McMaster University

SCIENCE

Department of Kinesiology

Sensorimotor foundations

KINESIOL 1E03 - Motor control and learning

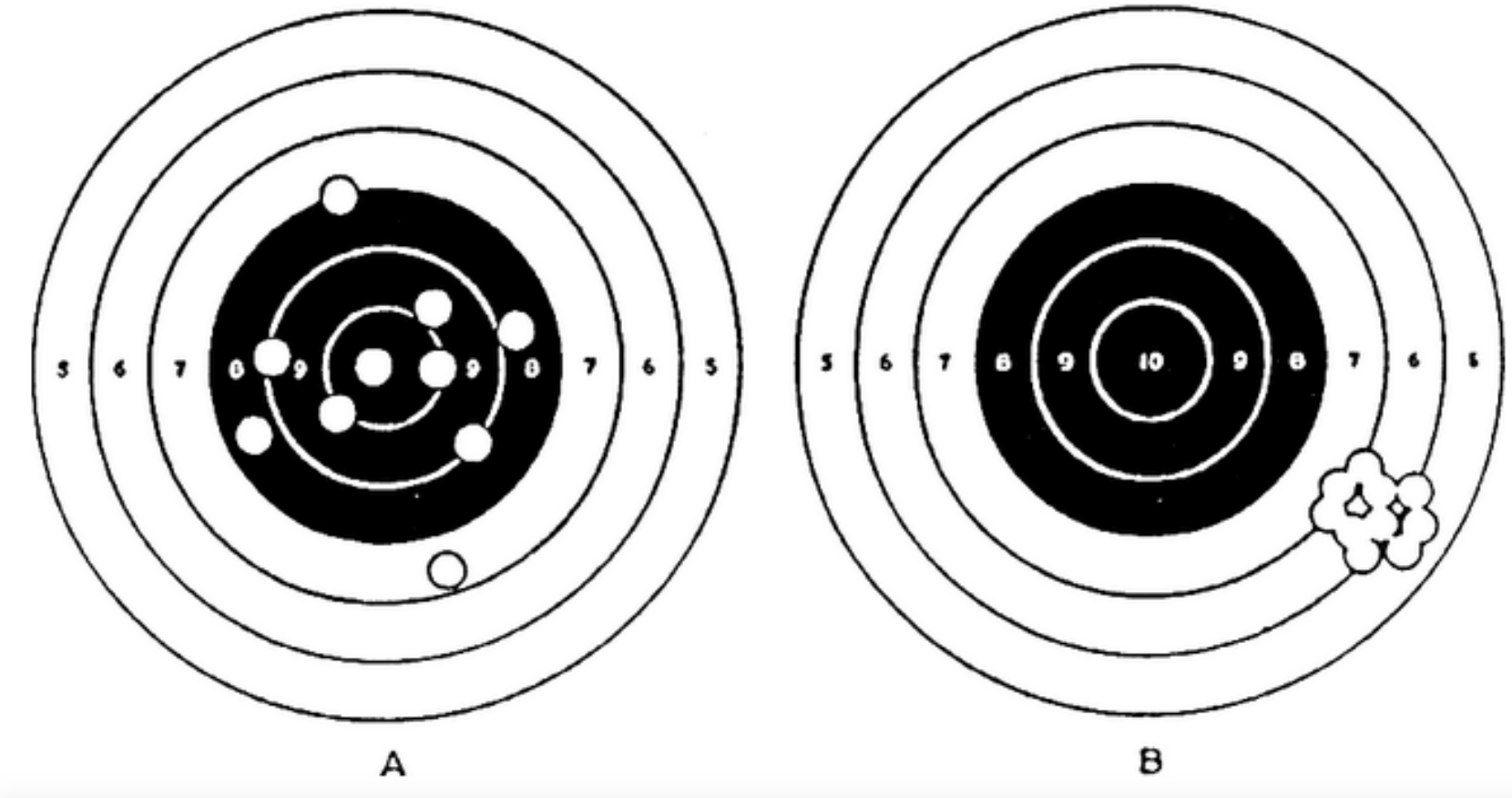
Mike Carter

Fall 2022 Week 2

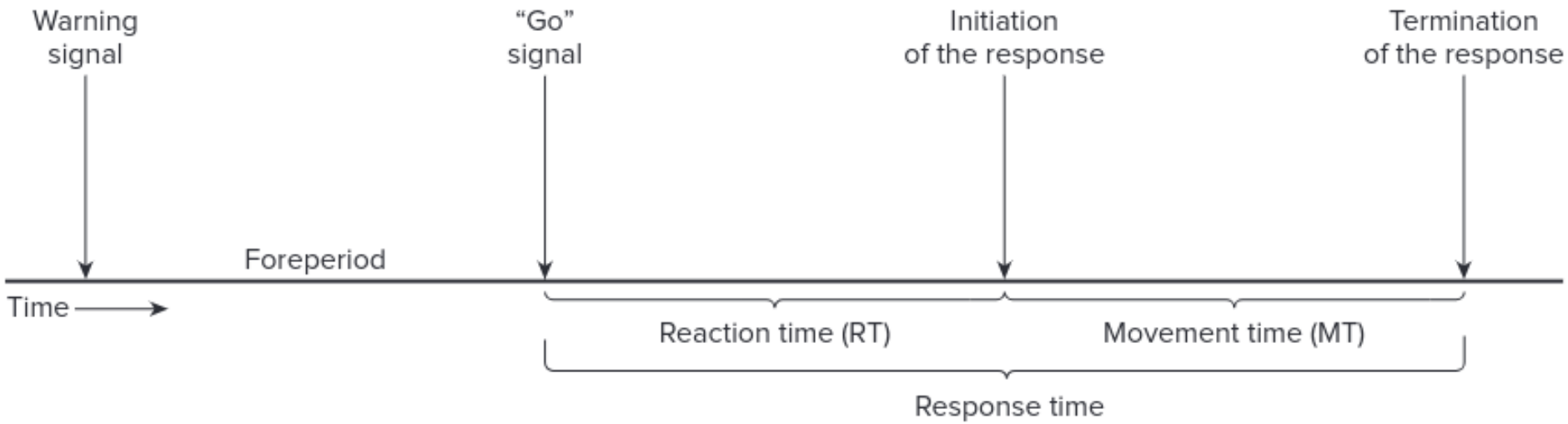
Lecture 5

Review from last lecture

Motor tasks with outcomes that vary in 2 dimensions need to be measured appropriately



Reaction time is a measure of the time required to prepare and initiate a movement

