The Eye is Part of the Brain: How do we really see?

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I have nothing to disclose
Resources

Cortical Visual Impairment
An Approach to Assessment and Intervention
Christine Roman-Lantzy
AFB PRESS

WHAT and HOW
Does This Child See?
Lea Hyvärinen and Namita Jacob
VISIONTEST Ltd.

VISION AND THE BRAIN
Understanding Cerebral Visual Impairment in Children
Amenda Hall Lueck & Gordon N. Dutton, Editors
AFB PRESS
How Do We See?
The image of what we “see” is in our minds!

- An image in our brain is created from our senses (sight, hearing and touch) so that we can:
  - Pay attention to any element in the scene
  - Use visual, auditory and tactual guidance to move our eyes, head and body to look and move at will
  - Recognize, know and learn from what we see
What we “see” gets basic processing in the occipital visual cortex.

A visual representation of the entire surrounding area is created in the posterior parietal lobes that are connected to the visual cortex by the **dorsal stream**.

This **unconscious** process provides the information for visual search and facilitates visually guided movements.
How we see (in a nutshell)

- A conscious process of matching incoming information with prior visual memories so we can recognize what is seen is processed in the temporal lobes (connected to the visual cortex by the ventral stream).
- The executive functions that process this complex network of interconnected systems takes place in the frontal brain.
How we see (in a nutshell)

- We “look” at the scene.
- Important elements are recognized, understood and given attention.
- Choices are made of where to move and at what to look.
- Anything that interferes with this process will compromise the ability to “see”!
- What we will be discussing is VISUAL BRAIN DAMAGE.

The Visual Brain

- **Parietal Lobe**: Visuospatial map, visual attention
- **Frontal Lobe**: Eye movement planning
- **Middle Temporal Lobe**: Motion perception
- **Occipital Lobe**: Shape, contrast, color
- **Inferior Temporal Lobe**: Object perception
- **Cerebellum**: Moderates eye movements
- **Midbrain**: Visual orientation and eye movements
- **Brainstem**: Eye movements integrated with vestibular input
Legal blindness is defined in terms of visual acuity (Worse than 20/200 in the better seeing eye) and visual fields (worse than 20 degrees in each eye).

There is no universally accepted definition of visual impairment.

Most agencies still use visual acuity (worse than 20/70 in the better eye) and visual fields (worse than 30 degrees in each eye).

Under this definition, a person with a hemianopia or altitudinal visual field deficit has no visual impairment nor does it consider other visual function deficits (oculomotor, processing.)
In the US, according to the Individuals with Disabilities Education Act (IDEA, 2004, P.L. 108-446), the current federal definition of visual impairment for entitlement to special education services is:

“Visual impairment, including blindness, means an impairment in vision that, even with correction, adversely affects a child’s educational performance. The term includes both partial sight and blindness”

Unfortunately, this is open to interpretation.

According to Dutton and Lueck, a better definition for children would be “damage to the visual system that impedes the ability to learn or perform visual tasks of daily life, given a child’s level of maturity and cultural environment.”
This definition should also be used when working with adults.

If the person’s vision is affecting their ability to perform necessary activities of daily living (reading, driving), it should be considered a visual impairment regardless of the visual acuity/visual fields.

For those adults that suffer brain injury, this definition then becomes “Damage to the visual system that impedes the ability to re-learn or perform usual tasks of daily life, given their pre-morbid level of activity.”
Visual Functions

- Visual functions - measures used to describe how the eye and visual system function and can be given a numeric value (visual acuity, visual field, contrast sensitivity, color vision)
- Usually measured in optimum situation – good lighting, high contrast, non-crowded – by optometrists/ophthalmologists
- Gives no information as to how the persons activities of daily living are affected
- Varies depending on many factors – age, cognitive ability, occupation, personality

Functional Vision

- How an individual functions using vision and involves evaluation of that person’s visual skills and abilities as applied to the performance of usual tasks of daily life in their usual and customary environment.
- Most optometrists/ophthalmologists are unable to provide accurate information concerning functional vision.
- Parents, caregivers, teachers – best source of information.

