Graded Motor Imagery

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Graded Motor Imagery

- Introduction and Definitions:
  - Graded motor imagery (GMI) evolved as a treatment approach born from the growing understanding of the underlying neuroplasticity of complex pain states such as phantom limb pain and CRPS (Moseley 2006)
  - The term “graded motor imagery” broadly means that in rehabilitation the focus is placed on synaptic exercise and health.

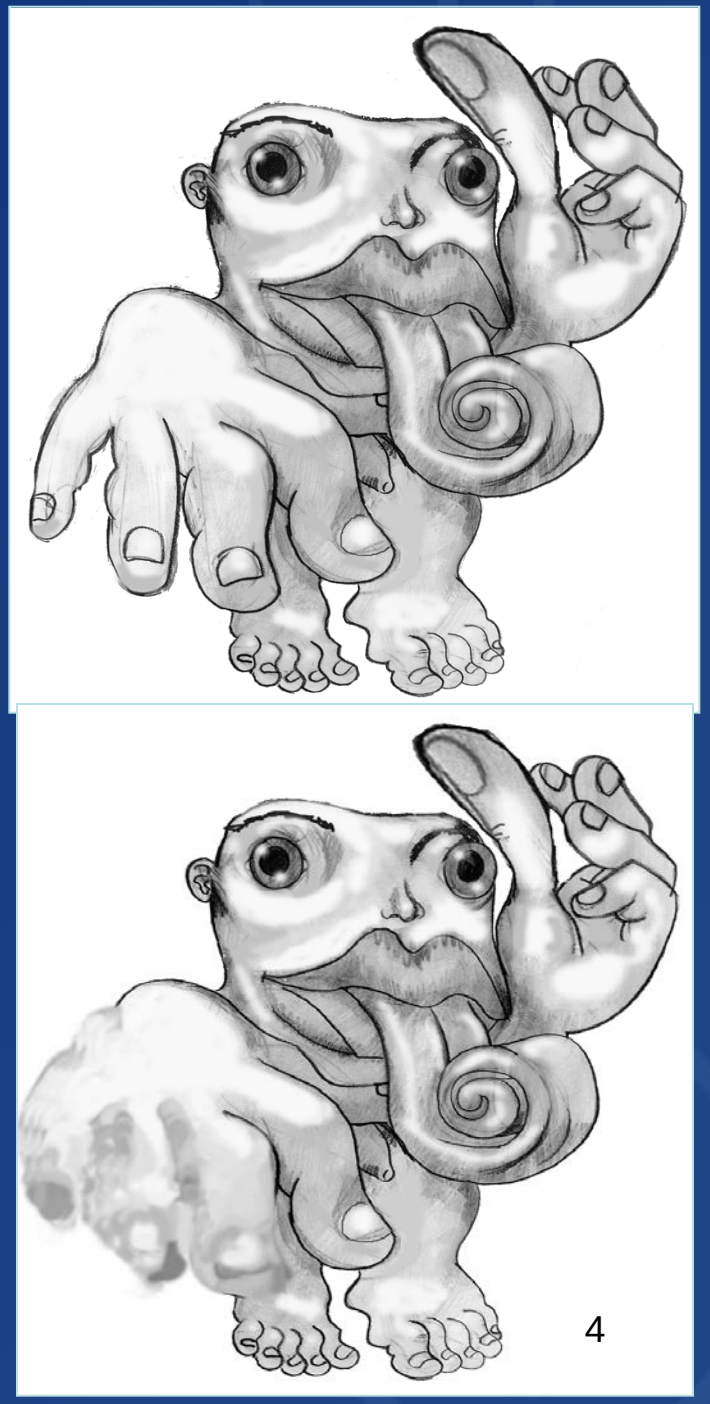
Graded Motor Imagery

- Introduction and Definitions (cont'd):
  - The exercising of synapses assumes that the brain is changeable and easily adaptable and gives hope to people with difficult pain states.
  - It involves the use of:
    - Computers
    - Flashcards
    - Imagined movements
    - Education
    - Mirror visual feedback
    - A lot of time and hard work!

Graded Motor Imagery

Smudging

- What is it?
  - Smudge:
    - Usually area of brain representation gets bigger
  - Shrink:
    - Severe CRPS and phantoms shrink
- Known to occur throughout the brain.
- Especially in sensory and motor cortices
- also M1, thalamus and spinal cord representations alter



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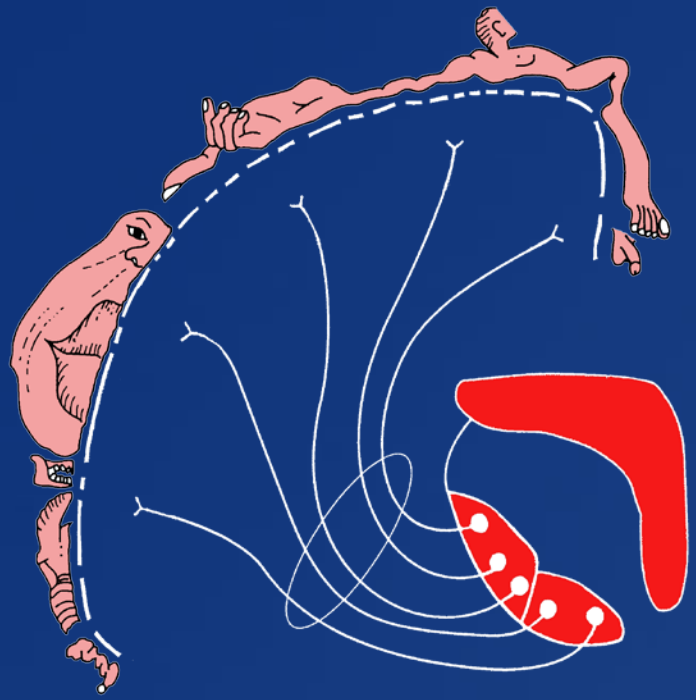
- Precious information: smudging/brain changes are normal