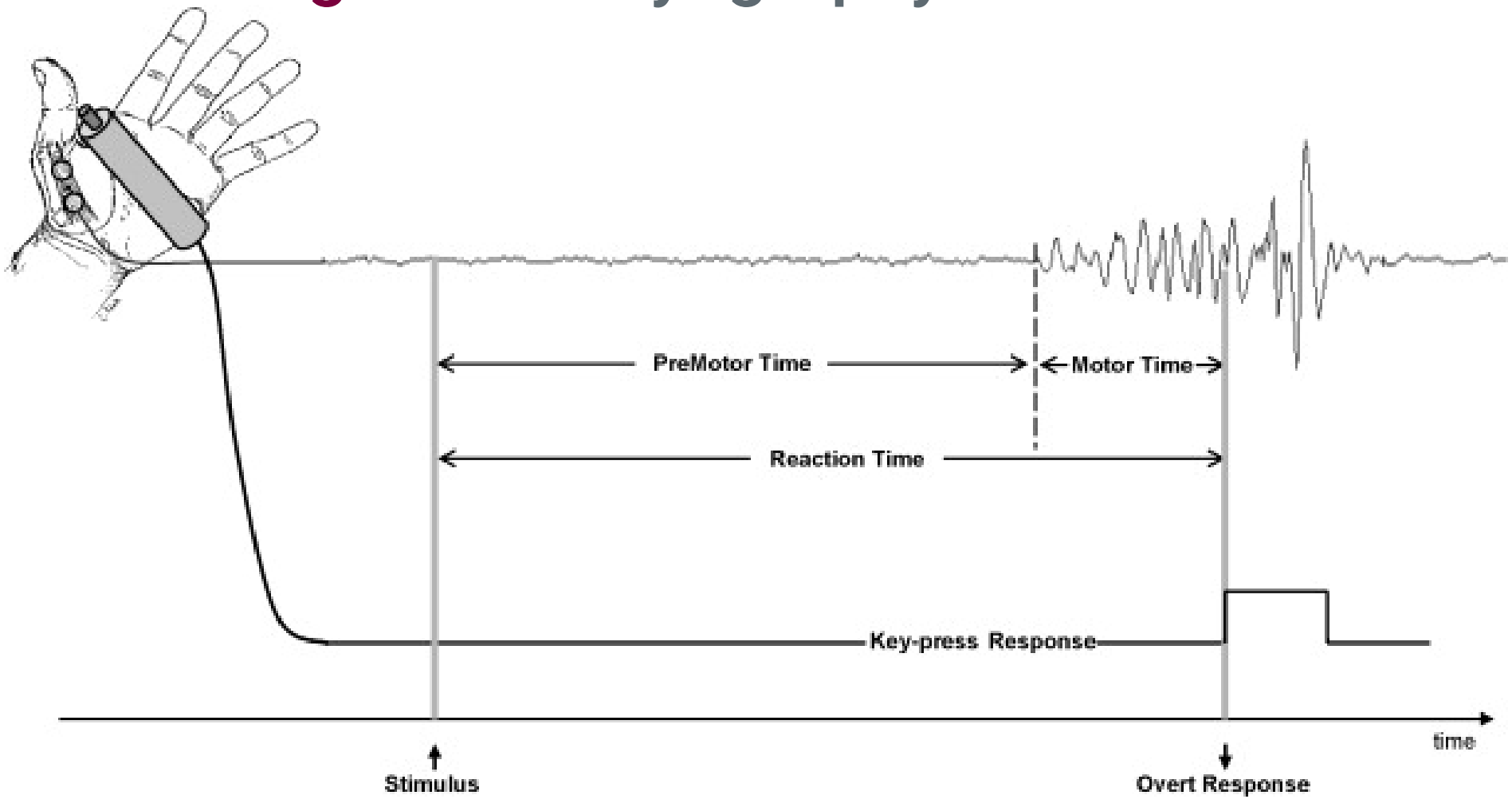


MOVEMENT TIME: the interval of time between the initiation and completion of a movement

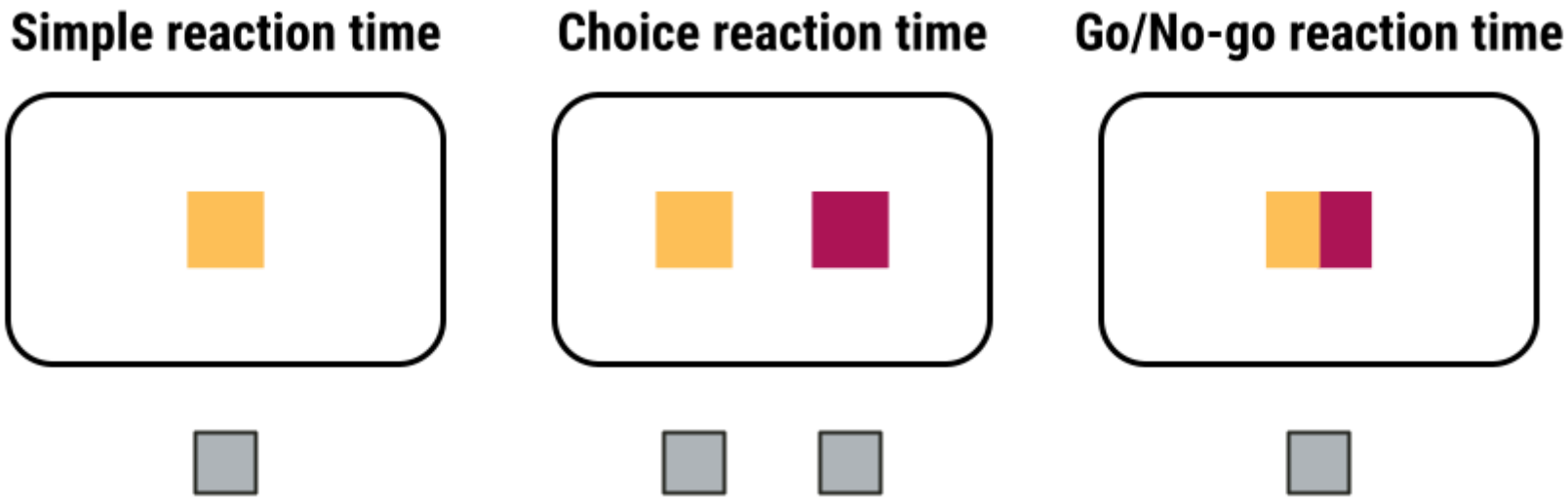
RESPONSE TIME: the sum of reaction time and movement time

Magill & Anderson 2017 (pg. 29)

We can gain further insight into the reaction time interval using electromyography

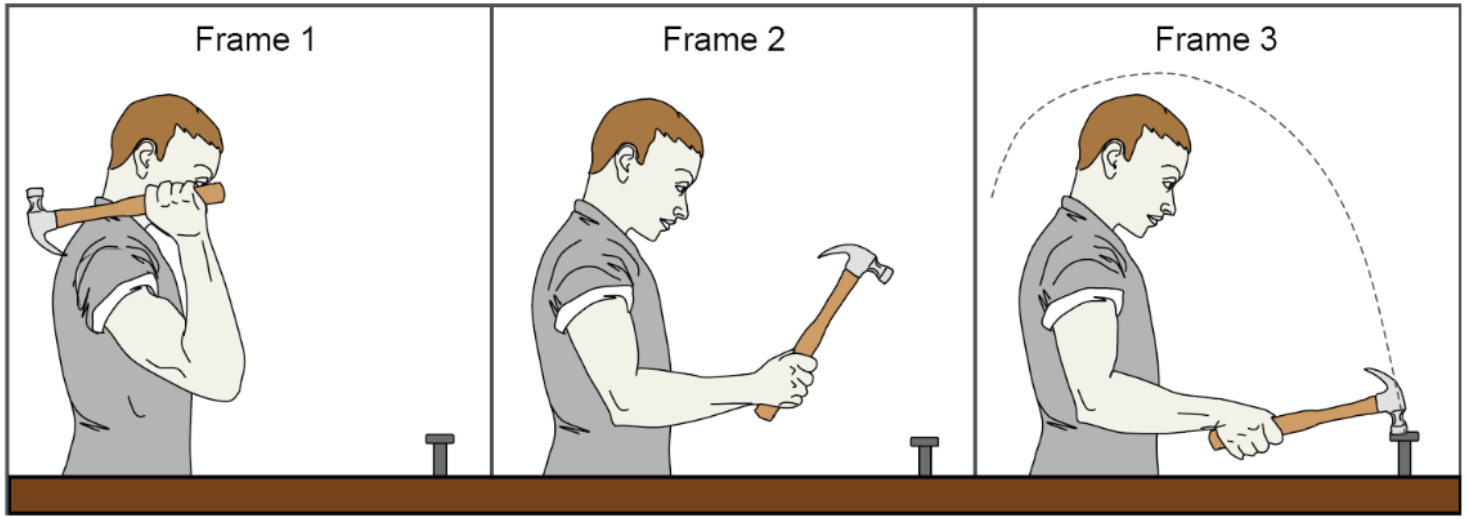


There are three main types of reaction time tasks



- **Simple reaction time**: 1 choice and 1 response
- **Choice reaction time**: 2 or more choices each with a corresponding response
- **Go/No-go reaction time**: 2 or more choices but only 1 is associated with a response

Measuring movement characteristics



KINEMATICS: the study and description of movement without consideration of the forces that cause the movement (e.g., position, displacement, distance, speed, velocity, acceleration)

DYNAMICS (or KINETICS): the study and description of the causal processes that produce movement (e.g., force and torque)

Fig: Tresilian 2012

Any questions?

Learning objectives

1. Discuss **general characteristics** of sensory receptors and perceptual processes.

2. Describe the **sensory receptors** in the skin that provide **tactile** information and those that provide **kinesthethic** and **proprioceptive** information to central nervous system.

3. Describe several procedures researchers use to **investigate the role of kinesthesis and proprioception** in motor control

Take-home message:

Sensory feedback is critical for skilled voluntary actions.

