Vision to the Brain

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Overview

- **Low Vision Rehabilitation - Why is it important to understand Brain Structure and function in relation to vision processing**
- **Assessment of vision following Acquired Brain Injury.**
- **Impact of additional cognitive and physical deficits**

Although I have spent most of my working life in the field of acquired brain injury I am by profession an Orientation & Mobility Instructor. So in my discussion about ABI today I will be drawing upon the examples of visual difficulties that my clients have demonstrated whilst developing their mobility skills.

I will also apologize in advance if I use terminology that is a little different to that which you are use to. Although we would all consider that we speak English there are many variations that occur depending on your country of origin. One example is the use of terminology relating to the people with whom we work; In Australia we use the term 'client ' in the UK I have heard the term 'Client', 'service user', learner' or 'student'. For those working within a medical environment the term 'patient' is probably most common. I was recently conducting training in Denmark and they referred to those referred for services as 'citizens'. I am probably well behind the times in political correctness so I apologize if my use of the term 'client' is out of fashion, but old habits die hard.

Brain Injury - Why is your understanding essential?

- The sheer numbers of people each year that sustain a brain injury will mean that you if you work in the area of Low Vision Rehabilitation services or the Education sector then you will come into contact with clients with ABI on regular basis
- Knowledge about the ABI will help to guide your assessment process

- To assist the person with the ABI to understand the nature of their vision loss and the functional implications.

If you are the professional providing an intervention or rehabilitation program then you will be best placed to explain the nature of the vision deficit to the client. You should also be able to explain how their vision problem will affect the person's performance in every day activities.

- Knowledge of ABI will allow you to provide appropriate therapy interventions.
- You will be able to identifying strengths that can be utilized in a therapy/rehabilitation program. An assessment process should not only focus on the identification of deficits but should also be identifying strengths that a person can use in order to minimize the impact of a deficit. There is nothing worse than being put through a whole barrage of tests to be told all the things that you can't do and not be given equal value to the strengths that will potentially be used to compensate for the deficits.

How do we assess vision following an ABI?

- Vision isn't just about how clearly we see or how much we see. Vision goes far beyond the sensory input that makes up the basic image.
- Vision is also about how we interpret visual information and integrate this information with other cognitive, sensory and motor functions.
- If we understand how vision is processed by the brain then we will be able to determine the level of processing at which the deficit occurs. If we understand the level of processing where the deficit occurs then we should be able to use this information to plan our intervention.

What constitutes a Visual Assessment? A Clinical Assessment of vision has the following features

- Defined by conventionally accepted measurements. For example, visual acuity or visual fields can be accurately and reliably measured.
- Quantifies vision deficit with a numeric value that we all generally understand, even across the metric and imperial scales.
- These quantitative measures are applicable to research and used in the statistical analysis of clinical data

- Allows for accurate measurement of change over time. The test / re-test reliability and validity of these standardized measures allow them to be used to determine change over time.
- The down side of these clinical measures is the limit in scope of 'What' can be assessed by the requirement to quantify these clinical methods of measurement.
    - Example: How do you quantify a visual skill such as recognition of objects?
    - We would all be aware that the clinical measures do not always relate to how an individual will function with a particular level of vision loss.

By comparison a Functional assessment serves a different purpose:

- Applicable to ADL tasks that are difficult standardize. The assessment of Mobility is a classic example of an important ADL skill that is hard to quantify and standardize.
- Functional tasks selected for assessment are often related to the individual's goals, or they should be. Why assess a person on a task that they will have no need to carry out?
- In a functional assessment the person's performance is influenced by many more variables
- The problem in not being able to control for the many variables makes it difficult to track change over time

Functional Assessment

- 'Top down' approach to Assessment
- Observation of a person's behavior does not necessarily inform us as to *why* a task is not performed successfully
- One Example:
    - Orientation to a particular location or landmark
    - What are the possible causes of difficulty with this task?

Landmark Recognition - What's involved?

