# Assessment of visual functions and functional vision for children with a suspicion of Cerebral Visual Impairment (CVI)

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# Multidisciplinary team

- The diagnosis of Cerebral Visual Impairment (CVI) requires the participation of a multidisciplinary team

- A multidisciplinary team should include:
  - Pediatric neurologist / pediatrician
  - Ophthalmologist / orthoptist / optometrist
  - (Neuro)psychologist
  - Low vision therapist / special education teacher

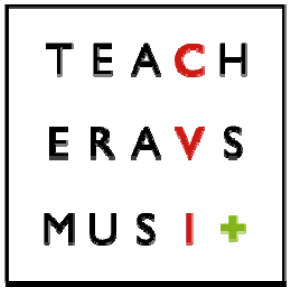
  And might also include:
  - Physiotherapist
  - Occupational therapist
  - Speech language therapist
  - Social worker / social care worker

# Assessment of visual functions and functional vision

- There are various assessments and observational tools available that can be used as part of the diagnosis of CVI. This list is intended to be comprehensive but should not be taken to be exhaustive. These tools are currently used by professionals in the countries participating in the TEACH CVI project.

# Definition and framework

# Definition – Visual functions and functional vision




- **Visual functions**
  - Describes how the eyes and the basic visual system functions.[1]
  - Is the ability to process visual stimuli of a particular dimension, e.g. form, colour or motion [2]

- **Functional vision**
  - Describes how the person functions [1]
  - The way vision is used in everyday life [2]
  - The assessment of functional vision determines the impact of visual function on everyday life [2]

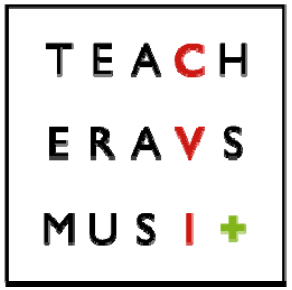
# Definition – Visual functions and functional vision

- **Overview**
  - Basic visual functions – Oculomotor functions [3,4]
  - Basic and middle visual functions. [3,4] – Sensory functions [2]
  - Relation between basic and middle visual functions and functional vision [3,4]
  - Higher visual functions – Visual perception (dorsal stream) [2,3]
  - Higher visual functions – Visual perception (ventral stream) [2,3]
  - Relation between higher visual functions and functional vision [3,4]

# Definition – Visual functions and functional vision

- **Check the visual status in children**
  - Visual interest sphere / working distance: the best visual reaction within the visual field (e.g. angle, position or distance)
  - Body position: comfortable position in order to maximize functional vision and visual reactions
  - Basic visual functions: oculomotor and sensorial functions [3,4]
  - Middle visual functions: motion perception
  - High visual functions: visual perceptual functions (if the intellectual level of the child supports this type of assessment) [3,4]
  - Functional vision: using vision in communication / social interaction, daily living and learning skills, near vision tasks, orientation and mobility

# Framework – Visual functions and functional vision [1]




| | Visual Functions<br>*How the visual system functions* | Functional Vision<br>*How the person functions* |
|---|---|---|
| *Examples* | *Visual acuity, visual field, contrast, visual adaptation, colour vision etc.* | *Orientation and Mobility, Daily Living Skills, Communication, Sustained near activities* |
| *Measured* | *For each eye separately* | *For the person as a whole* |
| *Method* | *Variable stimulus; fixed, threshold performance* | *Standardized task; variable performance or difficulty* |
| *Tests* | *Single variable, under controlled conditions* | *Multiple variable, under complex, real-life conditions* |
| *Criteria* | *Threshold performance* | *Sustainable, supra-threshold performance* |
| *Involves* | *Visual parameters only* | *May also reflect non-visual factors* |

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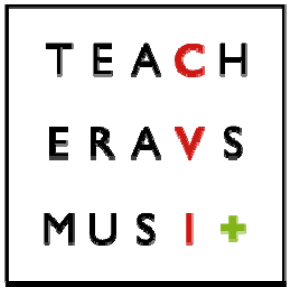
# Basic visual functions – Oculomotor functions

# Basic visual functions – Oculomotor functions




- Overview
  - Visual interest sphere / working distance
  - Fixation and following movements – Ability to detect visual stimuli
  - Shift of gaze and saccades
  - Nystagmus
  - Strabismus – Alignment of the eyes ortophoria , esotropia or exotropia
  - Accommodation ex. eye contact and social smile
  - Convergence / divergence [3]

# Basic visual functions – Oculomotor functions

- **Visual interest sphere / working distance**: the areas within the visual field where children give the best visual feedback




Examples of materials and toys than can be used for establishing visual interest sphere / working distance in children with a suspicion of CVI (materials shared by Roxana Cziker)

# Basic visual functions – Oculomotor functions

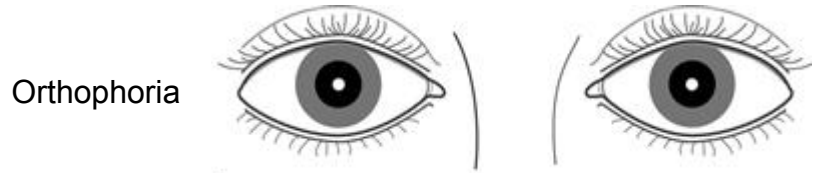
- **Visual fixation –** holding the image on the fovea or maintaining of the visual gaze on a single location
- **Eye movements** - allow the eyes to closely follow a moving object
- **Shift of gaze and saccades –** quick eye movements from one stimulus to another

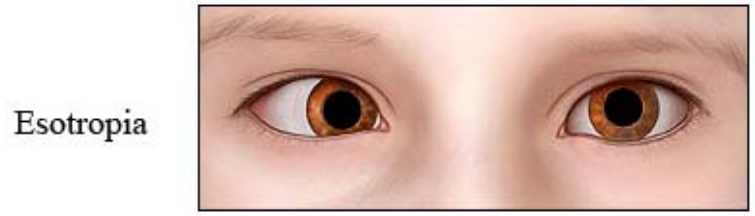
Examples of materials and toys than can be used for checking fixation and eye movements in children with CVI

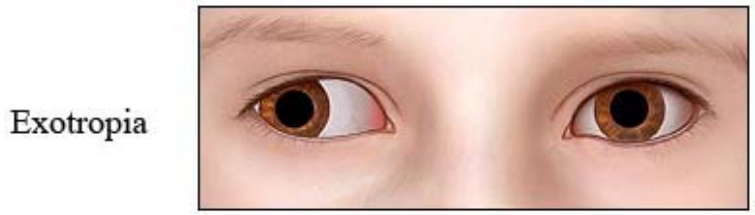
# Basic visual functions – Oculomotor functions

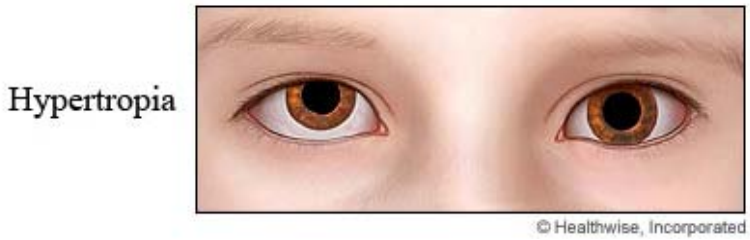
Black and white puppet and colour faces for assessing eye movements – visual fixation, following and saccades

# Basic visual functions – Oculomotor functions




- **Alignment of the eyes** – Ortophoria, esotropia, exotropia, hypo- and hypertropia
- **Strabismus** – Deviation of the eyes, when directing the gaze to the same point in space
- The ophthalmologist is responsible for the assessment of strabismus. But it's necessary for the members of the multidisciplinary team to recognize the effect of strabismus in functional vision assessment, since strabismus can have an effect on depth perception.