Sensory receptors respond to stimulation

Sensory receptors in the human body respond to **four** basic kinds of energy:

1. **Photoreceptor**: primarily responsive to light
2. **Mechanoreceptor**: primarily responsive to mechanical energy
    - e.g., vestibular receptors, touch receptors
3. **Chemoreceptors**: primarily responsive to certain chemical substances
    - e.g., taste receptors, smell receptors
4. **Thermoreceptors**: primarily responsive to thermal energy

Biological sensory receptors can be classified based on the origin of the stimulation to which they primarily respond

1. **EXTEROCEPTORS**: respond to mechanical, chemical, thermal, or electromagnetic contact with the external environment
    - e.g., mechanoreceptors in the skin, photoreceptors, and olfactory chemoreceptors
2. **INTEROCEPTORS**: respond to stimulation produced by physiological processes within the body.
    - e.g., thermoreceptors within deep tissues that respond to the internal temperature of the body, mechanoreceptors in arterial walls, mechanoreceptors in the gut wall, and a variety of internal chemoreceptors
3. **PROPRIOCEPTORS**: respond to mechanical stimulation associated with the angular positions of joints, movement of joints, the orientation of body segments, tensions in ligaments, tendons and other connective tissues, muscle length, and changes in muscle length

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

Tactile information is critical for dextrous behaviour

Normal; Full vision

Source: https://youtu.be/zGIDptsNZMo

Fingertip anesthesia; Full vision

Source: https://youtu.be/HH6QD0MgqDQ

There are 5 types of mechnoreceptors found close to the surface of human skin

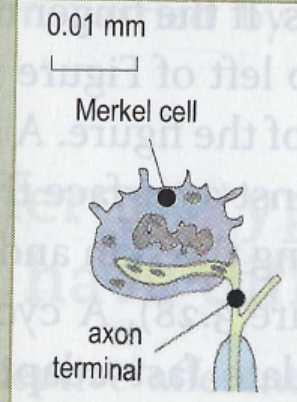
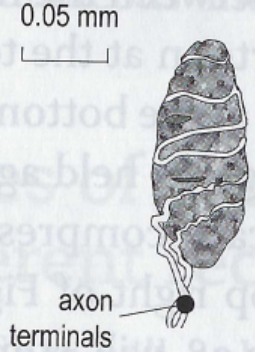
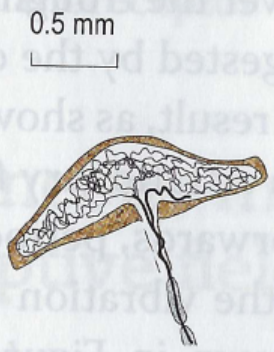
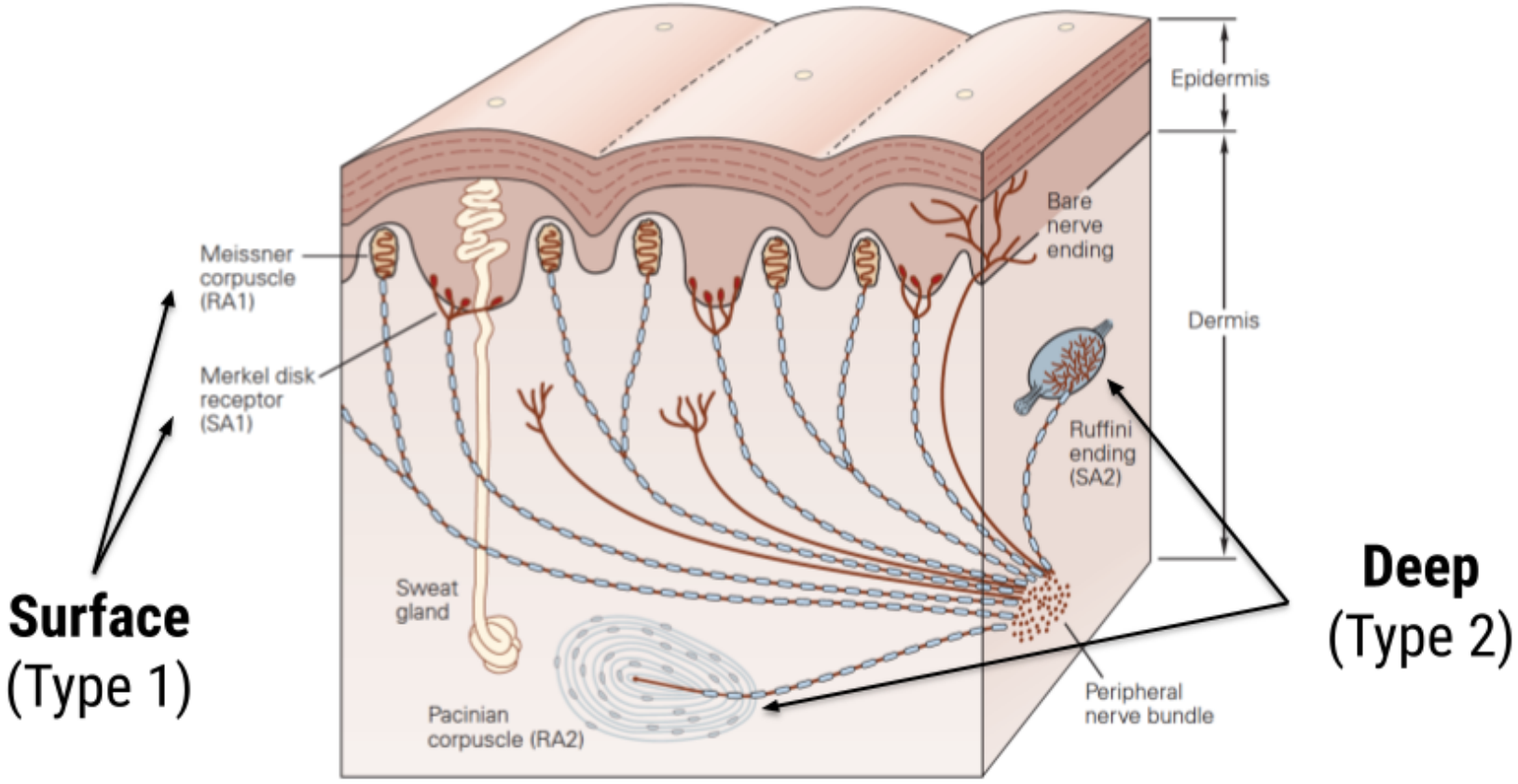
Receptor	Merkel disk receptors	Meissner corpuscle	Ruffini end organ	Pacinian corpuscle	Hair follicle receptor
Diagram					
Fiber group	Aβ	Aβ	Aβ	Aβ	Aβ
Adaptation characteristic	Slow adapting	Fast adapting	Slow adapting	Fast adapting	Fast adapting
Skin type	Glabrous & hairy	Glabrous & hairy	Glabrous & hairy	Glabrous & hairy	Hairy

Fig: Tresilian 2012

Cutaneous mechanoreceptors can be classified based on location and adaptation characteristic



Kandel et al. 2021

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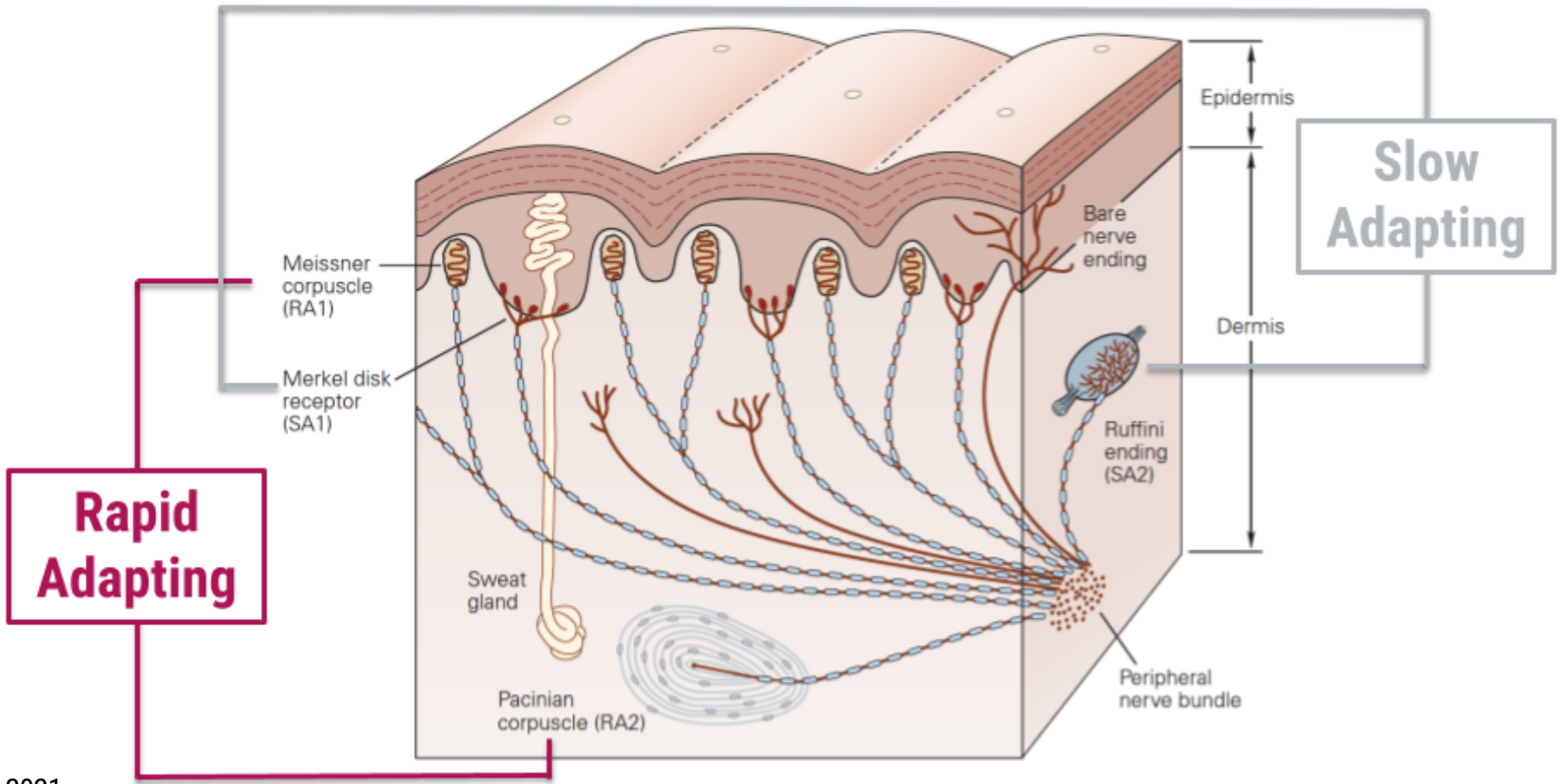