- Visual Acuity – being able to see the detail clearly aides identification, and also helps us to selectively filter out unnecessary information.
- Visual Fields

- Integrity of Eye Movements
- Being alert and attending to the task
- Attention to detail verses environment (Focal verses Global)
- Systematic and complete search pattern – the scanning behaviors that a person adopts to compensate for a visual field loss are extremely important in aiding location and identification of a landmark. Scanning behavior is influenced by visual fields and visual attention.
- Object Recognition – differentiating the target landmark from other similar structures ot items.
- Topographical orientation – being able to compile a mental map of an area and relate where you are in relation to locations that are not in necessarily in view.
- Visual Memory – relating what you see to visual information from past experiences.
- Goal directed behavior – being able to use visual information to plan, initiate and follow through to successfully complete a task.

Relating Brain Structure and function to assessment

So if we look to the brain to see how each area of the brain might be involved in these functions then we may be in a better position to understand why someone may have difficulties with the task of landmark recognition and other task heavily reliant on vision. Whilst I acknowledge that using a framework of 'localization of function' is a massive over-simplification of how the brain actually functions, I consider that this approach does provide a framework of understanding.

Therefore if we relate brain structure and function to the assessment process we can:

- determine the role that each area or lobe of the brain plays in a particular task
- we can use the traditional 'hierarchy of visual skills' to structure our assessment process
- develop keen observational skills and methods of structuring functional assessments that highlight specific visual skills

The hierarchical or 'Bottom up' approach

Looking at the Quality of 'image' or 'information' going to visual cortex

- Acuity

    - Static Acuity
    - Dynamic Acuity
    - Contrast Sensitivity
- Visual Fields
    - Hemianopsia, quadrant loss
- Ocular motor
    - Saccades
    - Convergence
    - Binocular Vision

Visual Acuity

- **Static Visual Acuity** measured using stationary optotypes with the observer seated. In many post chiasmal brain injuries static acuity is normal, however; in everyday life the identification of moving objects such as vehicles or other people is often required as we, as well as our surroundings, are continually moving.
- A more functional assessment is **Dynamic Visual Acuity**, However, this is rarely tested and often impaired by deficits in smooth pursuit eye movements, or nystagmoid fixation instability.
- Contrast Sensitivity is often decreased following an ABI. Some studies have found that over 80% of people following stroke have decreased contrast sensitivity. This leads to problems in clarity of vision is situations of poor lighting, or where objects might blend into the background.
- When acuity is reduced the increased effort required to process visual information should be a consideration. Even the smallest errors in refractive correction will lead to increased effort and therefore more rapid fatigue. This is of particular concern given that fatigue following ABI is already one of the key issues to manage.
- Decreased acuity affects the CNS ability to selectively attend to relevant information.

Affects of specific lesion sites on
Visual Fields

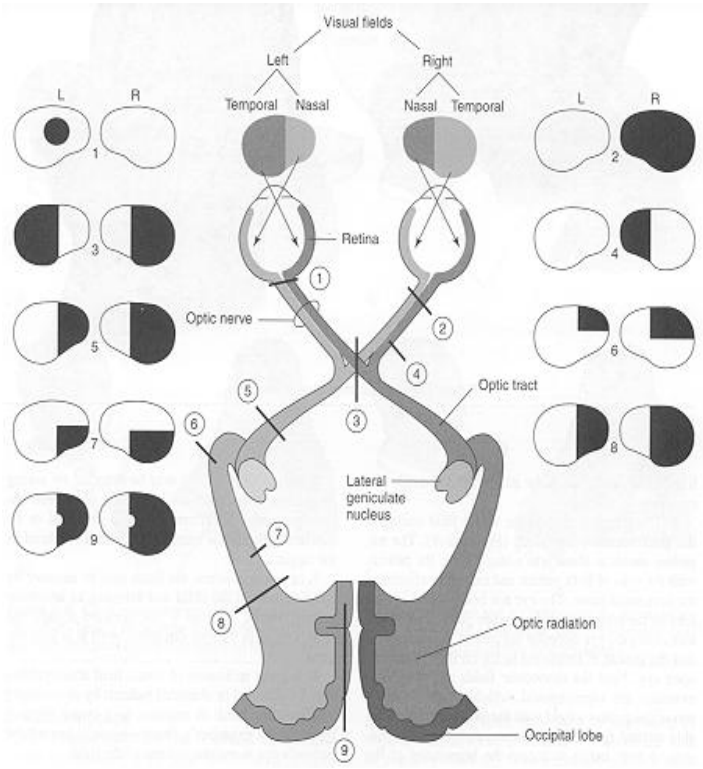

Figure 1: Visual Fields in relation to site of lesion.

