Behavioral Vision Care

Chapter 1

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What is Vision?

Vision is the deriving of meaning and direction of action as triggered by light. Vision is much more than sight or how clearly one sees, which is commonly measured and termed acuity and is better called *sight*. Vision is one's comprehensive ability to organize that which can be seen in such a way that one understands what is seen and can use that understanding to guide and direct one's actions to achieve the things wanted and needed to survive and to enjoy life.

What is vision? Arthur Zajonc catches the essence of the totality of vision in the opening paragraphs of his book, *Catching the Light - The Entwined History of Light and Mind*. He recounts the life of an 8-year old boy, blind since birth because of cataracts, on whom surgery was performed to restore sight.

"Following the operation, they were anxious to discover how well the child could see. When the boy's eyes were healed, they removed the bandages. Waving a hand in front of the child's physically perfect eyes, they asked him what he saw. He replied weakly, 'I don't know.' 'Don't you see it moving?' they asked. 'I don't know' was his only reply. The boy's eyes were clearly not following the slowly moving hand. What he saw was only a varying brightness in front of him. He was then allowed to touch the hand as it began to move; he cried out in a voice of triumph; 'It's moving!' He could feel it move, and even, as he said, 'hear it move,' but he still needed laboriously to learn to *see* it move. Light and eyes were not enough to grant him sight. The light of day beckoned, but no light of mind replied within the boy's anxious, open eyes. The lights of nature and of mind entwine within the eye and call forth vision."

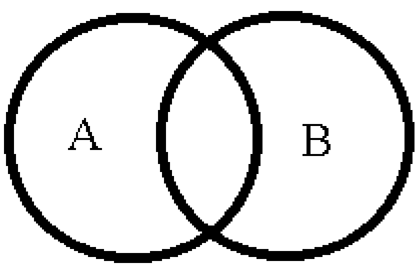
Vision is much more than the ability to see small detail at great distances. It is the total ability to organize light input and recognize spatial relationships between things and to build an internal representation of reality. From that internal representation of reality, which is by its very nature incomplete, vision provides the organism with the information necessary to make decisions about which actions to take and in what precise way to execute the chosen action.

To do this the person needs to extract huge quantities of information and data from nearly all parts of the body and use all the sensory input available from the external world. This information is then integrated into a whole which does not have discrete separate sensory parts, but which is assembled into a unified whole.

The Four Circles of Skeffington

Vision is a very complex, highly parallel processing activity involving nearly every part of the human being. In the written or spoken form, material must be presented in a sequential manner. Many different ways can be used to organize most complex systems both conceptually and for presentation. I have used the four-circle concept first put forth by the father of behavioral optometry, A.M. Skeffington, as a vehicle through which to explain my understanding of vision. The four circles of Skeffington are not presented as*the model* of vision. The four circle description is just one among many ways through which one may explain vision.

Sometime in the mid-1950's, Skeffington and a number of other optometrists were at an annual summer conference at Ohio State University. At these meetings, many of the concepts and ideas and theories of how the visual process works (which we now take for granted) were first being understood. Psychologist Sam Renshaw, the host of the meetings, was presenting to the group information on Boolean algebra and set theory. Two overlapping circles were drawn to represent two sets and their intersection. The areas of "Only - A", "Only - B" and "Both A-and-B" were being explained (Fig. 1.1).



Overlapping Sets A & B

Figure 1.1

At the time, the popular Ballentine beer logo was three rings arranged in an overlapped triangular pattern. Each ring stood for a different characteristic of the beer; *purity, body*, and *flavor* (Fig. 1.2). After a bit of doodling on napkins, the four circles were born, and Skeffington adopted them as a presentation tool (Fig. 1.3).