Kandel et al. 2021

The response of a sensory neuron declines when the level of stimulation does not change

- Receptor potentials and the firing rates of sensory neurons tend to decline over time if the strength of the stimulation remains constant, a phenomenon called **sensory adaptation**

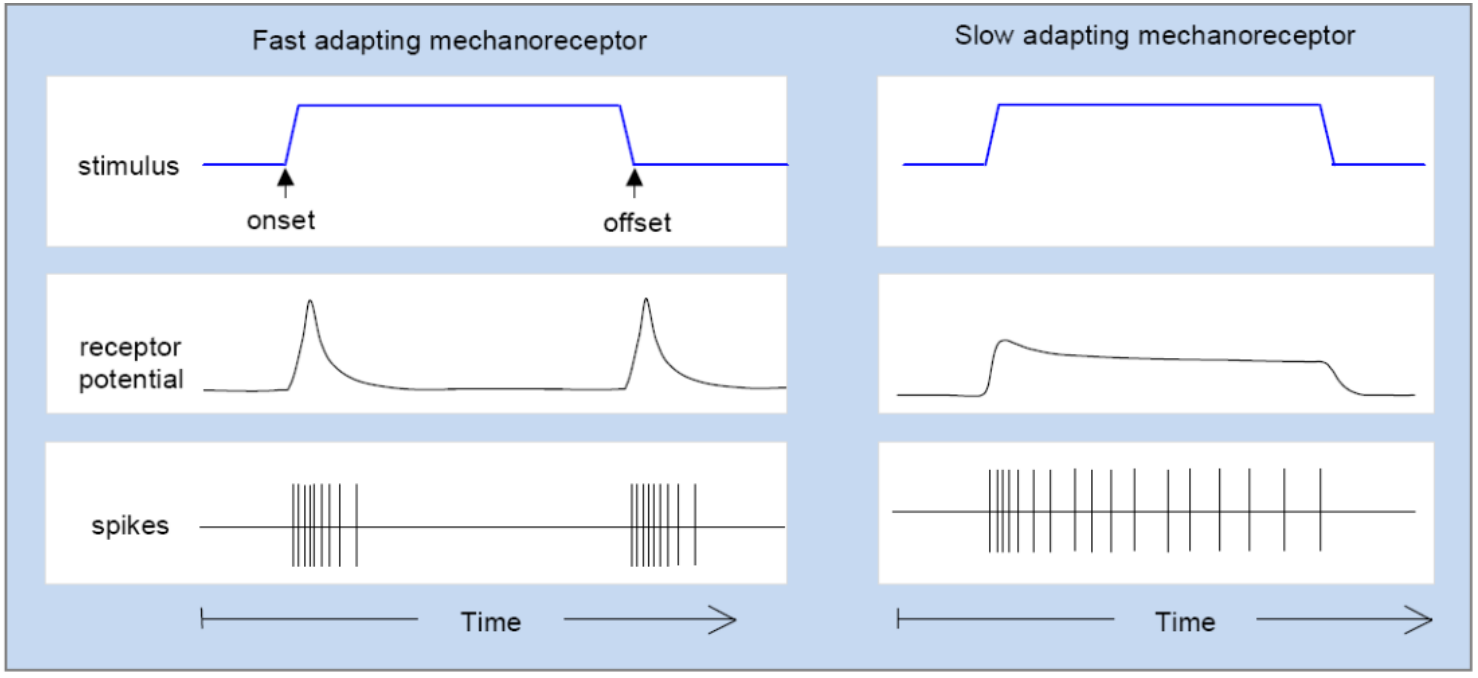
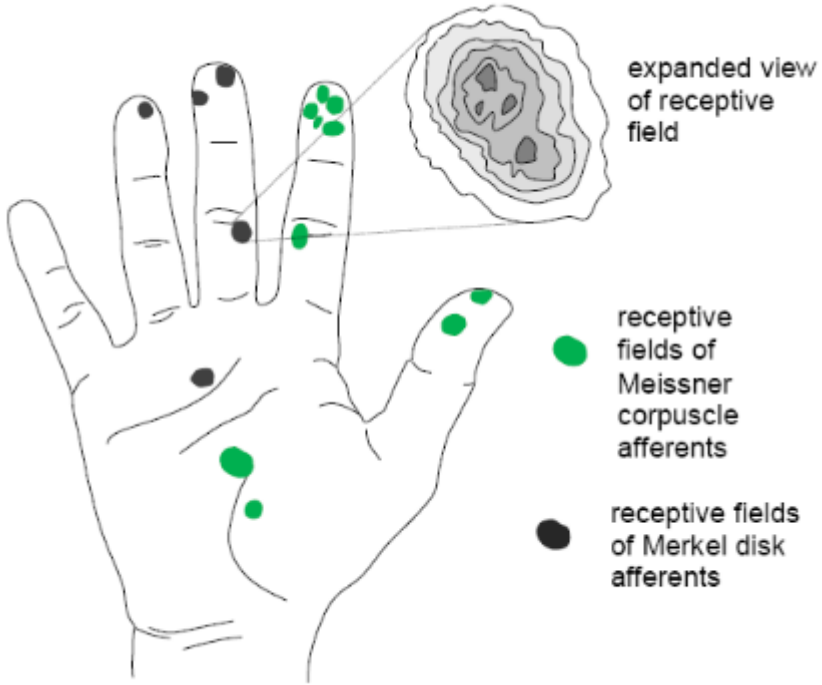


Fig: Tresilian 2012

Different types of cutaneous mechnoreceptive afferents have different receptive fields



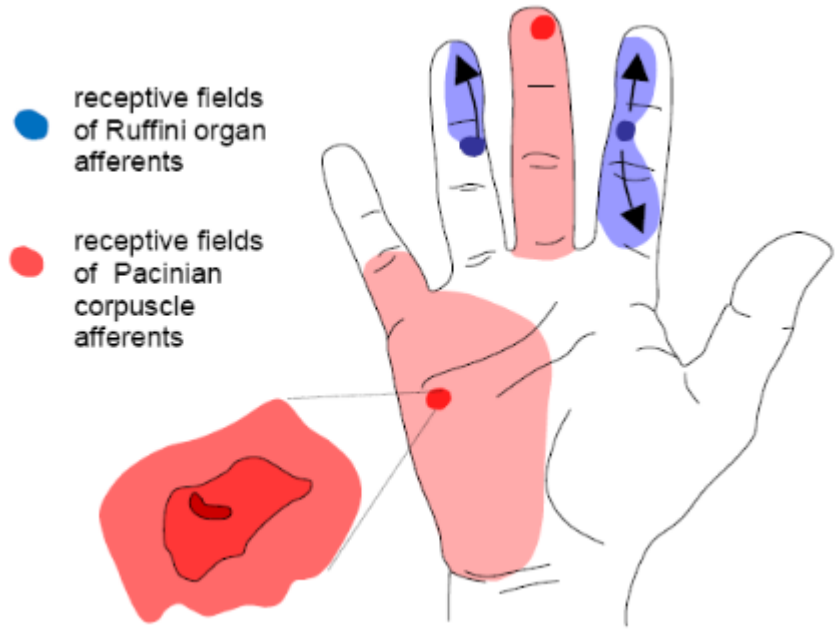
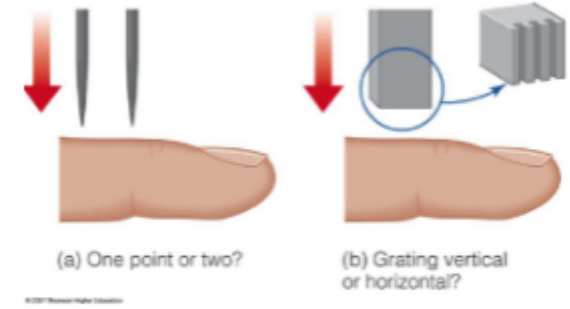


