Assessment of proprioceptive ability in healthy and disabled individuals

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OUTLINE

1. Some basics about proprioception
2. The truth about “Proprioceptive Matching”
   • Factors affecting tests of proprioceptive acuity
3. Moving beyond behavior: Using fMRI for mapping proprioceptive feedback processing
   • fMRI + Tendon Vibration
Traditional View of Sensation

Allegory of the Five Senses, 1668, Gerard De Lairesse
The sixth sense?

- Muscles have motor and **SENSORY** nerves
- “Muscle Sense”

- “Proprioception”
  - Prioprius – one’s own
  - Ception – perception
  - Sensory signals arising from one’s own actions

Sir Charles Bell - 1774-1842

Sir Charles Sherrington - 1857-1952
Proprioception:

- Conscience perception of body position and movement in the absence of vision

“Position sense”

“Kinesthesia”

Field Sobriety test of proprioception
The Proprioceptive Pathway

Skin, Joint, MUSCLE
Muscle Spindles

- Stretch receptors
- Located intramuscularly

- Firing pattern corresponds with muscle length (position sense) and changes in muscle length (kinesthesis)
Muscle Spindles

Tendon Vibration
– Stimulates Muscle Spindle Firing
– @ 80-120Hz get Illusions of altered position and movement
Central Processing of Proprioceptive Feedback

Primary Somatosensory Area

- Penfield (1954)
How Important is Proprioception?

Cup Stacking

Vision

No Vision
(Proprioception?)
How Important is Proprioception?

Deafferentation – A Clinical Example

“Pride and Daily Marathon” – Jonathon Cole
How to Measure Proprioception?

Direction Test
1. Move Joint
2. Subject Response

Pros
– Good indicator of whether pathway is intact.

Cons
– Can’t quantitatively measure acuity
– Can’t distinguish position vs. movement sense
How to Measure Proprioception?

Matching Test

1. Establish Target
2. Subject Match

Pros
- Pathway Intact
- Measure of acuity
- Position/Movement possible

Cons
- Increased cognitive and perceptual demands
Factors that influence estimates of proprioceptive acuity when using matching tasks

Motor Control Laboratory – Susan Brown, PhD
Experimental Set-up – Elbow Matching Task

10-20 participants, 30-60 trials

Potentiometer

Blindfold + Head Support

Programmable Servomotor
Factor #1 – Matching Task Type

Multiple ways to perform matching:

1. Ipsilateral Matching
2. Contralateral Matching
3. Contralateral Remembered Matching
Factor #1 – Matching Task Type

Multiple ways to perform matching:

1. Ipsilateral Matching
   • INTRA-limb match

Requires MEMORY
Factor #1 – Matching Task Type

Multiple ways to perform matching:

2. Contralateral Matching
   • INTER-limb Match

Requires
INTERHEMISPHERIC TRANSFER (IHT)
Factor #1 – Matching Task Type

Multiple ways to perform matching:

3. Contralateral Remembered Matching
   • INTER-limb match with delay

Requires both MEMORY and IHT
Factor #1 – Matching Task Type

↑ error with greater processing demands


1.25 deg = 1 cm
TAKE HOME – TASK TYPE

• Task type can bias estimates of proprioceptive ability

• Task Selection is key for:
  – Pop’n prone to memory deficits
  – Pop’n with degraded interhemispheric pathways
Factor #2 – Matching Hand

- Human are unique with ~90% “right-handed”
- Enduring across cultures and time

(Coren and Porac 1977)
Factor #2 - Matching Hand

Right arm MOTOR dominance

- Stronger
- Faster
- Less Variable

Dominant arm > Sinistral?

(Woodworth 1899; Liepmann 1908,1920; Provins 1967; Peters 1976; Annett et al 1979)

Left Hemispheric Specialization?
Factor #2 - Matching Hand

What about SENSORY feedback?

Vision?

Proprioception?

Two-handed tasks
Sensory Modality Hypothesis of Handedness (SMHH)

Preferred Arm

Vision

Non-Preferred Arm

Proprioception
Factor #2 - Matching Hand

Proprioceptive Matching

Visual Matching

(Goble and Brown 2008)
Factor #2 - Matching Hand

(Goble and Brown 2008)
Sensory Modality Hypothesis of Handedness (SMHH)

Faith Brynie

Preferred Arm

Vision

Proprioception

Non-Preferred Arm

Hemispheric Dominance??
Unilateral Brain Injury

• 8 Typical children
• 8 Cerebral Palsy
  – 4 Right Hemi*
  – 4 Left Hemi
• Ipsilateral Matching

(Goble et al, 2009)
• Non-preferred arm advantage for JPM

• Right-hemisphere specialization for proprioceptive feedback processing
  – Individuals with right hemisphere brain injury more prone to proprioceptive deficits?
  • Dukelow (2010) - stroke
Factor #3 – Target Establishment

How targets are established matters

1. Amplitude
2. Duration of Hold time
Factor #3 – Target Establishment

Amplitude

• ↑ target amplitude lead to greater error
• Due to sensorimotor noise???

(Goble et al, 2006)
Factor #3 – Target Establishment

Duration of Hold Time

• Encoding of target position more complete with longer hold time?
• Drift?

(Goble, Noble and Brown 2010)
TAKE HOME – TARGET EFFECTS

- Target presentation impacts perception and accuracy of matching

- Researchers/Clinicians must ensure consistent presentation of targets across time/patients to allow for comparison of data
Use of fMRI for mapping brain areas related to proprioceptive feedback – aging as an example

Motor Control Laboratory – Stephan Swinnen, PhD
Aging – it’s happening

- Proportion of individuals 65yrs+ is increasing
Proprioception across lifespan

• Changes in proprioceptive receptor number across lifespan

• Refinement of neural pathways with experience

(Goble 2010)
Proprioception in the Elderly

What do we know?

• Many age-related BEHAVIORAL assessments of proprioceptive ability.

• What about the brain?

(Goble et al, 2009)
How to study proprioceptive processing in the elderly?

Proprioceptive Brain Mapping

Tendon Vibration (TV) + neuroimaging (fMRI)

- TV Induces firing of muscle and illusions of position and movement @ 80-120Hz
- Problem: creation of non-magnetic TV device

MRI compatible vibration device

www.magconcept.com
Proprioceptive Brain Mapping - fMRI

20 young
20 older

Blocks (30s)
- No Vibration
- Tendon
- Bone

Mouse
- Attention

Vibration Devices
- Bone vs. Tendon
Results – Young and Old

Tendon > Bone
(i.e. muscle spindle related activity)

• Left foot – Pink
• Right foot – Blue
• Both - Green

FWE p<.05
Results - Young > Old

- 1/3 cells respond to passive limb displacement
- Decrease proprioception in Parkinson’s Disease
Does this mean anything functionally?

• Ipsilateral Matching for proprioceptive ability
Corr between JPM and TV Mapping

A. 

Bold Response (% Signal Change) vs. Joint Postion Sense (Total Error) for OLDER and YOUNGER groups.

- OLDER: r = -0.40
- YOUNGER: r = -0.39

R putamen
Take Home – Part #2

• Many areas involved in perception of proprioceptive feedback

• Proprioceptive Brain Mapping can be used to reveal differences in activation between groups of individuals

• Relationships between mapped areas and behavior on tasks requiring proprioceptive feedback processing are possible
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QUESTIONS????
What about Lefties?

Mirror Image?

• Unclear in literature
  – Variety of reasons

• Often referred to as less lateralized, more variable

(Goble et al., 2009)
Proprioceptive Mirror Image

(Goble et al., 2009)