Ballentine Company Logo

Figure 1.2

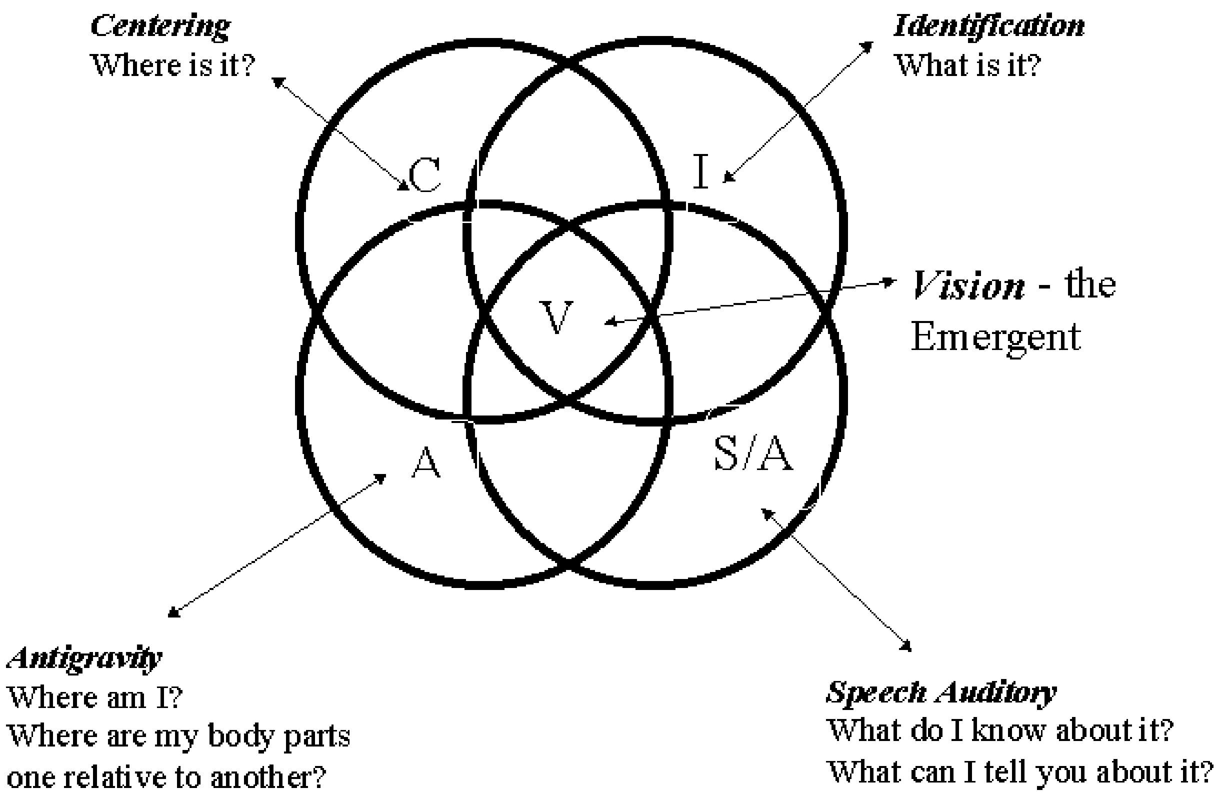


Figure 1.3

Antigravity

Skeffington named the first circle the *Antigravity* Circle. The name itself does very little to explain exactly what this signifies. What, then, constitutes that which is referenced by this circle? Included in the Antigravity Circle is everything a person uses to answer the fundamental question: "Where am I?" Sub-questions include: "Where am I in space?" and "Where are my body parts in reference to the other parts of me?"

Gravity is one of the most stable relative constants we have in our lives. Gravity defines for us "down," from which we establish for ourselves our own three-dimensional space coordinate system. Several key building blocks go into helping us build this internal space coordinate system and representation of reality.

Semicircular Canals

The first element is the bilateral semicircular canal system connected to the otoliths of the inner ear. From this we derive both positional information relative to the gravitational force as well as acceleration and deceleration information relative to gravity. We get an idea of where we are in reference to gravity, which is pulling down on us. We also get information about whether we are changing speeds relative to the constant. Interestingly, we do not get direct information about movement from the semicircular canals when we remain in a motion along a straight path at a steady velocity. We need other clues to shifting frames of reference whenever we are not changing positions relative to gravity. This information is coming from within our head. How then do we know where our torso is in reference to our head and where our legs are in reference to our torso and to our head?

Proprioception

Proprioception is the second piece of information used to help establish for each person where he or she is in space and where their body parts are, one in reference to another. The stretch receptors in our muscles and connective tissue throughout the body provide the information from which we derive the relationships of one part of our body to another part.

A minimum of two muscles operate any given joint in the body and, in many cases, many muscles operate around complex joints. Simplistically, during any joint movement there are both an agonist and an antagonist muscle. In simple joints this is accomplished with just two muscles. In joints with more degrees of freedom of movement, combinations of muscles may act as single agonist-antagonist pairs. The agonist muscle contracts and the antagonist muscle relaxes tension. By knowing precisely the degree of contractedness and the amount of stretch around a joint, one can know the exact angle of the joint. Taken together, one can know where all the parts of the body are in reference to each other. Obviously, then, the afferent or sensory fibers from the body are critical in building a complete representation of the self and in organizing all the parts into a whole.

Elliott Forrest described the body as being three inverted triangles, each with its apex pointed downward (Fig. 1.4). The first triangle consists of the pelvis, legs and feet. The second triangle consists of the torso from the shoulders to where the spine inserts into the pelvis. The third triangle is the head itself perched on top of the spine. It obviously takes a commitment of a certain amount of energy to keep the body from falling over. We must constantly monitor aspects of these complex relationships to keep the body from falling and to direct it knowingly through the complex series of movements we do to perform even the simplest act.