**Higher Visual Functions**

- **Visual perception**: the act of detecting and recognizing what is seen (the way in which something is seen, known and understood).
- **Visual cognition**: the capacity to process what is seen, to think about its significance and to manipulate and use both incoming image data and remembered imagery in the context of creative thought (the mental action or process of acquiring knowledge and understanding through vision).

Higher Visual Functions

- **Visual guidance of movement**: the mapping of incoming visual information that is utilized to guide movement of the limbs and body
- **Executive function**: the conscious visual process of choosing to pay visual attention (focusing on specific elements in a scene)
- **Visual attention**: a set of cognitive operations that mediate the selection of relevant and the filtering out of irrelevant

Visual Impairment vs. Visual Dysfunction

- Visual impairment: decreased visual acuity or visual field (as defined now).
- Visual dysfunction: a disorder of ANY visual function - oculomotor, accommodation, visual perception, visual cognition, visual guidance of movement and visual attention.
- **Adults and children with visual dysfunction often have very good visual acuity.**
- Undiagnosed, visual dysfunctions can affect school, work and other activities of daily living.
Deficiency in the functions of vision, due to damage or malfunction of visual pathways and visual centers in the brain (specifically those behind the lateral geniculate bodies), including the optic radiations, the occipital cortex and the visual associative areas, which may be accentuated by associated disorders of the control of eye movements.

This can occur in isolation or can accompany refractive error and anterior pathway visual dysfunction.


**Basic Brain Function**

- **Occipital lobes**: process information about visual images received by and then transferred from, the eyes.
- **Frontal lobes**: think, plan and control behavior (executive functions)
- **Parietal lobes**: feel and move the body and process language (left side)
- **Temporal lobes**: process language and speech and provide memory banks that are necessary for recognition
**Cerebellum** - timekeeper, ensuring that emotion controlled by the frontal lobes, movement of the body processed by the parietal lobes and vision processed by the occipital lobes are synchronized and coordinated.
Brain stem and midbrain house the nerves that go between the brain and spinal cord that bring about movement, sensation, and knowledge of position; receive and process information from the cranial nerves; contribute to the maintenance of balance, control of heart and breathing rates, and auditory and visual alertness to hazards.
Common Causes Of CVI In Infants and Children

- Anatomical disorders of the visual brain
- Brain malformations
- Hydrocephalus and blocked shunts
- Chromosomal and other genetic disorders
- Closed head injury (trauma, shaken baby syndrome)
- Focal damage to specific brain locations (hemorrhage, tumors, cortical dysplasia)
- Periventricular white matter hypoxic-ischemic encephalopathy in pre-term and term babies
Common Causes Of CVI In Infants and Children

- Encephalitis and meningitis (inflammation of the brain or the covering of the brain)
- Seizures
- Metabolic disorders
- Neonatal hypoglycemia
- Maternal intake of drugs


Common Causes of CVI in Adults

- Respiratory arrest
- Traumatic brain injury
- Complications of cardiac surgery
- CVA
- Brain tumors, aneurisms
- Hydrocephalus
- Seizures
- Meningitis and encephalitis

The underlying damage to the brain in adults and children is often hypoxia/anoxia.

- **Hypoxia** refers to the condition that occurs when the body or a region of the body is deprived of adequate oxygen supply.
- **Anoxia** refers to a total depletion of oxygen, an extreme form of hypoxia.
- The terms are used interchangeably but hypoxia is not as damaging, especially to the brain, as anoxia.
Visual Brain Damage in Children and Adults

- Diffuse damage—range of visual dysfunctions
- Focal damage—can lead to disorders affecting primary visual functions or dorsal or ventral stream functions, either as isolated conditions or in a variety of combinations.
- The CVI may be isolated or a range of other features of brain damage may be evident.
- Unique patterns of visual, perceptual and visuomotor dysfunction