The use of this basic mapping of visual filed deficits outlining how a lesion in a particular part of the visual pathway might affect visual fields is undoutbedly well known to us all. The skill lies in your ability to be able to explain this to a person with a vision loss as a result of an ABI, without completely confusing them. In the case of a homonymous field loss, it is their understanding that is it the same vision field deficit in both eyes that is important information for the person to understand. It is a more substantial field loss than being monocular.

Perhaps more improtant is the presence or absence of macular involvement.

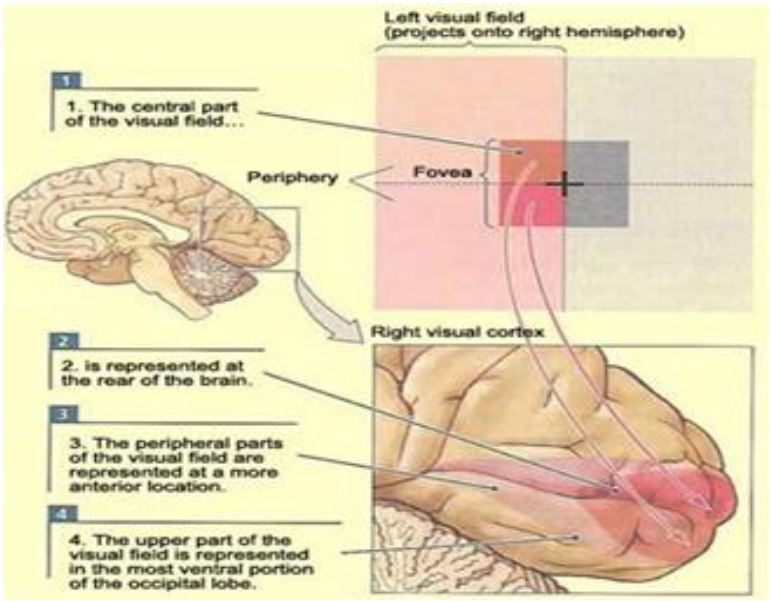

Figure 2: Central visual fields distribution as processed by the occipital lobe.

- Visual images related to peripheral fields are processed in the more anterior area of the Occipital Lobe
- Central Macular images processed at the Occipital poles
- The presence of **Macular sparing vs. Macular splitting** is crucial for the presence of Hemianopic Alexia

The third foundation skill affecting the quality of the visual image reaching the occipital cortex is the control of eye movement

- There are <u>two</u> mechanisms that control eye movement:
    - Central neural mechanisms
    - Cranial Nerve innervation of eye muscles
- Disruption of the ocular motor function can occur through damage to the neural structures in the brain, cranial nerve damage or weakness of the extra ocular muscles
- Any disruption of eye movement will diminish perceptual stability

Concentrating on the neural mechanisms I will just briefly touch on the control of Saccades and Pursuits

The **saccadic system** controls rapid conjugate eye movement and maintains fixation (foveation) on the object of regard.

- Horizontal saccades are controlled by contralateral frontal eye fields in the Frontal Lobe.

  The right Frontal Lobe controls saccades to the left, and the left Frontal Lobe controls horizontal saccades to the right.

The **pursuit system** controls smooth tracking to follow slow-moving objects.

- The pursuit movements are controlled by the ipsilateral Parietal Lobe .

  The right pursuit is driven by the right Parietal Lobe, and left pursuit is driven by the left Parietal Lobe).

Most voluntary eye movements are a combination of saccade and pursuit eye movements.

