

How each EYE functions, How the PERSON functions

Smith-Kettlewell – September 2019

August Colenbrander, MD - San Francisco

Vision is a complex phenomenon

- In-depth analysis can reveal different layers

Broad Aspects of Visual Functioning

Each EYE

The PERSON

Structure

Function

Abilities

Consequences

Tissue

Organ

Person

Society

Scar
Atrophy
Loss

Acuity
Field
Contrast

Reading
Mobility
ADLs

Participation
Quality of Life



Comprehensive Care asks for TEAM work, including the PATIENT



Different Viewpoints

How each EYE functions

How the PERSON functions

Structure

Function

Abilities

Consequences

Tissue

Organ

Person

Society

Scar
Atrophy
Loss

Acuity
Field
Contrast

Reading
Mobility
ADLs

Participation
Quality of Life



but viewpoints differ



Comprehensive Care requires attention to ALL aspects



Different Viewpoints

How each EYE functions

Structure	Function
Tissue	Organ
Scar Atrophy Loss	Acuity Field Contrast

How each EYE functions

How the PERSON functions

Abilities	Consequences
Person	Society
Reading Mobility Activities of Daily Living	Quality of Life Participation Safety



The **patient's** view

Doctor, I cannot read

How the PATIENT functions

Different Viewpoints

How each EYE functions

Structure

Tissue

Scar

Atrophy

Loss

Function

Organ

Acuity

Field

Contrast

How the PERSON functions

Abilities

Person

Reading

Mobility

ADLs

Consequences

Society

Participation

Quality of Life

Safety

The “eye” doctor’s view

The patient lost 3 lines

How each EYE functions

Doctor, I cannot read

How the PERSON functions



Different Objectives

How each EYE functions

Structure

Function

How each EYE
functions
VISUAL
FUNCTIONS

Acuity
Field
etc.

Underlying
causes

How the PERSON functions

Abilities

Consequences

How the PERSON
functions
FUNCTIONAL
VISION

Reading
ADL
etc.

Societal
consequences



Embrace both Objectives

How each EYE functions

How the PERSON functions

Structure

Function

Abilities

Consequences



Protecting Sight

Empowering Lives

Different Interventions

How each EYE functions

Structure

Function

How the PERSON functions

Abilities

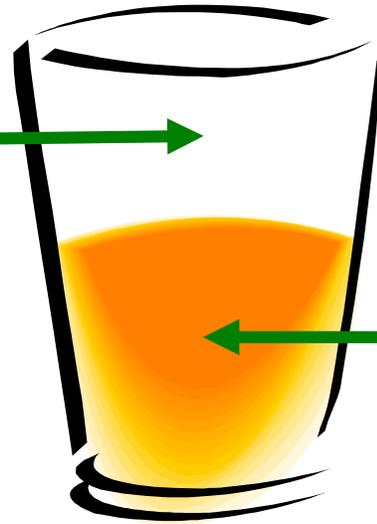
Consequences

**MEDICAL / SURGICAL
TREATMENTS**

**REHABILITATIVE
INTERVENTIONS**

RESTORE
what is LOST

BUILD on
what REMAINS



Different Interventions

How each EYE functions

Structure

Function

How the PERSON functions

Abilities

Consequences

RESTORE what is LOST

BUILD on what REMAINS

Glasses

restore focus

Cataract surgery

restore clarity

Glaucoma Rx, surgery

restore pressure

Strabismus

restore alignment

Residual acuity

magnification

Hearing

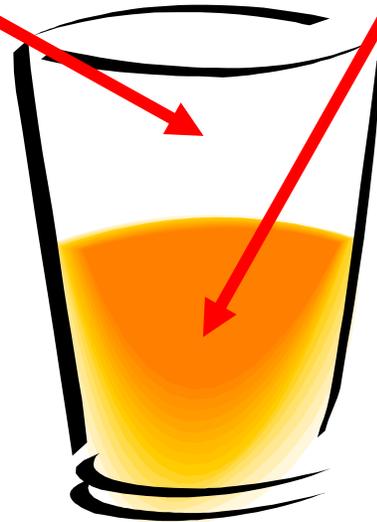
talking books

Touch

Braille

Haptic

Cane travel



Different Scales

How each EYE functions

Structure

Function

How the PERSON functions

Abilities

Consequences

Scale of LOSS

Scale of ABILITY

No loss

Full ability

Typical for
medical
scales

Appropriate
for
rehabilitation

Total loss

No ability

Dis-ability = Loss of ability



What happens at the red line ?

How each EYE functions

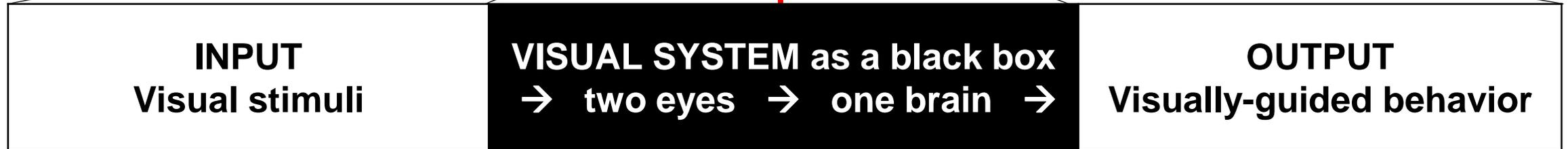
Structure

Function

How the PERSON functions

Abilities

Consequences



Visual Functions

“How each EYE functions”

Visual Impairment

Functional vision

“How the PERSON functions”

**Visual Ability
or Dis-ability**





Different categories

Acuity
Field
Contrast
Color, etc.
Strictly visual

to describe
the different aspects

Reading
Writing, drawing
Grasping, reaching
Navigating, etc.
Visual + Motor

Different measurement methods

Each eye separately
Manipulate stimuli
size, contrast, etc.
Threshold
50% correct

How to measure

What to measure

Criterion

Both eyes open
Observe performance
speed, errors
Sustainable
Near 100% correct

What happens inside the black box?

INPUT
Visual stimuli

VISUAL SYSTEM as a black box
→ two eyes → one brain →

OUTPUT
Visually-guided behavior



What happens inside the black box?