Types of Cerebral Visual Impairment

- CVI can be considered in the context of which parts of the brain are considered dysfunctional and which are not:
  - the visual pathways and occipital lobes
  - the middle temporal lobes (perception of movement)
  - the ventral stream and temporal lobes (recognition and orientation)
  - the dorsal stream and parietal lobes (search and visual guidance of movement)

Damage to Visual Pathways and Occipital Lobes

- Visual acuity, color perception, contrast sensitivity and visual fields
- Occipital lobes are the most active parts of the brain, having the highest blood flow and having the greatest oxygen and glucose demand
- Prolonged period of reduced oxygen to the brain can affect occipital lobes the most
- Extent of functional loss is dependent upon when damage occurred and whether one or both sides are affected.
Visual Pathways and Occipital Lobes

- If damage to only one side, will usually have visual field loss on the opposite side with no loss of visual acuity, color or contrast
- Early onset bilateral damage – profound visual impairment
- High level blindsight- if the middle temporal lobes are not damaged, may have normal intellect and limb movement and retain visually guided movement with limited conscious movement

Damage to the Middle Temporal Lobes

- Damage to the middle temporal lobes or the nerve fibers pathways that support them impairs perception of movement.
- Akinetopsia – cannot perceive motion despite being able to see stationary objects.
- Rarely seen in children as an isolated phenomenon.
Damage to the Middle Temporal Lobes

- Functionally, unable to see fast moving objects - movement makes things seem to disappear
- Unable to see quickly changing facial expressions
- Cannot see fast moving movies/videos
- Fast moving stimuli while walking are not seen
No formal standardized clinical test for disordered perception of movement

- Observed behavior – startled by fast moving animals, unable to move quickly, difficulties seeing facial expressions, avoids fast moving movies, videos, can only see slow traffic
- Counting fingers test
- Facial expression test
Cognitive visual dysfunction arises from damage to the visual area of the brain, the peristriate cortex. These areas of the brain process visual information arising from the primary striate cortex in the occipital lobe. Two functional visual pathways are responsible for cognitive visual function – the dorsal stream and the ventral stream.
A normal eye exam does not imply that the patient has a normal visual system because it does not exclude cognitive visual dysfunction.

The more severe the neurological deficits, the more difficult it is to obtain visual acuities and other functional information about the child’s or adult’s visual system.
Ventral and Dorsal Stream

Dorsal or “where” stream
- Location movement
- Spatial transformations
- Spatial relations

Ventral or “what” stream
- Color
- Texture
- Pictorial detail
- Shape
- Size

Object processing

Frontal
Parietal
Temporal
Occipital
Damage to the Temporal Lobes and Disorders of Ventral Stream Function

- Visual recognition and orientation
- Temporal lobes provide the long term visual memories of what we have seen before
  - Right temporal lobe stores the images of all of the faces we have seen
  - Left temporal lobe stores the images of shapes and objects


Damage to the temporal lobes and Disorders of Ventral stream Function

- **Ventral Stream**: Perceptual pathway
- The visual pathway between the occipital lobes and the temporal lobes
- Recognition of shape, color, texture, people and orientation within the surroundings
- The “what” pathway
- Commonly associated with impaired visual acuities, visual field disorders and varying patterns of dorsal stream dysfunction
- If isolated, more common in acquired brain damage
Damage to the temporal lobes and Disorders of Ventral stream Function

- Right temporal lobe
  - Prosopagnosia: inability to recognize people
  - Topographic agnosia: tendency to get lost
- Left temporal lobe dysfunction
  - Shape and object agnosia

(Agnosia – inability to process sensory information)


Damage to the Posterior Parietal Lobes and the Dorsal Stream Pathways

- Visual guidance of movement, visual search and attention
- Dorsal Stream: Action pathway or “Where” pathway (where is it)
- Visual pathway between the occipital lobes and the posterior parietal lobes
- Subconsciously maps the environment to facilitate immediate visual guidance of movement, visual search and the facility to switch attention from one element of the scene to another
Damage to the Posterior Parietal Lobes and the Dorsal Stream Pathways