Deficits of ocular motor function are relatively common following an ABI

Vision Deficit	**% Occurrence in Visually Symptomatic TBI***	**% Occurrence in Stroke #**
Blurred vision	41% (Accommodation)	32% (Convergence)
Slower inaccurate reading skills	51%	26%
Diplopia eliminated with monocular occlusion	56%	16%
Visual- vestibular deficits	56% - 58%	12%
Decreased contrast sensitivity	Not recorded	82%
Visual field deficit	38%	24%

Light Sensitivity	49%	Not Recorded

Table 1:

*** Optometric management of visual sequelae of Frontal Lobe-related Traumatic Brain Injury.** Lowell, L. Cohen, A H. Kapoor, N. *Journal of Behavioral Optometry 2010* Vol. 21 No.1.

 # Ref: Visual impairment following stroke: do stroke patients require vision assessment? Rowe et al *Age and Ageing 2009;* ***38: 188–193***

Having assessed the foundation skills of vision, acuity, fields and ocular motor function we can turn our focus toward how someone might use their residual vision to attend to information. In the case of visual field deficits this relates to scanning behaviors.

Visual Scanning

- There are two major factors influencing scanning:
    - **Visual fields**
    - **Visual attention**

    One or both may be affected by the injury

- Lack of scanning or 'neglect' of a particular area will contribute to a lack of awareness of the environment as a whole, leading to poor orientation. *For example: A person in a setting that has a corridor, such as a school building with rooms off either side of a corridor. If they have inadequate scanning behaviors they may come out one door and walk along the corridor only observing one side. They might have a left field loss and fail to adequately scan the corridor; hence, they may only see the right side of the corridor. When they turn around to reverse the route, the corridor will look completely different to them, and they may consider that they are in an entirely different corridor, adding to their spatial disorientation.*
- Object (pattern) recognition is dependent on organised, thorough scanning. *One example of how inadequate scanning can cause errors in object recognition that I observed, was a patient in a Rehab hospital who was walking down the corridor and was asked to identify an obstacle in his path. He looked at what was a wheelchair and saw only one wheel. He then concluded that it was a bicycle based purely on the fact that it had a wheel.*

- Effective scanning consists of a series of foveal fixations executed in an orderly, sequential fashion, in which the most important details are re-examined several times to ensure accurate identification

Figure 3: As these photos illustrate, the situation of having to search shelving to locate one particular item, amongst similar looking items, is a common occurrence in ADL tasks such as shopping. The need for a systematic scanning pattern, at a speed where the person can fixate on objects and recognize one item from another is often a skill affected by an ABI.

Inefficient Scanning

- Visual field deficits can result in poor scanning patterns or inefficient eye movements towards the affected field
- Tendency to search intact visual field first, then to make small stepwise eye movements towards the affected field
- Inefficient scanning leads to difficulties when viewing moving objects

Inefficient scanning can affect tasks that require a broad search pattern, such as crossing roads, or smaller eye movement, such as those required for reading. In the case of reading, depending on which field is affected, it can lead to difficulty seeing all of the word, line or the page. Inaccuracies in identifying words, or just slow scanning, when reading will obviously affect comprehension.

Visual Attention

- Visual attention is a crucial lower level skill required for effective visual processing.
- A person may be unable to utilise **selective visual attention** to meet the demands of complex visual tasks.

- The complexity of the task or the environment can lead to apparent inconsistencies in perception and functioning.

If we look at brain function in relation to attention it is apparent the there are hemispheric differences in how we focus our attention. This means that we can actually relate the type of attention deficit to the area of the brain that has been injured.

Hemispheric differences in Attention

The Left Hemisphere

- Mechanism for **directing attention to <u>the right</u> visual field.**
- This attention is responsible **for Focal , detailed** analysis
- This **sequential, systematic** analysis has a distinct advantage if the information is related to reading.