How each EYE functions

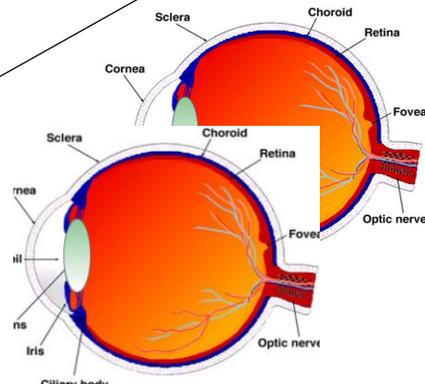
Structure

Function

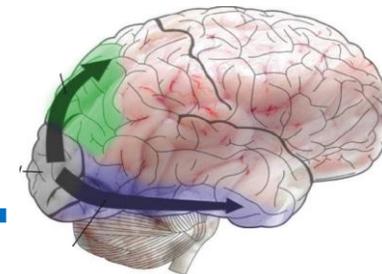
How the PERSON functions

Abilities

Consequences



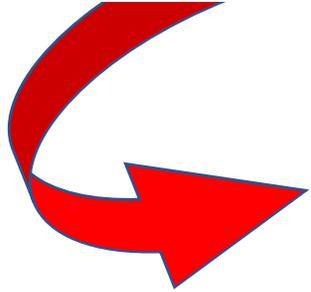
The brain combines
→ outside information
with stored knowledge ←



Environment



Retinal image



Short term Memory

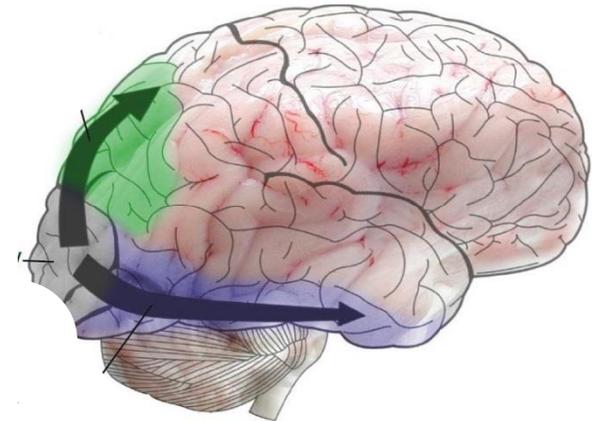
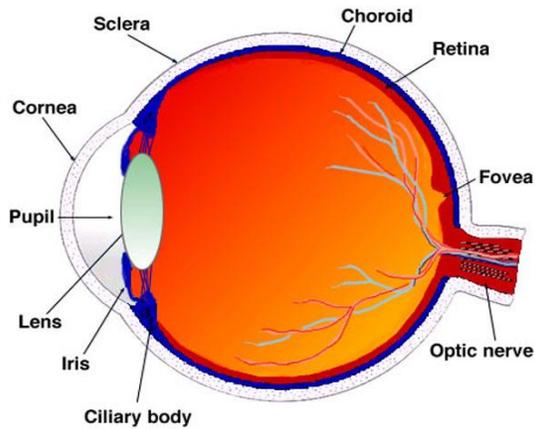
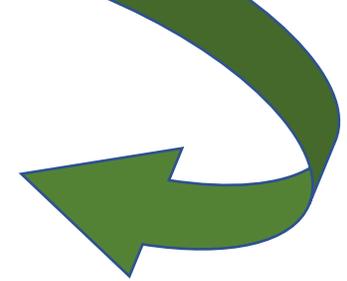


Perception, Recognition

Long term Memory



Concepts

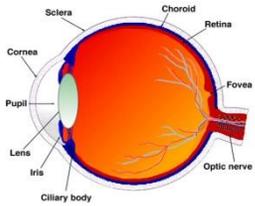
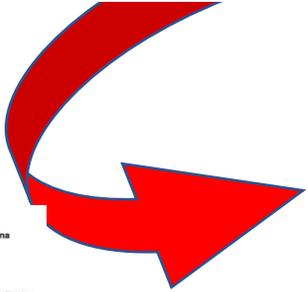


Differences

Environment



Retinal image



Fleeting

Short term Memory

Mental Model

of the environment

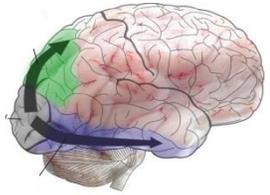
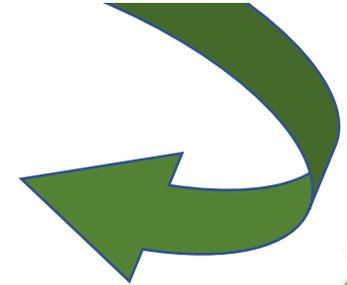


Perception

Long term
Memory



Concepts



Stable

**Retinal
image**

PERCEPTION

**Concepts
in memory**

**Image of the
environment
moves across
my retina**



**I move through
a **stable**
environment**



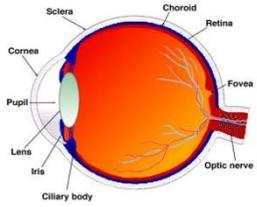
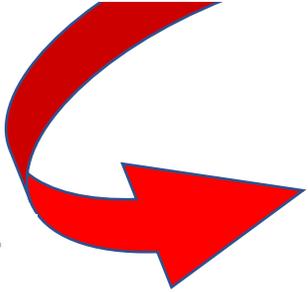
**Concept of the
environment
is STABLE**

Movement derives from the retinal image
Stability of the environment derives from stored concepts

Environment



Retinal image



Fleeting

Triggers
the Mental Model

Short term Memory

Mental Model

of the environment

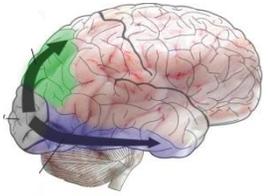


Recognition

Long term
Memory



Concepts



Stable

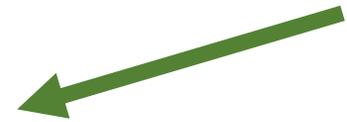
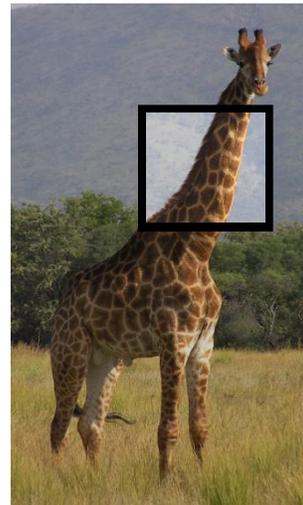
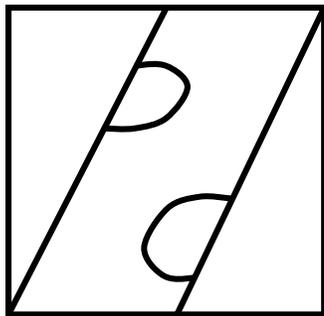
Interprets
the retinal image

**Retinal
image**

PERCEPTION

**Concepts
in memory**

**Matches the retinal image to
concepts in memory**



“window”

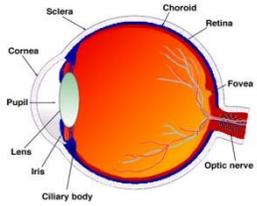
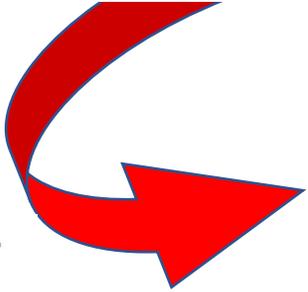


“giraffe”