The Body as Three Triangles

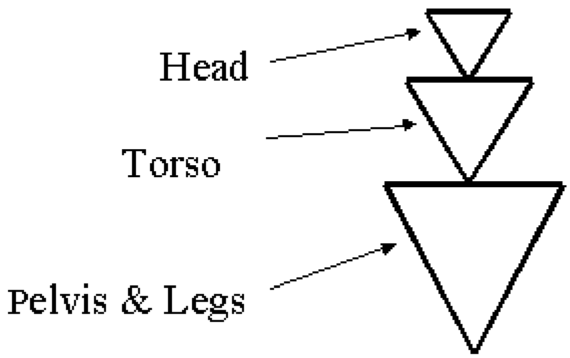


Figure 1.4

Darell Boyd Harmon first described the functions of connections between each of the triangles as transducers of relative positions in space. The most important transducer was noted to be the intersection between the head and the torso, located at the top of the spine. The muscles of the neck can supply the necessary information of relative position, but much more precise information is needed from this critical junction.

To help understand the need for precise information, imagine the following. Look at an object far to your left for a moment, turning your head as far to the left as you can. Make sure you look directly at the object. The chief ray of light from the object falls on your fovea. Now, turn your head far to your right and pick an object to look at. Be sure to look directly at it. The light from the chief rays from that object are now falling on your fovea. Are the two objects in the same place in space? Of course not. However, they were both, at one point in time, being looked at directly. The difference was that, over time, you moved your head from side to side. Position of the object on the retina gives no *absolute* information about where an object is in space. The information derived from where images of objects fall on a retina yields only a relative spatial mapping.

To translate this relative information into absolute information, one needs information about the relative position of the eyes in the orbit, the position of the head relative to the torso, and the position of the torso relative to the legs, and so on. In addition, the quality of this information must be consistent. Any loss of granularity, fineness, or precision in the data will degrade the entire system.

How do we know where the eyes are in the sockets and how do we control the movements of the eyes so precisely? The answer lies in the richness of the connections of the cranial nerves that connect to the twelve extraocular muscles and the relative sizes of the muscles in relation to the mass of the eye. Each eye is surrounded by six muscles that are used to point the eyes toward the area of space selected by the person.

Individual contractile fibers in muscle tissue contract in an "all-or-none" response. When activated, each individual sarcomere contracts fully. One way to have fine control would be to have a plethora of additional nerve fiber endings, or motor plates, per unit area of muscle. Another would be to have a large muscle mass in relation to the amount of mass to be moved. By having much more muscle than is necessary and maintaining the same number of motor end plates per muscle mass, one would have the additional fineness for incredibly accurate control as well as fine feedback from the stretch receptors to know where the eye is in the socket.

Without this fineness of control there would be no need to have such a dense packing of the receptor cells in the retina. The fineness of detail in the flow of data streaming down the optic nerve to the brain would be lost without precise aiming abilities and without the precise knowledge of where the eye is in the head. It is critical to have sensitivities in all three areas (aiming of the eyes, proprioception of the eyes' position in the orbit, and density of detail within the flow of visual data from the retina to the brain) that are all at nearly the same level of fineness. If any one system is below the levels of the others, the validity and reliability of the data obtained by the organism from its environment will be degraded or compromised.

Eye muscle mass is five times bigger in relation to the mass of the eye that has to be moved than any other muscle-to-mass ratio in the entire body. This provides the necessary fineness of control, and provides enough muscle mass from which the afferent fibers can give back the fineness of data from which to know exactly where the eye is in the orbit.

C1, C2, C3 Afferents

We need very precise information about where our head is in reference to our torso. It might be possible to get this information from the cumulative proprioceptive data from the muscles that form and bridge the neck. These muscles move the head and keep it balanced atop the spine. Additional information is gotten which is extremely significant in keeping the fineness or the granularity of the inputs small to help know precisely where the head is in space. The afferent fibers from the C1, C2, and C3 dorsal cervical nerves serve this purpose.

In a series of studies reported by Leonard A. Cohen, it was shown that these inputs affect orientation abilities of a monkey in ladder-climbing tasks more than did complete bilateral removal of the semicircular canals. In fact, the monkeys recovered more function at a quicker pace when the semicircular canals were removed than when inputs from these three dorsal cervical ganglions were severed. Cohen believes that too much emphasis has been put on these vestibular components because it is easy to see and understand what their role is. Understanding the role of the information from the dorsal cervical gaglion is more difficult and, until Cohen's pioneer work, might never have been achieved at all.

Case Examples

Before discussing the key inputs from the flow of visual data from the optic nerve to the antigravity process, a few cases might help to clarify the roles of the inputs described above.

Mr. McGregor: In his book, *The Man Who Mistook His Wife For a Hat,* neurologist Oliver Sacks describes the case of Mr. McGregor, a 93-year-old former carpenter with advanced Parkinson's disease. Mr. McGregor walked with a list, or tilt, to his left of nearly 20 degrees, but had no awareness of his tilt whatsoever. The concern, of course, was that he might fall.

Sacks videotaped him walking and together they watched the tape. Seeing the tape, Mr. McGregor became aware for the first time that something was wrong. He thought for a moment and said to Sacks, "It's like the spirit level in my head is broken." To which Sacks replied, "YES!" However, realizing what was broken and fixing it were two different things. Eventually, Mr. McGregor ended up devising an addition to his glasses that suspended the bubble assembly from a carpenter's level at about 9-10 inches directly in front of his eyes.