- Occurs as a normal part of life
  - Musicians
  - blind persons

- eg. Elbert T et al (1998) Neuroreport **9**: 3571

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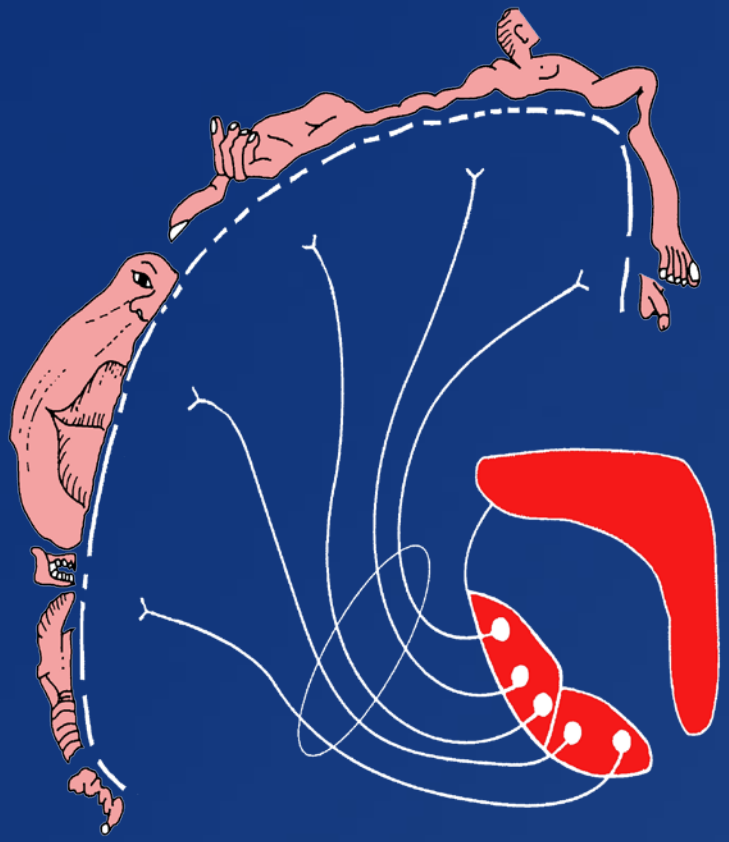
Numerous injury states have been studied



Phantom limb pain as the great leveler

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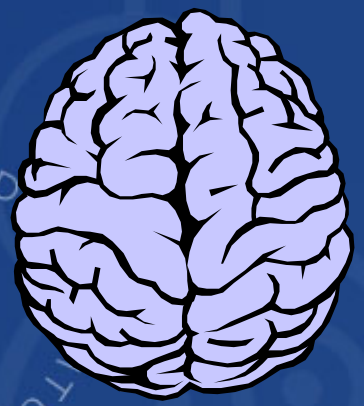
Smudging/brain changes in pain states

- Phantom limb stories
- Some correlations with pain level and chronicity
- Syndactyly stories
- Probably immune related



- Juottonen K et al 2002 Pain 98: 315
- Milligan ED et al 2003 The Journal of Neuroscience **23**: 1036
- Flor H. 2000 Progress in Brain Research, 129
- Stavrinou et al 2006 Cerebral Cortex

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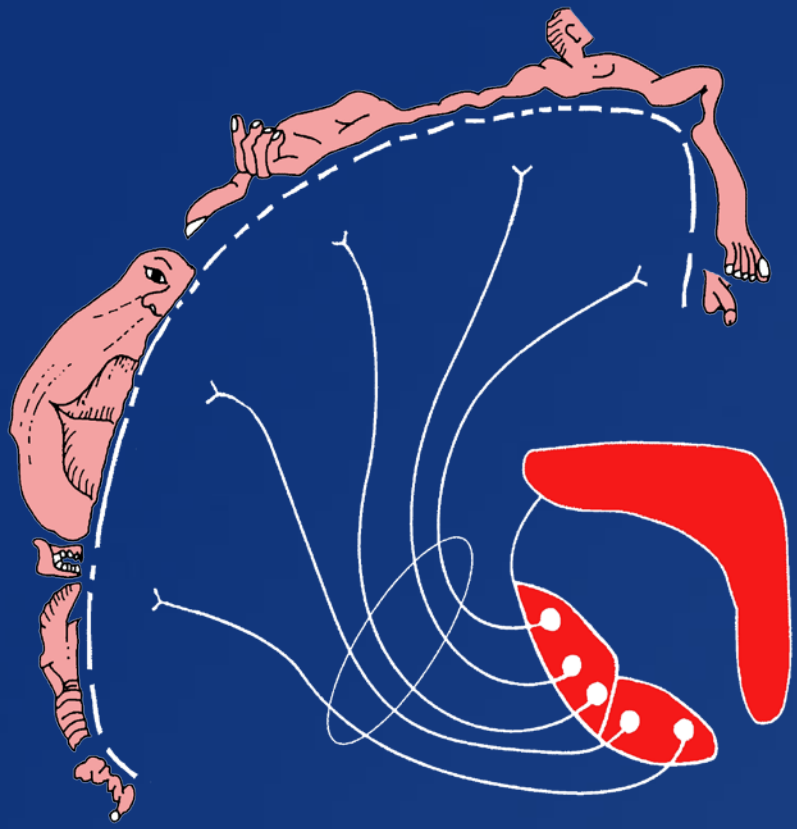
“Smudging”



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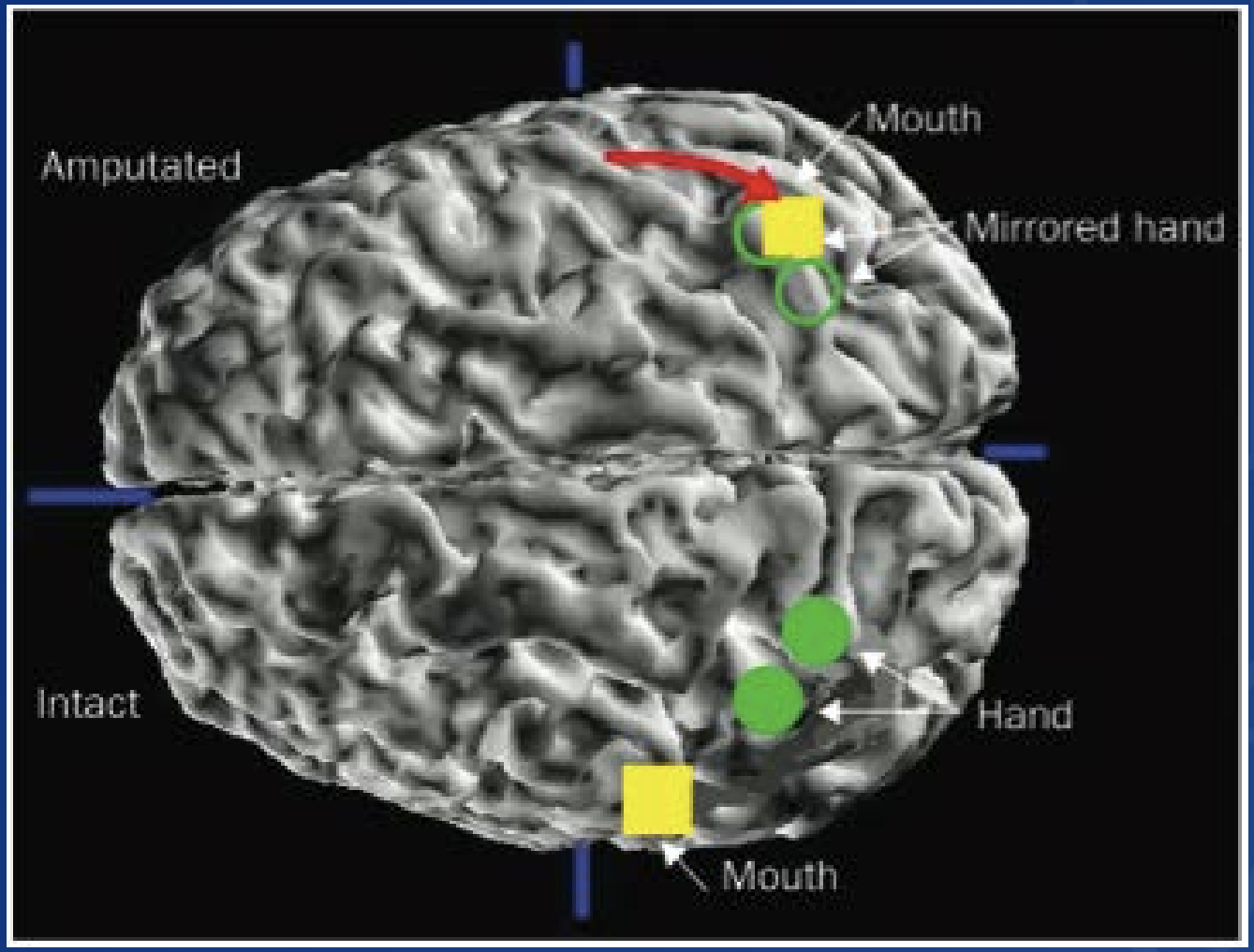
Re organisation caused by many factors