Environment



Retinal image



Fleeting

Triggers
the Mental Model

Experience



Short term Memory

Mental Model

of the environment

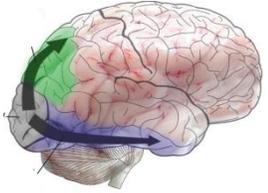
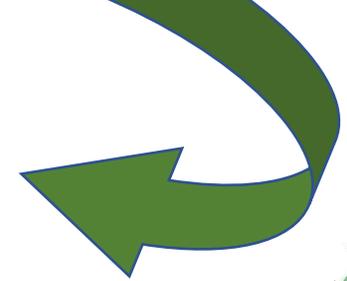


Recognition

Long term
Memory



Concepts



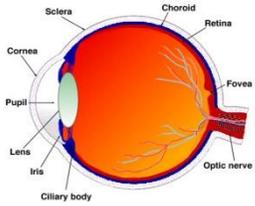
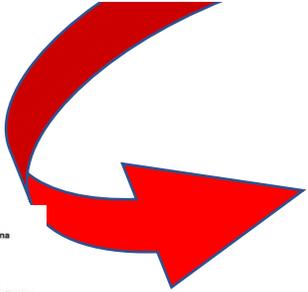
Stable

Interprets and understands
the retinal image

Environment



Retinal image



Fleeting

Triggers and updates
the Mental Model

Has gaps

Short term Memory

Mental Model
of the environment

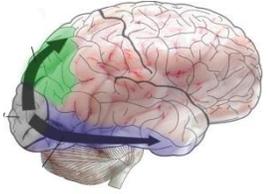


Recognition

Long term
Memory



Concepts



Stable

Interprets and understands
the retinal image

No gaps

unmodified; not aware



black tunnel



blurred tunnel



black parts



blurred parts



missing parts



Glaucoma patients were asked to select the image that best reflects their vision ...

How Does Glaucoma Look?

Patient Perception of Visual Field Loss

Crabb et al. Ophthalmology, 2013

26 %

unmodified; not aware



black tunnel



blurred tunnel



black parts



blurred parts



missing parts



Asked about their vision ...

26 % were NOT aware of any change.

How Does Glaucoma Look?

Patient Perception of Visual Field Loss

Crabb et al. Ophthalmology, 2013

unmodified; not aware



black tunnel



blurred tunnel



black parts



blurred parts



missing parts



54 %

16 %

Asked about their vision ...

70 % described blurred or missing parts.

How Does Glaucoma Look?

Patient Perception of Visual Field Loss

Crabb et al. Ophthalmology, 2013

unmodified; not aware



black tunnel



0 %

blurred tunnel



black parts



0 %

blurred parts



missing parts



Asked about their vision ...

NONE described black parts.

How Does Glaucoma Look?

Patient Perception of Visual Field Loss

Crabb et al. Ophthalmology, 2013

unmodified; not aware



black tunnel



0 %

blurred tunnel



black parts



0 %

blurred parts



missing parts



These images reflect the RETINAL image, but NOT the **PERCEPTION** which is based on a **MENTAL MODEL**

How Does Glaucoma Look?

Patient Perception of Visual Field Loss

Crabb et al. Ophthalmology, 2013



You can HEAR
people yelling.

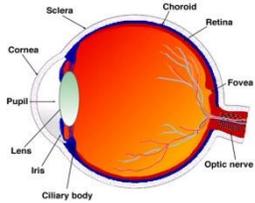
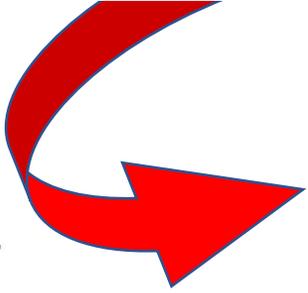
You cannot HEAR
an island of silence.

Similarly,
you cannot SEE
a blind spot.

Environment



Retinal image



Fleeting

Triggers and updates the Mental Model

Has gaps

Strictly visual

Short term Memory

Mental Model
of the environment

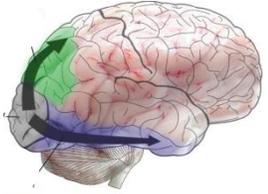
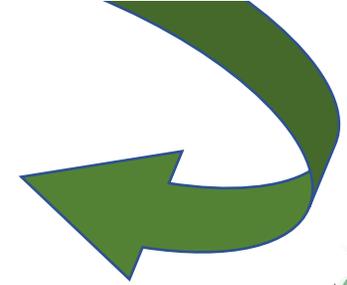


Recognition

Long term Memory



Concepts



Stable

Interprets and understands the retinal image

No gaps

Multi-sensory

Visual
Tactile
Auditory
Smell
.....



Sometimes,
the match is
wrong

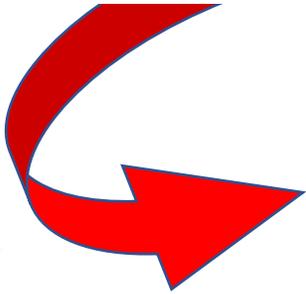


We call that an
optical illusion.

Environment



Retinal image



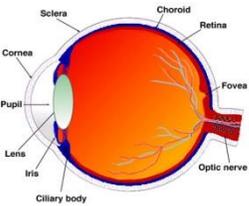
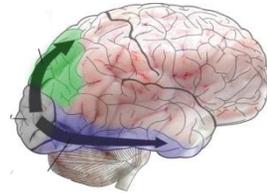
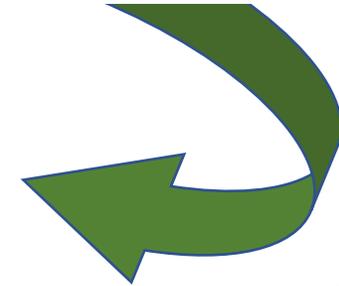
Short term Memory