# Basic visual functions – Oculomotor functions

- **Nystagmus**: fast involuntary and repetitive eye movements
- It often takes the form of horizontal oscillatory eye movements, which seem to badly disturb fixation
- Nystagmus should be observed during reading, play and training situations and observations
- How the child compensates for the nystagmus should be noted (position of head, eyes, etc.), when possible

# Basic visual functions – Oculomotor functions

- **Accommodation** – Changing the focus from near to distance and vice versa

- **Convergence / divergence**
  - Convergence – Turning inward of the eyes when looking at close distances
  - Divergence – Turning outward of the eyes when looking on objects farther away
  - Assessment – Objects or images brought closer to the eyes and the gaze should shift from close to target far away

# Basic visual functions – Oculomotor functions

- **Accommodation - Eye contact and social smile**: e.g. distance, reactions and visual behaviour
- **Eye contact** is one of the most important sign which confirms the accommodation and the first stage of visual communication

Eye contact and copying facial epxression of mother (pictures from Lea Hyvarinen)

# Basic visual functions – Oculomotor functions

- **Role of oculomotor functions in daily life activities** – Oculomotor functions are important in:
  - Selecting and detecting information within the environment
  - Noticing objects, people or actions in different areas of the visual field
  - Following visual stimuli in movement in playing situations, detection of landmarks in orientation situations, both indoor and outdoor
  - Using eye contact in communication with people
  - Seeing objects clearly both near and in distance
  - Able to switch the eyes from one point to another – e.g. from one picture to another in order to find the target picture or from one text line to another when reading

# Basic and middle visual functions – Sensory functions

# Basic and middle visual functions – Sensory functions

- **Overview**
  - Visual acuity
  - Visual field
  - Contrast sensitivity
  - Colour vision
  - Stereopsis
  - Visual adaptation
  - Motion perception[3]
  - Role of sensorial visual functions and movement in daily life activities

# Basic visual functions – Sensory functions


- **Visual acuity (VA)** – Ability to resolve or recognise fine details [3]
  - The ability to see details provides information about forms of objects, surfaces and textures
  - Recognition of very fine detail supports reading, which requires recognition of small images placed closely together
  - Visual acuity should be tested both near and at distance
  - You can use one of the three types of VA (detection, resolution and recognition) according to the child´s level of development

# Basic visual functions – Sensory functions

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- **Visual acuity at distance (3m or less) – Detection acuity**
  - Target detection requires only the perception of the presence or absence of an aspect of the stimuli, not the discrimination of target detail
  - The task of detection involves stating wheater the spot or line is present:
    a) Bright test object on a dark background
    b) Dark test object on a bright background

# Basic visual functions – Sensory functions

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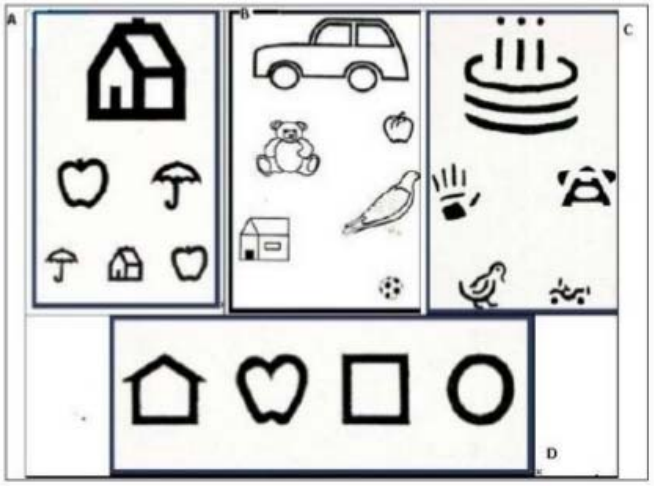
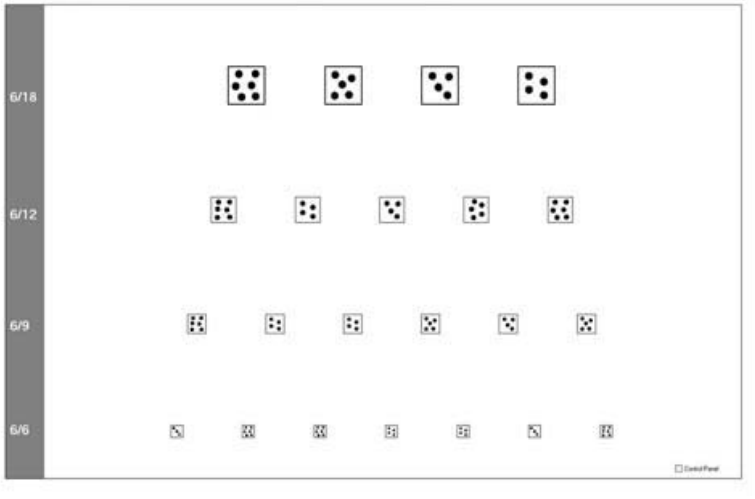
- **Visual acuity at distance (3m or less) – Detection acuity**
  - Dot visual acuity test
  - Catford Drum Test
  - Boek Candy Bead Test
  - STYCAR graded ball´s test



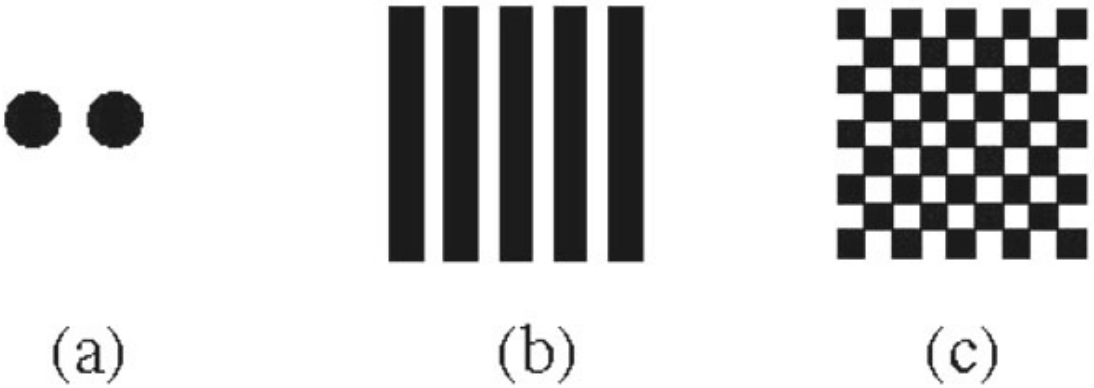
STYCAR test




Dot Visual Acuity Test

# Basic visual functions – Sensory functions

- **Visual acuity at distance (3m or less) – Resolution acuity**
  - Target resolution thresholds are usually expressed as the smallest angular size at which subjects can discriminate the separation between critical elements of a stimulus pattern such as a pair of dots, a grating or a checkerboard
  - The task of resolution:
    a) Double dot target
    b) Acuity grating
    c) Checkerboard