The Right Hemisphere

- Mechanism for **directing attention to <u>Right and Left visual fields.</u>**
- This attention provides for a **broad , global view**
- This allows us to take in the 'big picture' more general , non-detailed analysis
- This assists with spatial relationships (object to object, and object to self)

With this knowledge it becomes more apparent that a focal brain injury could lead to a bias in attention

Left Hemisphere Deficits:

- A more random approach to scanning resulting in a poor search pattern
- Focus on the 'big picture', unable to easily detect the detail.
- Lesions of the Left Temporal region result in decreased focal recognition of written language

Attention – Right Hemisphere Deficits

- Avoidance in eye shift towards the left affected side
- Poor awareness of the environment

- Tendency to fixate on visual stimuli on right side first, then difficulty disengaging from the stimuli
- Lesions of the right parietal lobe are associated with a greater incidence of **visual neglect syndrome**

Picture 1: View of starting point for travel route

Picture 3: View of reverse route from admin building

Picture 2: Destination of admin building

Picture 4 Selection of tape on RHS posts as cue for orientation.

Figure 4 - Pictures 1-4:

If I can use these pictures to illustrate this bias in attention. I was working with a client who had sustained a Traumatic Brain Injury. The brain injury was bilateral, involving the right occipital parietal area, the left temporal area and the frontal lobe. Visually the client had a right upper visual field loss as a result of the left temporal lobe damage. The left inattention was consistent

with the right occipito-parietal lesion. The frontal damage may also explain how she approached this mobility task.

Her task was to locate visual cues that would assist her to find her way from the ward where she was an inpatient to another building within the rehab complex, and to locate visual cues that would help her to find her way back. At the first position (Picture 1) I asked her what she would use as landmarks to find her way back to where she had come once she had reached the admin building. She gave me an unusual answer.

Despite the presence of large features such as car parks, buildings and open spaces she indicated that she would look for the small stripes of tape on the right hand posts along the walkway. She focused in on the <u>detail</u> on her right side (See picture 4). She did not see the larger environment and because of her poor problem solving skills could not appreciate that she would be unable to see these visual cues for orientation form a distance, as shown in the reverse view, picture 3.

As illogical as her approach might seem it was consistent with the location of her brain injury and the impact that this injury would have on her focus of attention and scanning.

So let us go back to the brain structures and look at how the hemispheres differ in their function as it relates to visual processing.

There are 'levels of processing' for all sensory information including visual information

- Primary – Visual cortex
- Secondary – Association area**s lie adjacent to primary visual processing areas**
- Tertiary – Boundary between Parietal, Occipital and Temporal Lobe

Greater asymmetry of function occurs at the secondary and tertiary level of processing within each hemisphere

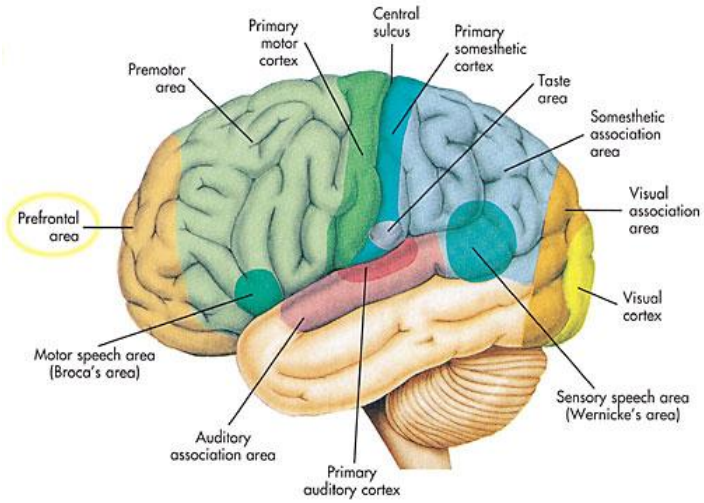

Figure 5: Secondary and tertiary processing of sensory information

Secondary Visual Cortex (Association Areas)

Interpretation of visual information

What is it?

- Visual information such as shape, colour, form and texture.

Where is it?