Mental Model
of the environment

Long term
Memory



Concepts



Fleeting

**Triggers and updates
the Mental Model**

Has gaps

Strictly visual

May be ambiguous

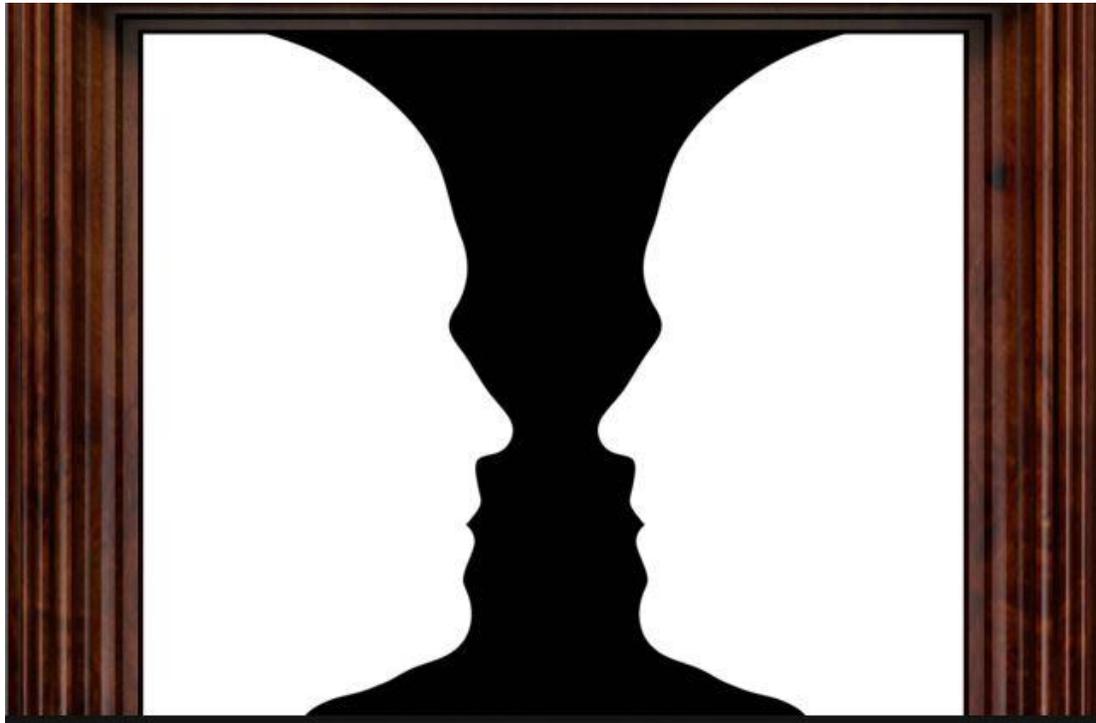
Stable

**Interprets and understands
the retinal image**

No gaps

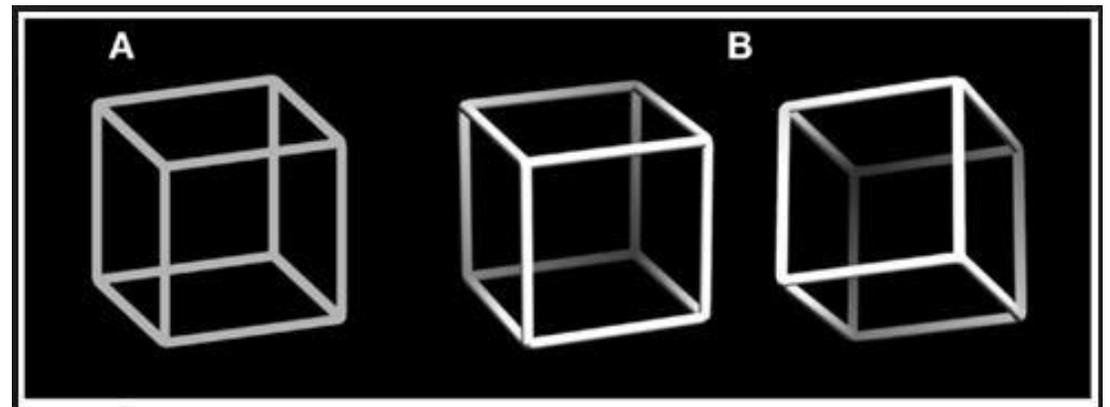
Multi-sensory

Discreet choices

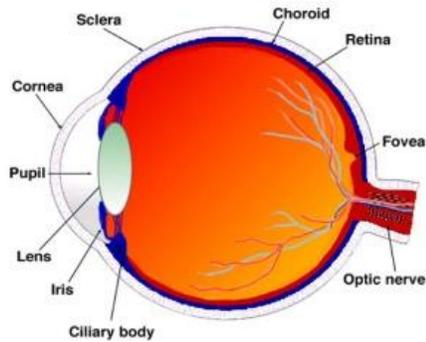
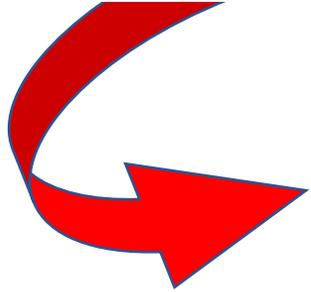


Two interpretations
can alternate rapidly
They cannot co-exist.

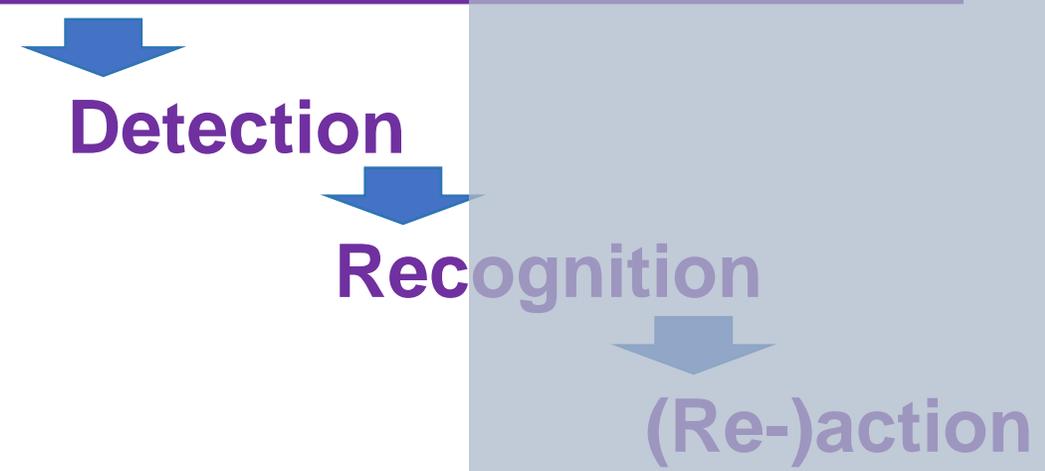
Especially when depth
is involved.



