McMaster University

SCIENCE
Department of Kinesiology

Visuomotor foundations

KINESIOL 1E03 - Motor control and learning

Laura St. Germain
Fall 2022 Week 2
Lecture 6

Review from last lecture

Reponses of individual sensory receptors may carry four different kinds of information about their stimulation

1. **Information about stimulus strength**: the size of the receptor potential (and consequently the firing rate of the afferent axon) carries information about the strength of stimulation

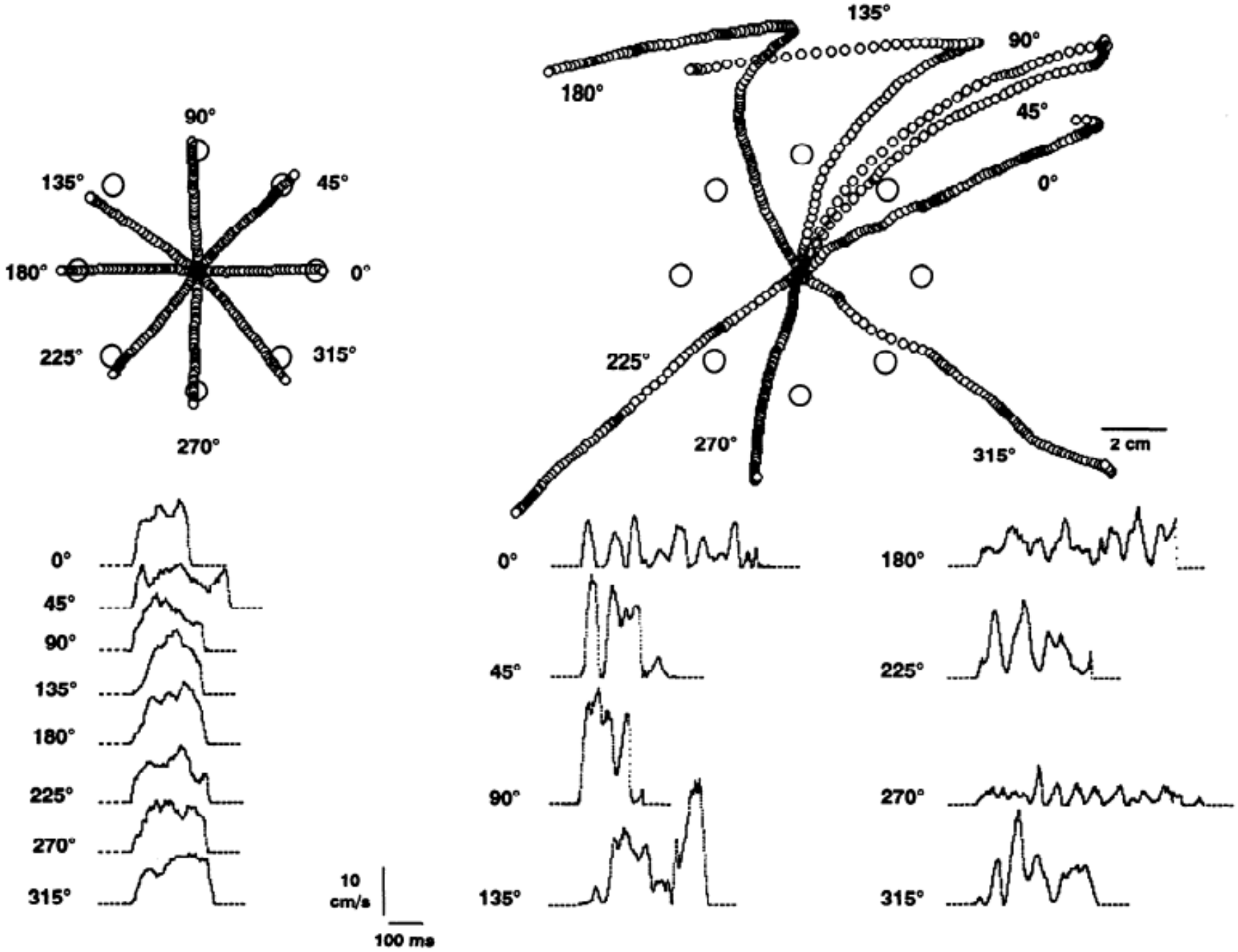
2. **Information about the timing of stimulus**: the length of time for which the receptor responds carries information about the length of time for which stimulation is present

3. **Information about stimulus type**: due to its selectivity, when a receptor responds, its response carries the information that that type of stimulation is present

4. **Information about stimulus location**: a particular receptor is located at a particular place and responds to stimulation applied at that location

Characteristics of skin stimulation to which the cutaneous mechanoreceptors are thought most likely to be responsive

- **Merkel disks**: sustained skin contact and pressure, slowly changing skin deformations (frequencies less than ~5 Hz)
- **Meissner corpuscles**: lateral movement, vibration and fairly rapid changes in skin deformation (~5 to 50 Hz)
- **Ruffini end organs**: sustained and slow changes in skin stretch or tension
- **Pacinian corpuscles**: high frequency vibration (~40 to 400 Hz), contact events and rapid skin deformations


90°
135°
45°
180°
0°
225°
315°
270°
135°
90°
180°
45°
0°
225°
270°
315°
2 cm
0°
45°
90°
135°
180°
225°
270°
315°
10
cm/s
100 ms
0°
45°
90°
135°
180°
225°
270°
315°

Muscle spindle afferent endings are sensitive to muscle length and speed of muscle lengthing

- The muscle spindle is **elastic** and is lengthened (stretched) or shortened as the muscle in which it is embedded lengthens or shortens
- Muscle spindles are innervated by **Type Ia** and **Type II** afferents
- An extrafusal fibre can typically generate 30 to 40 times as much force as an intrafusal fibre

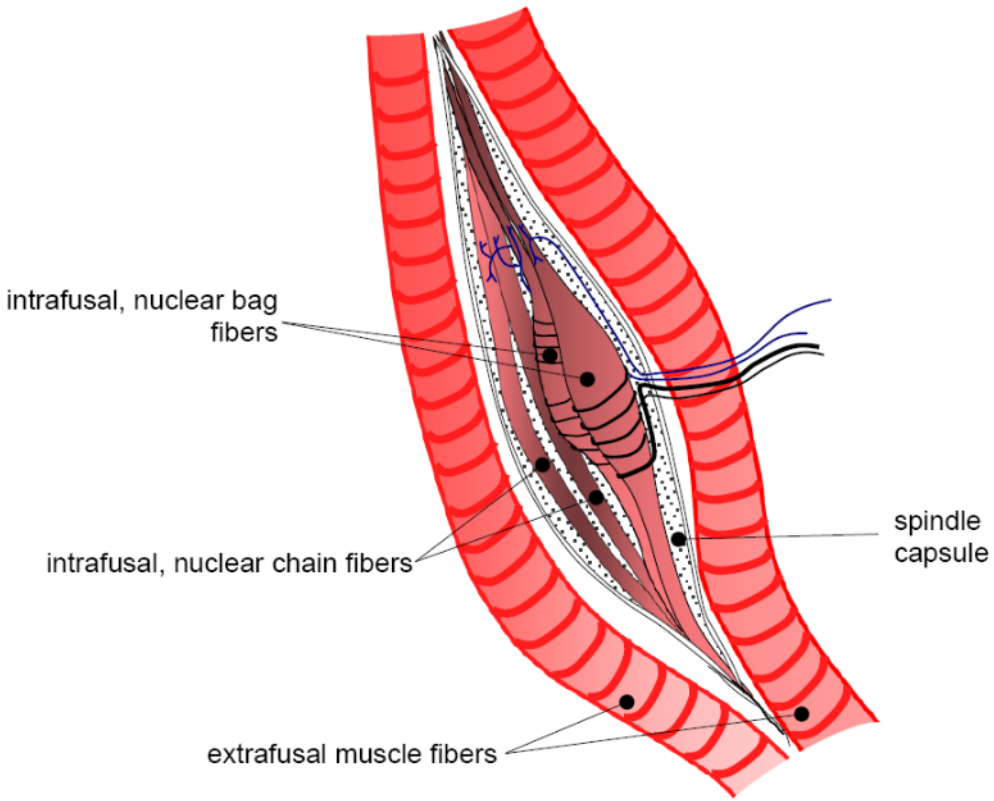


Fig: Tresilian 2012

Golgi tendon organs are muscle force sensors

- It is an encapsulated bundle of collagen strands innervated by afferent axons that branch into numerous fine terminals within the organ capsule and intermesh with the collagen strands
- Not actually located in the tendon but at the **junctions** between muscle and tendon
- The axons innervating tendon organs are referred to as **Type Ib** afferents
- Force will only be applied when muscle fibres are actively developing force