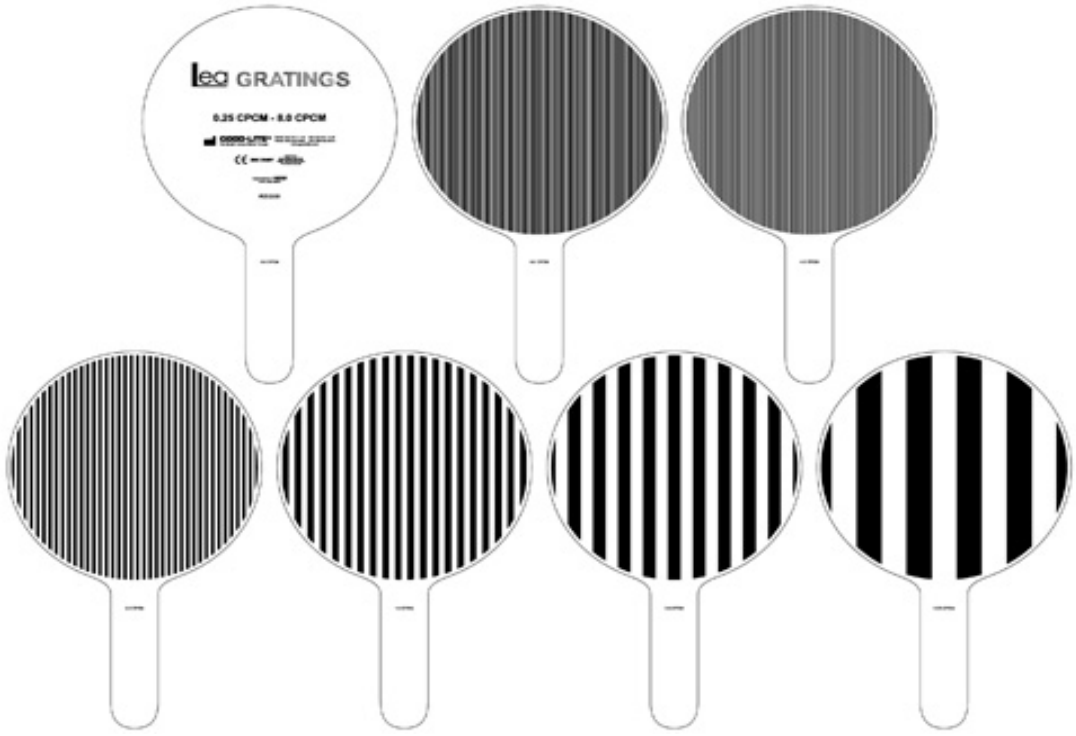


# Basic visual functions – Sensory functions


- **Visual acuity at distance (3m or less)**
  - **Resolution acuity**- Grating acuity
    - Preferential looking methods - LEA Paddles
    - Tellers Acuity Cards
    - Cardiff Acuity Test

# Basic visual functions – Sensory functions

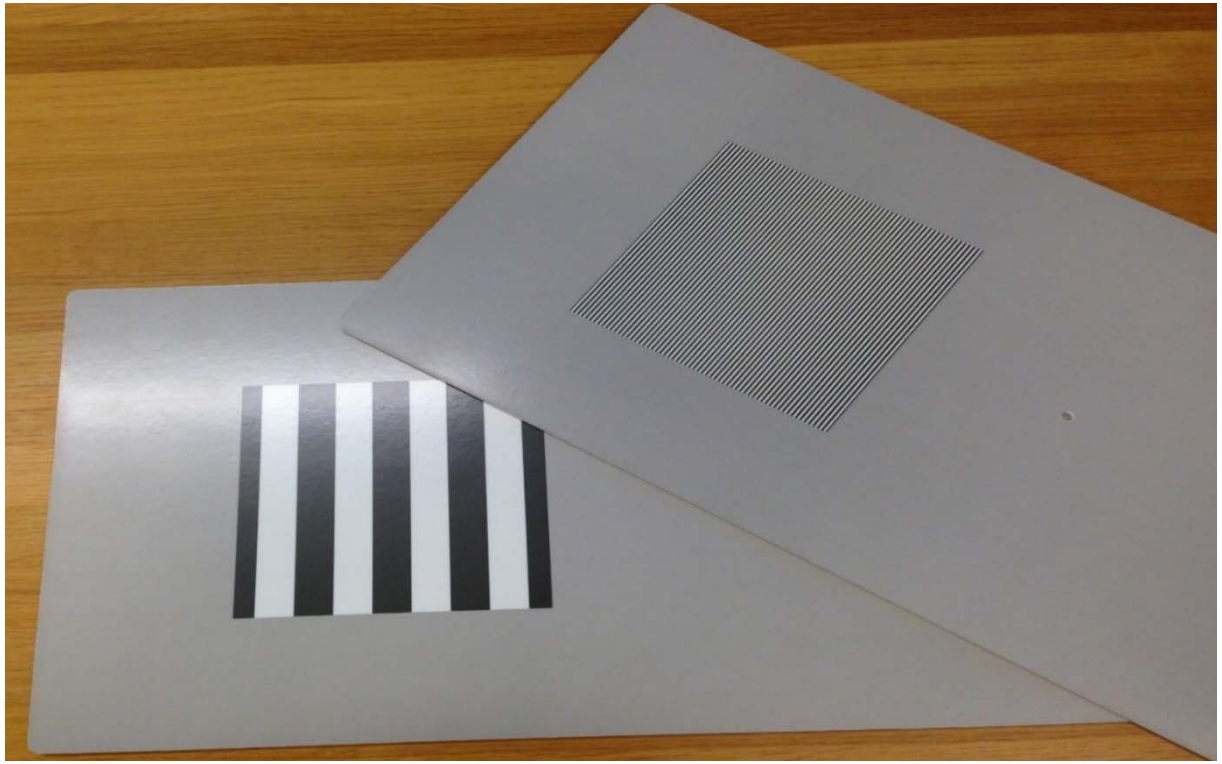
- **Visual acuity at distance (3m) – Resolution acuity**
  - Grating acuity




Lea Grating Preferential Looking Test

# Basic visual functions – Sensory functions

- **Visual acuity at distance (3m) – Resolution acuity**
  - Grating acuity



Teller Acuity Cards

# Basic visual functions – Sensory functions

- **Visual acuity at distance (1m or 0,5m) – Resolution acuity**


Cardiff Acuity Test

# Basic visual functions – Sensory functions

- **Visual acuity at distance (6m or less) – Recognition acuity**
  - Target recognition tasks, which are most commonly used in clinical visual acuity measurements, require the recognition or naming of a target, such as Snellen letters or Lea tests


The task of recognition: naming the test objects, in this case letters of the alphabet (Snellen)

# Basic visual functions – Sensory functions


- **Visual acuity at distance (6 m or less) – Recognition acuity**
  - Optotypes
    - Symbol pictures: LEA or BUST (perception of form/visual acuity test)
    - Letters: HVOT or KM
    - Single symbols
    - Symbols in line (crowding)
    - Kay Pictures Test

# Basic visual functions – Sensory functions

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- **Visual acuity at distance (6m or less) – Recognition acuity**
  - Optotypes

LEA Symbols Flash Cards

LEA Symbols Single Symbol Book

# Basic visual functions – Sensory functions

- **Visual acuity at distance (6m or less) – Recognition acuity**
  - Optotypes


Kay Pictures Test

# Basic visual functions – Sensory functions


- **Visual acuity near (40cm or less)**
  - Symbols (LEA or BUST) or letters
    - Single symbols or letters
    - Linear array of symbols or letters
    - Crowding
  - Maclure reading test
    - Reading acuity
    - Words and sentence in sizes N5 – 48