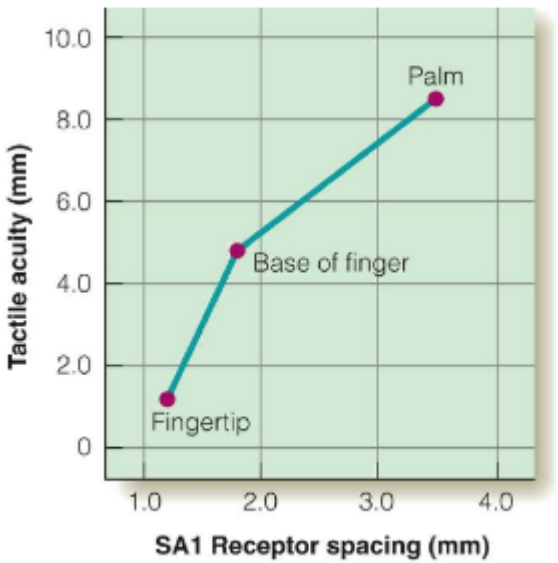
Fig: Tresilian 2012 based on figures presented in Johansson & Vallbo 1986 (https://doi.org/10.1016/0166-2236(83)90011-5)

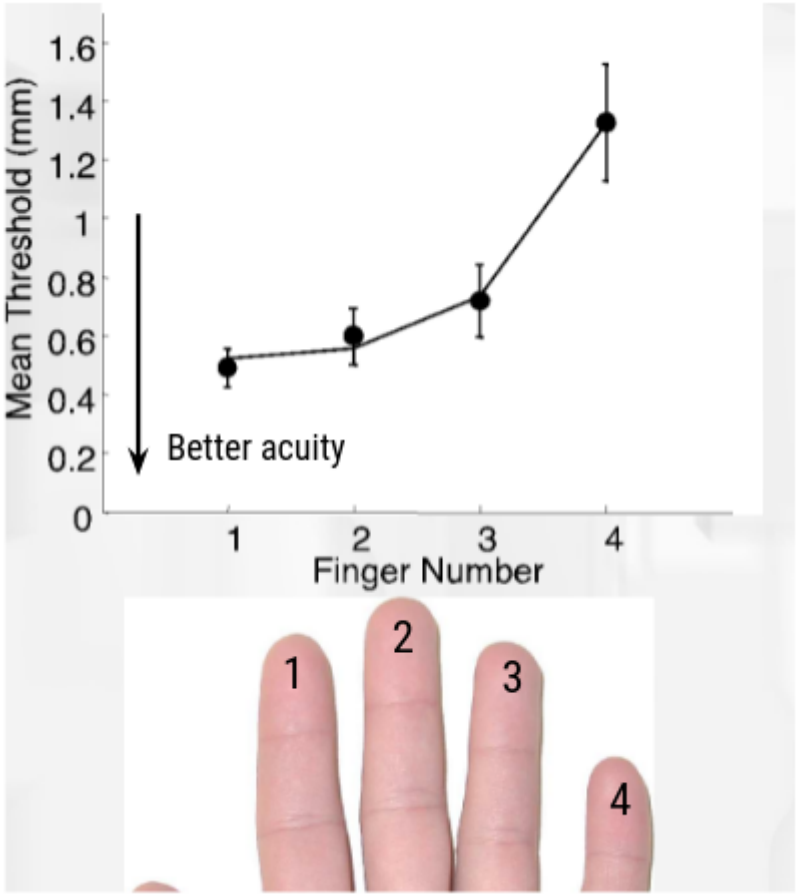
Characteristics of skin stimulation to which the cutaneous mechanoreceptors are thought most likely to be responsive

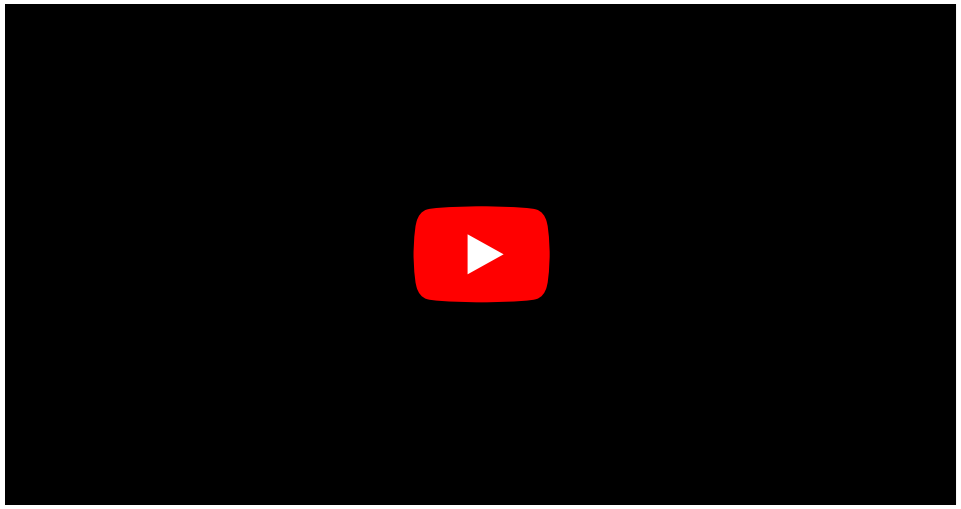
- **Merkel disks**: sustained skin contact and pressure, slowly changing skin deformations (frequencies less than ~5 Hz)
- **Meissner corpuscles**: lateral movement, vibration and fairly rapid changes in skin deformation (~5 to 50 Hz)
- **Ruffini end organs**: sustained and slow changes in skin stretch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