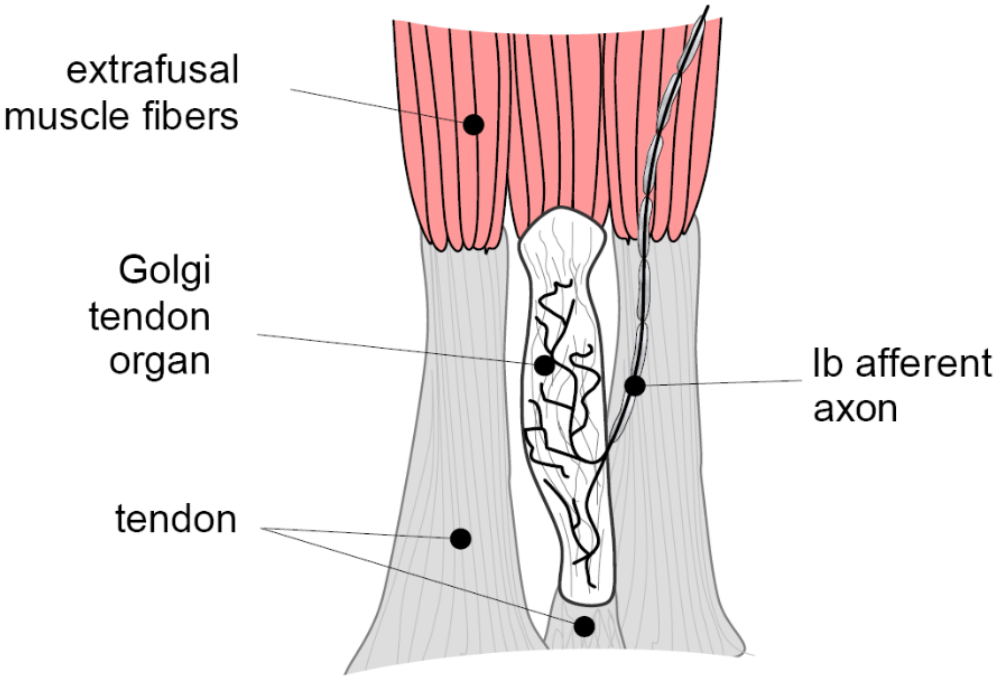


Fig: Tresilian 2012

Assessing kinesthetic and proprioceptive abilities

Matching tasks

- try to match position or movement of a body segment (the target) with something else
- another body segment or a moveable device
- can be **simultaneous** or **successive**

Discrimination tasks

- try to tell the difference between two or more situations
- e.g., set joint angles for right and left elbow, ask to judge whether left elbow is more flexed/extended
- can be used to establish the **discrimination threshold**

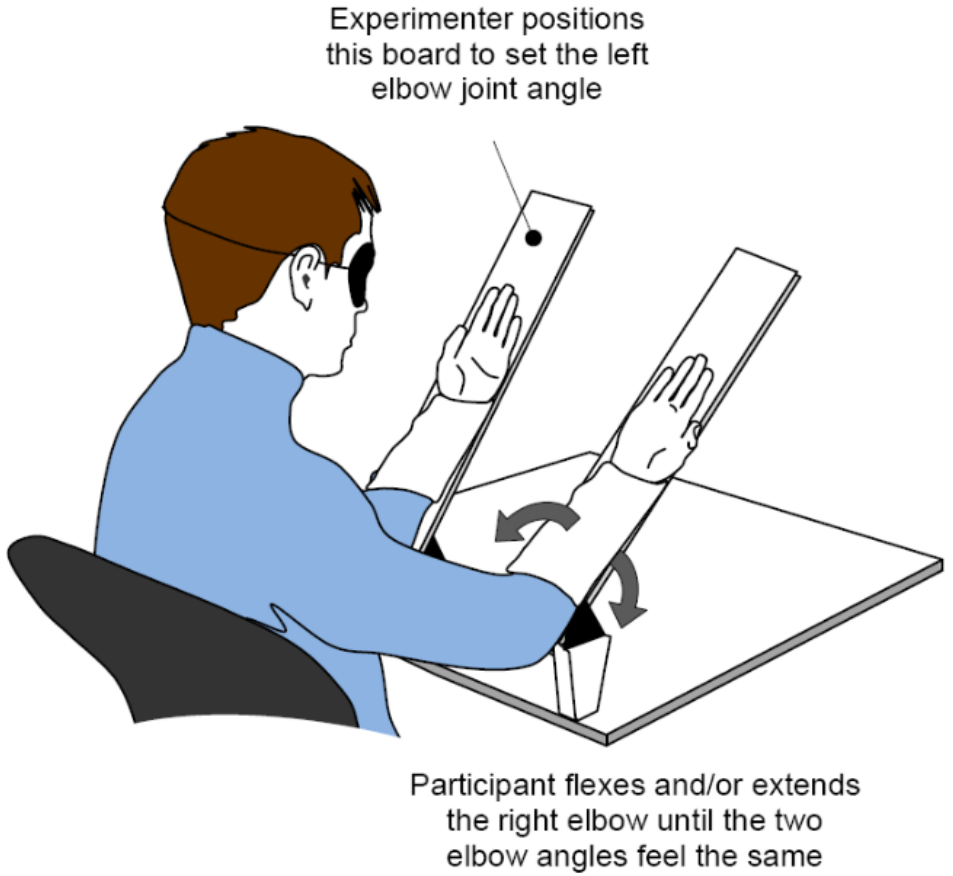


Fig: Tresilian 2012 based on Allen & Proske 2006 (https://doi.org/10.1007/s00221-005-0174-z)

Any questions?

We tend to give vision a predominant role when we perform motor skills

Source: https://youtu.be/F4xenlulg_8

Source: https://youtu.be/FupiZi-HuQ4

Learning objectives

1. Identify and describe key **anatomical components** of the eye.
2. Describe how **visual information** is transmitted.
3. Identify and describe **different types** of eye movements.
4. Describe our **two visual systems** and how motor behaviour is affected when **damage** occurs in them.

Take-home message:

Sensory feedback is critical for skilled voluntary actions.

Images projected onto the retina stimulate an array of photoreceptors

- The retina contains photoreceptors: the **rod** and **cone** cells
- Rods contribute to **scotopic vision** (i.e., *night vision*)
- Cones contribute to **photopic vision**

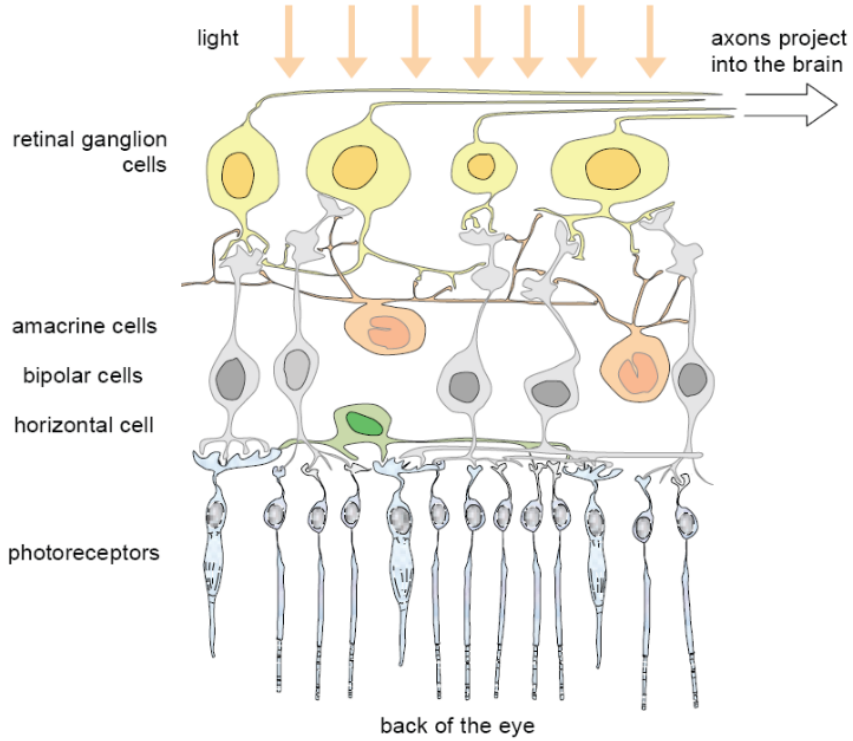


Fig: Tresilian 2012

Rods and cones detect different types of sensory information

Rods

- ~100-120 million in each eye and found in the **periphery** of the retina outside the fovea
- Respond to **low levels** of light
- Critical for **peripheral** vision (due to location)
- **Cannot** distinguish color
- Provide greater discernment concerning **movement** in visual field