# Basic visual functions – Sensory functions

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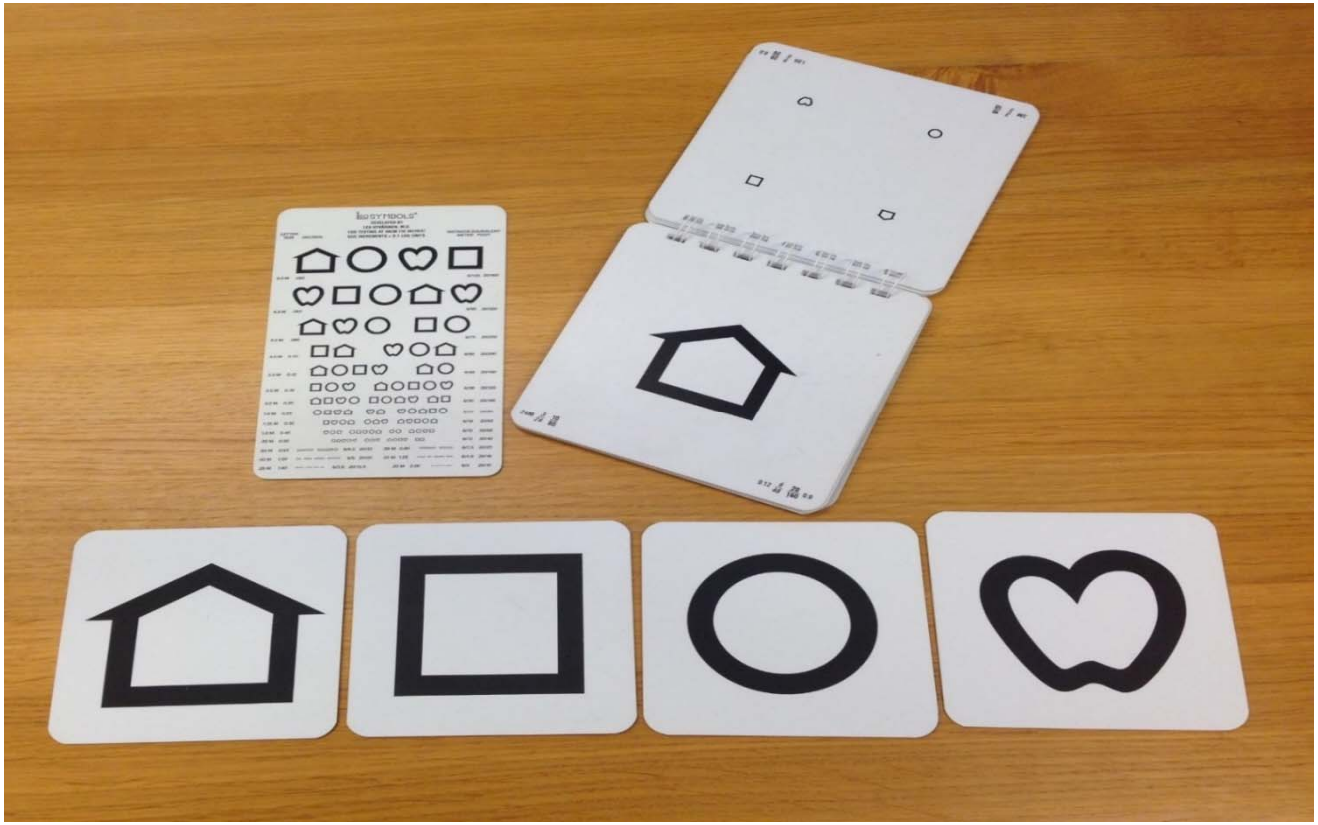
- **Visual acuity near (40cm or less)**



LEA symbols

# Basic visual functions – Sensory functions

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- **Visual acuity near (40cm or less)**



Maclure reading test

# Basic visual functions – Sensory functions

- **Visual field** – The peripheral fields extend our view almost to our shoulders on either side of our body. Our lower field gives us a view of the ground and the upper visual field covers space above our head. Thus the large field of vision allows us to easily manoeuvre safely in space.
- The binocular field is around 120 degrees.
- The monocular field extends 90 degrees from the midline to the sides and it is limited by the nose to the midline
- The vertical field extends 60 degrees above and 70 degrees below [3]

Assessing the visual field in young children can be a challenge

# Basic visual functions – Sensory functions


- **Visual field**

  - Assessment can be done by observation and by using standardized instruments
  - Examples of assessment tools
    - Rolling balls – observational tool
    - Ball on a stick – observational tool
    - LEA Flicker Wand (light spot) - observational tool
    - LEA Campimeter - standardized
    - Goldmann perimeter - standardized; best results when children are older then 7 to 12 years of age