- Spatial relationships, motion

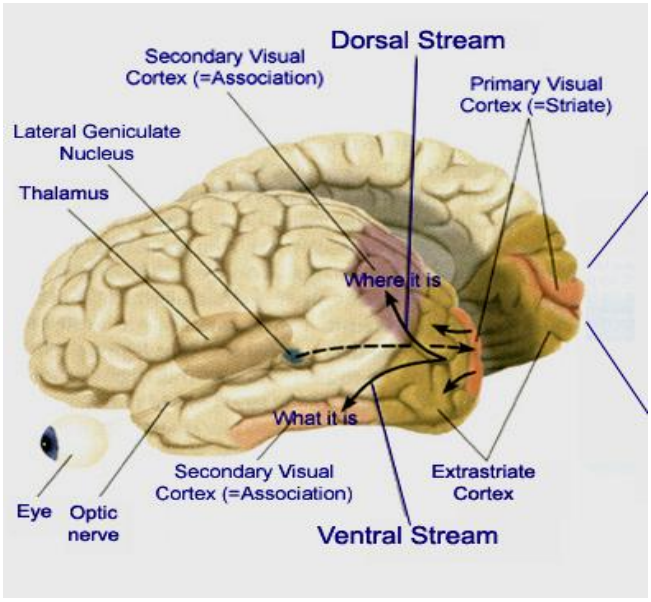

Figure 6: Dorsal and Ventral stream processing of visual information

Hemispheric localization of Function

Left Hemisphere

- Object recognition – recognition by interpretation of shape, colour, form.
- Also recognition of symbols for language, mathematics

Right Hemisphere

- Spatial visualization and analysis
    - In relation to ourselves and other objects
    - The formation of the visual map of an area

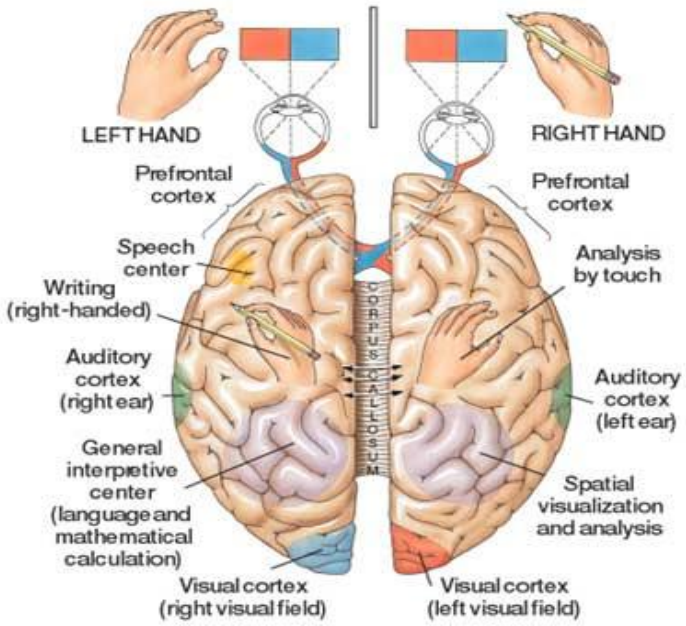

Figure 7: Hemispheric differences in function

Tertiary processing allows for our capacity for Visual Cognition

- The ability to mentally manipulate visual information
- Integrate visual information with other information in order to solve problems, formulate plans and make decisions
- Examples:
    - Speed of processing

- Spatial reasoning

Tertiary Processing - Integration

- Combines information from parietal, temporal and occipital lobes
  - Gnosis– recognition beyond sensory input. Some examples of visual agnosias include prosapagnosia -Recognition of faces.
  - Praxis – ideation concept formation, planning & motor execution
  - Body Scheme – perception of one's own body position and the relationship of ones body parts.

I can recall a graphic example of a deficit of body scheme with a client who had body neglect and a hemianopia. If she was not watching what she was doing with her left arm she would be unaware that it was being held out away from her body. She had a particularly treacherous trip through a department store where she had hooked up some clothing as she walked past the racks and was unaware that it was trailing beside her.