Cones

- ~6-7 million in each eye and predominantly found in the **fovea**
- Respond only to **bright** light (i.e., require high levels of illumination)
- Critical for **central** vision and **visual acuity** (due to location)
- **Can** distinguish color
- Provide better information about **details** in visual field

The human retina has a small blind region and a small acute region

- There is a small region with no photoreceptors called the **optic disk**
- There is another small spot in the retina called the **macula**
- The **fovea** is a roughly circular depression in the center of the macula
- The fovea is very small (~ 1 to 1.5 mm across; corresponds to ~ 3 to 4 degs of visual field)

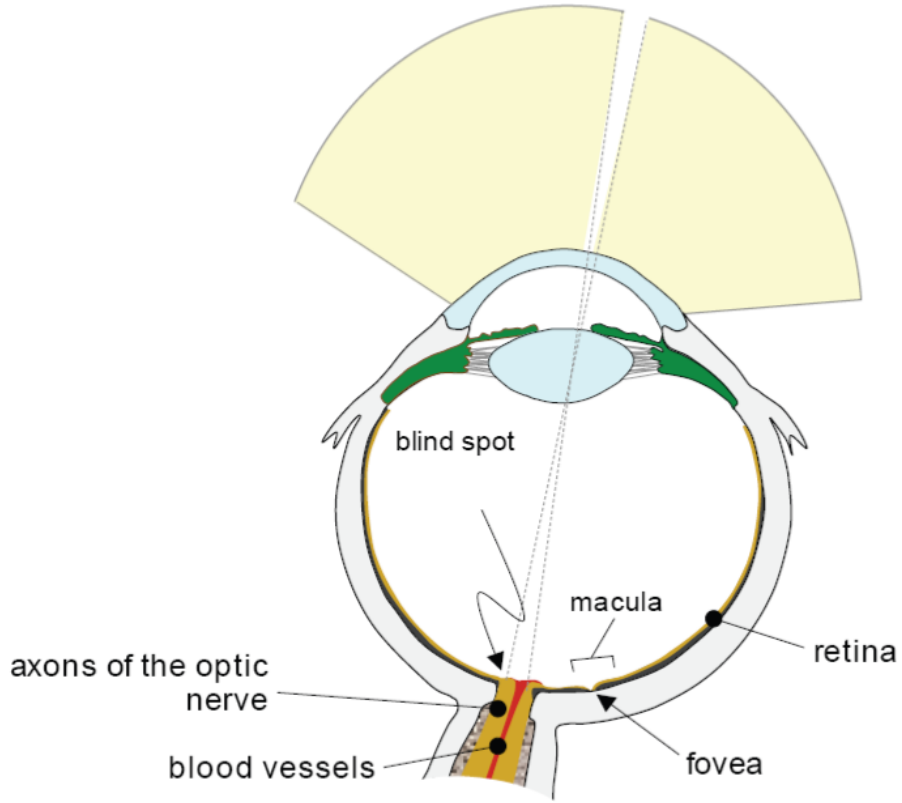


Fig: Tresilian 2012

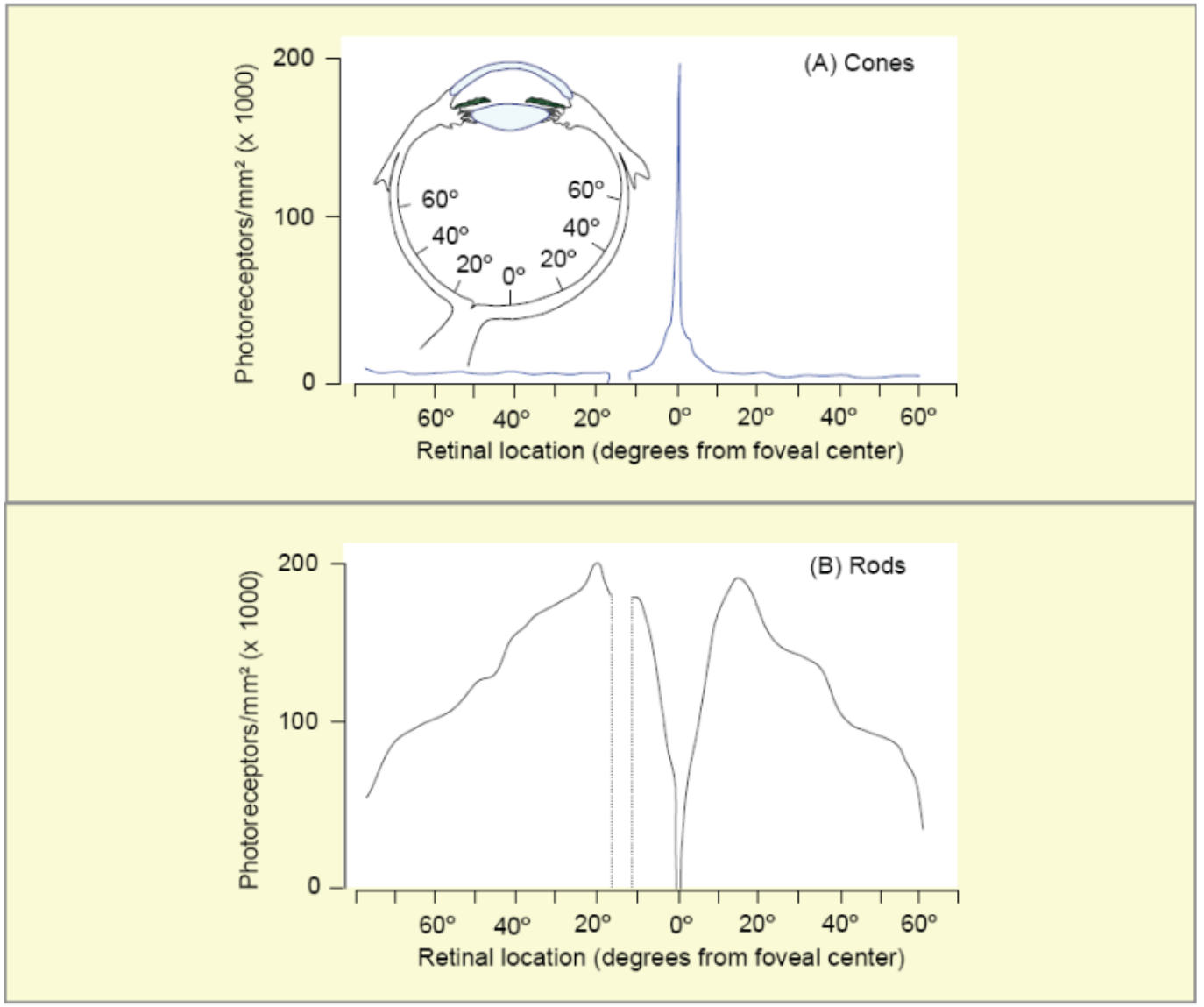


Fig: Tresilian 2012

Foveal vision has high acuity; peripheral vision has low acuity

- **Fine details** can only be discriminated in the central part of the visual field
- Vision mediated by the fovea is **foveal vision** (the central 3 or 4 degs of visual field)
- The part outside the macula (~95% of total retinal area) is **peripheral retina**
- Vision mediated by the peripheral retina is called **peripheral vision**