- Impaired visual search: difficulty handling complex visual scenes (crowding)
- Optic ataxia: inaccurate visual guidance of movement
- Apraxia of gaze: difficulty following and tracking a moving object


Cognitive Visual Dysfunction

- Impaired simultaneous perception – an inability to locate an object in a crowded visual field, such as toys in a box, parent in a crowd, **difficulty reading**, and difficulty seeing moving objects.
- Inaccurate movements of the arms and especially the legs compounded by visual field deficits and any other motor deficits.
A mirror neuron is a neuron that fires both when the individual acts AND when observing the same action performed by another.

In humans, brain activity consistent with that of mirror neurons has been found in the premotor cortex, the supplementary motor cortex, the primary somatosensory cortex and the inferior parietal cortex.

Allows for the development of communication, responding to emotions and learning to copy motor tasks.

Newborn Monkey in Mirror Neuron Study
Little is known about the development of this system in children and how it is impaired by disorders of vision.

- Should assume that children with cognitive visual dysfunction may have limitations in this system.
- This will most certainly affect the child’s ability to learn by copying the actions of others.

Visual Problems Associated with Brain Injury

- Cerebral Vision Impairment
- Cognitive Visual Dysfunction
- Decreased visual acuity.
- Visual field losses – central, congruous and incongruous homonymous hemianopias, altitudinal defects.
- Eye movement dysfunctions – fixation, pursuit, saccade, nystagmus.
- Ocular muscle dysfunctions – strabismus, anisocoria, lagophthalmos, ptosis.
Visual Problems Associated with Brain Injury

- Binocular dysfunctions – exophoria, convergence insufficiency, vertical phorias, fusional instabilities
- Accommodative dysfunctions – amplitude, flexibility, sustainability
- Perceptual dysfunctions - body image, left-right discrimination, spatial relationships, agnosias, “subjective visual disturbances”
- Photosensitivity
How to Begin?

- Important to get as much information as possible concerning the patient’s visual functions.
- Neuro ophthalmologists/optometrists and low vision specialists that specialize in neuro patients are usually better able to gather the necessary information.
- A team approach is necessary – the family’s/therapist’s input is invaluable.
Visual Acuity

- Visual acuity can range from no light perception to normal visual acuity.
- Visual acuity is simply the ability to recognize a particular sized symbol at a particular distance – resolution acuity.
- It is only one measure of visual function.
- Normal Snellen visual acuity and normal stereopsis do not preclude cognitive visual dysfunction.
Determining Visual Acuity

- For adults with ABI, knowledge of visual acuity, visual field and oculomotor function is necessary for rehabilitation
- Mobility, reading, activities of daily living
- Other comorbidities (aphasia, cognitive dysfunction) can make it challenging.
OKN Drum
Utilized in adults with severe TBI and very low functioning children

Optokinetic nystagmus (OKN) is an eye movement that occurs in response to a rotation movement.

The presence of optokinetic nystagmus means there is vision.

This is very useful when the question is whether the child/adult has any vision.
Grating Visual Acuity – Preferential Looking

- Used to estimate visual acuity in very young children.
- Designed for children of normal development, not children with neurological deficits or children with vision impairment.
- However, it does gives us an idea as to level of functioning vision.
- Used in adults with ABI
Teller Cards
Lea Gratings
Grating Visual Acuity – Preferential Looking

- Teller cards – do have a conversion to Snellen acuity but it is not measuring resolution acuity so it is not accurate, especially in children with vision impairment and/or CVI.