# Basic visual functions – Sensory functions

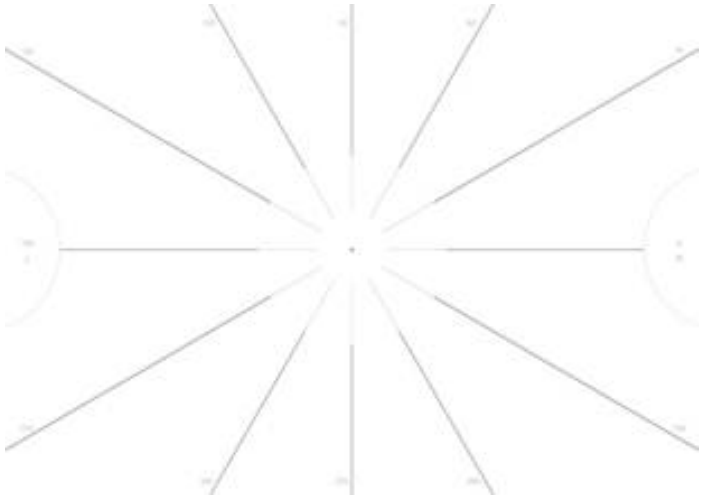
- **Visual field**

Ball on a stick –
observational tool

# Basic visual functions – Sensory functions

- **Visual field**

Lea Flicker Wand – observational tool



Lea Campimeter – standardized tool

# Basic visual functions – Sensory functions

- **Visual field**

Arc perimeter – standardized tool

# Basic visual functions – Sensory functions

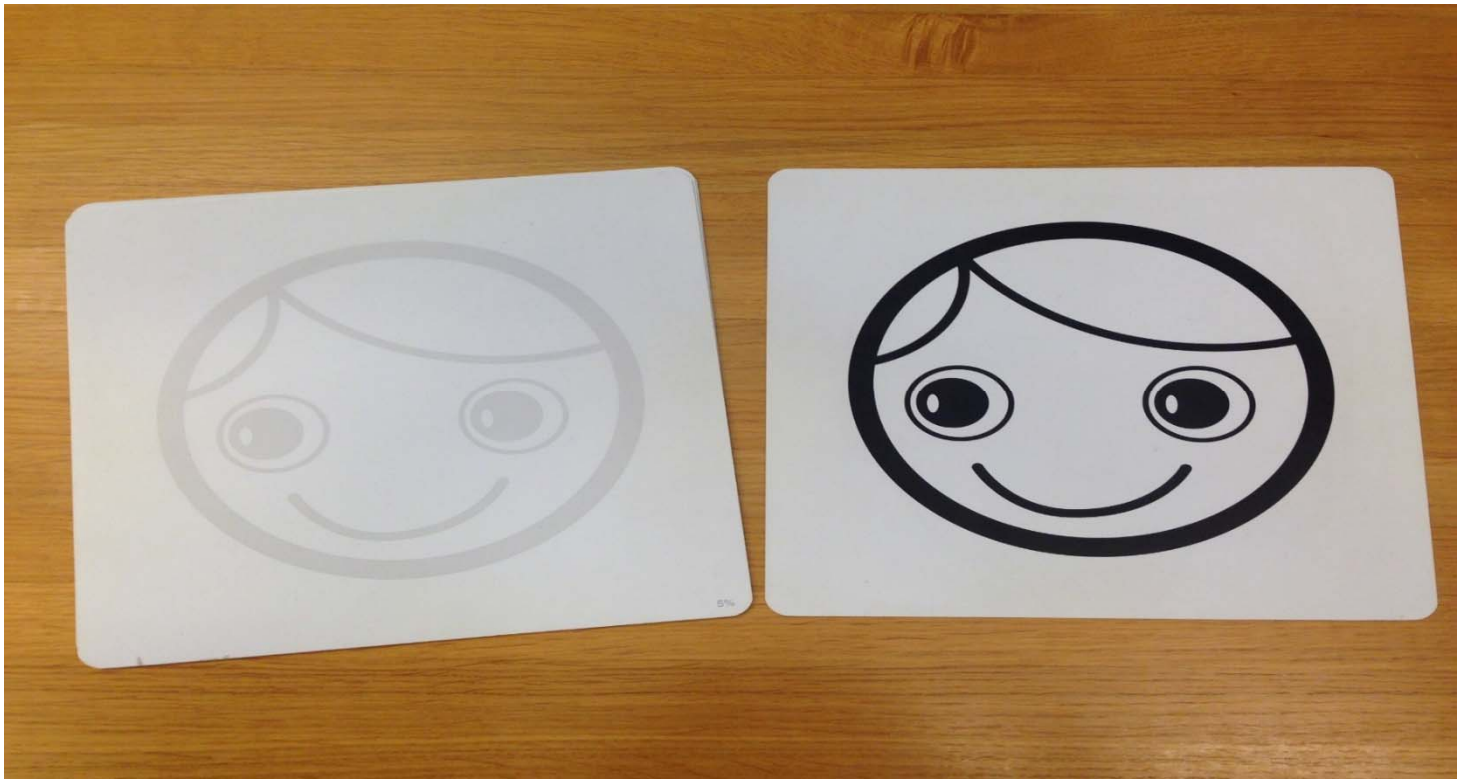

- **Contrast sensitivity**
  - Ability to see differences in the amount of light reflected from adjacent surfaces. The ability allows us to notice edges and shadows that define objects and also shows us their depth and placement in space.
  - It is one of the most important visual functions in assessment, because it gives information about communication and perceiving the environment, which are mostly at low and intermediate contrast. [3]

# Basic visual functions – Sensory functions

- **Contrast sensitivity**
  - Assessment tools:
    - Hiding Heidi (schematic faces)
    - LEA contrast test
    - Cardiff Contrast Test
    - KM contrast test (optoypes)

# Basic visual functions – Sensory functions

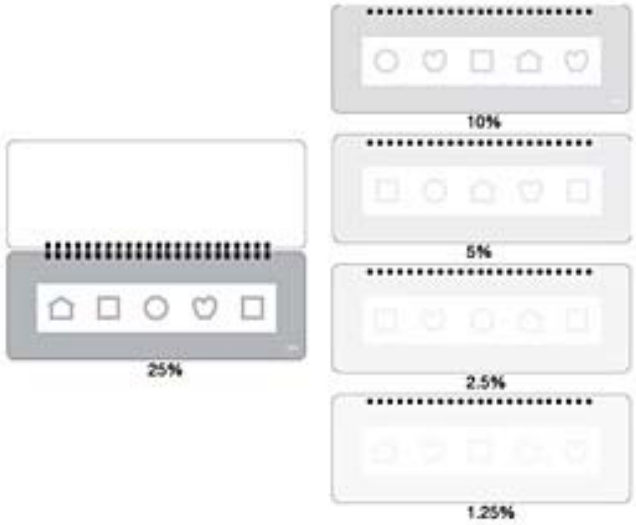
- **Contrast sensitivity**



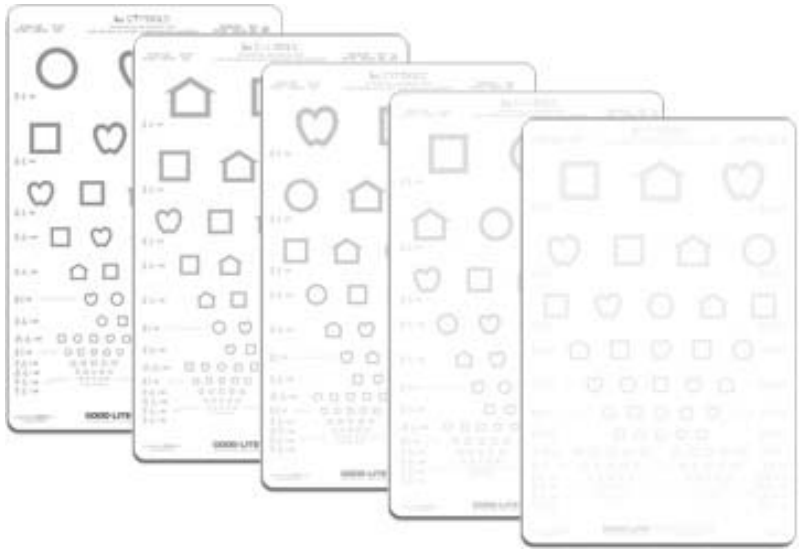
Hiding Heidi

# Basic visual functions – Sensory functions

- **Contrast sensitivity**




Lea Symbols Low Contrast Test
10M Symbol Size



Lea Symbols Low Contrast Visual Acuity Charts

# Basic visual functions – Sensory functions

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- **Contrast sensitivity**


Cardiff Contrast Test

# Basic visual functions – Sensory functions

- **Stereopsis**
  - Fine stereopsis is the highest function of binocular vision
  - Fine depth perception that results from the brain´s interpretation of the slight difference between the disparate pictures of the same visual scene provided by the two eyes[2]

- **Gross stereopsis** appears to be used to judge stereoscopic motion in the periphery. Gross stereopsis is important for orientation in space while moving, for example when descending a flight of stairs

- **Fine stereopsis** is mainly based on static differences. It allows the individual to determine the depth of objects in the central visual area. Fine stereopsis is important for fine-motorical tasks such as threading a needle

# Basic visual functions – Sensory functions


Assessment tools:

- Stereo Acuity Test Butterfly – test both gross and fine stereopsis
- Stereo Fly Test – test both gross and fine stereopsis
- Lang stereotest – test both gross and fine stereopsis

# Basic visual functions – Sensory functions

- **Stereopsis**
  - Assessment tools


Stereo Acuity Test Butterfly


Stereo Fly Test

# Basic visual functions – Sensory functions

- **Stereopsis**
  - Assessment tools



Lang stereotest

# Basic visual functions – Sensory functions


- **Visual adaptation**
  - The term visual adaptation describes the processes by which the visual system alters its operating properties in response to changes in the environment.
  - In very low light levels, vision is scotopic: light is detected by rod cells of the retina
  - In brighter light, such as daylight, vision is photopic: light is detected by cone cells which are responsible for colour vision [5]

# Basic visual functions – Sensory functions

- **Visual adaptation**
  - Assessment – Cone Adaptation Test [3]


The Cone Adaptation Test is used to assess a person's ability to adapt to lighting changes. The task is to sort the red, blue and white squares in the least amount of light necessary. Disturbed cone function may cause photophobia.

# Basic visual functions – Sensory functions


- **Colour vision**
  - Colour vision is possible due to photoreceptors in the retina of the eye known as cones. These cones have light-sensitive pigments that enable us to recognize colour. Found in the central part of the retina, each cone is sensitive to either red, green or blue light.
  - Normally, the pigments inside the cones register different colours and send that information through the optic nerve to the brain. This enables you to distinguish countless shades of colour.