- Unmasking and sprouting. Chen et al (2002) Neuroscience 111(4): 761-773
- Change in recruitment patterns. Sacco et al (2006) NeuroImage 32: 1441-1449
- Change in membrane excitability. Sohn et al (2003) J Neurophysiol 90: 2303-2309
- Altered neuroimmune response

- **Altered neuromatrix!**

- Cortical reorganisation in S1 and other areas - Smudging



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•(Flor 2002)

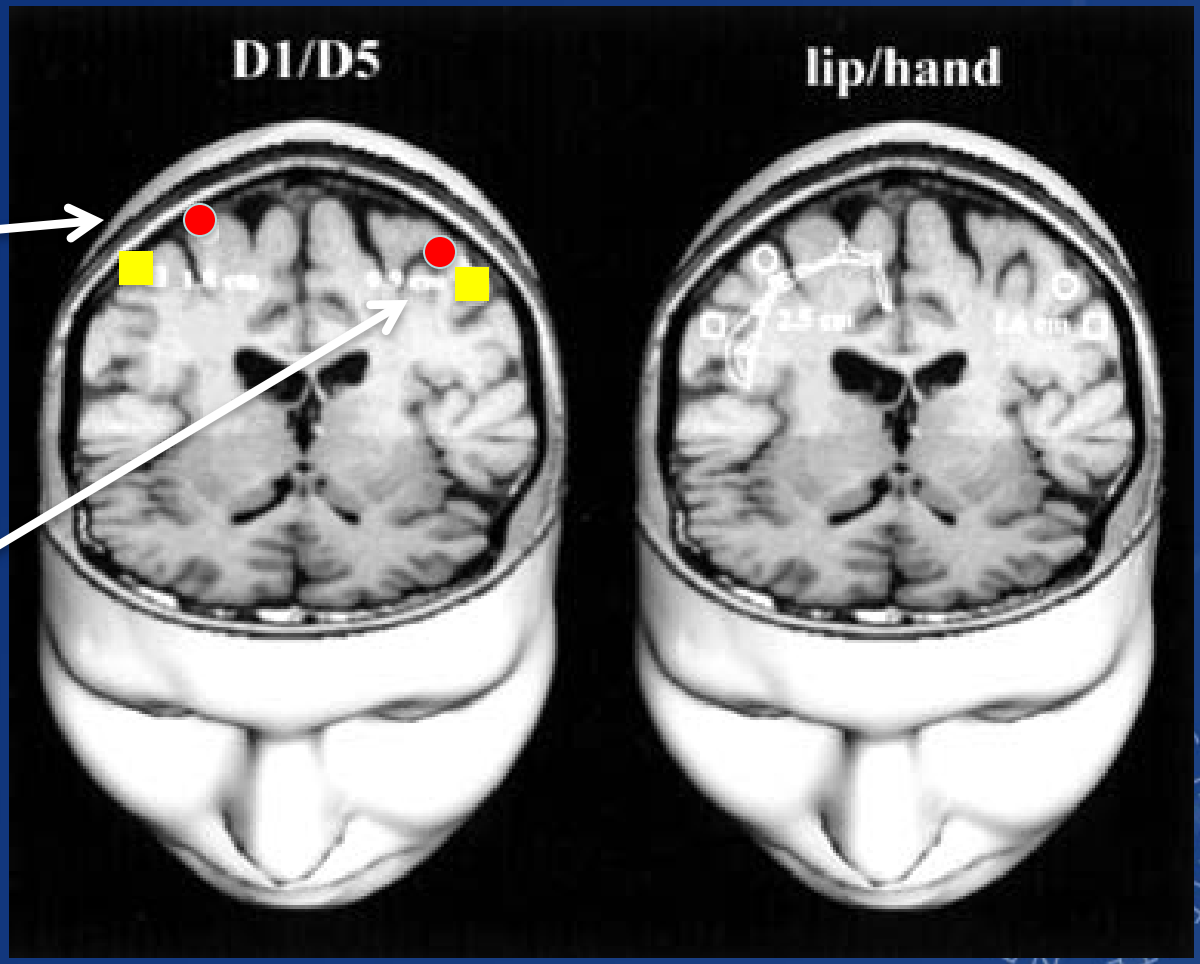
•Acute CRPS – Sensitisation?