- Lea gratings – have a graph that shows what size grating the child should respond to at a certain age (birth to 18 months); can tell whether a child is visually responding normally for his/her age.
Lea Symbols

- High contrast simple figures that most children can identify or be taught to identify.
- Can use pointing or even forced choice technique in shy or non-verbal children.
- Can be used to measure distance and near visual acuity.
- Can be used in adults with aphasia.
Lea Symbols
Lea Symbols

- Usually will do forced choice (apple vs. circle)
- If the child/adult is able, can also do matching
- For adults with aphasia, symbols are easier than numbers and numbers are easier than letters.
- Is an excellent way to measure resolution acuity
- NOT measuring functional acuity if using the cards because crowding is not an issue.
Adults with ABI

- Start with large isolated letters
- If can identify them, try an isolated line
- If crowding is an issue (dorsal stream dysfunction), may do well with isolated letters but not a line
- If unable to name letters, try isolated numbers. In aphasia, numbers are easier than letters. Again, try a line to see if crowding is an issue
Adults with ABI

- If they are unable to name numbers, try Lea symbols.
- If they cannot name the symbols, they may be able to match.
- If they cannot match them, use forced choice circle vs. apple.
- May need to be at 5 feet rather than 10 feet.
Adults with ABI

- Low Vision Distance Acuity Chart (Bernell)
- Great for patients with dorsal stream dysfunction since only has 4 numbers per page so can easily isolate
Assessing Visual Function

- If none of the previous techniques can be used, other targets are used to elicit a fix and follow” response.
- Patients with ABI respond well to photos of beloved family members, friends, pets, cars, motorcycles.
- Best success is with taking a photo of the photograph on a cell phone and presenting it that way.
Accommodation is often affected in ABI so measuring near acuity is important to assess even in pre-presbyopic adults.

All of the cognitive tests require reading/near tasks.

The smallest Lea symbols can be utilized to determine the size text that is necessary.
Near Cards
Single Letter Acuity vs. Text Acuity

- Single letter acuity is what is usually measured but it is not a good indicator of the ability to read text.
- Both central scotomas (blind spots) and constricted visual fields can adversely affect ability to read text, especially for long periods of time.
- Scanning, tracking, smooth pursuits, ability to accommodate and crowding all affect reading as well.
The hen was sitting on the shed.

Patty spilled some jam on the rug.

I will make a wish for a red pen.

The big circus cats ran in the cage.

A pet shop is a nice place to visit.

The children took Grandma some flowers.

My dog likes to play catch with a stick.

The arrow on the compass points to the north.

Dogs make good friends.

Jack can make a good cake.

My bird sings.

The three elephants in the circus walked around very slowly.

We could not guess what was inside the big box on the table.
Crowding is more of a factor in the patient with a neurological component (dorsal stream dysfunction).

Crowding can be addressed by measuring near acuity in a crowded environment compared to a non crowded environment.

Crowding ratio – the acuity when presenting a single optotype, divided by the acuity presenting several optotypes (linear).
Crowding

- A crowding ratio ≥ 2 is the standard for abnormal crowding.
- One study found the crowding ratio has fairly good sensitivity (67%) and specificity (79-86%) to distinguish children at risk for CVI.

Crowded vs. Non-crowded Acuity
Crowding
Rely heavily on the observations of the other therapists, including BROS (blind rehab outpatient specialist)

Will often co-treat with PT, OT, SLP, RT

Will often need to rely on the observations of the family members

Even if the patient is unable to respond reliably, speak TO the patient.
Visual Fields in ABI

- Rule of thumb: assume visual field loss unless proven otherwise
- Homonymous hemianopsia is most common
- Can have visual neglect alone, hemianopsia alone or both
- Almost always have visual field abnormalities in anoxic brain injury since it usually involves the occipital lobes
- The therapists or family members will usually identify it
Can be very challenging to do after brain injury.

Necessary to know best corrected acuity because services are based upon best-corrected visual acuity.

We want to know if glasses or contact lenses will improve the visual acuity.

May have to rely on objective measures – retinoscopy and autorefraction.
Retinoscopy

- Often have to rely on objective testing like retinoscopy
- Can be performed bedside in ABI inpatients
- Often will need to perform a cycloplegic refraction.
Autorefractor

- A very expensive second opinion!
- Handheld auto refractor is ideal for children and ABI patients (wheelchair, bedside)
- Very helpful in children since they do move around a lot – can often get one quick reading that is a good starting place.
Use a trial frame rather than a phoropter in most cases.

