Spatial perception in persons with TBI

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The question is “How does the world appear to a person with TBI? What can we, as Optometrists, do to help?

When we encounter a person with TBI and are doing a history, the patient’s usually mention one or more symptoms, such as: Mild to severe headache, Loss of coordination, sleeping disorders Ringing sound in ears, Sensitivity to light or sound, Memory problems, Hormone Disorders, speaking disorder, Depression or Anxiety, Digestive Issues, Mood Swing, Dizziness or fatigue, Blurred/Double Vision, Dysgraphia to name a few. There are others.

When it comes to describing how they see, they have a very difficult time explaining how they see. Parts of the world look distorted in some way; the parts of the world appear to move or shimmy. But, generally very vague.

To help understand how they see we are going to talk about: Spatial Mapping; Visual Midline Shift Syndrome; Size/shape Constancy and Relative Size concepts.

Spatial Mapping: When talking about spatial maps the Euclidean coordinate system is used to describe mapping. There is the Egocentric or body centered internal spatial map and the allocentric or object external spatial map. These coordinate systems map the body space onto the object space in order for us to navigate through our world. This is nothing new, because Skeffington talked about this with the “where and I” and “Where is it” circles.

To build the body spatial maps, the body needs input. It gets input from the exteroceptors, the eyesight, touch, smell, temperature and hearing; the receptors outside the skin. Then within the skin there is the proprioceptors located in the muscles, tendons and joints.

We can use each of these systems to guide movement. The visual guided movement uses visual space to identify the target goal and then guide the limb to the target. This does not use information from fixation, pursuit or tracking. Proprioceptive guidance is when the attention is guided by the limb, such as looking at your watch.

Then there is feedback, which corrects for the error after the movement occurs and compares the desired outcome to the actual outcomes.

Then there is feed forward which utilizes the predicted sequence of the movement plan and sensed disturbances to compensate for anticipated error before it occurs.

So, to complete a movement: There is visual spatial alignment of the various visual spatial maps available and the target is identified. Based on the information a kinematic movement is programmed. The coordination of the maps is verified through the feedforward and proprioceptive feedback system. To accomplish the movement goal requires a consistent adaptive movement.

The spatial alignment system uses the perceptual-motor system to link and connect body and object spatial maps to link and connect body and object spatial maps to identify and reach the goal, i.e., reach for a cup or touch lights on the fixator or in pegboard rotations. This requires the integration of thousands of sensors, neurons, and motor units. The muscles and joints have to work in synergy as one unit.

Alain Berthoz says: …the bran is used to predict the future, to anticipate the consequences of action (its own or that of others), and to save time.

But when the visual spatial map is altered through TBI or wearing prism goggles, the adaptive movement also changes.

Bill Paddula identified the Visual Midline Shift Syndrome (VMSS). He noted that persons with brain injury often had unique postures based on a midline shift and he gave them a name so we could communicate what we saw. Then he provided guidelines about how to help these persons by using prism. His thinking was to use prism to shift the displaced midline back to the middle which would then allow the person to stand more erect.

He wrote, "Could the visual system somehow be involved in creating a distortion of space affecting the person's perception of their own erect posture? We have an elaborate neural organization of proprioceptive feedback and feedforward systems to give us an accurate spatial representation. We have axon collaterals from retina sending signals to areas other than the occipital cortex which communicate with kinesthetic, proprioceptive, tactile and vestibular systems."

When there is a neurological When there is a neurological event and the body posture shifts to one side or the other, a hemiparesis is considered to have occurred. Hemiparesis is a total or partial paralysis or weakness on one side of the body that results from disease of or injury to the motor centers of the brain.

When this happens, the kinesthetic and proprioceptive input from each side is different and this difference results in a spatial mismatch. "That the ambient visual process attempts to balance this mismatch by neurologically creating an expansion and contraction of space in attempts to manage this dysfunction."

Walking and balance posture is often observed by watching a person lean to one side or the other. Functional treatment is often using adaptive aids or providing feedback so the person can develop strategies to have a more erect posture.

Another question I have is this, "If the VMSS postural adaptations are related to muscle weakness, then how is it that with the application of prism these patients magically develop instant strength for a more erect posture"?

What if it was the other way around? What if there is a change in visual spatial map, due to TBI, where the programmed kinematic and motoric movement results in a postural tilt?

We organize our behavior around our perceived reality. When we change our perception, we change our behavior. After all the visual system plays a larger role than vestibular to control body balance, posture and movement.