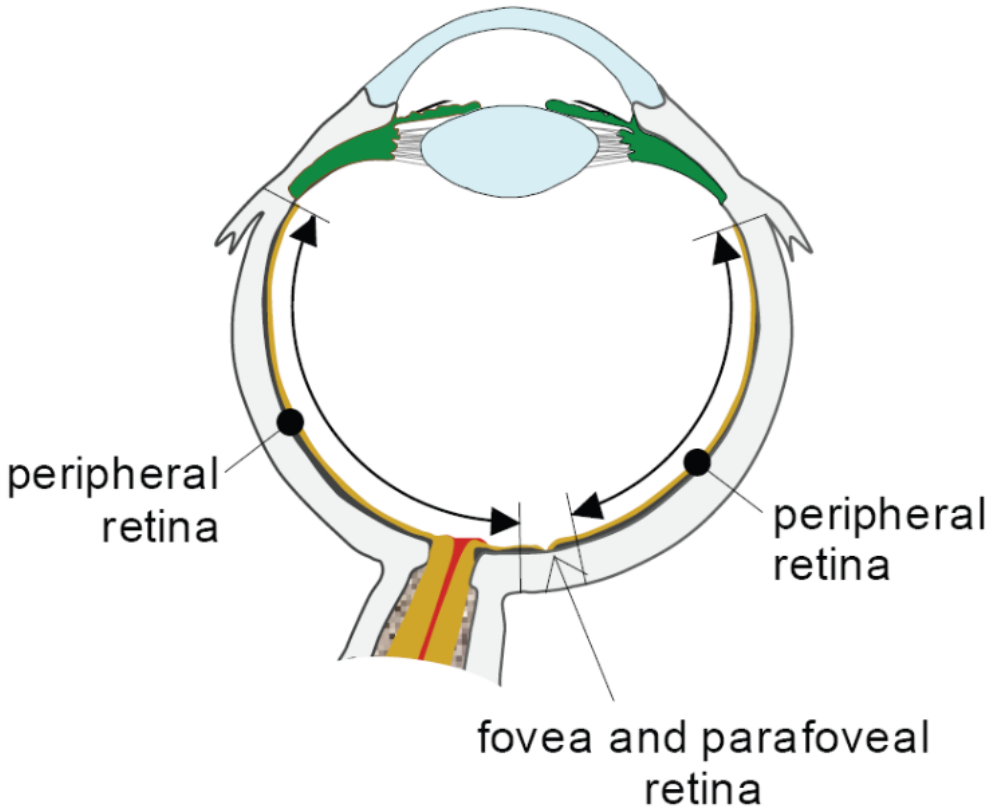


Fig: Tresilian 2012

Foveal vision has high acuity; peripheral vision has low acuity

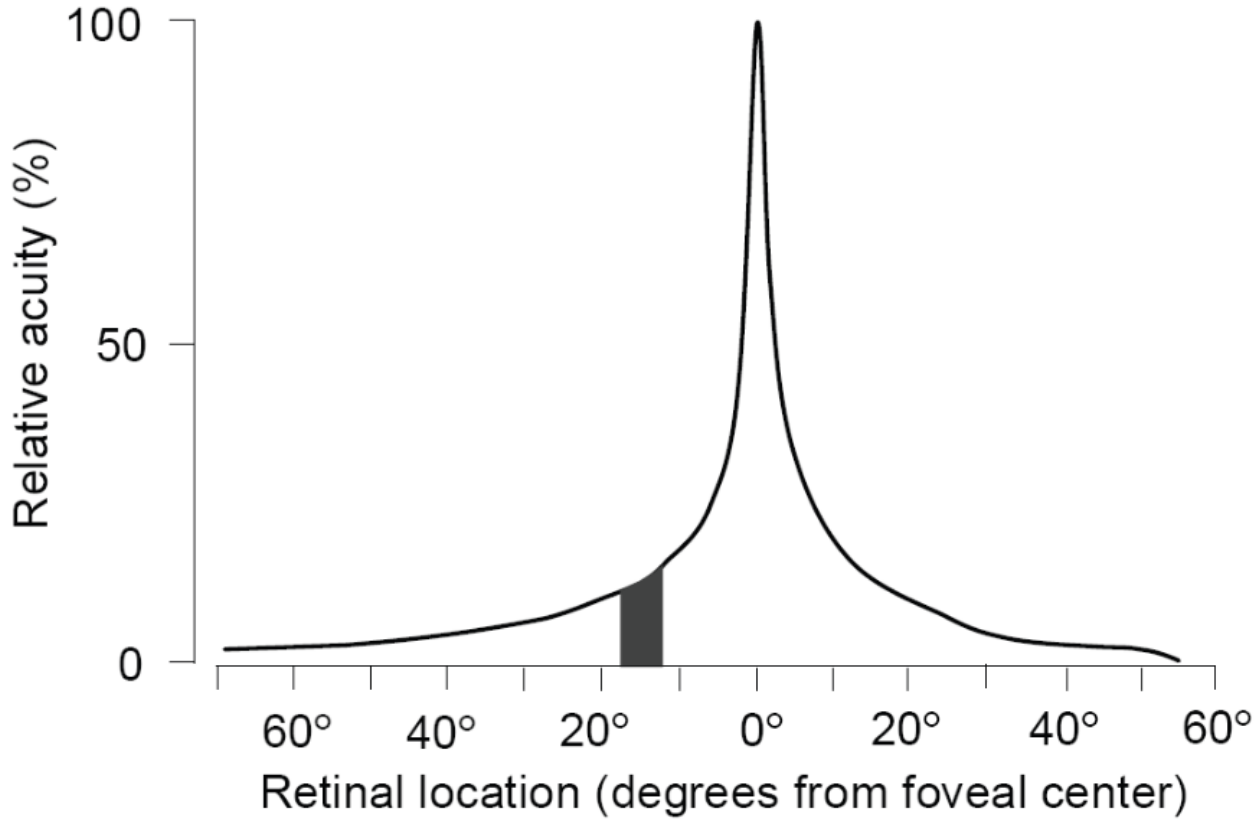
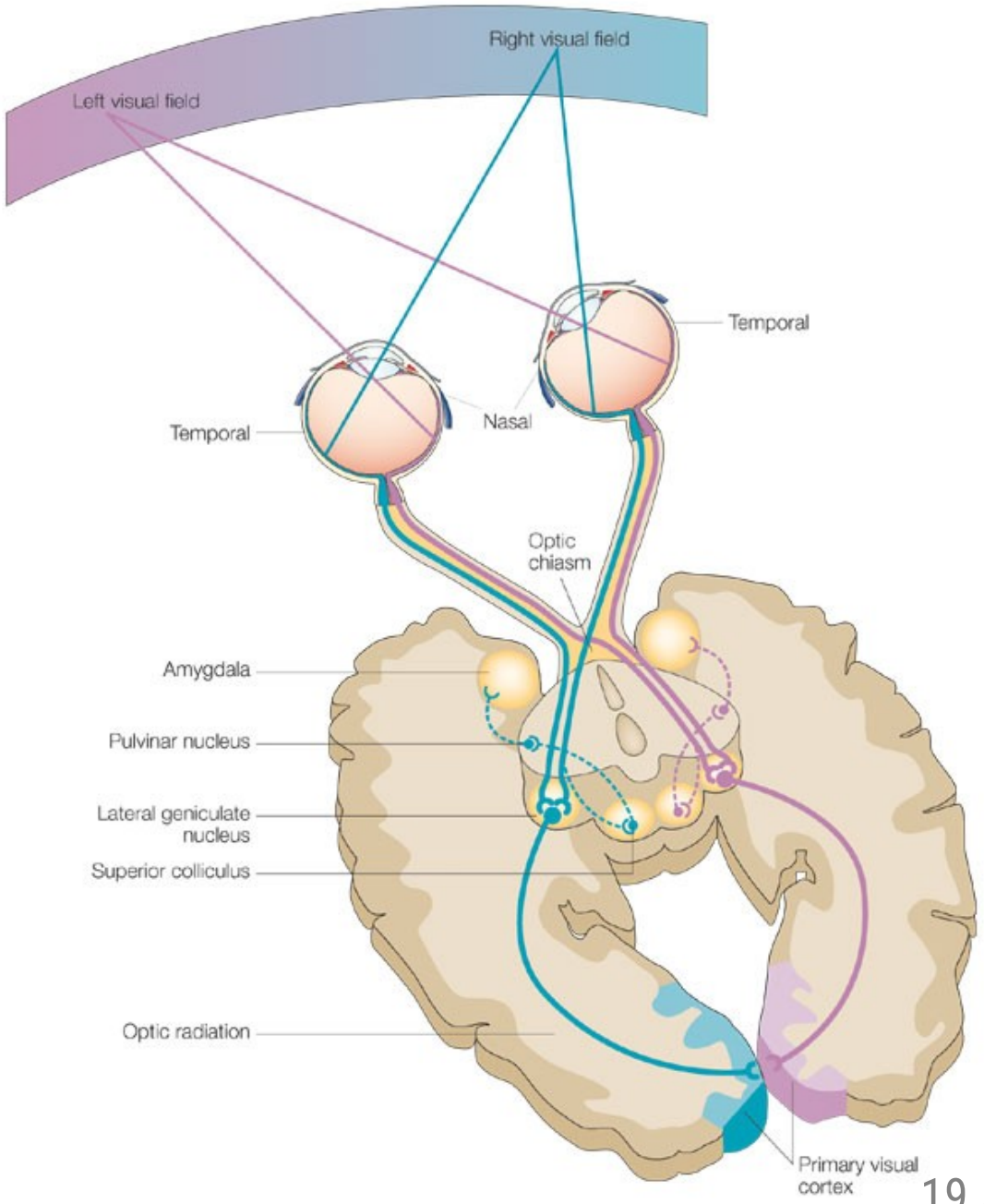