Tactile acuity is determined by Merkel receptors

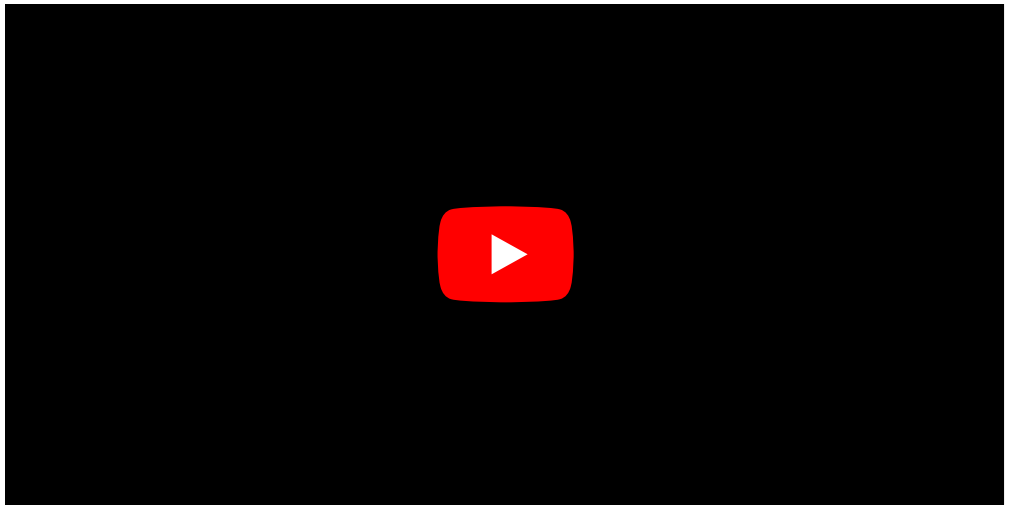








Source: https://youtu.be/W3CLCVLq_CU



Source: https://youtu.be/B4Qs5wQTTec

Source: https://youtu.be/QK0EryOV6LE

Source: https://youtu.be/Me0cBor6y-o

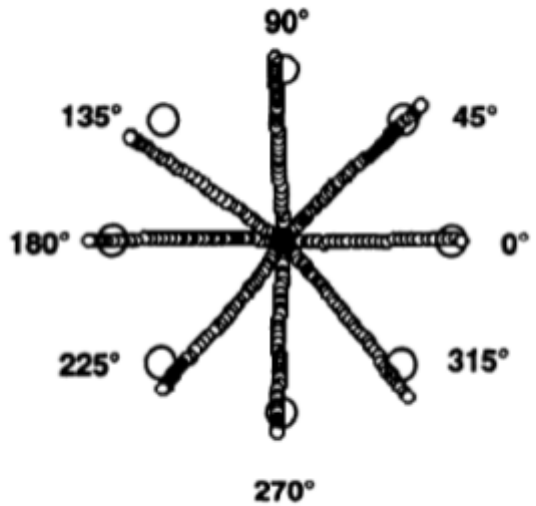
Meet Patient GL

- GL was 27 years old when she suffered a first episode of acute polyneuropathy with a complete paralysis (including her respiratory muscles)
- A 2nd episode of extensive sensory polyneuropathy occurred 4 years later (April 1979). This episode selectively affected the large myelinated sensory fibers
- GL has complete loss of touch, vibration, pressure, and kinesthetic/proprioceptive senses (pain and temperature are present)

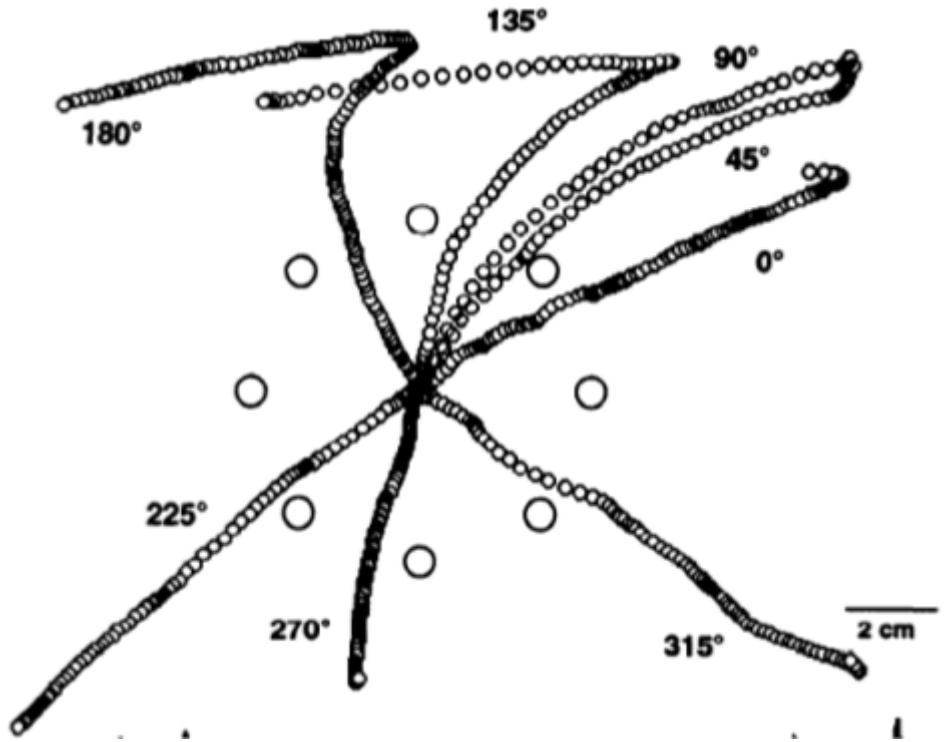
Left: https://sites.google.com/site/sarlegna/_/rsrc/1341002803993/photos-and-videos/gl.jpg

Loss of sensory information disrupts reaching movements

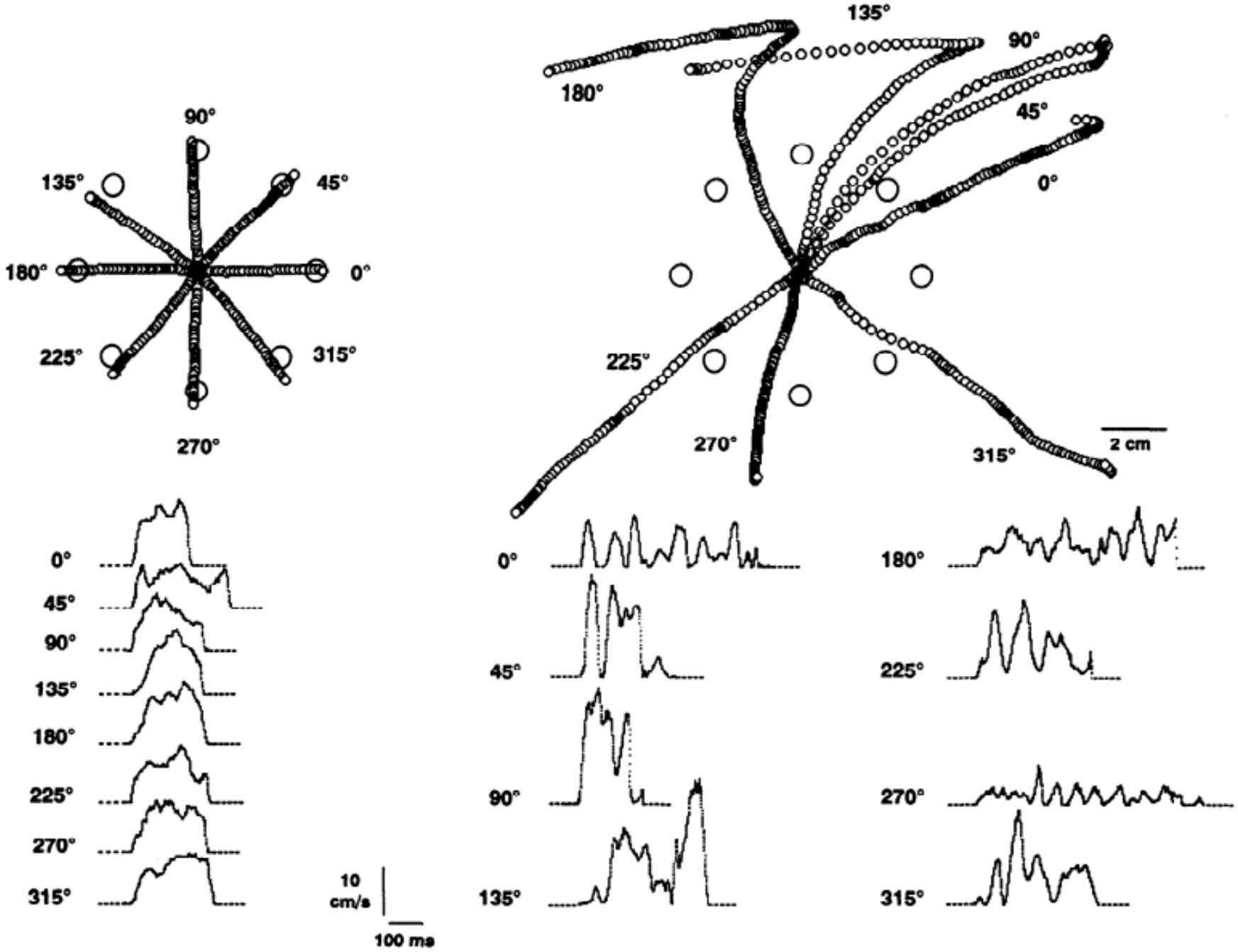
Control MFG



Patient GL



Gordon et al. 1995 (https://doi.org/10.1152/jn.1995.73.1.347)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The perception of body movements and position

- Afferent signals generated by exteroceptors in response to the external stimulation is referred to as **exteroceptive afference**
    - contains information about external objects, substances, and events
- Afferent signals generated by somatosensory mechanoreceptors in response to internal stimulation is referred to as **proprioceptive afference**
- The perception of body position and movement from proprioceptive afference is called **kinesthesis**
- **Proprioception** is a general term for perception based on proprioceptive afference and includes the perception of muscular effort and force