Mr. McGregor soon learned to walk with the level as his guide. At first, he had to look constantly at the level and got very tired. Gradually he was able to pay less and less conscious attention to the level device and learned to use the information from the level subconsciously. Finally he learned to walk straight, using the visual information about gravity as a replacement for the information he should have been getting from the semicircular canals in his inner ear. This case demonstrates very well the importance of the information used by the visual process in constructing our internal representation of space. This is but one part of the antigravity process, the foundation upon which vision is built.

The Case of the Disembodied Lady

Another of Sacks' patients was a woman who entered the hospital to have some gallstones removed. It became evident that she had acute polyneuritis that purely affected solely the sensory roots of the spinal and cranial nerves throughout the entire neural structure. All inputs to the brain from proprioception were blocked.

(Remember that proprioception tells us where our body parts are in reference to each other. Information from muscles and ligaments throughout the body communicates the degree to which they are in tension. Using all the information from all these muscles and ligaments together, we construct an image of our body and place our body parts all in reference to each other. Thus, if I decide to grab something, in order to give the correct set of orders to my arm, I must first know where my arm is. How to direct a hand movement if I do not know where my hand is? How to pick up food if I do not know where my mouth is? It is proprioception's job to constantly monitor all of this.)

In this instance, the poor woman lost it all! Proprioception was completely knocked out and never returned. She had sensation to deep pressure (meaning that she could distinguish between her arm and her leg if either was squeezed tightly) and retained awareness to heat and cold. She could tell when her hand was touching something hot or if it was in cold water. But she had no idea where her hand was in reference to any other part of her. Thus, without knowing where her arm was at the time, she had no idea what direction to move it to get away from the heat or toward safety. She had become unable to direct actions because she did not know where her body parts were by feel.

It was decided to use vision to help her learn to move again. The patient was surrounded by mirrors and learned how to move again exclusively by using visual input and visual information. She noted, "What I must do then, is use vision, use my eyes, in every situation where I used -- what do you call it? -- proprioception before. I've already noticed, that I may 'lose' my arms. I think they're one place, and I find they're another. This 'proprioception' is like the eyes of the body, the way the body sees itself. And if it goes, as it's gone with me, *it's like the body's blind*" (italics in original). Sacks noted that her new movements were all very highly stylized, such as a dancer or actress might do. They were very unnatural but she could function sufficiently and eventually lived independently again.

Some Neurology

At this point, some insight into the neurology underlying the Antigravity Circle would be helpful. The optic nerve, which connects the eye with the brain, at first appeared to be a fairly simply nerve. It was believed that the eye and retinal complex converted light energy to chemical energy then to electrical energy and that the electrical energy somehow transmitted a "picture" to the brain. Phenomenologically this is what must happen because it matches our experience. We know that cameras take pictures of the world. We also know that what we see and the image we are aware of are just like the picture a camera takes or that a television shows us. So the eye must be like a camera, and somewhere in our head we view the picture when we are conscious.

But it turns out that this simple picture is not true. In reality, aside from the main branch of the optic nerve (which proceeds to the visual cortex), nine additional branches of the optic nerve feed visual data to other areas of the brain.

Another startling fact, discovered by Karl Pribram in the early 1980's, is that the optic nerve is not a one-way conduit of information towards the brain. Pribram demonstrated that in monkeys, 8% of the optic nerve was actually carrying information from the brain to the retina. The exact purpose of these fibers is yet to be determined. However, some speculation about the role these fibers fill might relate to how we recognize things we are already thinking about much sooner than things that we did not think about beforehand.

As an example, many have experienced driving in a new place and looking for a specific street. As we approach a street with a name other than the one we're looking for, we have to get very close before we can actually read the street sign. When the street we are actually looking for is indeed the one in front of us, we recognize the sign much further away. We may not be able to decipher the individual characters that make up the sign, but we "know" that we've found the right street. We relax and know we are there. Only as we get closer can we actually read the street sign. Does the brain transmit the pattern of what we are looking for forward to the retina to allow a match to occur with incredible speed? The answer is unknown at this time.

One branch of the optic nerve that accounts for about 20% of the fibers in the optic nerve connects directly to the superior colliculus. I first learned about this branch not in optometry school, but at a seminar of behavioral optometrists the summer after I completed my optometric education. When I first learned of it I considered it insignificant. I was totally convinced that, because I did not learn about it from my neurology teachers, the behavioral optometrist presenting the information certainly must have been misinformed. I didn't think I could possibly have missed that, given the expensive education I had just completed.

Current neurology research, and, most recently, research by Lawrence Weiskrantz, a British neuroscience researcher, states that until recently the role of these fibers was not understood. In his article on blind sight Weiskrantz notes that this 'little' branch coming off the optic nerve was actually 10 times the size of the auditory nerve, through which everything we hear comes to us! I had to stop thinking of this branch as being "insignificant"!