Can use larger increments to make it easier to determine if the view is better or worse.
Oculomotor Dysfunctions

- Strabismus (eye turns) 2° nerve palsies, mechanical restrictions.
- Saccadic dysmetria (inaccurate saccadic amplitude; over or undershooting a visual target).
- Saccadic pursuit (maintaining fixation on a moving target).
- Unstable fixation (unable to maintain fixation on a stationary target).
- These abnormalities may manifest as blurring of vision, double vision or sensation of movement in the environment (My eyes don’t work together).
Oculomotor Dysfunctions

- Oculomotor dysfunctions are common in children with neurological problems such as CVI or cerebral palsy and adults with ABI.
- The oculomotor functions (pursuits, saccades and fixation) are extremely important in reading.
- Those with visual brain damage may have good visual acuity but poor oculomotor skills and will have difficulty reading.
<table>
<thead>
<tr>
<th>Cranial Nerve Name</th>
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<tbody>
<tr>
<td>I - Olfactory</td>
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<tr>
<td>II - Optic</td>
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<tr>
<td>III - Oculomotor</td>
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<td>IV - Trochlear</td>
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<td>V - Trigeminal</td>
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<td>VI - Abducens</td>
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<td>VII - Facial</td>
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<td>VIII - Vestibulocochlear</td>
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<td>IX - Glossopharyngeal</td>
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<td>X - Vagus</td>
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<tr>
<td>XI - Spinal Accessory</td>
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<tr>
<td>XII - Hypoglossal</td>
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</tbody>
</table>
Vision therapy techniques can be utilized in children with good cognitive function.

Compensatory techniques can be utilized.

Patients may read more easily by keeping the head still and moving the reading material from side to side (eliminates the need for accurate saccades and pursuits).

Use of low vision devices may help.
Video Magnification

- The tray moves back and forth so the patient does not need to move their eyes.
- Can isolate a line or even a word to make it easier for those with oculomotor dysfunction.
- Some have text to speech option as well.
Accommodation is the ability of the eyes to focus at near.

Brain damage may lead to incomplete accommodation, persistent hyperopia (farsightedness) and blurring of near images.

Reading glasses may be necessary.
Managing Cerebral Impairment in ABI Patients

- Most will have visual field deficits, cognitive visual dysfunction
- Oculomotor and accommodative dysfunction are common
- Cranial nerve palsies are common so many will have diplopia
- All of these will usually improve over time
- May need 2 separate pairs of glasses since bifocals can interfere with walking
Managing CVI in ABI

- Isolating lines, using line guides are helpful for reading
- Encourage them to use their finger to keep their place
- Enlarging the font initially will help with crowding.
- Prism can be utilized for both visual field loss/neglect and diplopia
- Vision therapy for oculomotor and accommodative dysfunction is helpful
Managing CVI in ABI

- Requires a team approach.
- We work closely with BROS, OT, PT, SLP, neuropsych, RT, psychology and the family.
In my experience, this occurs with anoxic brain injury.

Visual acuity is often severely reduced and initially, the patient may appear totally blind.

Start with lighted objects.

Use photographs of family and friends.

As they improve cognitively, begin using simple flash cards with color.

Reinforce with tactile information.
Managing Severe CVI in Adults
Managing Severe CVI in Adults

- Use flash cards with simple pictures
- Color is better so they have additional cues.
- Use other senses – touch, smell, taste.
- Some patients do not do well with drawings – will need actual pictures
Resources

- Cortical Vision Impairment: An Approach to Assessment and Intervention
- Christine Roman-Lantzy
What and How Does This Child See?
Lea Hyvarinen and Namita Jacob
Resources

- Vision and the Brain: Understanding Cerebral Visual Impairment in Children
- Amanda Hall Lueck and Gordon N. Dutton
Thank You!

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