# Basic visual functions – Sensory functions


- **Colour vision**
  - Assessment
    - Name, identify and recognize colours
    - Colour images, choose among different colours
    - Discriminate, sort and classify colours
    - Assessment of colour vision defects with standardized tests

# Basic visual functions – Sensory functions


- **Colour vision**
  - Examples of assessment tools
    - LEA puzzle
    - Waggoner Colour Vision Testing Made Easy
    - PV 16
    - Ishihara

# Basic visual functions – Sensory functions

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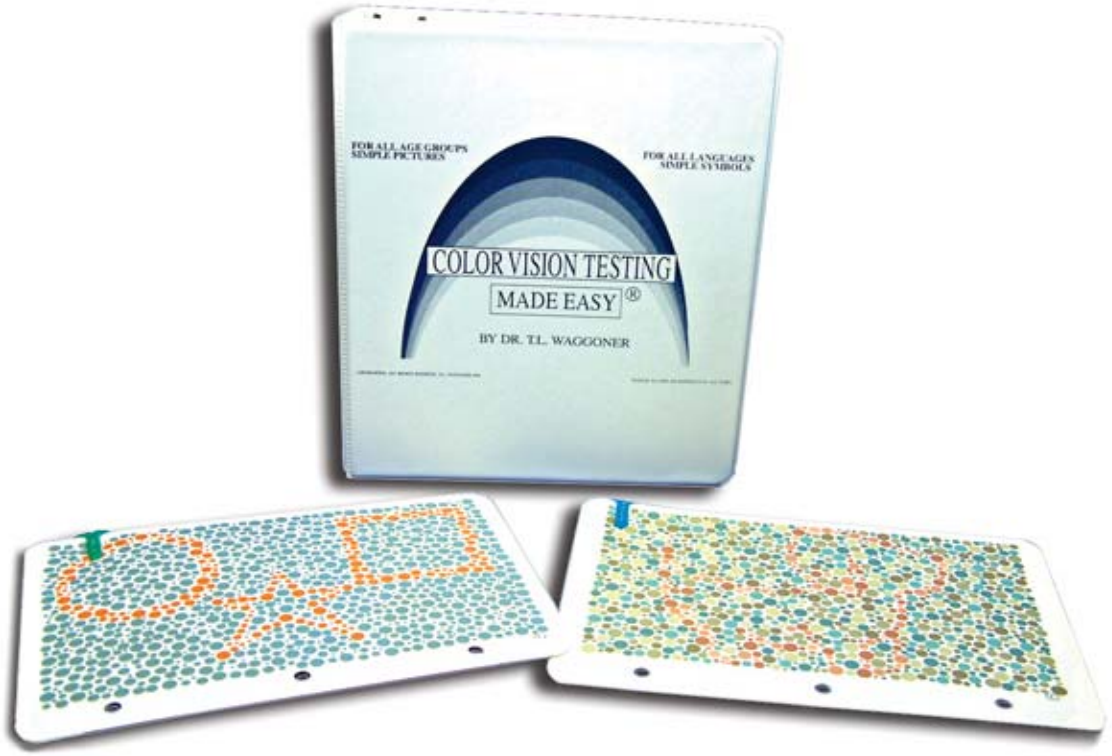
- **Colour vision test**

Lea Puzzle

# Basic visual functions – Sensory functions

- **Colour vision**




Waggoner Colour Vision Testing Made Easy

# Basic visual functions – Sensory functions

- **Colour vision test**

Quantitative Colour Vision Test PV 16

# Basic visual functions – Sensory functions

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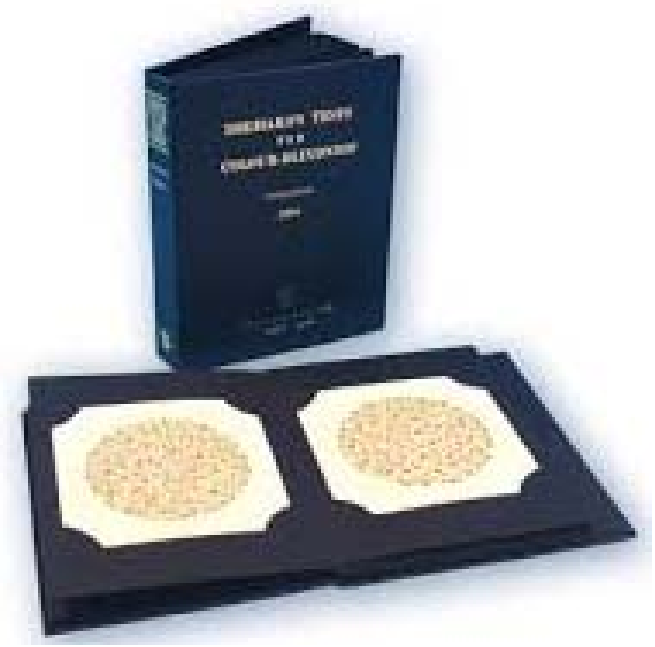
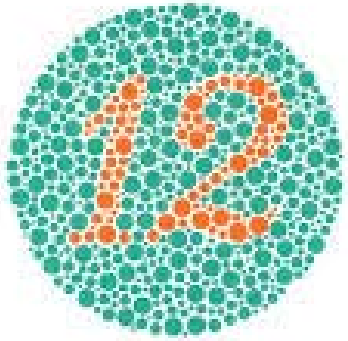
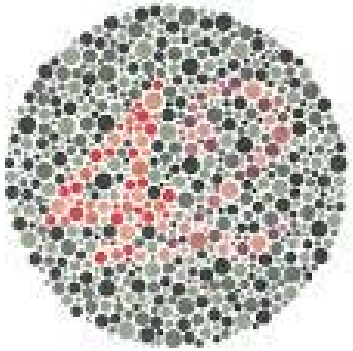
- **Colour vision**







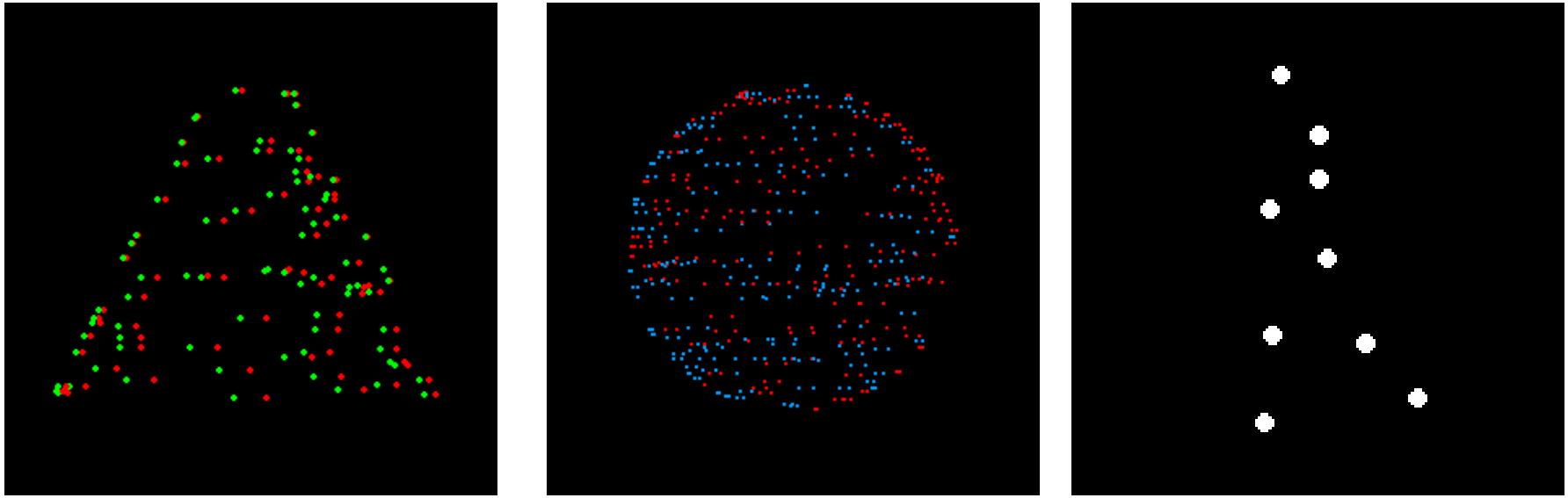
Ishihara Colour Vision Test

# Middle visual functions


- **Motion perception**
  - The capacity to see movement
  - Bilateral damage can cause impaired or absent visual perception of movement (akinetopsia) (Zihl et al. 1983 ) [3]