•1.8 cm

•normal

•0.9 cm

•CRPS

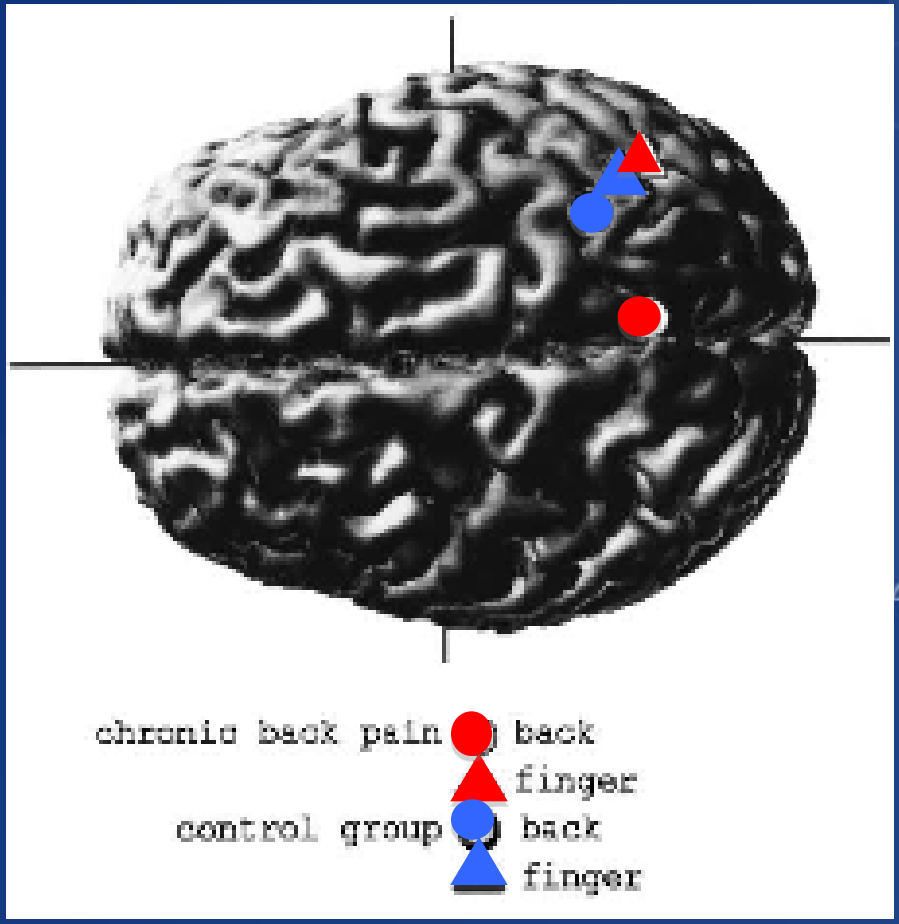


•D1

•D5

•(Maihofner *et al.* 2003 Neurology 61:1707-1715*)*

Low Back Pain – sensitisation & disinhibition?



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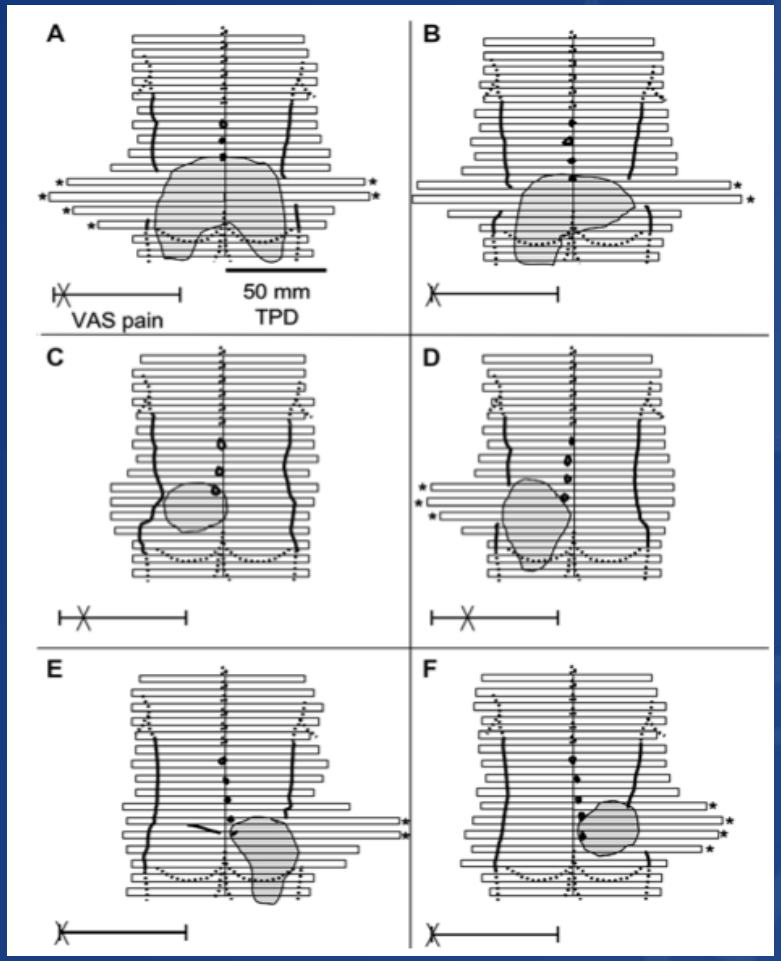
- (Flor et al 1997 Neurosci Lett 224: 5-8)

LBP – Altered neurotag? Experiential/perceptual change?



- Moseley 2008 Pain 140:239-243

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Graded Motor Imagery

- Introduction and Definitions (cont'd):
  - The strategies in the GMI program are:
    - Laterality Reconstruction (Implicit Motor Imagery)
      - Restoration of the accuracy and speed of identifying whether a picture or actual body part is a right or left part of the body, or identifying if the body part is turned to the right or the left (as in the neck for example)
    - Motor Imagery (Explicit Motor Imagery)
      - Watching and imagining movements and postures which are progressively more complex and contextually variable
    - Mirror Therapy
      - The use of a mirror to present a reverse image of a limb to the brain

Graded Motor Imagery

- Introduction and Definitions (cont'd):
  - ***'Graded'*** broadly refers to a sequential process of laterality reconstruction, motor imagery and mirror therapy and the need to provide graded exposure to the body representations in the brain, rather than body tissue.
  - The concept of GMI relies on basic sciences and some clinical studies. It is still a very "young" technique.
  - There are no "recipes" and its use requires strong clinical reasoning skills.
  - There are some neuroscience basics which underpin its use (neuromatrix paradigm, neuroplasticity, mirror neurones).

Graded Motor Imagery

- Graded Exposure and Application to GMI:
  - Graded exposure:
    - ***Graded activity*** is generally based on predefined quota of activity and will include specific exercises depending on the person's functional capacity.
    - Positive reinforcement is given when someone reaches a desired goal.

Graded Motor Imagery

- Graded Exposure and Application to GMI:
  - Graded exposure (cont'd):
    - ***Exposure in vivo*** is considered more of a cognitive process in which the person challenges the expected fear or catastrophic thinking expected with a certain task (eg. pain with bending over).
    - This type of approach is commonly used with the management of phobias.
    - A fear hierarchy is established and the different components of that stimulus considered and challenged (Leeuw et al, 2008; Vlaeyen et al, 2002).

Graded Motor Imagery

- Graded Exposure and Application to GMI:
  - Graded exposure (cont'd):
    - ***Graded exposure*** requires identification of both physical and contextual fear-related challenges.
    - It therefore combines the principles of both graded activity and exposure in vivo.

Graded Motor Imagery

- Graded Exposure and Application to GMI:
  - Novel and traditional rehabilitation strategies:
    - Graded exposure concepts are critical for functional restoration.
    - With careful questioning, a patient may be able to come up with a hierarchy of threatening activities.
    - These can be graded to allow us to breakdown the fear of these movements and slip in under the radar of the pain neurotag.
    - This has been done experimentally with low back pain (Leeuw et al, 2008) but the principle can be applied to any clinical state.