This branch to the superior colliculus seems to be the most heavily implicated in going to the areas where the information from the semicircular canals, proprioception information from the entire body, and the afferent inputs from the C1, C2, and C3 dorsal cervical roots all go. This, therefore, is where the information from the balance centers and the proprioceptive information from the muscles and tendons and ligaments of the body are combined with input from our lighted environment. From this and more we construct a representation of space, with us placed at the origin. Our final goal is to create a representation of reality.

Thus, the Antigravity Circle is that which includes everything we use to know where we are in space and where all our body parts are in reference to each other and everything else. This is the first step toward vision. Within each of us we build a representation of reality. That reality has to be built around something, and we build it around a sense of where we are in space.

Skeffington said, "He who is insecure in his space world is insecure in his ego!" Without a stable representation of space and self within that space, difficulties of the self may emerge. These may manifest, as the severity changes, as various psychoses, including schizophrenia, agoraphobia, autism, and dissociative personalities.

Antigravity; Everything the person uses to answer the fundamental question, Where am I?

Centering

The second part of the formal definition of vision is that vision directs action. Once we know where we are and where our parts in space (Antigravity) and we lock on target or on a stored representation of the target (Centering), we can then direct our actions to that specific place in space.

Centering is the second of the Four Circles of Skeffington. It is one thing to know where one is in reference to gravity and to know where one's parts are in relation to the rest of the self. It is something else to know where one is in relation to another object in space. To manipulate something in our environment, to perform work, to do *anything*, we must relate to something in our environment, in the past, the present, or the future. Centering is everything the person uses to know where something is in reference to themselves. We must orient ourselves to the task. Everything involved in orienting ourselves to the task and coming to balance with the task is part of centering.

If I am thirsty and remember that I have a cup of water on my desk and I want to take a drink, I must do several things to quench my thirst. Centering helps me to locate and then to know exactly where the cup is in relation to where I am so I can begin the process of directing my actions to that specific place in space.

The entire body is used in centering. If the target we have selected to look at or need to look at is nearly straight ahead of us, the bulk of the three body triangles takes on a supportive role, allowing us to lock onto the target by simply moving our eyes so that each eye is now directed toward the target. However, if the object we wish to look at or manipulate is off to one side, we may turn our head and eyes to locate the object. Because this might put us out of balance to pick up or to manipulate the object, we might take a step or realign the lowest triangle (legs and pelvis) toward the object. As we do this, the second triangle (torso) also rotates so that the object is also centered. As soon as a particular triangle is finished moving to bring it in balance with the task, that triangle then takes on a supportive role. The head is brought around by the neck muscles, supported by the two triangles below. The muscles of the lower and upper back are critical in getting us on target and helping us know where the object of regard is relative to us.

In a very complex part of the centering process, the eyes are also brought into alignment with the object. Each eye has six muscles that surround it. Normally, the eyes lock on target or lead the direction of movement toward the target. To reduce the expenditure of effort and energy, to bring about a homeostasis, the person rotates and realigns the lower triangles to come to balance with the task. Each person derives the location in space of themselves and objects; once both are known, the person can direct actions accurately and efficiently. Vision directs the action. Any inaccuracy in knowing either where the person is, or where their body parts are relative to each other, or where the object is will result in motor inefficiencies.

The 12 eye muscles must be used in a coordinated manner. The level of coordination between them, or lack thereof, is critically important in determining how accurately and efficiently the person carries out myriad daily tasks. Here is the difference between the average athlete and the superstar. Here is the difference between most children with learning problems and the child who does extremely well in school. Here is the difference between the person who works at a computer terminal all day and goes home invigorated by the experience and the person who can't wait to go home after just 45 minutes at the screen.

A part of centering, then, is the use, control, and coordination of these 12 muscles to align the two eyes with the object in space. If the object is closer to the person, the eyes must converge. If the object is further away than the last object the person looked at, the eyes must diverge to coincide with the new object. These movements occur in three-dimensional space over time. Often both the person and the object are actually moving through space while these calculations and these redirecting movements are taking place.

The person selects the area of space on which to focus attention to facilitate the person's ability to derive meaning from that location in space. The location in space is selected based upon the person's perceived need for more information about what is in (or happening in) that area of space. If the area has been preprocessed in such a way that no new information is needed, the person may choose not to look directly at an area and choose to direct action based on the previously stored information about a particular object.

Interestingly, our perception is that we are continuously in visual touch with the lighted world around us. In actuality, we sample information from our lighted world about five times per second. About five times per second we turn on our sampling devices and take a sample of the energy around us emanating from a particular place in space. The recording devices are turned on for a brief burst, a brief update, and then shut down.

