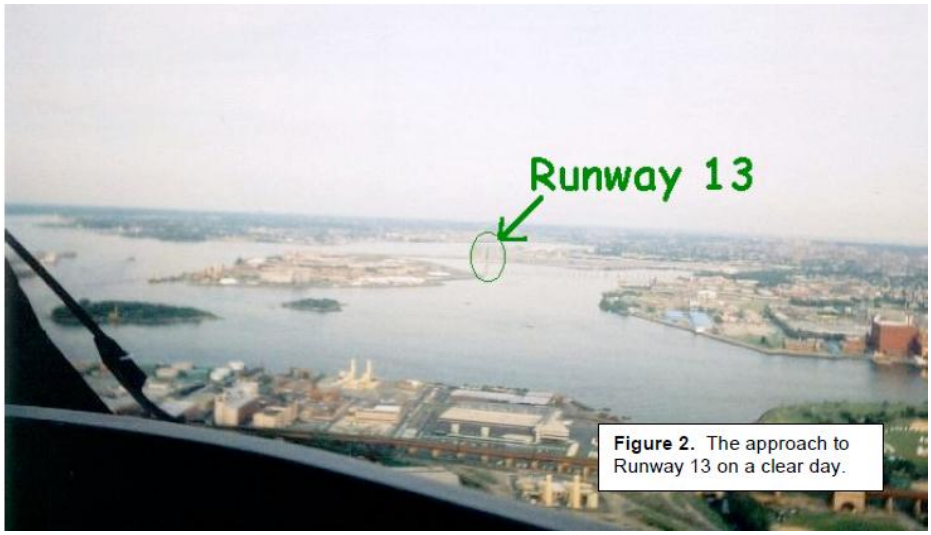

Figure 14.2 *The approach to runway 13 on a clear day.*

BINOCULAR VISION, DEPTH PERCEPTION & THE CASE OF DELTA FLIGHT 554

Finally, after the investigators discovered that the pilot had been wearing monovision contact lenses they identified this as the major cause of the accident. The NTSB concluded that,

... the probable cause of this accident was the inability of the captain, because of his use of monovision contact lenses, to overcome his misperception of the airplane's position relative to the runway during the visual portion of the approach. This misperception occurred because of visual illusions produced by the approach over water in limited light conditions, the absence of visible ground features, the rain and fog, and the irregular spacing of the runway lights.
Contributing to the accident was the ... incomplete guidance available to optometrists, aviation medical examiners and pilots regarding the prescription of unapproved monovision contact lenses for use by pilots.

Figure 14.3 *The approach to runway 13 with degraded visual conditions.*

This accident was the topic of an article, written by Dr. Van Nakagawara, research optometrist for the Federal Aviation Agency (FAA), in the June 2000 issue of Optometry, the Journal of the American Optometric Assocation. He and other doctors who understand the principles of stereopsis and binocular vision have questioned the conclusion of the NTSB report.

Quoting from one expert, Dr. Robert Liddell, past Director of Aviation Medicine in Australia, stated: "I am astounded that the (US) aviation community lets the NTSB get away with some of their comments and flawed conclusions.... Blaming monovision for the MD-88 accident immediately implies that all monocular pilots can no longer be expected to operate safely.... Equally it negates the hundred of successful landings under all sorts of conditions.... Unfortunately, the NTSB tends to blame accidents on any misdemeanor possible."

(http://www.airlinesafety.com/editorials/Delta554.htm)

The reduced stereopsis (due to monovision), probably did not contribute significantly to this accident. Following this incident, the FAA banned the use of monovision for pilots, mainly because of the NTSB's conclusion about this accident.

The NTSB report is available for download at (http://www.ntsb.gov/Publictn/1997/AAR9703.htm).

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