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

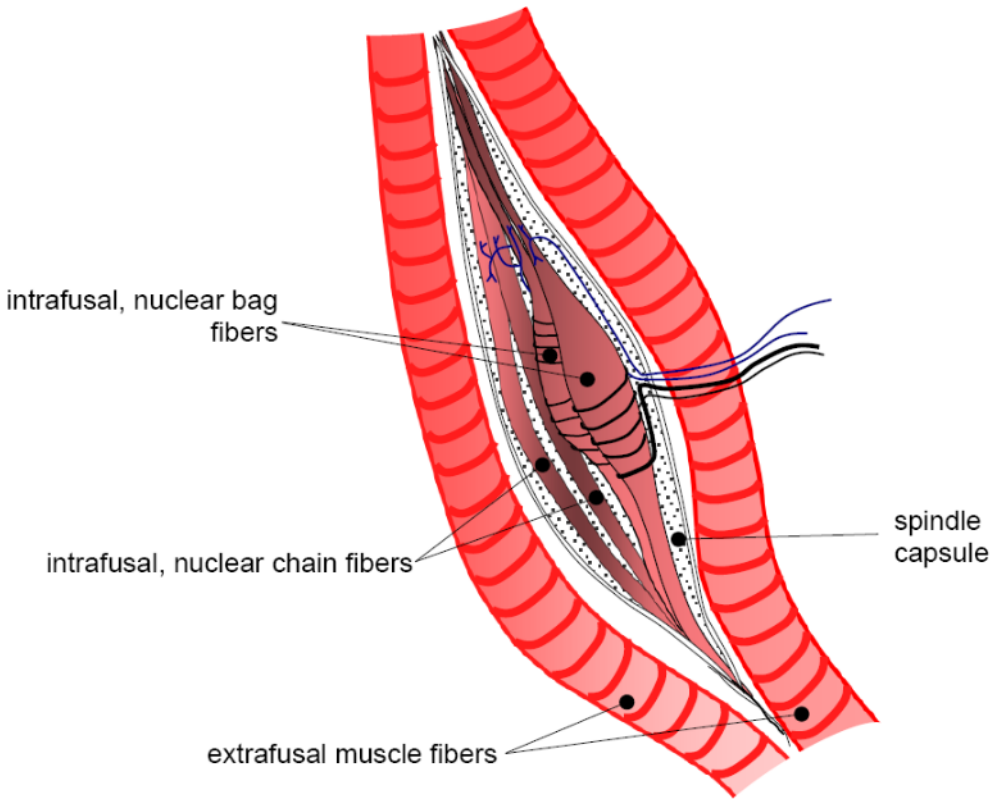

Fig: Tresilian 2012

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

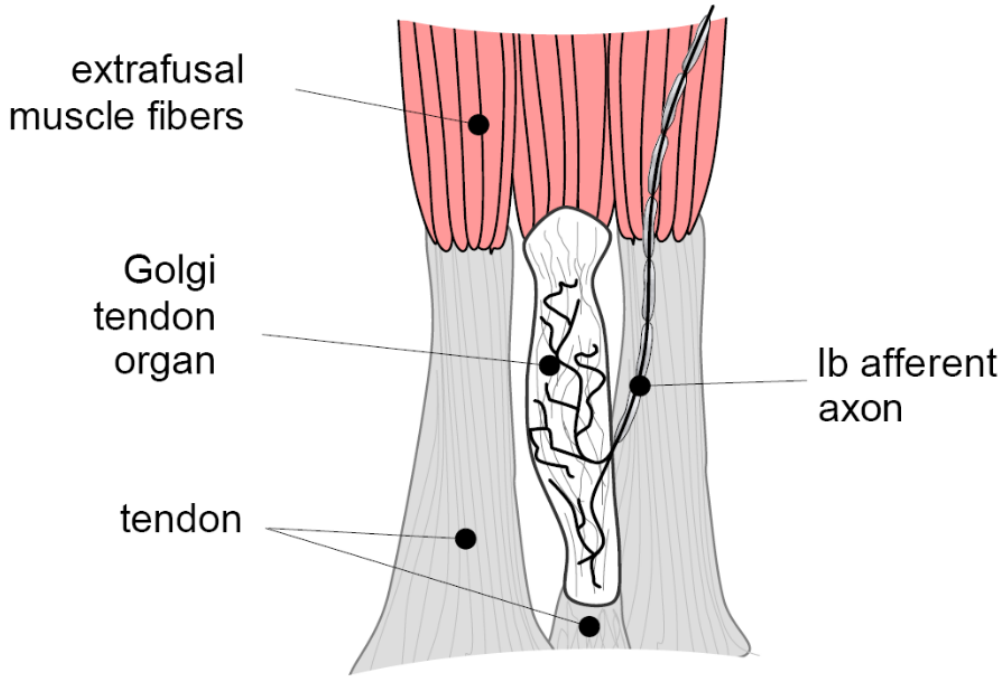

Fig: Tresilian 2012

Tendon vibration selectively stimulates Type Ia spindle afferents and produces kinesthetic illusions

- The tendon deflection **stretches** the muscle very slightly but does so quite rapidly
- When frequency is high enough (20 to 100 Hz), the speed of stretching can be sufficient to stimulate Type Ia afferent endings
- Tendon vibration has been found to evoke **illusory** perceptions of **joint movement** if the person **cannot see the joint**