Graded Motor Imagery

- Graded Exposure and Application to GMI:
  - Novel and traditional rehabilitation strategies (cont'd):
    - Variation in these attributes of rehabilitation are not interdependent.
    - The patient may be performing motor imagery to a very high level of threat using all the emotional loading that can be applied, yet be performing active movements in a very safe and secure environment at the same time.

Graded Motor Imagery

- Graded Exposure and Application to GMI:
  - Novel and traditional rehabilitation strategies (cont'd):

"Traditional" Rehab. Strategies:

- Do part of movement but don't involve painful part
- Do part of movement involving painful part
- Do larger movements
- Increase number
- Increase resistance
- Add equipment
- Cross midline

Graded Motor Imagery

- Graded Exposure and Application to GMI:
  - Novel and traditional rehabilitation strategies (cont'd):

"Novel" Rehab. Strategies:

- Utilize premotor association areas
- Watch static position
- Imagine static position
- Watch active movement
- Imagine active movement
- Mirror

Graded Motor Imagery

- Graded Exposure and Application to GMI:
  - Contextualization:
    - Any task can be broken down into parts.
    - A simple way of doing this is to consider a more physical aspect and a contextual component.
    - For each level of task, context can be varied.
    - ***Therefore, an identical movement could be represented by different neural populations depending on the context.***

Graded Motor Imagery

- Graded Exposure and Application to GMI:
  - Contextualization (cont'd):
    - Contextual option examples:
      - Threat and threatening equipment
      - Vision
      - Emotion
      - 'non-contaminated' representations
      - Meaning
      - Expectation
      - Place
      - Distraction
      - Gravity
      - Balance
      - Sliders
      - Metaphors
      - Knowledge
    - Contextualization, where possible, can be used for all components of the graded motor imagery process.

Graded Motor Imagery

- The sequence is important
- "graded" because of the sequence requirements and the need of graded exposure (pacing) principles

- Laterality reconstruction

- Motor imagery

- Mirror therapy

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- Graded Exposure and Application to GMI:
  - Examples of grading the components of exposure for GMI:
    - Laterality (Implicit Motor Imagery) reconstruction:
      - Number of images
      - Speed of images
      - Rotation of images
      - Threat value of images

Graded Motor Imagery

- Graded Exposure and Application to GMI:
  - Examples of grading the components of exposure for GMI:
    - Motor (Explicit) Imagery:
      - Duration
      - Complexity of mental imagery

Graded Motor Imagery

- Graded Exposure and Application to GMI:
  - Examples of grading the components of exposure for GMI:

    - Mirror Feedback:
      - Duration
      - Complexity of mirror action

Graded Motor Imagery

- Graded Exposure and Application to GMI:
  - Examples of grading the components of exposure for GMI:

    - Active Movement:
      - R.O.M.
      - Repetitions
      - Resistance

Graded Motor Imagery

- Laterality (Implicit) Reconstruction:
  - Body neurosignature:
    - There are representations of the body within the spinal cord, thalamic and cortical structures which have a role in guidance of **imagined** and **actual** movements.
    - This is the ***body neurosignature.***
    - Melzacks' ***Neuromatrix*** describes the **self,** distinct from **others** and the **world.**
    - There may be a genetic basis sculpted by life experiences (nature and nurture).

Graded Motor Imagery

- Laterality (Implicit) Reconstruction:
  - Body neurosignature (cont'd):
    - Modified by observation of others-***mirror neuron system*** (Rizzolati et al, 2009)
    - *Modified by tool use-increases influence of body.*
    - *Modified by experience-skill acquisition such as musical instruments and using Braille increase the representation of the hand.*
    - *Nociceptive barrage or deafferentation also alter the representations of S1 and S2 (Acerra et al, 2007, Flor, 2003,2008).*

Graded Motor Imagery

- Laterality (Implicit) Reconstruction:
  - Laterality recognition:
    - It is the ability to select whether a presented image of a limb is left or right sided.
    - The reaction time (RT) for laterality recognition can be measured and is proportional to the angular position of the limb.
    - A response requires:
      - Initial selection of a left or right limb
      - Then mental spatial transformation to confirm choice
    - As such, the spatial transformations are constrained by biomechanical principals and require an intact body representation.

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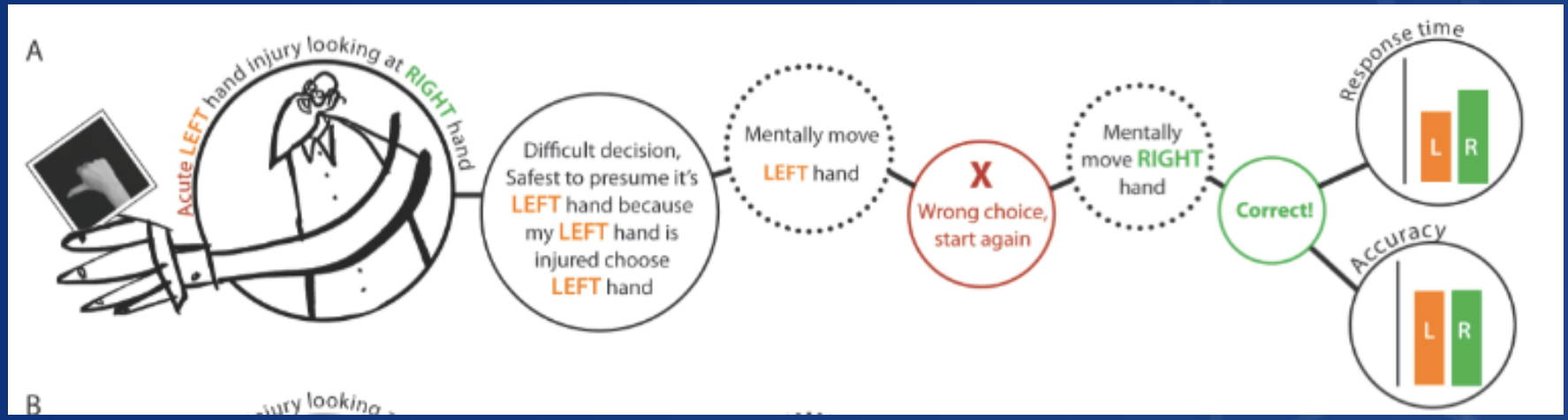
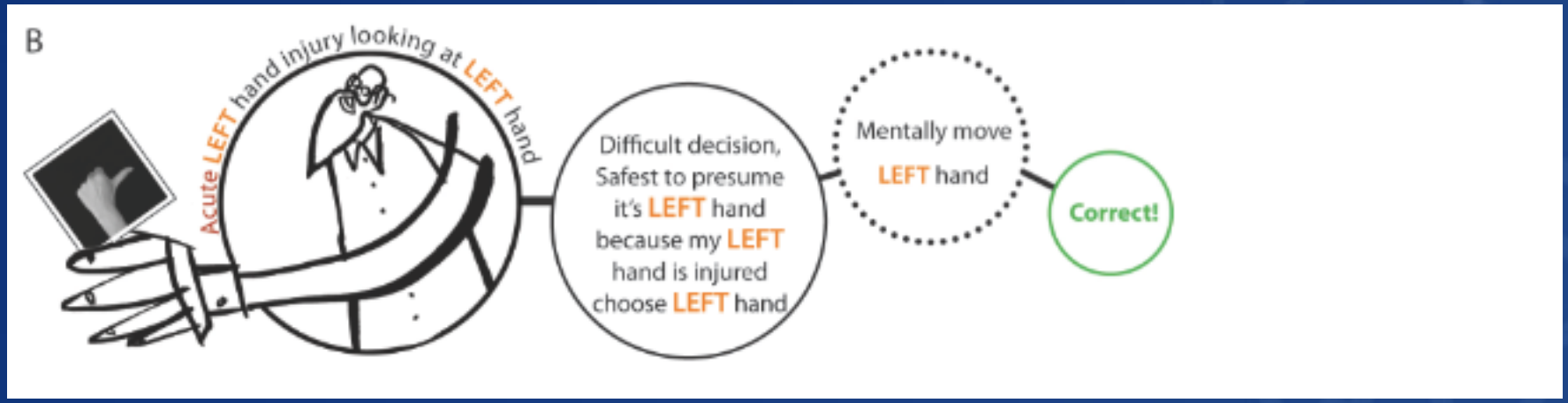
Laterality (Implicit) Reconstruction





