The role of the vestibular system in the learning process
Verena Prinsloo

1. The anatomy and physiology of the vestibular system

Balance is a biological system, which informs us about the position of our body in space and enables us to maintain a certain posture (Anon, 1999). A stable posture is characterized by the centre of gravity being “over the base of support, which can be a foot (see picture, A/N), two feet, two hands or the head and hands” (Pica in De Jager, 2009a:147). This way, the base of support bears the weight in an equated manner. The inability to position the gravitational centre correctly can be noticed in a person that starts oscillating around the midlines with feet trying to grasp the ground for hold as soon as the person has to stand still with closed eyes.

Balance starts developing in uterus: “The reflex system prompts the muscles to move in a stereotype manner to jolt the body parts and the vestibular system into action. These reflexive jolting movements act as training for the muscles and balance system.” (De Jager, 2009a:147). Later in life, the primitive reflexes make way for the more mature postural reactions which will from then on aid to maintain a certain posture.

The vestibular organ is a part of the inner ear and situated on both sides of the petrosal. It consists of three semicircular canals and two macula organs (utricule and saccule).

There are two sorts of balance: the static and the dynamic balance.
The static balance functions like a handyman’s spirit level, which indicates every derivation from the perfectly balanced position: Every change in the position of the head while the body is in a stable position or moving in a linear way is immediately noticed in the macula organs. The movement of the head moves the otholites and with it the gelatinous mass these little stones are embedded in. Inside the gelatinous mass, hair cells are pushed out of their resting position which sends a signal through the vestibular nerve to the cerebellum.

Dynamic balance is controlled by the three semicircular canals. They are arranged on all three spatial levels and can therefore detect every rotational movement of the head as for example on a swing, a roundabout or on a boat (see drawing below). The movement of the head initiates the flow of the endolymph which pushes the cupula with its hair cells out of its resting position. The hair cells convey the information about the change of position to the vestibular nerve from where it is sent to the cerebellum for further processing.

The stimulation of the three semicircular canals brings along the crossing of the three midlines of the body:

- **Frontal midline:** divides front and back half of the body
- **Medial midline:** divides right and left half of the body
- **Transversal midline:** divides upper and lower half of the body
2. Balance and the near senses

Maintaining balance is a group effort of the far and near senses. While the eyes supply fixed points from outside the body, the proprioception, kinesis and vestibular system gather information from inside the body.

Proprioception is the perception of position and movement of the body via specific receptors (proprioceptors) which gather information about muscle tension (golgi-receptors), muscle length (muscle spindle) and position and movement of joints (De Gruyter, 1998:1297).

Kinesis is the sensation of the movement of the body (De Gruyter, 1998:819). It allows us to coordinate movement in terms of strength, extent, speed, pressure, etc.

3. GPS

Before a Global Positioning System (GPS) can guide a traveller safely to his destination, two questions need to be answered first: Firstly: Where am I? And secondly: Where do I go? Only then, the GPS can come up with the answer for the third and essential question: How do I get there?

“The pull of gravity interacts with the body (vestibular system) to work like a Global Positioning System (GPS) (De Jager, 2009a:151)

1. Where am I? The position of my head derives from the midline and my body weight is solely carried by one leg: I’m falling!

2. Where do I go? Back to the midline to position my gravitational centre above my two feet.

3. How do I get there? With a sidestep of the free foot.
A functional GPS, which enables the person to perform coordinated movements across all three midlines, to successfully handle the pull of gravity and to experience a feeling of centeredness, is named by Jean Ayres “gravitational security” (Ayres in De Jager, 2009a: 152).

De Jager (2009a:152) identifies the following abilities which result from gravitational security:

- Spatial orientation
- Orientation in time
- Sensory Integration
- Development of muscle tone
- Planning of action: praxia
- Judging depth, height, weight, strength, speed, distance
- Social interaction
- Sense of self

According to Goddard (in De Jager 2009a:152) gravity “provides us with a centre, whether it be in space, in time, motion, depth or sense of self, acting as the nucleus from which all operations become possible.”

Here are some examples of how the GPS function of the vestibular system guides us through everyday life and learning situations:
<table>
<thead>
<tr>
<th>Area of learning</th>
<th>Example</th>
<th>Where am I?</th>
<th>Where do I go?</th>
<th>How do I get there?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Writing</strong></td>
<td>Distinguishing the letters b and d</td>
<td>starting point of the pencil writing direction</td>
<td>b: following immediately after the preceding letter d: with distance to the preceding letter b: to the right d: to the left</td>
<td>coordinated hand movement across the medial midline</td>
</tr>
<tr>
<td><strong>Reading</strong></td>
<td>What is written there: bread or beard?</td>
<td>eyes are directed on the left verge of the word the eyes pull to the right</td>
<td>coordinated eye movement across the medial midline</td>
<td></td>
</tr>
<tr>
<td><strong>Algebra</strong></td>
<td>5 + 3 = ?</td>
<td>mental positioning on the number line in the positive direction (to the right) on the number line</td>
<td>moving mentally forward along the number line in three steps</td>
<td></td>
</tr>
<tr>
<td><strong>Social interaction</strong></td>
<td>Approaching an unknown person</td>
<td>knowledge about the own position and personal space closer to the person having regard to the own and the other person’s personal space</td>
<td>correct judgement of the distance to be crossed, moving forward while holding eye contact</td>
<td></td>
</tr>
</tbody>
</table>
The points of orientation we can distract from the comparison with a GPS are implemented in the following exercise for spatial orientation in the writing process:

2 D Spatial Orientation Mind Moves: The Mouse Pad ABC (De Jager; 2009b: 45)

Place a Din A4 paper in landscape format in front of the child. Draw two horizontal lines dividing the paper in three equal blocks. Ask the child to draw an infinity sign which fills the middle block. In the middle of the page, the child draws a stickman with the head in the top block, the body in the middle block through the middle point of the infinity sign and the feet in the bottom block.

“Explain to the child, that the most important person in the world is in the middle of the paper – that person is the child. It is the child’s job to fit the lower case letters of the alphabet one by one in the infinity sign. [The child will] always start on the figure in the middle”

1. Where am I? → starting point of the pencil is on the stickman.
2. Where do I go? → Filling in the letters: training consistently to distinguish between right and left as well as top and bottom.
3. How do I get there? → Complete an infinity sign after every letter starting to the left top side. This trains the crossing of the medial midline with hands and eyes.

Letters turning from the stickman to the left: a, c, d, g, j, o, q, s.
Letters turning from the stickman to the right: b, e, h, k, m, n, p, r, t, u, v, w, y.
Letters lying on the stickman: i, l.
4. If the GPS is not working...

The influence gravity has on our planning of action, can best be observed “in a gravity free environment like cosmonauts in space. Educated and literate cosmonauts start to write from right to left, reverse numbers and letters and even produce mirror writing” (De Jager, 2009a: 82).

According to Goddard (in De Jager, 2009a: 152) “problems in the balance system affect the sensory systems, because all sensations pass through the vestibular mechanism at brainstem level before being transmitted elsewhere for analysis”.

If a child has to navigate his way through his learning career without a functioning GPS, the following problems might become visible:

- trouble with letter recognition, shape and direction, spelling and reading (Dyslexia)
- [...] trouble with numbers, concepts of size and shape, calculations and sequencing (Dyscalculia)
- [...] trouble to do with movement (Dyspraxia)
- [...] trouble to do with the movement of the muscles which produce speech (Verbal dyspraxia)” (de Jager, 2009b:52).

De Jager (2009b: 52) stretches in her book Mind Moves - moves that mend the mind, the importance of the interdisciplinary approach in the treatment of the above named dysfunctions as they fall in more than one therapeutic domain. The following suggestions are meant to serve as a guideline and source of ideas for parents and teachers to support the therapeutic intervention in a meaningful way. (De Jager, 2009b: 52, 53)

2. Exercises to establish gravitational security: (De Jager, 2009b: 62, 80, 71, 94)

- **Antennae Adjuster:**
  Massage both ear lobes simultaneously from top to bottom in circling movements.

- **Mind Moves Massage:**
  The child stands upright and holds both arms 90° to the side of the body. Stand behind the child and firmly trace the outline of the body from head to toe. Repeat 3x.

- **Gravity Crawl:**
  Crawl with the tummy flat on the floor while the arms and legs bend to propel the body forward.

- **Vestibular Rock:**
  Stand on all fours, gently rock to and fro, while turning the head in different directions.

3. Exercises to establish spatial orientation:
   - Depict shapes and letters with a rope on the ground and let the child walk along the rope
   - Feel out shapes and letters
     - made of clay
     - draw the shape/letter with glue on a paper and sprinkle saw dust over the glue - once the glue is dry, let the child close his eyes and feel the shape / letter (de Jager, 2009b: 44)

4. Exercises to establish rhythm and timing
   - train clapping rhythms
   - play clapping games
   - clapping on the syllables of a word (won-der-full)
5. Exercises to establish laterality (de Jager, 2009b: 66, 64)

Core Workout:
The child is lying on the back
1. Lift up arm and leg on the same side, turn the head to the active side. Change sides. 10x.
2. Lift up arm and leg on the same side, turn the head to the passive side. Change sides. 10x.
3. Right arm touches left leg, the head stays in the midline. Change sides. 10x.

Bilateral Integrator:
Hold two pencils between thumbs and index fingers resting on the web between the thumb, index finger and middle finger. Move the arms in a mirror image as though conducting a choir.


Mouse Pad:
Focus on the thumb held at elbow distance from the eyes. Move the thumbs upwards, first around the left eye and then around the right eye. Repeat 3x. Swap hands and repeat the same process again starting with the left eye.

Midline Workout:
Work in pairs, sitting with legs wide apart and feet touching. Hold hands and start rocking to and fro until each partner leans back as far as possible.

Trunk Twister:
Stand with legs shoulder width apart, upper body dropped forward and arms hanging down. Slowly rotate clockwise to create a circle with the body and arms. Stop, change direction.
Bibliography


De Jager, M. 2009b. **Mind Moves – moves that mend the mind.** Johannesburg: Mind Moves Institute, South Africa.