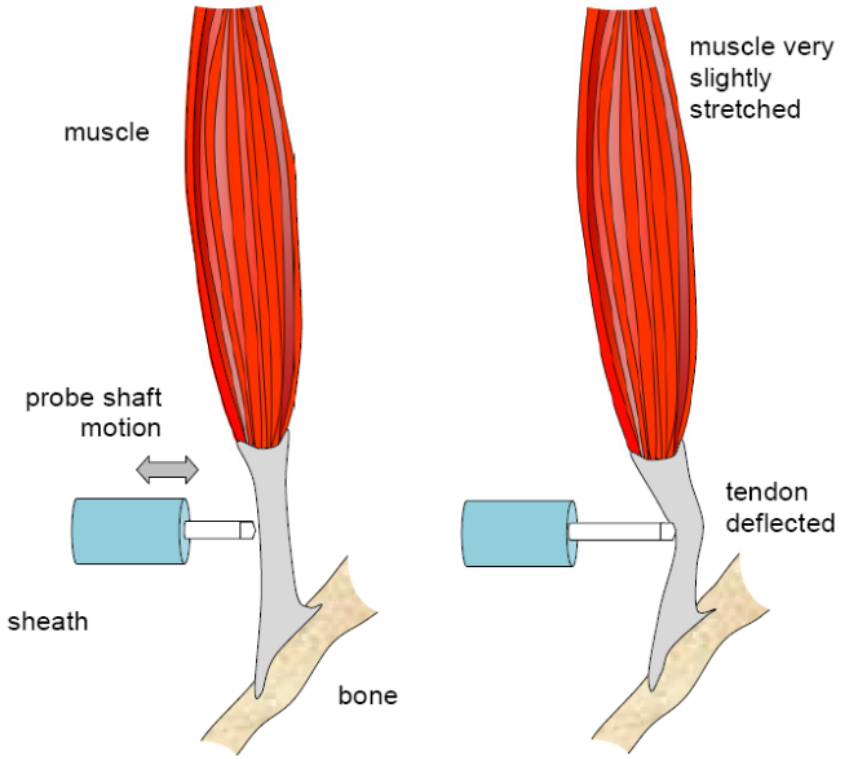

Fig: Tresilian 2012

Spindle information dominates information from other proprioceptors

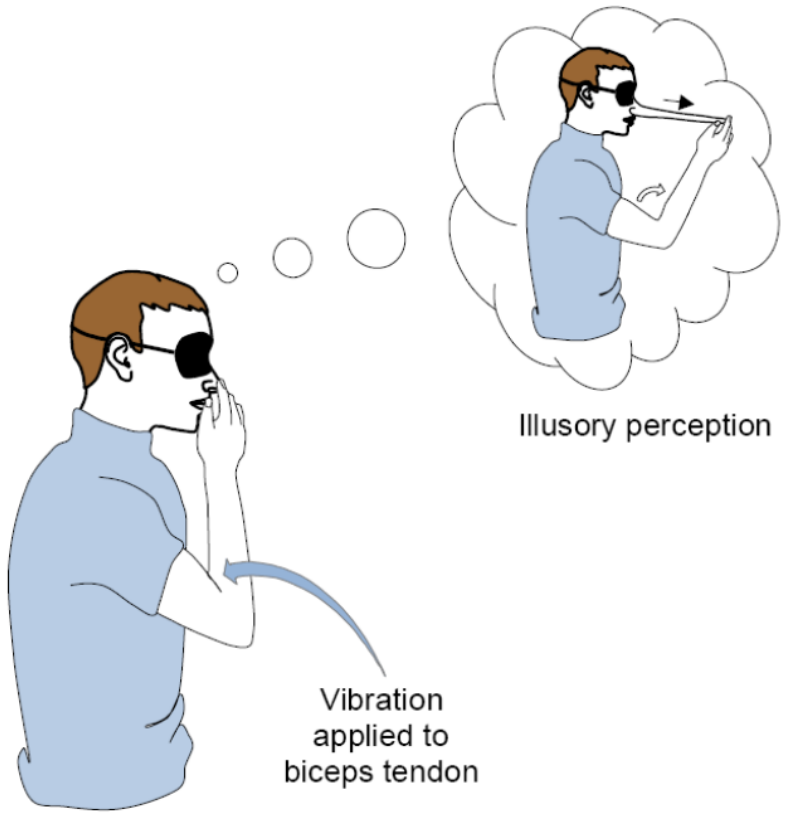

Fig: Tresilian 2012

- Resolving a conflict between different sources of sensory information about a single perceived quantity by using one source and ignoring the other is called **sensory dominance**
- Recall that these kinesthetic illusions **depend on not having vision** of the joint
- Reveals how visions dominates the other sensory modalities whereas the other examples show how spindle afferents signals can dominate **within** a modality

A limb can be felt where it is seen and not where it actually is

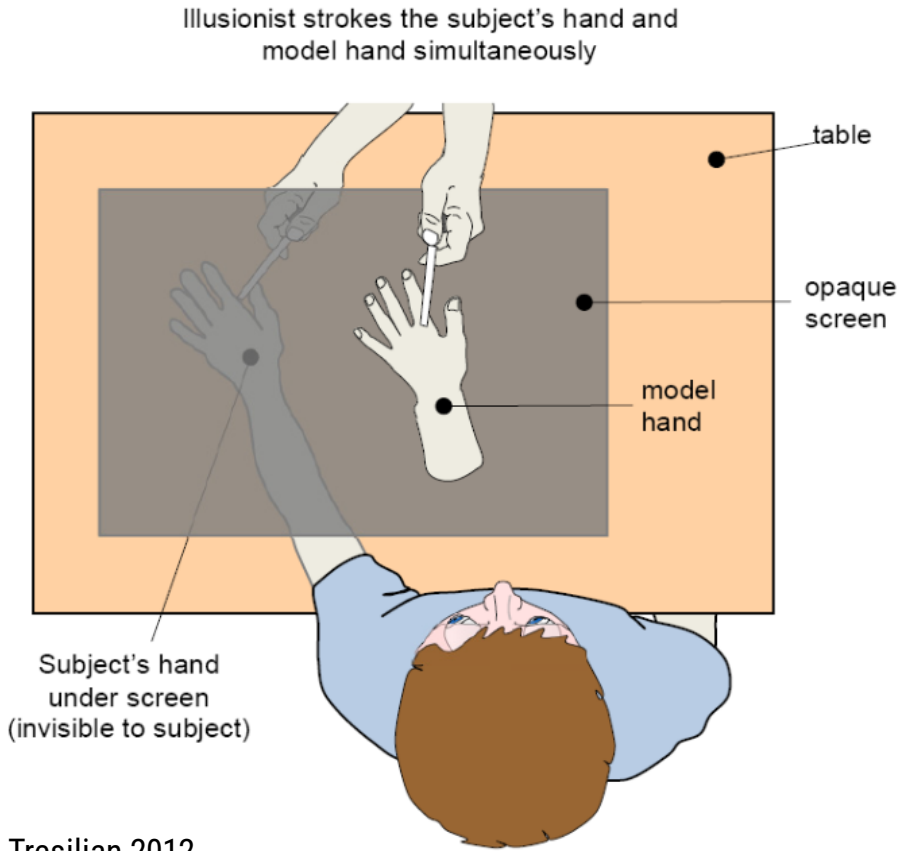

Fig: Tresilian 2012

- If illusion works, hand is felt where they see rubber hand (**visual capture of kinesthesis**) and refer their feeling of stroking to rubber hand (**visual capture of touch**)

Source: https://youtu.be/DphlhmtGRqI

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**

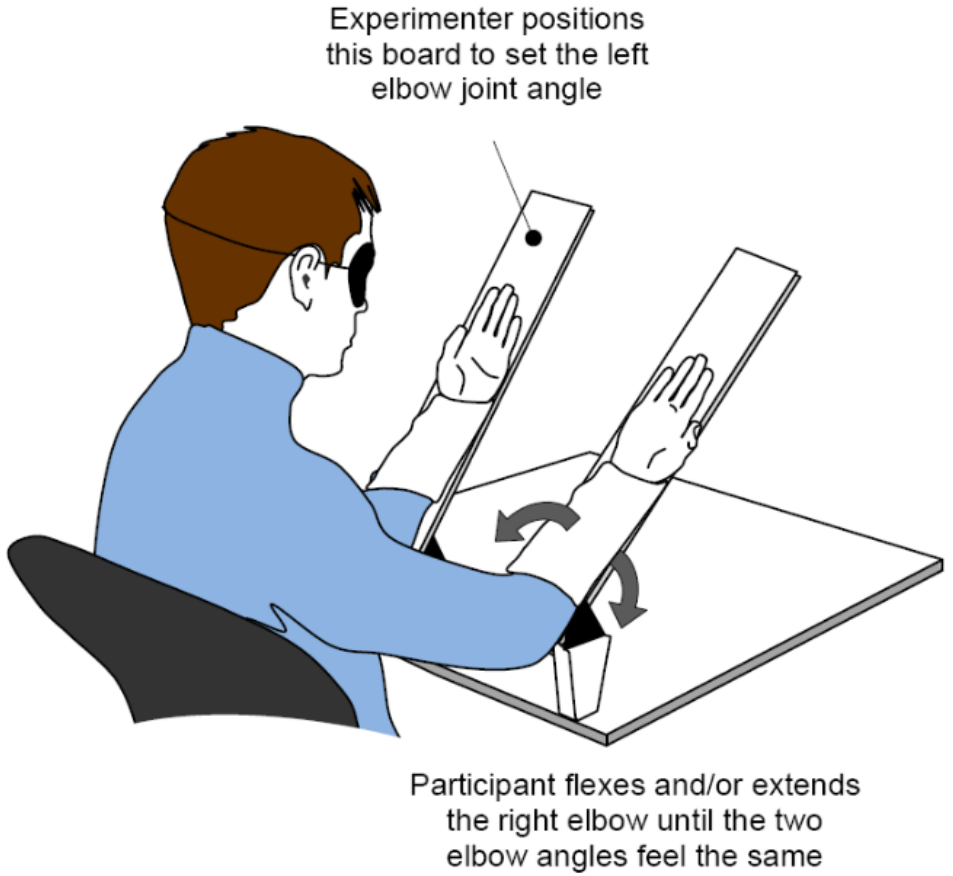

Fig: Tresilian 2012 based on Allen & Proske 2006 (https://doi.org/10.1007/s00221-005-0174-z)

Assessing kinesthetic and proprioceptive abilities

Source: https://youtu.be/zvbzDVIEFuc

Learning objectives

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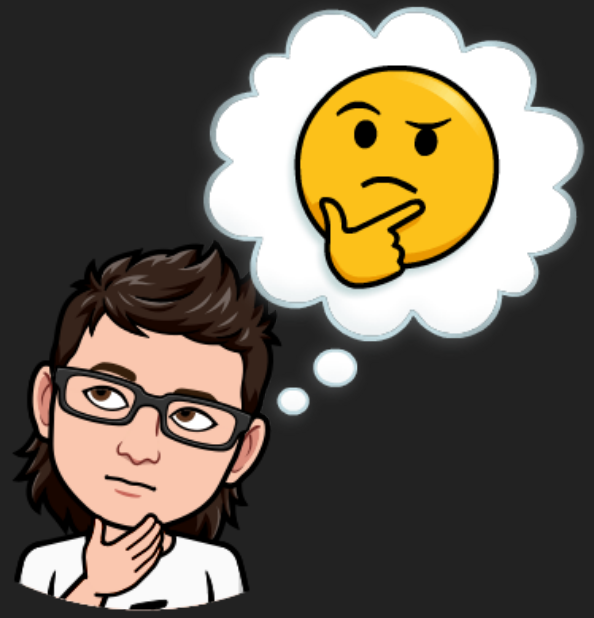
Take-home message:

Sensory feedback is critical for skilled voluntary actions.

What questions do you have?



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