# Middle visual functions – Motion perception

- **Motion perception**
  - Assessment



Animation for assessing the ability to perceive the motion

# Relation between basic and middle visual functions and functional vision


- **Role of oculomotor functions in daily life activities** – Oculomotor functions are important in:
  - Selecting and detecting information within the environment
  - Fixate on objects, people or actions in different areas of the visual field
  - Following visual stimuli in movement in playing situations, detection of landmarks in orientation situations, both indoor and outdoor
  - Using eye contact in communication with people
  - Seeing objects clearly both near and in distance
  - Able to switch the eyes from one point to another – e.g. from one picture to another in order to find the target picture or from one text line to another when reading

# Relation between basic and middle visual functions and functional vision


- **Role of sensorial visual functions and movements in daily life activities** – Sensorial functions and movement are important in:
  - Clearly seeing details about elements, pictures and text
  - Reading texts in different seizes and different backgrounds
  - Seeing details both near and at distance space
  - Moving freely in space by covering stimuli in different areas of the visual field
  - Noticing people in a group, making difference among stimuli within environment in different levels of contrast

# Relation between basic and middle visual functions and functional vision


- **Role of sensorial visual functions and movements in daily life activities** – Sensorial functions and movement are important in:
  - Identifying and discriminating size, colour, shape of objects, pictures, people or actions
  - Adapting the vision in different light situation
  - Being independent in organizing and finding personal things by different criteria (size, shape, colour, etc.)
  - Perceiving movement scenes outdoor or on television

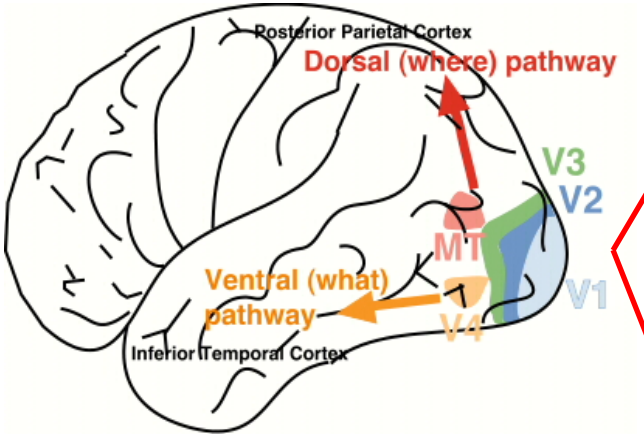
# Higher visual functions – Visual perception

# Higher visual functions – Visual perception

***The ventral stream*** integrates occipital lobe functions with those of the temporal lobe structures that serve as the brain's 'visual library', serving conscious recognition and visual memory.

***The dorsal stream*** integrates occipital lobe and posterior parietal lobe function. It affords subconscious analysis of the visual scene integrated with analysis of data from other sensory inputs such as hearing. This brain area is thought to continuously map the components of the visual scene, providing a real-time, constantly refreshing, virtual, multimodal mental representation of the surroundings. [2]

# Higher visual functions – Visual perception [2, 3, 4]




**Dorsal stream "Where" – Parietal Lobe**:
- processing of movement stimuli and visual guidance of movement
- control of ocular movements
- prehension of objects, visual guided
- crowding of text
- simultaneous perception
- finding people in a group
- visual attention

**Ventral stream "What" – Temporal Lobe**:
- details of objects
- recognition of shapes, objects, letters, numbers, words, landmarks
- recognition of human faces and facial expressions

# Higher visual functions – Visual perception


- Screening tests
  - LEA Puzzle – Form perception
  - LEA Mailbox – Direction
  - Complex pictures – Recognition of details
  - LEA Faces – Recognition of facial expression
  - Coloured photos
  - Recognition of familiar faces

# Higher visual functions – Visual perception

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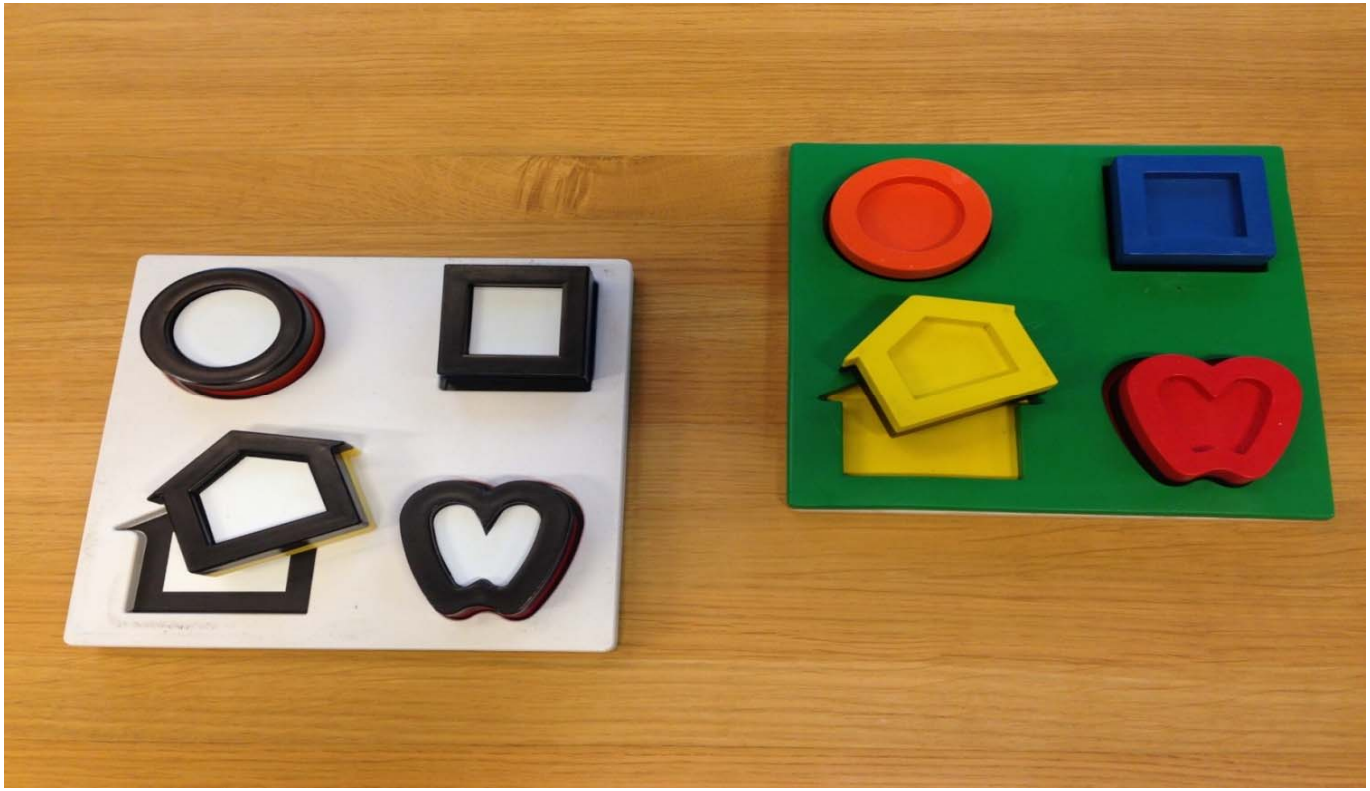
- Screening tests