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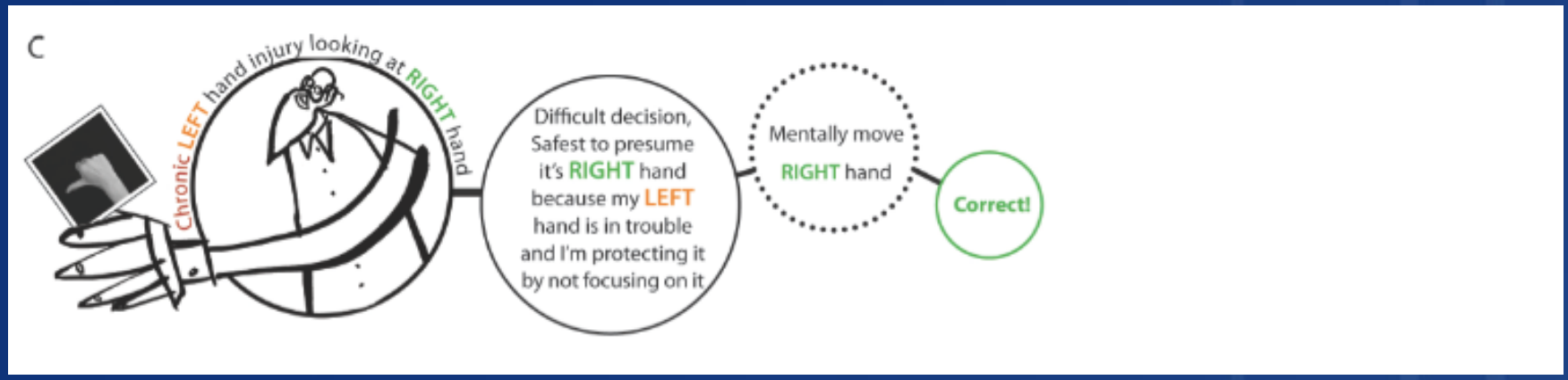
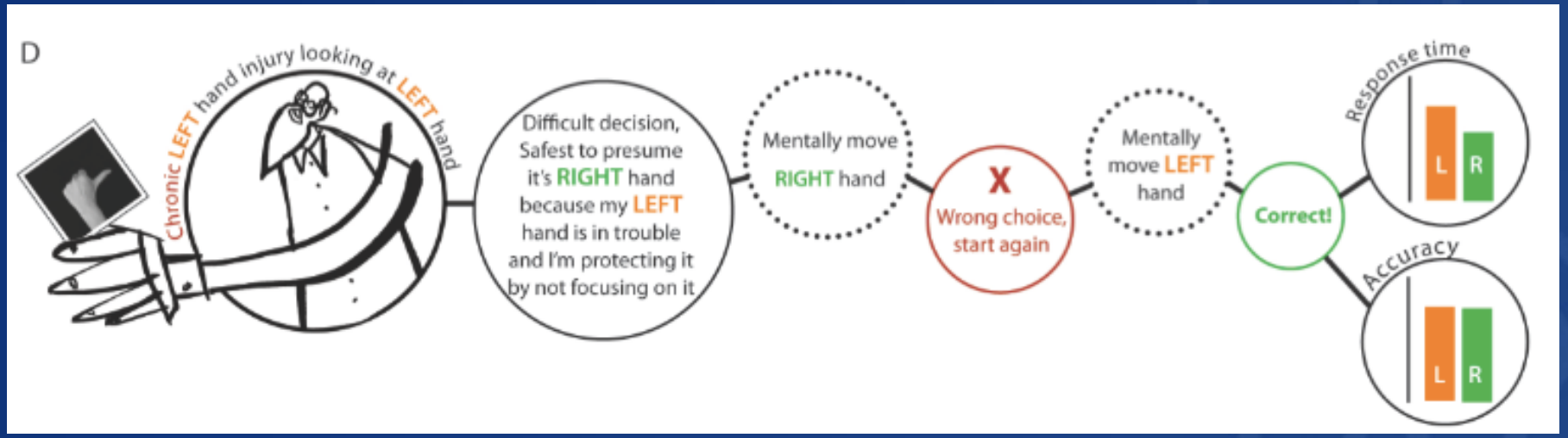
Butler & Moseley, et al., 2012

Graded Motor Imagery

Laterality (Implicit) Reconstruction





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Butler & Moseley, et al., 2012