Remember visually guided movement. There is visual spatial alignment of the various visual spatial maps available and a target is identified. Based on this perceived map, a kinematic movement is programmed. The coordination of these maps is verified through the feedforward and proprioceptive feedback systems. To accomplish the movement goal requires a consistent adaptive movement.

Shape or Form Constancy: Real objects are perceived to keep their shape or form despite the orientation of the image and the changing image size on the retina.

Size Constancy: Real objects are perceived to keep the same apparent size no matter how close or far away they are.

Relative Size: Retinal image size helps to determine how close or how far an object may be located.

For us to have an accurate visual spatial map we have to have intact neurology, the perceptual decision about object size, shape and form begins in early visual cortex-V1. Then follows the dorsal stream to the parietal cortex with connections in V5 and MT and the parietal cortex. And information from the axon collaterals.

Through the work of Hubel and Wiesel; Steve Cool; and Bill Ludlam, they found that each neuron or neuron cell had a specific response. Some responded to vertical lines, horizontal lines as well as various angles. Then some responded to movement in one way and then another cell responded to another. A very intricate designed system.

These systems are integrated and connected. In general, the left side the left parietal cortex is more sensitive to higher spatial frequencies or smaller objects. The right parietal cortex is more sensitive to lower spatial frequencies or larger objects. When integrated it helps us to perceive a well-structured world.

Additionally, the brain if very active with inhibition and establishes a balance in perception and movement. Berthoz writes that about 50% of the activity in the brain is active inhibition.

The spatial maps are discorded. The ability to determine the shape/size constancy is disconnected and then the brain is unable to filter out the inaccuracies so there appears to be an irregular compression and expansion in the spatial maps.

Which then interferes with the relative size because the interpretation of these irregular compressions and expansions of closer and farther are viewed in a different way than they were used to seeing and the world looks different.

“Damage to the frontal lobe cause an apparent displacement of the vertical to the side of a lesion.” Bender and Young 1948

“Damage to the cerebellum on one side has been found to cause vertical lines, houses, trees, etc. to appear to tilt in the same direction.” Halpern 1949

“Damage to the occipital lobe did not result in a disturbance of the apparent vertical, even when such damage was accompanied by hemianopia.”

The result seems to be a very confusing situation and one way of describing it is like an Ames Room.

With vision therapy or Vision rehabilitation we have the application of prisms to help. I think it is the spatial transformation properties of prism that make the difference because of the way they transform space.

The prism produces a linear asymmetric compression and expansion of real object space. The perception of this illusion is that parts of the real object will appear closer and other parts farther away. The prism also shifts the real object image and rotates it around the X, Y and Z axis planes.

The prism adaptation paradigm evokes in the perceptual-motor system both ordinary and extraordinary capacities.

Ordinary Capacity: This is what when we work with a non-TBI patient. We are looking for the rapid adaptive performance in the face of normal imprecision in perceptual and motor processes. For example, when we have a patient toss a bean bag into pail or put a peg in the pegboard. We watch for the direct effect and then remove the prism and watch for the after effect and evaluate the adaptive process.

Extraordinary Capacity is the gradual adaptive adjustment in the spatial mapping functions that enable spatial alignment among internal representations. In other words, using the spatial transformation properties to help match the discordances between the real object space and the perceived illusory space so that the world looks more “natural”.

Because prism, in any amount, have the same basic spatial transformational properties that will give the illusion that the floors and walls tilt in different ways depending on the base orientation.

Case number one: TBI patient who notices that the walls tilt backward. In addition, she had residual hip pain; trigeminal pain in her front teeth (she has no nerves in her front teeth); head pain and neck tension; poor reading and processing. With her prism glasses she has reduced hip pain; Reduced trigeminal pain in her front teeth – has no nerves in her front teeth; reduced headaches and tension in the neck; improvement in thinking and information processing. Her prescription is pl Sph +1.75 add with a 1 BD prism OU. She is currently in VT

Case number two: TBI with poor balance and dizziness; no endurance to work a job. Through VT she has Improved gait and balance; less dizziness; has returned to work. Part of her office therapy included the use of 0.5 BR prism, these were not prescribed daily wear. Her prescription is +0.75 -0.75 x 180 with at +2.75 add OU. Currently not in VT.

Why were the prisms so impactful?

- Prism transformed the visual environment in which the person lives.
- As a person adjusts and adapts to the newer spatial environment, they change their perception.
- As their perception changes, they alter their motor behavior which brings them into harmony with their visual world.
- Prism transformed the real object visual environment in which the person lives.
- The newer illusion of the external object environment map was now more aligned with the internal body spatial map.
- Better spatial alignment brings the person into better harmony with their world.

Thank You,