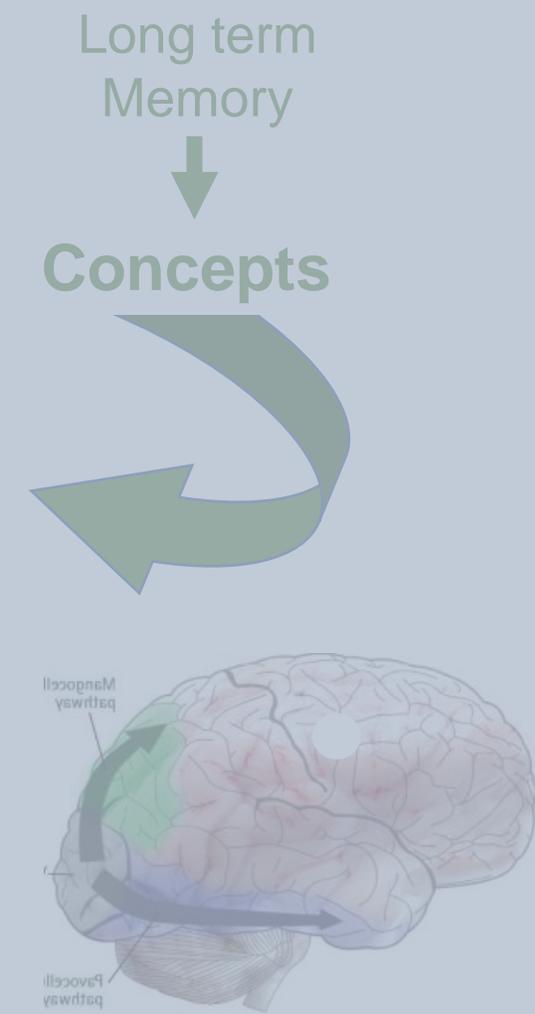
Environment
↓
Retinal image



Many models consider
only the **INPUT** side



**They ignore the OUTPUT,
for which VISION exists**



(Dis-)agreement between senses

Tactile

Visual

Solid

Glass

Non-existent

Non-existent

Shadow

Prominent

3D objects

Content

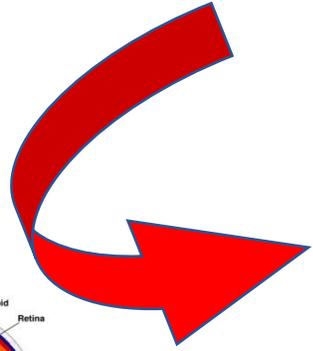
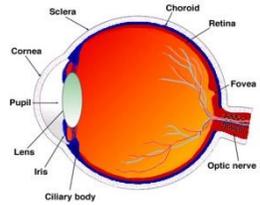
Retina: 2D shapes
3D added in brain

Constant

Size

Depends on distance
Parallel lines converge

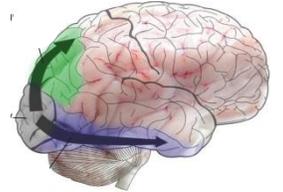
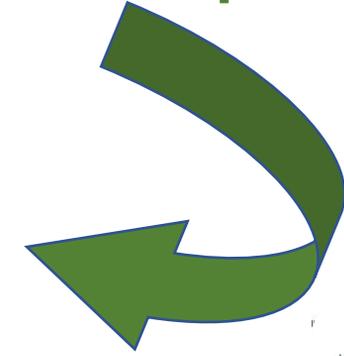
Retinal image



Short term Memory



Concepts

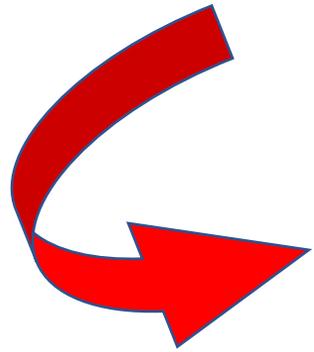


Take-home message

Visual Perception is based on
a **Mental Model** that has TWO sources

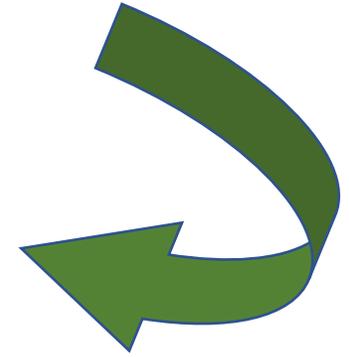
- ✓ The Retinal Image
- ✓ Concepts in Memory

How are the two sources combined??