- Focal hand dystonia shows changes in implicit motor imagery

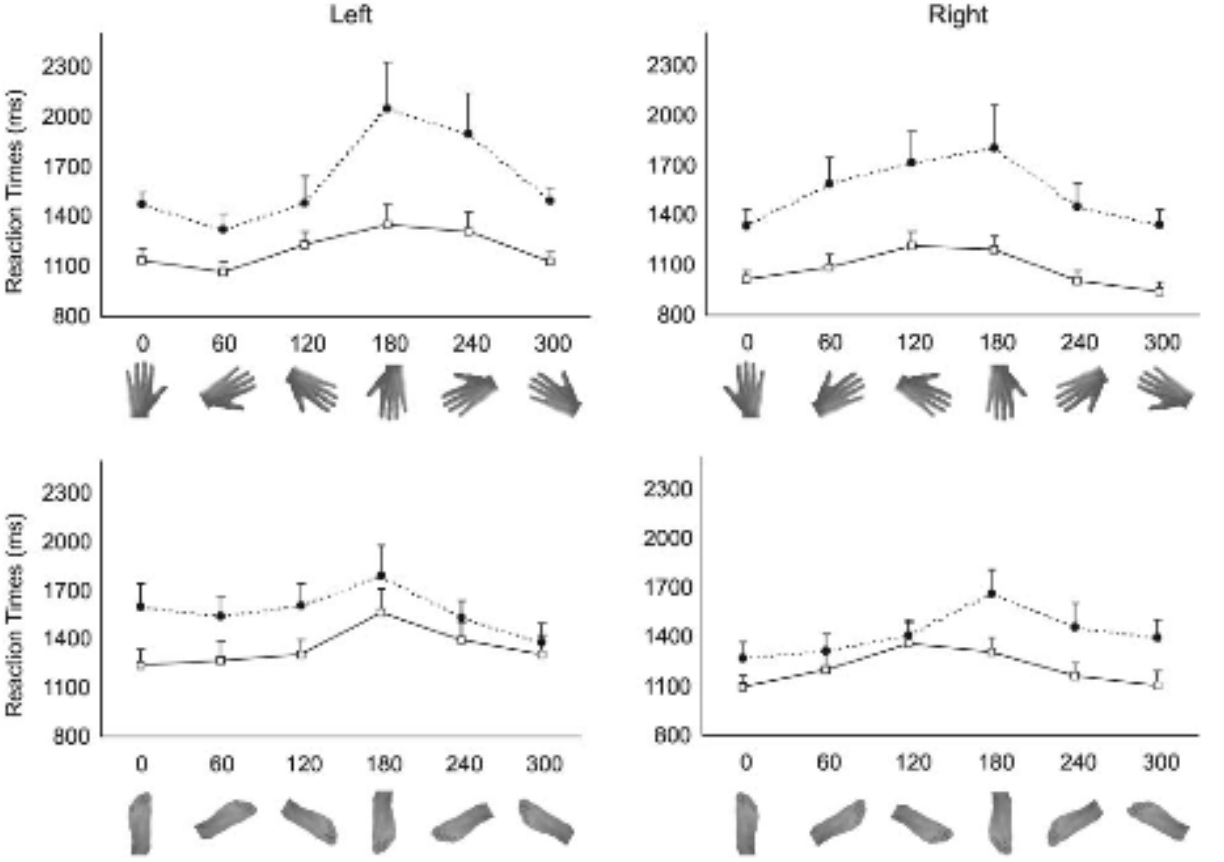
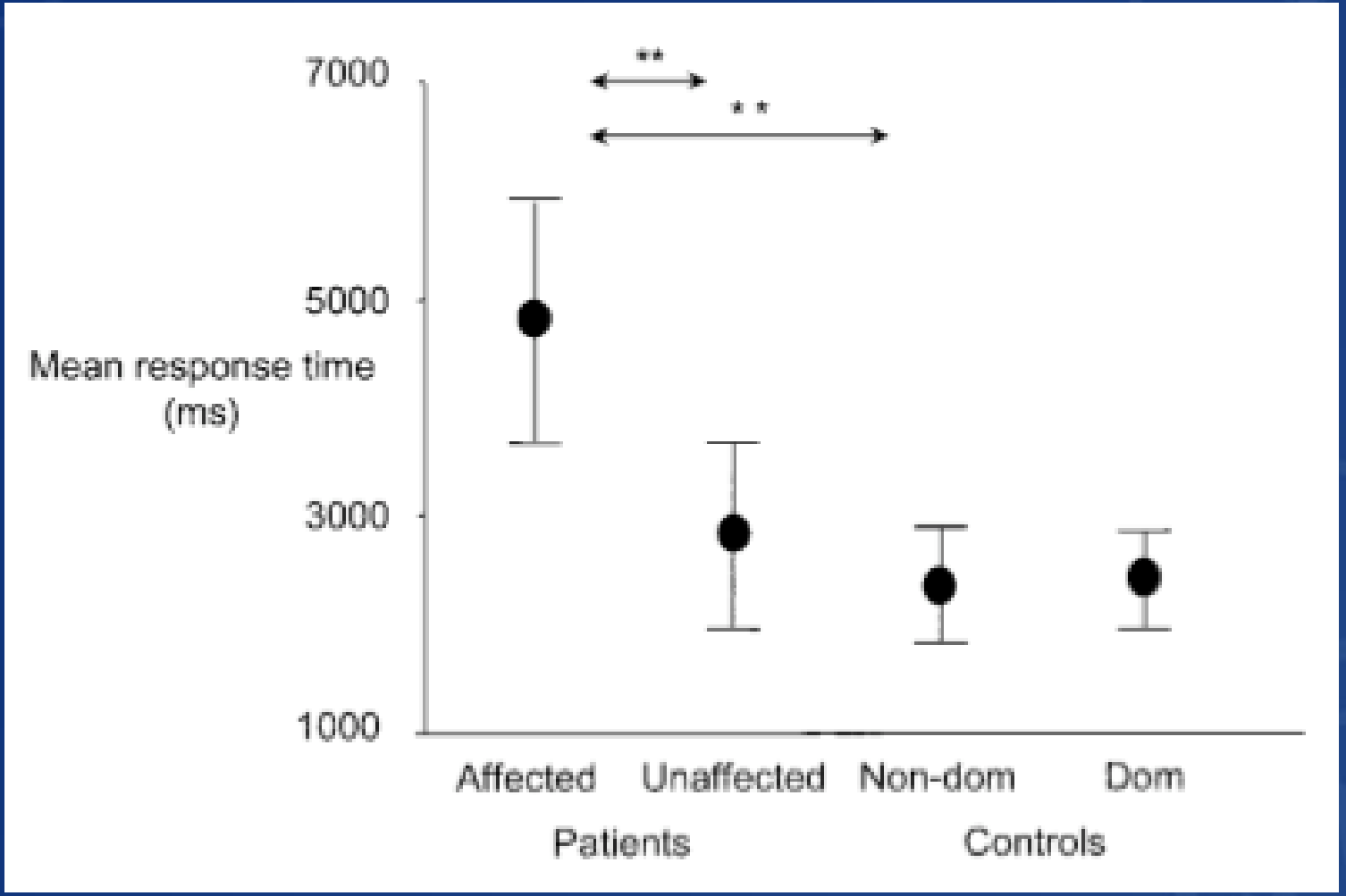


Fig. 2 Reaction time profiles at different stimulus orientations in writer's cramp (black circles) and control subjects (white squares) for left and right hands (upper inserts) and feet (lower inserts). Error bars indicate standard errors.