It takes about 1/10th of a second for light energy to be transformed into chemical energy and then to be transformed to electrical energy then to travel through the optic nerve to the lateral geniculate body and then to the primary visual cortex. Attention centers in the midbrain also get their share of information both directly and from areas where this parallel information has been more highly processed. Somehow this disperse parallel processing is reassembled into a single whole of which we are conscious. We know that there is no homunculus (little man in the head with a view screen) and we know that the information does not converge neurologically to a central place where the mind sits and is conscious. Through a complex process, which is just beginning to be understood, each person combines all this information, makes judgments, and prepares to sample the world again to update their internal representation of the world. This aspect of vision is covered in more detail in chapter 2; The Space World.

Centering is the total process whereby a person orients toward a particular object in space to prepare to derive meaning and to direct action in that area of space. Centering involves the entire body and includes directions given to the three triangles and, in particular, to the muscles of the back and neck, and the 12 extraocular muscles. Input is needed from all these muscles about their relationships to each other and from the spatial mapping of the light patterns over time flowing onto the retina.

Centering; Everything the person uses to answer the fundamental question, Where is it?

Identification

The third circle is the *Identification Circle*. Included in this is everything the person uses to answer the fundamental question, "What is it?" It is how we identify the objects we have located in space and to which we have oriented ourselves in space. To identify something we must have had previous experience with that object or a similar object. Developmental psychologist Jean Piaget spoke of the *object concept*. We are not born with object concepts. We must build them.

An *object concept* is everything we know about a particular thing. For example, I might look at a cup. As a result of the cumulative experiences that I have had in life, I have developed an object concept of "cup." This includes everything I know about cups such as: there are some for hot drinks, some for cold drinks, some that can go in a dishwasher and some that can't, some that are for ceremonial use and some that can be thrown away, some for special occasions, and some for everyday use. Some cups we use when we just want a quick drink, some we use when we are really thirsty.

My object concept represents the cumulative meaningful and totally personal experiences that I have had throughout my life. My object concept, although very similar to most peoples' object concept of cups is, however, uniquely my own. I may have had some experience with some cups that someone else has not had. A cup in the middle of a Passover table -- Elijiah's cup -- may have more significance to me than to someone who is not familiar with what Passover is. Someone might know that it is called Elijiah's cup but have no idea what it represents. Conversely, I may look at some cups that are used by others for special purposes or times and have no concept of the significance of that cup to a specific person.

Our object concepts are unique. However, the core concepts are most often shared between members of the same group of people. I don't call a car a cup. If one did this consistently one would find oneself being viewed very differently and perhaps institutionalized. Although each of us builds our own unique object concepts about the things we know, we do so following social guidelines. Our customs and our language are very involved in the development of our object concepts. The recent work of Nobel prize winner Gerald Edelman (*Bright Air Brilliant Fire)* points out that our neurology has specifically evolved to support the types of reentrant processes that would support the development of object concepts and the consciousness necessary to hold the concepts active long enough to think about and to be useful. Reentrance is when the output of a computational area is fed directly back into the same section that it was just input for.

The data are subtly changed each time through the system. The concept is that loops can be set up that seem to resonate within the system or persist through this reentrance.

At times we come in contact with a new or novel object or a situation. If the object is not too foreign to us, if it is not too different from anything we have already experienced, we may become puzzled by it. We activate or turn on the object concepts we feel are related in some way. We attempt to resolve the conflict between that what we know and what we are experiencing. We can resolve this conflict in one of three ways: flight, fight, or fright.

Flight Response

The first response may be no response at all or we may simply ignore the situation. We may be too challenged by the new information, concept, experience and turn away from it. We may not even be aware of the new object or situation and it just passes us by. This response leads to no new development and doesn't help us reclassify things or build more complete, more accurate object concepts. This is not the goal of education or early childhood developmental programs. Too frequent flight response from too much conflict results in a lack of overall development, and may be a major factor in the development of juvenile delinquency and other social problems (*reference future chapter*).

Learning

A person may already know a lot about the experience they are involved in. Their stored object concepts may be sufficient to understand this new situation. It takes on a slight *accommodation* (used in a Piagetian sense) of their stored object concepts to incorporate the new information from the experience. The stored object concepts already held are not radically altered or rearranged, but are slightly elaborated or modified. As a result of the new experience, the person develops a more richly constructed object concept.

Development

A person may know enough about the new experience to avoid fleeing a situation, but, they may have things organized or classified in such a way that the new experience causes some stress and cannot easily be incorporated into their old pattern of thinking. Each time they try to incorporate the new concepts into the old organization, they see or feel something is wrong. Stress levels may build to a point that, suddenly, a spontaneous reorganization of the underlying object concepts allows for the emergence of a new underlying organization and classification system. This is called development and it occurs continuously in the young child. These major changes tend to occur less often as we age and as our ensemble of object concepts grows to meet most of our new encounters with ease. As we mature we experience fewer and fewer new things (unless, of course, we lead a highly unusual life).