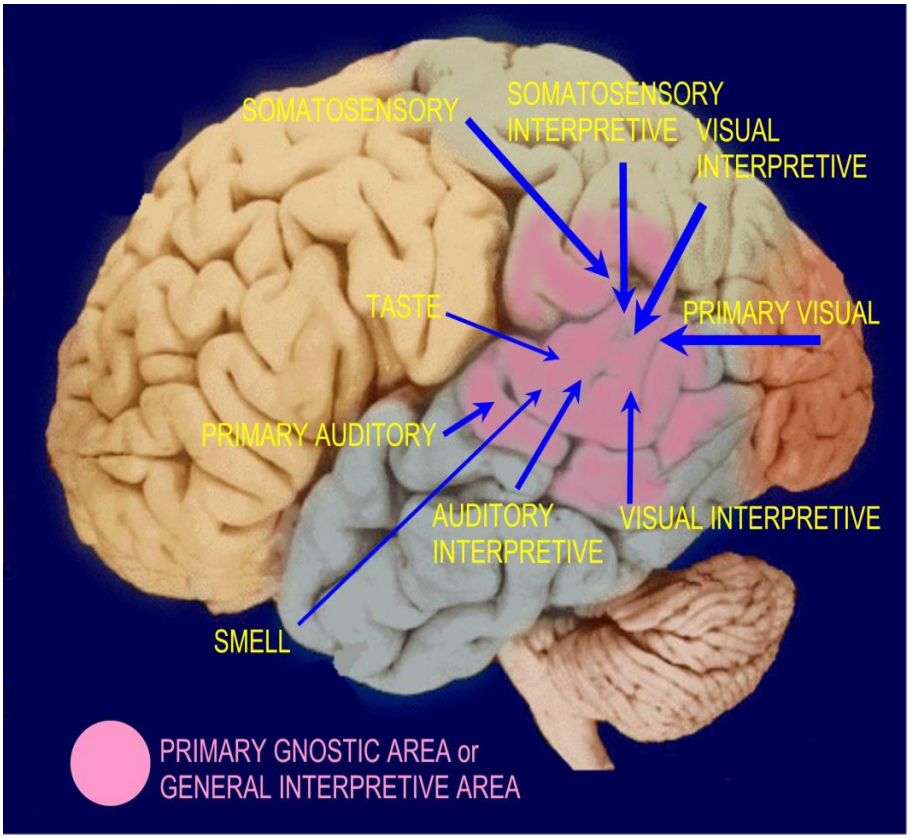

Figure 8: Tertiary integration of vision with other sensory input

Frontal Lobe functions in Vision

- Areas in the Prefrontal cortex are responsible for Visual Executive functions. These involve:
    - Motor planning required to shift, or sustain eye movements by utilizing spatial information gathered by the pre motor cortex
    - Initiates visually guided movements via the **frontal eye fields** and primary motor cortex
- Frontal eye fields responsible for voluntary ocular motor and saccadic eye movements
- Injury impacts on fixation, pursuit and saccades

Other Frontal Lobe functions include:

- Filtering out extraneous information (Auditory, visual, somatosensory etc)
- Selective focus of attention on important visual input
- Planning and problem solving
- Goal directed behavior
- Initiation and self monitoring
- Impulse control
- Insight

Being able to filter out irrelevant visual, auditory and other sensory information is something that most of us take for granted. If you watch the effort involved by someone with poor capacity to do this as they move through busy, noisy shopping complexes you will sense the problems that this creates. You can see them physically relax when they get out into a more quite open space.

Speed of Processing

May be due to:

- Inability to obtain a clear image of an object (primary visual cortex)
- Slow recognition of object (secondary association area)
- Slow integration with other sensory information. (Tertiary processing)

- Slow reaction times – integration with motor planning via prefrontal cortex. (Frontal lobe)

Slow speed of processing greatly affects how we make use of our vision in a dynamic environment.

Reverting back to my example of how particular vision skills can affect orientation, we can include speed of processing. Take the situation where a person has slow visual processing and is a passenger in a car. They may have difficulty being able to fixate on an object, recognize it before they have moved past it. Consequently, even in previously familiar places they may be unable to know where they are.