LEA Puzzle

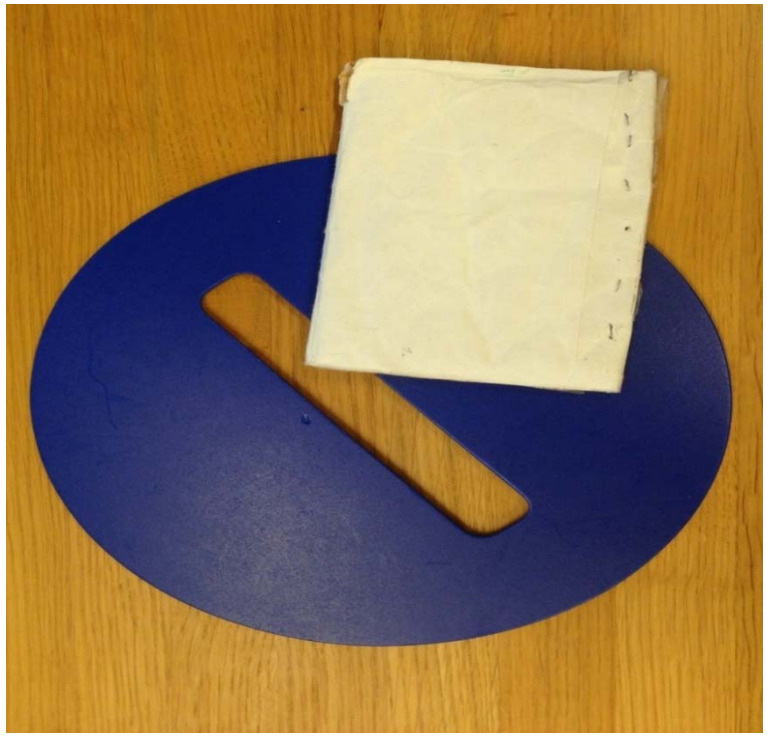
# Higher visual functions – Visual perception


- Screening tests – **Lea Mailbox**
- Assess visual perception of line orientation. Tests two components:
  - Information for the hand movements in the parietal lobe
  - Picture perception in the inferior temporal lobe

# Higher visual functions – Visual perception

TEACH
ERAVS
MUSI+

- Screening tests



LEA Mailbox

# Higher visual functions – Visual perception

TEACH
ERAVS
MUSI+

- Screening tests


Pictures – Recognition of details

# Higher visual functions – Visual perception

- Screening tests

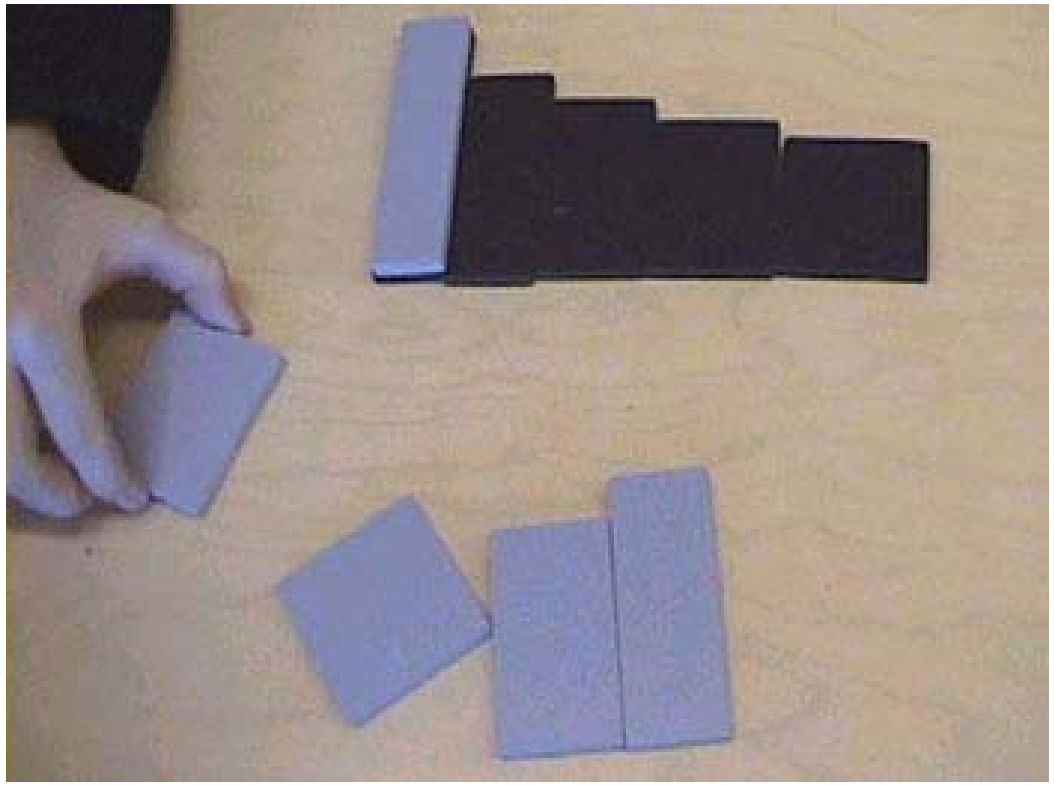
# Higher visual functions – Visual perception


- Screening tests - **LEA Rectangles Game**:
  - Interpretation of length
  - Assessment of eye-hand coordination
  - Capacity of grasping
  - Interpretation of comparing lengths of the model
  - Ability to handle, grasp and move the rectangles over the model

# Higher visual functions – Visual perception

TEACH
ERAVS
MUSI+

- Screening tests



LEA Rectangles Game

# Role of higher visual functions in daily life activities

The **higher visual functions** are important in:

- Recognize, identify and discriminate objects – orientation – recognize landmarks like buildings, trees, pathways; reading – recognizing letters and words
- Recognize and identify simultaneously multiple objects or people – finding a friend in a group of children in different spaces
- Build words from different letters and give a meaning (writing and understanding the written text)
- Copying pictures, drawings, letters, words, text under the visual control
- Recognizing people by their facial features and facial expressions – communication
- Moving freely in space in a very busy scene and objects / people in movement

# References


1. *Report prepared for presentation at the World Ophthalmology Congress – Hong Kong, 2008 of the International Council of Ophthalmology.*
2. Zihl, J., & Dutton, G.N. (2015). *Cerebral visual impairment in children. Visuoperceptive and visuocognitive disorders.* Springer.
3. Hyvarinen, L., Jacob, N. (2011). *What and how does the child see?* Vistest Ltd.
4. Lueck A.H & Dutton G.N. (2015). *Vision and the brain. Understanding Cerebral Visual Impairment in Children. AFB Press.*
5. Clifford C.W.G, Webster M.A., Stanley G.B., Stocker A.A., Kohn A., Sharpee T.O. & Schwartz O. *Visual adaptation: Neural, psychological and computational aspects.* Vision Research, Volume 47, Issue 25, November 2007, Pages 3125–3131

# Final thoughts

# Final thoughts

- Please note that provided information are not exhaustive
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- Find more information about the TeachCVI project on the website: http://www.teachcvi.net
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