Fig: Tresilian 2012

- The **visual field** refers to the image or scene being viewed
- Light waves pass through the **cornea and lens** and hits the rods and cones within the retinas (**nasal** versus **temporal**)
- The light waves are **refracted** (i.e., bent) such that observed image is **inverted** and **reversed** on the retina
- Axons of neurons in the retina called ganglion cells form the **optic nerve** (CN II) which is the means of information transmission from the eye to the brain
- Information reaches the **optic chiasm** where nerve fibres either continue within the same hemisphere or cross over the the opposite hemisphere

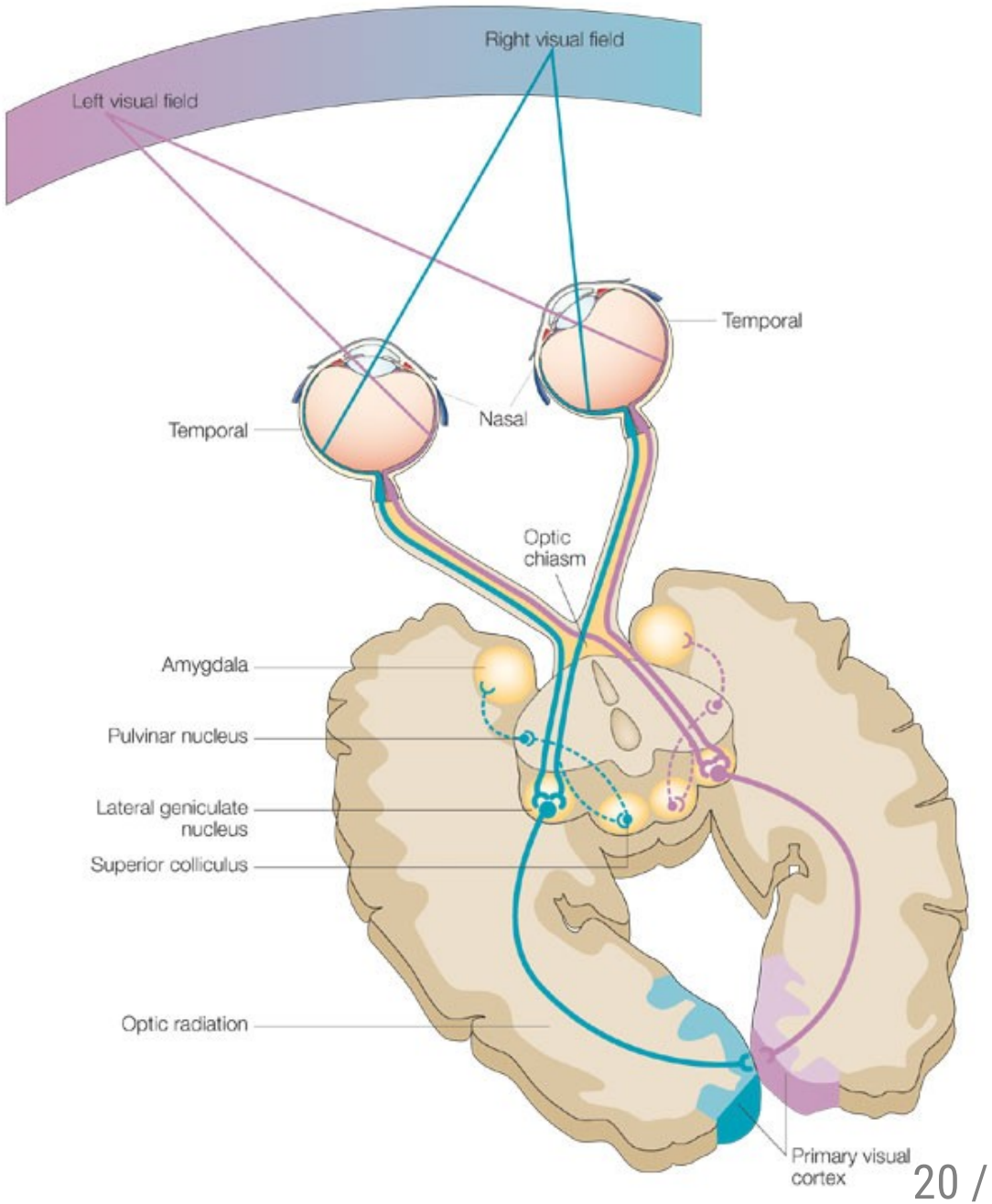


- Optic nerve fibres associated with the **nasal part cross over** at the optic chiasm to the opposite hemisphere whereas optic nerve fibres of the **temporal part remain** in the same hemisphere

- Information arrives at the **lateral geniculate nucleus** before continuing to the left and right **primary visual cortices (V1)**

- V1 unites the images in a way that allows us to see 3D images (i.e., the spatial organization of the visual scence is determined)

- Information is then sent to the **superior colliculus** where it is integrated with other incoming sensory inputs (allows head/eye coordination and involved in attention and visual perception)



There are 2 basic types of coordinated movement of the two eyes

CONJUGATE (OR VERSION) EYE MOVEMENT: a coordinated movement of the two eyes in which both eyes move in the same direction at the same time through the same angle

DISCONJUGATE (OR VERGENCE) EYE MOVEMENT: a coordinated movement of the two eyes in which the eyes move in opposite direction at the same time through the same angle

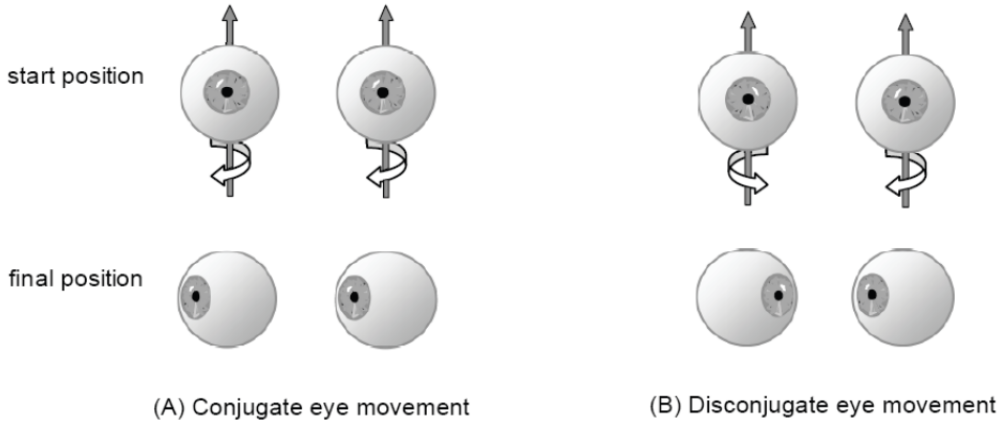


Fig: Tresilian 2012

The eyes move for two basic reasons: to keep them steady and to bring images onto the foveas