When we look at an object in our environment, most often we do not see purely that which is available in the flow of data in the sensory streams. We don't often pay conscious attention to the precise curvature, color, contrast, or light patterns from the object we are looking at whose "picture" is viewed somewhere in our mind. Rather, the distribution of light that hits our retinas triggers off our stored object concepts. When I see a cup in space, I don't just see the image of that one cup. Rather I see a cup generated from my internal stored object concept of "cup" that has been triggered from the sensory flow. It is from this stored object concept being triggered that the information I know about cups is brought alive for my conscious and/or subconscious use of the information. A glance at the cup may bring about a complex process that has me checking out whether or not I am thirsty and may start a complex process whereby I take a drink of water or decide to forestall that drink and continue doing what I am doing. I may not even be consciously aware that all this is going on, even though its actually occurring at some level in my mind and brain.

Selective Attention and Signal-to-Noise Ratio

Selective attention and signal-to-noise ratio involve the use of the accommodative mechanism of the eye. It should make sense to the reader that in trying to attend to a specific object in space we are dealing with signal-to-noise ratios. To distinguish a figure from complex background noise we must select that object and find a way to give it more relative importance than the objects surrounding it. Only then can we focus on deriving meaning and possible direction of action relative to that object in space.

Some fairly simple physics are at work here. The Webner Fechner law describes the relationship between signal (figure) and noise (ground). If a person has difficulty selecting an area of space for deriving meaning and directing action (a definition of selective attention), they may have problems with signal-to-noise discrimination.

Larry McDonald, in a series of papers recently republished by the Optometric Extension Program Foundation (OEPF), demonstrated how the retina evolved into a selective attender. The macula or fovea area of the retina and its neurological connections down the line are well suited for dealing with figures and for extracting a high degree of detail. The further breakdown into magnocellular (transient) parvocellular (sustained) channels within this figure channel allow for tremendously fine classifications and categorizations. As one moves away from the fovea or macula we see a rapid drop-off in resolution and architecture better suited to processing ground, from which will emerge new figures. Channels that react to changes in the sensory continuum act as an early warning system and are planted throughout the peripheral/ambient processes. The focal aspects of the system deal with figural aspects, which are sustained and require an enormous amount of processing, whereas the ambient aspects deal with ground aspects, which are more transient and more quickly processed.

The process of identification can be highly compromised by any problem that does not result in adequate signal-to-noise ratios. An example is a refractive or accommodative problem. If the objects were blurred because of myopia, high hyperopia, astigmatism, or an inappropriately adjusted accommodative mechanism of the eye, then the signal-to-noise ratios would be reduced. Less signal and a lot more noise would result. The person has to put forth extreme amounts of effort to stay on task. If they don't have the motivation or the ability to expend this extreme effort, they may be seen to flit from one thing to another. They may appear to have a brain disorder that affects the limbic system or other attentional centers of the brain, although these neurologic conditions are very rare. The point is that many things masquerade as physiologic brain damage, but are actually manifestations of functional problems in either development or selection of areas of space from which to derive meaning and direct action.

From the above discussion of the specialization of the fovea and macula area versus the rest of the eye, we know that any inaccuracy in pointing the eye or eyes precisely at the object will result in non-optimal signal-to-noise ratios. These non-optimal ratios will again impair the person's ability to accurately and efficiently identify the object seen. In fact, if we weigh the relative importance of fixation versus accommodation in bringing about optimal signal-to-noise ratios, one would have to conclude that accurate fixation is most critical. One can use the analogy to a microscope. Microscopes can have two different focus controls: a coarse wheel, to bring the focus "in the ballpark," and a fine wheel, to optimize the focus. It would be extremely inefficient to use the fine wheel only. Fixation is like the coarse wheel and the control of the posture of the mechanism of accommodation is like the fine wheel. Thus, the accuracy of the centering process directly impacts on the person's ability to identify an object accurately.

Identification: Everything the person uses to answer the fundamental question, What is it?

Speech/Auditory (Communication)

The fourth circle was originally labeled the Speech/Auditory Circle. I prefer the less limiting *Communication Circle* because much of communication is not exclusively spoken or heard but rather felt, sensed, stored, and recalled in other ways. Body language, *where* someone looks with their eyes, inflections, cadence, rhythm, and, most importantly, consciousness, which may take on qualities of knowingness that have nothing to do with language, are all involved.

For me this circle includes all the ways we become aware of what we feel, see, hear, taste, smell and know. It is both the internal communication system (that we have within ourselves) and the system that each of us has to communicate with the other.

We develop our communication system based on the experiences we have, which are tied into our development of object concepts. We give names to the object concepts we have experienced and these names allow us to refer to those object concepts both within ourselves and in communication with others. These names or lexemes (sound sequence we assign to an object), which are assembled from phonemes (individual sounds), then become objects themselves. These are then manipulated, strung together, and related to other names of things in very loosely, when learning new material, and later by a socially acceptable syntax.

Communication development occurs both within the individual, and between the individual and others in their social domain. How much of our time with the infant and the toddler is spent in pointing to an object and uttering its name over and over? How much time is spent echoing children's speech sounds and positively reinforcing certain sounds to raise the probability that they will be said again and again? How much time teaching the names of the child's body parts? In this way, the people in a developing child's life interact with the child and influence so heavily the development of the child's object concepts and the names the child gives those object concepts.