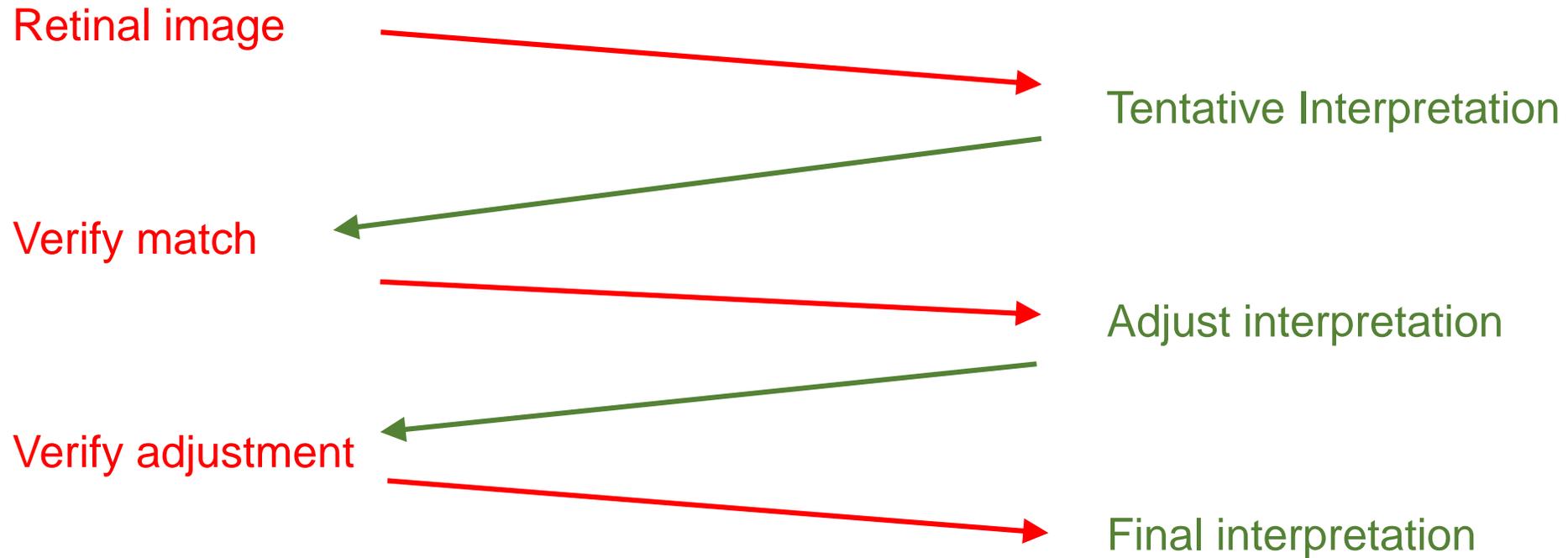


Short term Memory

Mental Model
of the environment

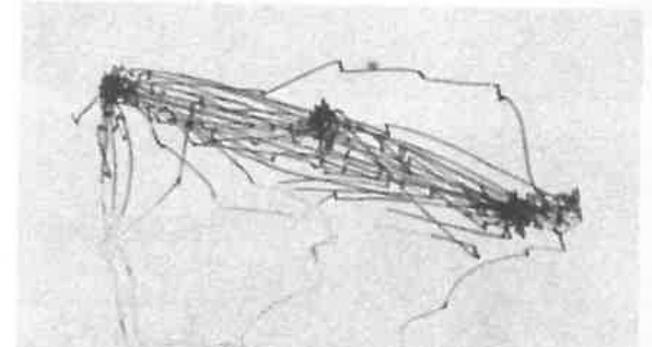
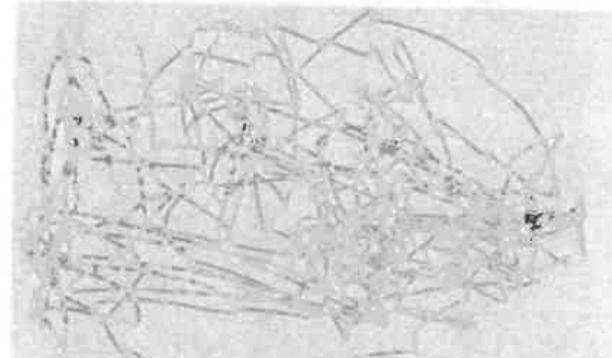
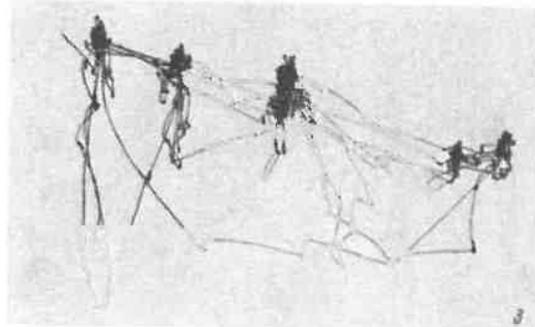
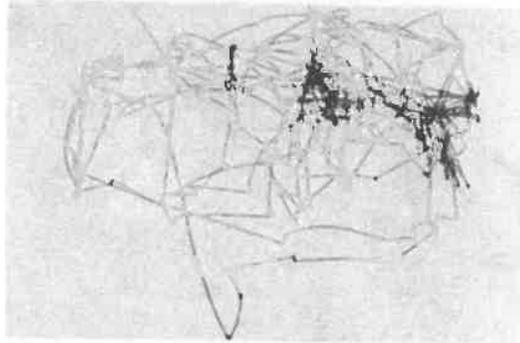
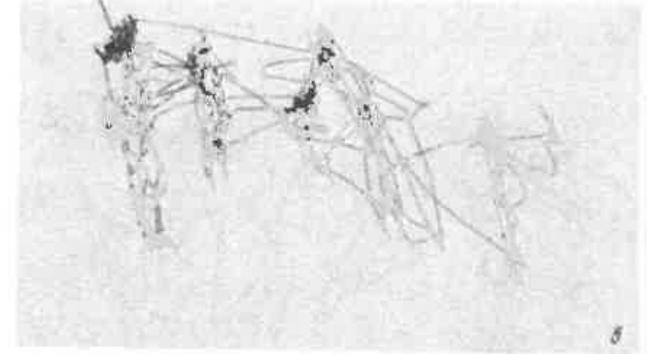
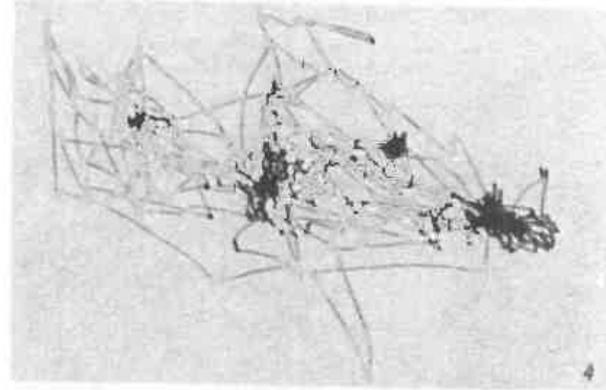
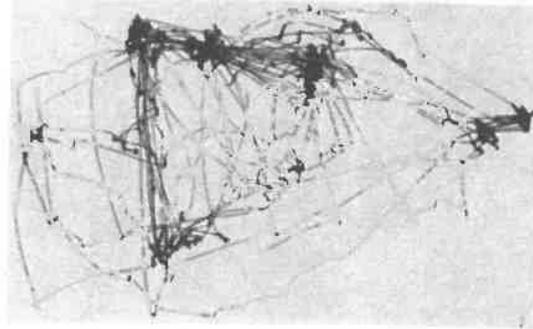


Matching requires back-and-forth between the two sources



Verification process is modifiable by Intention

Different scan patterns

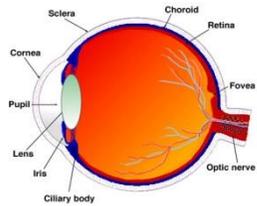


Scan patterns vary, depending on the type of interpretation requested

Free viewing / rich or poor family / ages / what they were doing / clothes / position of people / how long was visitor away

Relative contributions may differ

Environment
↓
Retinal image



Relies on the
current
retinal image
not on
memory

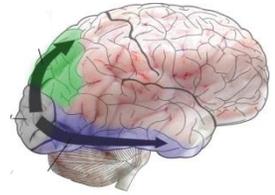
Mental Model

of the environment



Long term
Memory

↓
Concepts



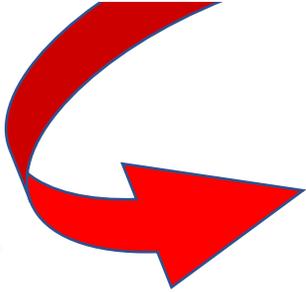
Navigating a
complex
dynamic
environment