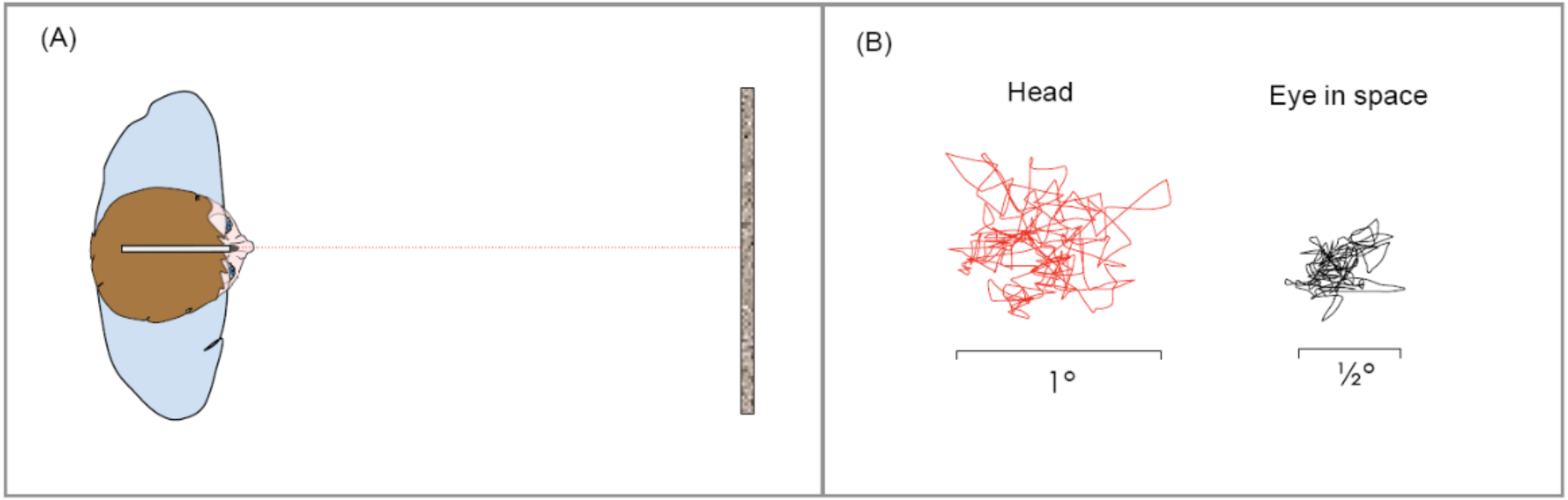


Fig: Tresilian 2012

Two eye movement systems keep images stable when the head moves

Vestibular and Cervical Reflex System

- **Function**: Keep the whole image steady on the retina when the head jiggles, bobs, nods, rolls, or sways
- **Movement type**: Conjugate
- **Process**: Eye movements generated in response to stimulation of vestibular organs (vestibular-occular reflexes). Eye movements in response to stimulation of neck proprioceptors (cervico-ocular reflexes) exist, but normally contribute very little

Optokinetic Reflex System

- **Function**: Keep the whole image steady on the retina during smooth, sustained movements of the head
- **Movement type**: Conjugate
- **Process**: Eye movements generated in response to wide-field image flow stimulation of the retinal photoreceptors

Animals with foveate eyes have 4 systems to bring images onto the foveas and hold them there

1. **Saccadic system**: rapidly shift gaze from one location in the visual field to another (Movement type = conjugate)

2. **Fixation system**: maintain the direction of gaze so that the images of an object remain on the foveas (Movement type = variable)

3. **Smooth pursuit system**: shift gaze so that the images of a laterally moving object remain on the foveas (Movement type = conjugate)

4. **Vergence system**: align the eyes so that images of an object fall on corresponding foveal locations in the two eyes (Movement type = disconjugate)

Saccadic eye movements are always much the same

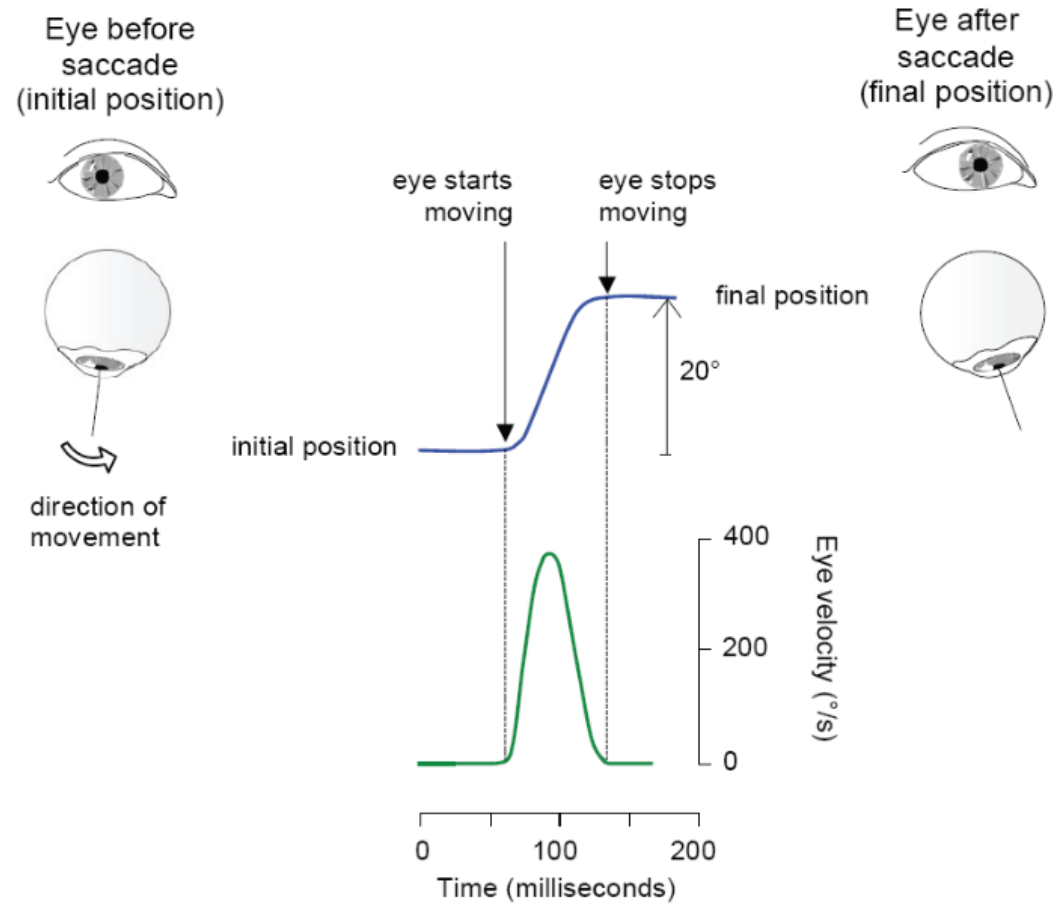


Fig: Tresilian 2012

Fixation involves tiny eye movements

- **Fixational eye movements** are composed of three distinct components: *physiological tremor*, *slow drift*, and *small, rapid jumps in position*
- Looking at the figure we can see that during the fixation, the gaze direction remains within a range of ~0.25 deg

- We can see the 3 movements:
  - sudden changes in position where the trace steps abruptly (**microsaccades**)
  - more gradual changes (positional drift)
  - very rapid, very small wiggles in the trace itself (physiological tremor)