Other Physical deficits

Balance

- Attention to balance takes precedence over all other processes. Nothing grabs the attention more than a fear of falling.
- Poor balance forces people to steady their gaze usually by looking at the floor.
- Poor balance results in a restricted range of head and eye movement to decrease the vestibular input
- Balance problems narrow the attention

The involvement of language

- Adequate language skills are required for any assessment of function following a brain injury
    - Understanding instructions
    - Communicating a verbal response
    - Imparting an understanding of strategies that compensate for any deficits present

Therefore a basic understanding of the nature of language deficits following ABI is essential knowledge for all practitioners working in the area of vision rehabilitation.

Example: *I was speaking with a teacher of the vision impaired at a conference in Georgia. She was discussing the case of a child who had sustained a brain injury following a MVA where he was unrestrained and had hit the windscreen of the car in which he was a passenger.*

She questioned the reason why it was the case that he was able to see particular letters of words but was still not be able to read. When I asked "was his brain injury left sided, right sided or both" she could not say. She was trying to determine the lack of reading in terms of vision alone, without knowledge of the impact of the ABI on language skills.

Questions related to language

- Where is the Brain Injury; Left, right or bilateral?
- What is the hemispheric dominance; are they right handed? Most of us are left hemisphere dominant, and therefore have our language skills under the control of our left hemisphere.
- So if it was left hemisphere how might language be affected, is it a receptive language problem, expressive or both?
- If it is a receptive language problem, is verbal and written information affected?
- What were their language skills prior to the brain injury?

Visual Memory

- Making sense of the image is essential to being able to lay down new memory traces and recalling it at a later date. If something does not make sense then it is difficult to remember. Take learning a new language for example. If we cannot give meaning to the vocabulary then it will be easily forgotten.
- All new visual information is compared to our memory of previous information. This acts as an aid to the speed of recognition. If we had to look at every last detail of every object it would take forever to recognize something. Instead we make comparisons to stored visual memories to quickly find a match.
- Whilst there are many areas of the brain involved in memory – damage to the Frontal Lobe and anterior Temporal Lobe will affect memory.

I had been told about a client who had significant difficulties with visual spatial tasks. Although her acuity was 20/20 and she had full visual fields she was unable to make sense of visual information that related to spatial tasks. She could park her car and walk a short distance from it and be unable to find her way back to it. She could not recognize familiar features in her neighborhood such as houses or streets. She could not make sense of what she saw as she was unable to piece together single images to form the whole picture. Because things did not make sense she could not remember the visual information and use it for orientation. So although on

the surface it would be considered to be a visual memory problem, at a more basic level it was a visual spatial deficit.

So I have spoken at length about 'what' we assess and 'how' with regard to vision. I would like to just finish this discussion with a brief consideration of 'where' and 'when'.

Where we assess vision will make a huge difference on the skills displayed by the person.

- Visual demands – lighting, clutter, figure/ground
- Environments demands – static or dynamic
- Additional physical demands - balance
- Additional sensory demands – filtering and selective attention
- Memory – familiarity of the environments

Optimum lighting will decrease the impact of poor contrast sensitivity commonly associated with ABI

The demands of identifying a specific item against a visually complex background, or amongst other similar looking items, are extremely high. This requires more focused attention to detail which requires more conscious effort and mental energy.

When we assess Vision

- When the person is fatigued
- Impact of fatigue on **attention** and the subsequent affect on perception.
- Increased fatigue due to the effort required for focal attention and fine discriminative vision
- Visual Perception is not a stable, constant but fluctuates in a similar way to other aspects of function following brain injury

Overcoming additional deficits

- Using the strengths
    - Verbal verses visual
- Planning & problem solving
    - Establish a routine

    - Minimize the occurrence of the unexpected via a routine
    - practice at strategies to apply in the event that the unexpected occurs
- Memory deficits
    - Practice and repetition
    - Build upon familiar tasks

Take up the challenge

- Insist on having access to a comprehensive history of the brain injury
- Understand what functions might be affected in light of the location and type of brain injury
- Become keen observers and solvers of puzzles
- Use the strengths to overcome the deficits
- Foster a team approach as there are many benefits of working as part of an multi-disciplinary team
- Document what works and share your experience.

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