Relative contributions may differ

Environment



Retinal image



Mental Model

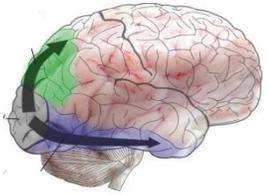
of the environment



Long term
Memory



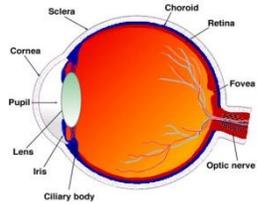
Concepts



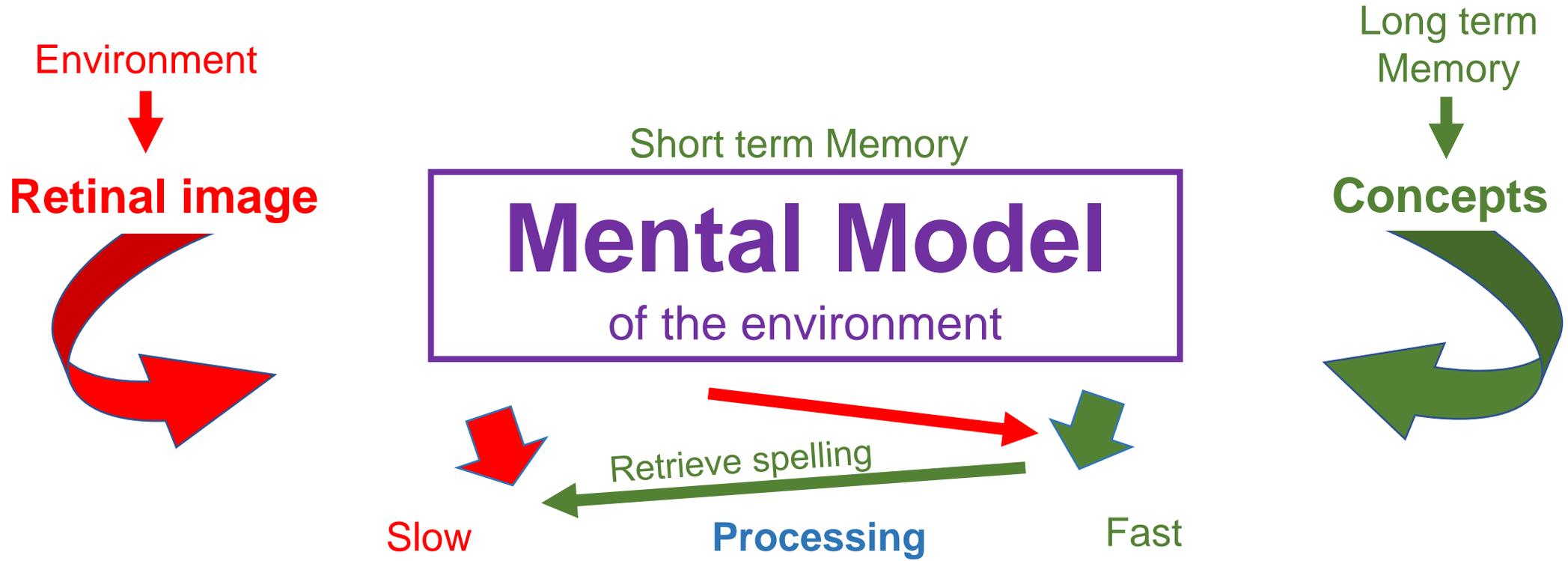
Seeing an
image in
a cloud



Relies mainly
on stored
imagery



According to research at an English university, it doesn't matter in what order the letters in a word are, the only important thing is that first and last letter are at the right place. The rest can be a total mess and you can still read it without problem. This is because we do not read every letter by itself but the word as a whole. Ceehiro



Proofreading mode

Serial processing,
letter sequence matters

Content suffers

- **Speed / Accuracy trade-off is an intentional decision**

Does the content make sense?

Parallel processing,
letter sequence doesn't matter

Typos are overlooked

- **Reading with context is about 3x faster than reading without**

Matching the two sources

Retinal image



Tentative Interpretation



Reflex-like action

Reading what makes sense

Verify match



Adjust interpretation

Verify adjustment



Final interpretation



Intentional action

Correcting spelling errors

Take-home messages

- Models based on a **single stream** from visual stimulus to perception are too simplistic.
- The **MENTAL MODEL** concept
 - implies TWO sources: **retinal image** and **stored concepts**
 - And a constant **back-and-forth** on a TWO way street.

VISION supports ACTION

Normal vision:

Salient peripheral stimulus sends alert

→ fixation movement

→ central vision recognizes

→ appropriate action.

Central scotoma:

Alert → fixation → object disappears

→ frustration → develop PRL, seek help

Peripheral field loss:

Peripheral stimulus not seen → NO alert

→ NO recognition → NO action

→ NO awareness



Conscious / Autonomous processing

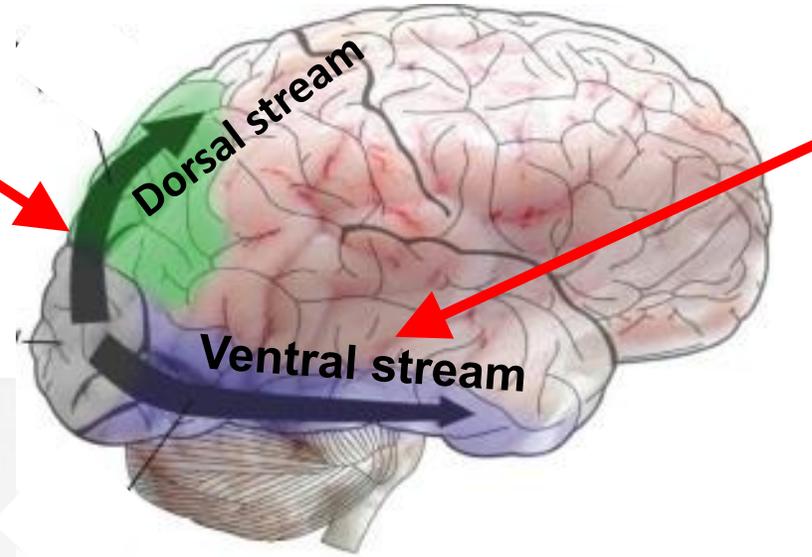
Autonomous processing for Motor control

Connects directly to various
motor systems

Can react faster

Reactions are reflex-like,
autonomous,
not under conscious control

Most bodily functions
(breathing, heart rate)
are processed this way



Conscious processing for Recognition

Connects to vast repositories
of stored information
and experience

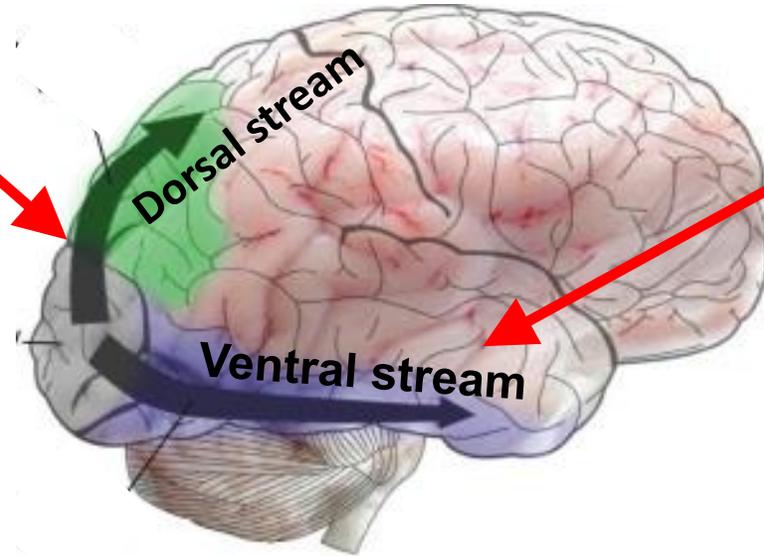
Allows conscious decisions
and intentional actions

**Conscious vision is only
the tip of the iceberg**

Conscious / Autonomous processing

Autonomous processing for motor control

Connects directly to
motor systems
Serves fast motor actions
“WHERE” system



Conscious processing for Recognition

Connects to stored information
Serves interpretation
“WHAT” system

Both systems are needed and are tightly interconnected:

Reading:

Move eyes from word to word

Understand words, context

Mobility:

Avoid obstacles, potholes

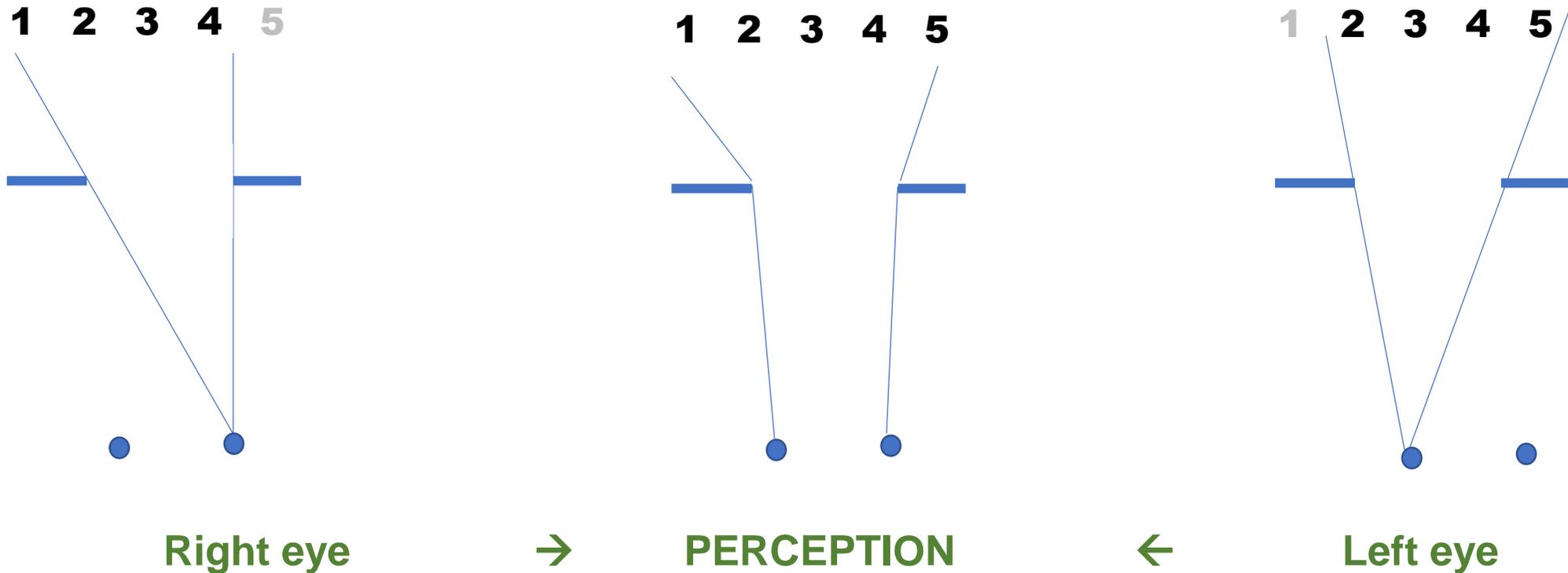
Where am I ? Where do I go ?

Size and location for recognition

RECOGNITION does not care about absolute size or location



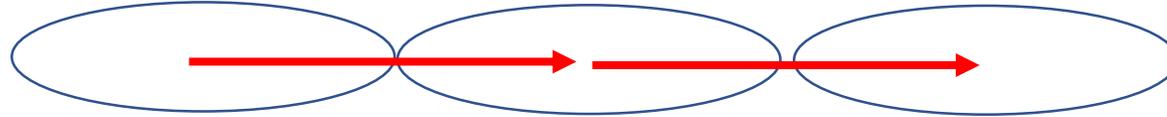
Size and location for recognition



RECOGNITION does not care about absolute size or location

Size and location - Autonomous

Reading: Saccades must match the visual span



Grasping: Hand position must match the object



Walking: Foot movements must match the terrain



MOTOR reactions require accurate size and location

Vision-Motor Coordination

AUTONOMOUS

Limb–Eye Coordination



Involves
body, leg, arm
movements

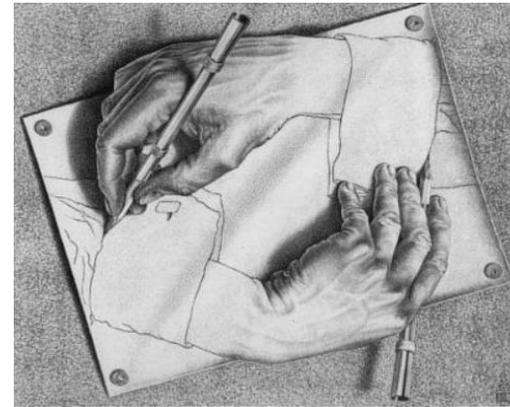
“**Mobility**”
(peripheral vision)

- Based on 3D Mental Model
- Can be completed with **eyes closed**
- Requires **absolute** references
- Often involves a timed motor sequence

INTENTIONAL

Hand–Eye Coordination

Coordination



Involves
finger, hand, wrist
movements

“**Manipulation**”
(mostly central vision)

- Requires continuous feedback
- Can **only** be done with **eyes open**
- Requires **relative** references
- Can be interrupted and resumed

Terminology

How each EYE functions

Visual acuity

ocular aspect of detail vision

Visual field

map of retinal sensitivity
precludes eye movements

Central vision

Peripheral vision

describe retinal topography

How the PERSON functions

VISION (→ visually-guided behavior)

Detail vision

detail and shape recognition

Surround vision

visually-guided spatial awareness
requires scanning and search

Color vision

Movement, etc.

Ventral stream

Dorsal stream

describe cerebral topography

Surround vision – three modes

Top – down conscious, intentional

- **Intentionally** move attention to a target in the **Mental Model**
- Then, use **central vision** to examine the target more closely

Target must exist in the Mental Model.

Target may be outside the visual field.

Action is NOT limited by field restriction.

Intentional action involves **ventral stream** in brain.

Starts and ends consciously.

Surround vision – three modes

Bottom – up

occasional, reflex-like

- A “**salient**” event in the **retinal image** triggers an alert to the central vision system
- **Central vision** is used to examine the object more closely

Target must exist in the **retinal image**, therefore, it is limited by field restrictions.

This action occurs only **occasionally**.

Starts in the **dorsal stream**, ends in the **ventral stream**.

Surround vision – three modes

Autonomous continuous monitoring

- Objects in surround are detected and screened.
- If considered to be an **obstacle**, a command is sent to the motor system to avoid it.
- Conscious awareness is not required.

This screening occurs **constantly**.

Starts in the **dorsal stream**,
ends in the **motor system**.



Take-home messages

- **Matching the retinal image to stored concepts** requires a **back-and-forth** on a TWO way street.
- Much of the processing occurs **in parallel** it is **autonomous** and bypasses consciousness.
- **Visual-spatial relationships** occur in TWO distinct modes
 - absolute parameters for body movements
 - relative localization for perception and manipulation.
- **Visually-guided actions** can occur in THREE different modes
 - Intentional
 - Reflex-like, occasional, triggered by salient stimuli
 - Autonomous, constant monitoring for obstacles.

Thank you

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