When a person experiences a new situation or object, they may be at a loss to classify or label the object or the event. It may register only at some subconscious level, if even then. In this instance, where there is no registration of the event, no classification of the event, nor awareness that the event occurred, the event has passed the person by.

Can we pay attention to everything?

Bruce Wolff stated that "Most visual problems are problems of omission, not commission." This profound statement has strong implications in understanding the visual process. This is obvious in the way we deal with the light energy that impacts the eye. The eye selectively reacts to a very narrow band of the electromagnetic spectrum. Therefore, much potential information is lost because we can react only to this very narrow band.

Our attentional mechanisms are involved in selecting those aspects of the visual, tactual, proprioceptive, auditory, and other sense fields we determine are important at any given time. As discussed in the section on identification, the setup of the retina itself and the neurologic linkages between the retina and the rest of the brain are highly developed to facilitate global alerting, orienting, and localization and focal discrimination, so as to be intimately tied into giving certain objects of regard more importance and others less. This is a visual way for the organism to extract what is needed from the environment at any moment to direct the organism's further actions.

By its very nature this process cannot possibly take in every bit of information about everything all at once. We are just not built to process every detail about everything simultaneously. We are built to parallel-process phenomenal amounts of data. Calculating where we are in space, calculating where the object or objects of regard are relative to us and to each other, simultaneously activating object concepts from which we understand about the objects currently being viewed and their relation to each other and to us, and finally, knowing about all this consciously and subconsciously and to communicating this to others.

Our diagnostic evaluations tap into this directly. When we perform we set the stage and include some props, such as a lens, a target, specific light conditions, etc. We then give some instructions and let the patient know when to begin relating their observations. If the patient fails to respond to some aspect of the test we may wonder whether their underlying mechanisms are sufficiently developed to respond to the testing environment.

For example, we may present the patient with a target to look at through Risley prisms (variable prisms in front of both eyes). We slowly increase base-out prism in front of both eyes and ask the patient to describe the changes they notice as they occur.

What can we make of the person who sits there silent? Many changes might be occurring that the patient is not communicating to us: changes in size, distance, clarity, contrast, figure-ground relationships, or the images may double or remain together. The patient may feel different and feel changes in parts of the body that they may not relate directly to what they're experiencing.

Why don't patients tell us about these changes? The implication is that the patient will respond with the underlying mechanisms they have developed. Some patients will tell us about size differences they notice, but if distance changes are not significant to them, they won't report these types of changes. The opposite is also true; some talk only about the blur and don't report seeing double until their attention is directed to that specific condition. These varying responses occur in what appear to be normal, healthy people who, on outward appearance, seem to be using both eyes together normally.

Back to the quote from Bruce Wolff for a moment. The end of the quote, "*not commission,"* means that an accident is not a result of having too *much* information from the visual scene. The basis of most accidents is the fact that something that was present, that could have been seen, that could have been paid attention to was not. In most cases, accidents occur because of too little information, not too much. How many times do we hear from a person just in a car accident, "The other car came out of nowhere!" or "I didn't see him until it was too late."? The other car did not come out of nowhere. It could have been seen but wasn't. It was in the person's visual field. It could have seen it in a way that allowed them to take that information into account and to have taken a different course of action. They just didn't!

In a way, the goal of good vision care is to allow the patients to simultaneously take in and more fully process more information from more of their world at once. More information allows us to make better and more accurate decisions.

Communication: Everything the person uses to answer the fundamental questions, "What do I know about what is going on?" and "What can I communicate to others concerning what I know about what is going on?"

Vision the Emergent

Vision, *the deriving of meaning and the direction of action as triggered by light,* is an emergent from the balanced interplay of each of the sub-processes that compose the four circles of Skeffington. Any limitation in any of the sub-processes will result in a compromise in the efficiency and processing ability of the total process of vision. Athletic performance, reading ability, workplace productivity, enjoyment of hobbies will all suffer as a direct result.

The only way to accurately diagnose a dysfunction in the visual process is to put the patient into action settings and watch them perform. This is exactly what the behavioral optometrist does. We set a series of stages. We use certain props such as lenses and red/green glasses and Polaroid glasses and various targets with different lighting conditions. We set the stage and begin the play with an instruction. We change something and observe the patient deal with the changes and see how they perform. What actions do they take? What changes were important to them? What changes were ignored?

At the same time, the optometrist does much introspection. We constantly ask, "How does this person have their visual process organized to have just done what they did or to have just said what they said?" There are no *rights* or *wrongs* in the patient's response. The challenge is to understand the visual process of the patient. Once this is understood, then a treatment program utilizing lenses, prisms, and visual training procedures can be established for that patient. The goal of the treatment is to facilitate more rapid and more efficient processing of potentially meaningful information from all senses to allow for better and faster judgments, which allows the person to attain more of their goals with less effort and energy.

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