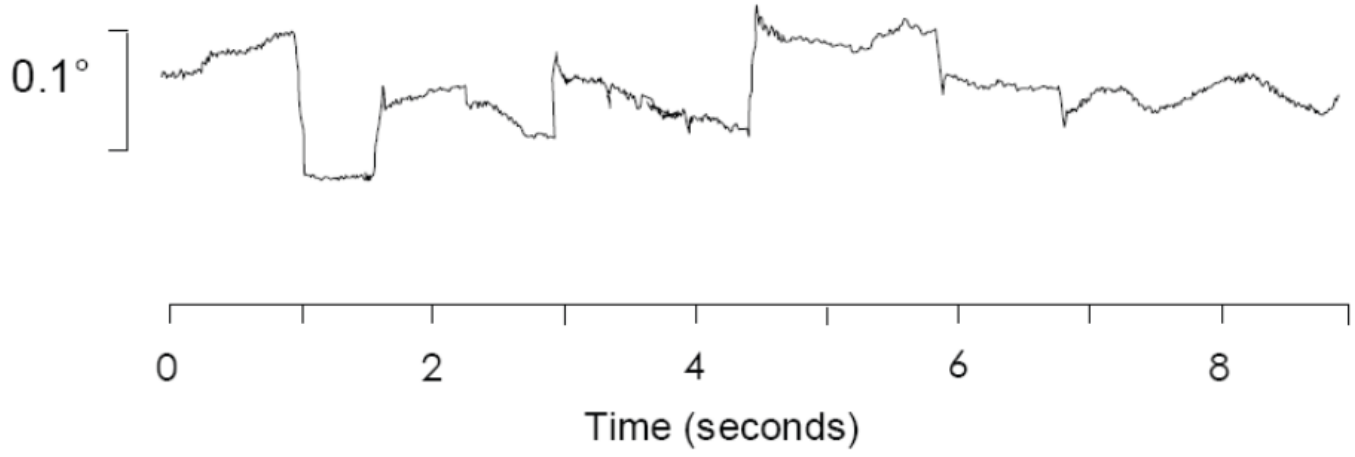
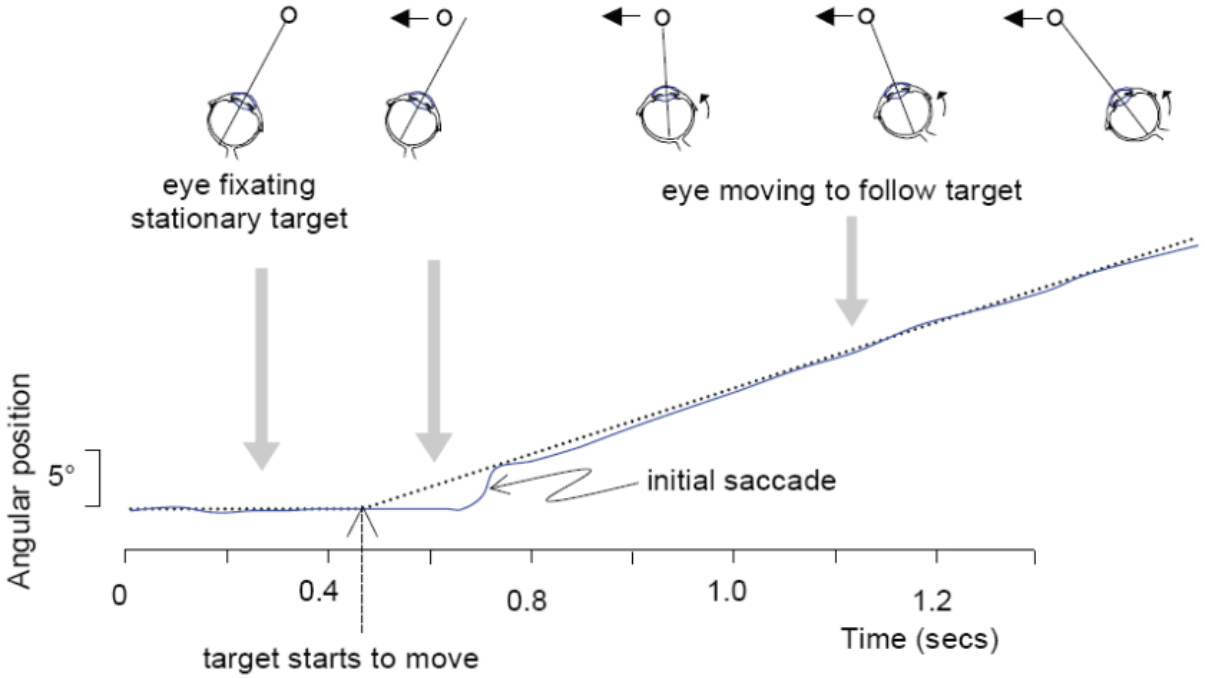


Fig: Tresilian 2012

Pursuit eye movements are used to follow a moving object



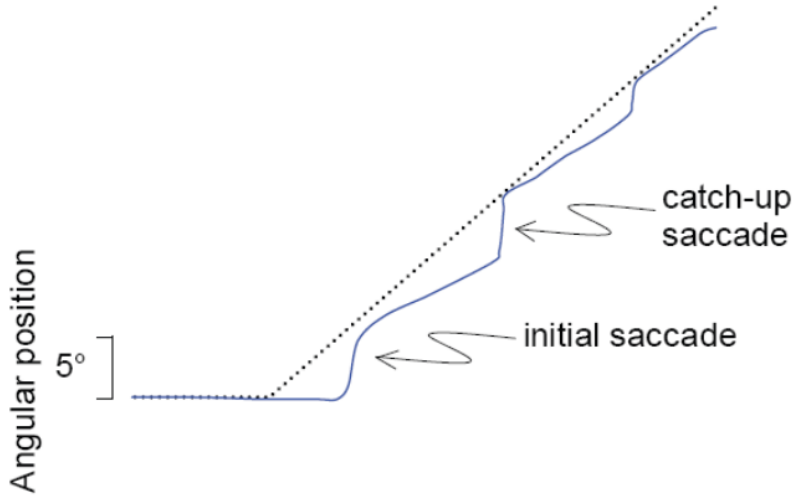


Fig: Tresilian 2012

Cortical processing of visual information proceeds along two primary streams

- **Visual area 1 (V1)** receives information that underlies our conscious visual perception and is part of a larger area called **visual cortex**
- The region outside of V1 is the **extrastriate visual cortex** and is made up of many individual areas based on type of visual information primarily respond to:
  - e.g., cells in **V4** primarily involved with color information
  - e.g., cells in **V5** primarily involved with processing motion information

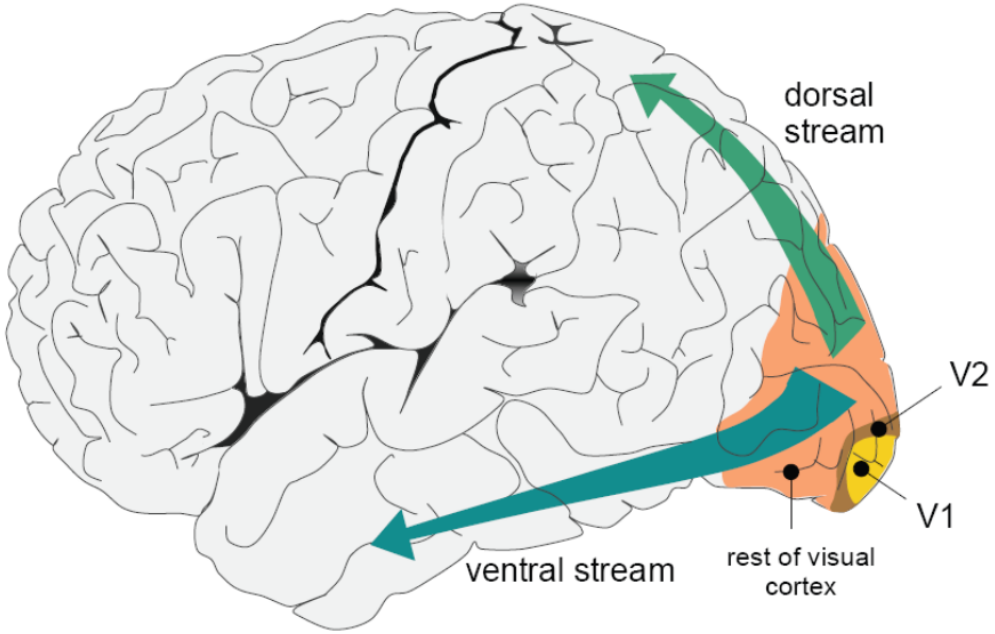


Fig: Tresilian 2012

What are the functions of the two visual streams?

We can **distinguish** the two streams based on the **use to which the information is put**

Ventral stream

- underlies what we normally think of as **seeing**
- i.e., *vision-for-perception*

Dorsal stream

- underlies the **visual control of voluntary action**
- i.e., *vision-for-action*

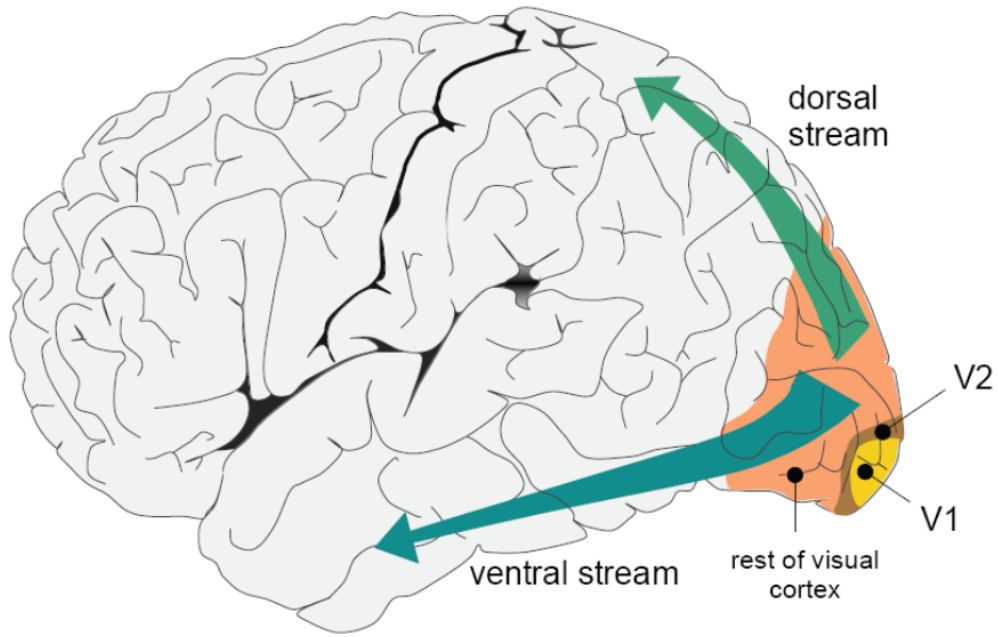


Fig: Tresilian 2012; Goodle & Milner 1992

Brain damage can impair conscious vision but leave visuomotor skill intact

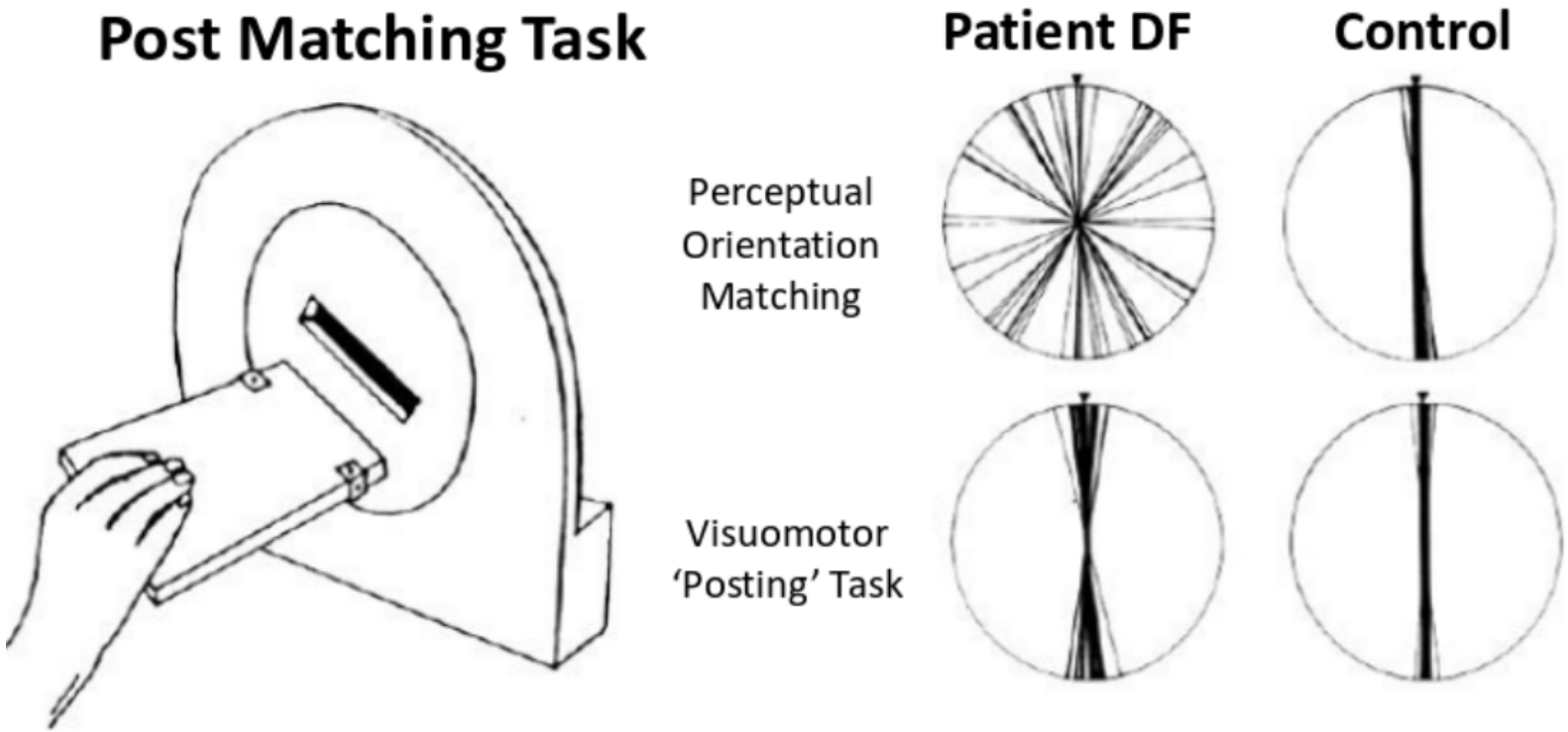


Fig: Milner & Goodale 1998

Brain damage can impair visuomotor skill but leave conscious vision intact

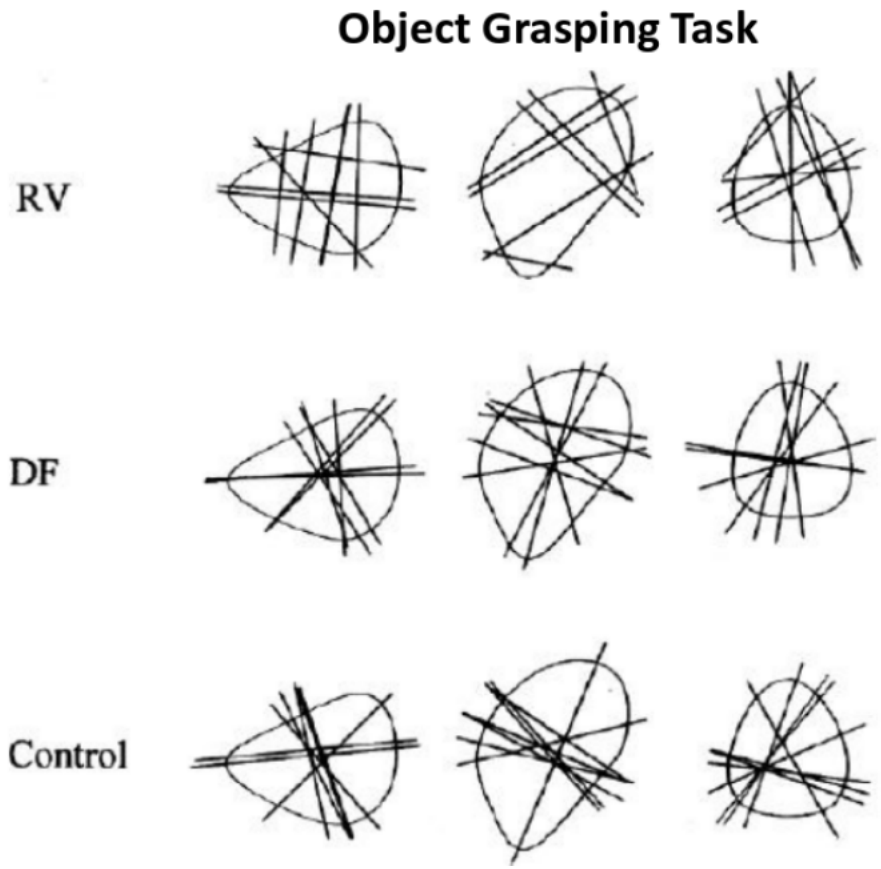


Fig: Milner & Goodale 1998

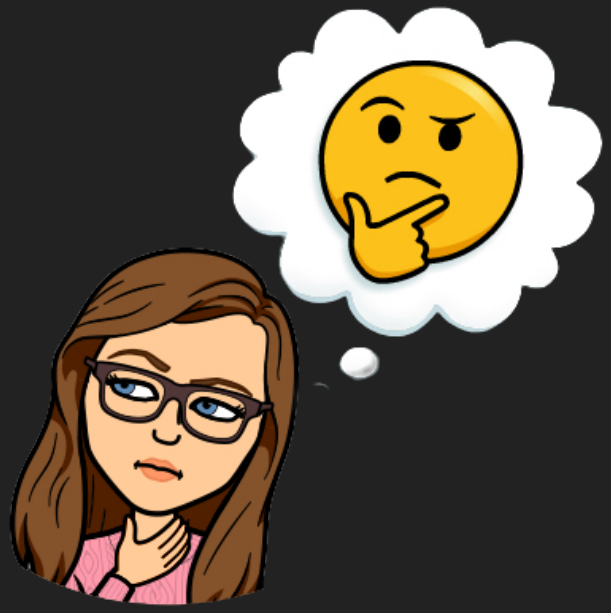
Learning objectives

1. Identify and describe key **anatomical components** of the eye.
2. Describe how **visual information** is transmitted.
3. Identify and describe **different types** of eye movements.
4. Describe our **two visual systems** and how motor behaviour is affected when **damage** occurs in them.

Take-home message:

Sensory feedback is critical for skilled voluntary actions.

What questions do you have?



@_LauraStGermain
@LauraStGermain
www.cartermaclab.org