- (Fiorio 2006 Brain 129: 47-54)

- Slower on affected side in CRPS



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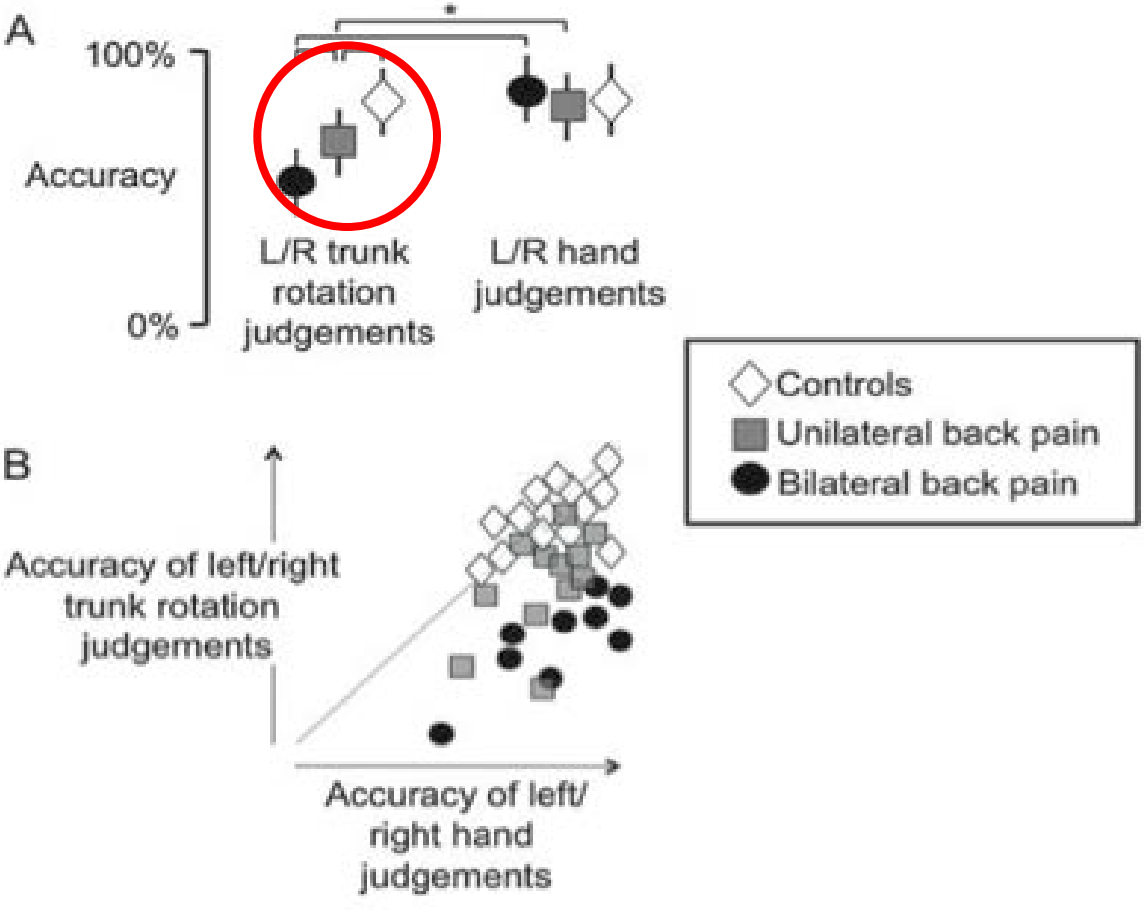
- (Moseley 2004)

•What about back pain?



- (Bray & Moseley 2010
- Br J Sports Med Epub)

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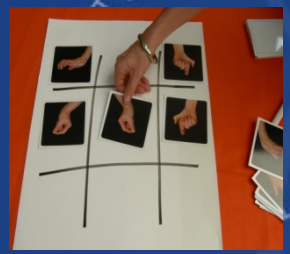
Laterality Reconstruction (Implicit Motor Imagery):

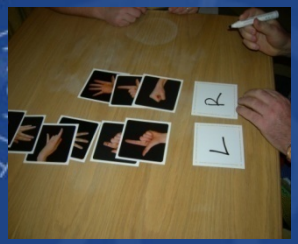
- What is normal?

- Accuracy of 80% and above
- A speed of 1.6 sec quite normal for backs and necks
- Hands and feet a little slower at 2.0 sec
- Patient results should remain fairly stable so they don't fade out with stress and are consistent for at least a week
- Judgemnt needs to be made on the personal relevancy of the responses eg. minor discrepencies in someone with severe pain

Graded Motor Imagery

- Laterality Reconstruction:
  - Laterality reconstruction as treatment:
    - Limb laterality recognition activates premotor (association) cortices, **not primary motor cortex.**
    - Imagined movements **activate both** (Moseley et al, 2008), allowing a basis to the GMI progression.
    - Techniques:
      - Recognize Online
      - Magazines
      - Flash Cards
      - Contextualize
      - Digital Cameras





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Graded Motor Imagery

Implicit Motor Imagery (left/right judgements):	**Explicit Motor Imagery (Imagined Movements):**
•You don't know you are mentally moving •Premotor cells modify primary motor cells without activating them	•You know you are mentally moving •Primary motor cells are activated
•Less likely to activate the pain neurotag	•More likely to activate the pain neurotag

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Graded Motor Imagery

- Laterality (Implicit) Reconstruction:
  - Response times and pain:
    - RT's are known to be slower in CRPS1 (Moseley, 2004).
    - The delay in RT is proportional to both the duration of symptoms and the predicted pain related to adopting the hand position.
    - Phantom limb pain has also shown changes in laterality recognition (Nico et al, 2004), however, the picture is less clear.
    - There may be RT changes depending on different variables such as limb dominance and use of prostheses.

Graded Motor Imagery

- Laterality (Implicit) Reconstruction:
  - Response times and pain (cont'd):
    - In acute experimental pain (Moseley et al, 2005) and expectation of pain (Hudson et al, 2006) there is delayed recognition of the opposite limb with no change to the affected limb.
    - This shows that the slower RTs found in patients with chronic pain are unlikely to be due to nociceptive input.
    - In acute experimental pain there is unlikely to be a disruption in the representation.
    - It also does not evoke protective premotor processes likely to be present with a problem which is perceived as threatening (ie. the volunteers know that the pain will go away!)
    - It is likely to show an attentional bias towards the painful side, making it more difficult to access the representation of the unaffected limb.

Graded Motor Imagery

- Laterality (Implicit) Reconstruction:
  - Laterality reconstruction as treatment (cont'd)
    - Let's demonstrate the use of the Recognize Online program:
      - Go to www.noigroup.com
      - Then go to Recognize Online
      - Then either:
        - » Try demo
        - » Log in if you are registered clinician license holder
        - » You can give patients a trial or 2 month paid license
        - » You can monitor their progress
        - » Patient must practice many times per day (think of it like you would stroke rehab)

Graded Motor Imagery

- Recognise online
  - Left and right body parts are presented randomly in predetermined;
  - numbers
  - time
  - context





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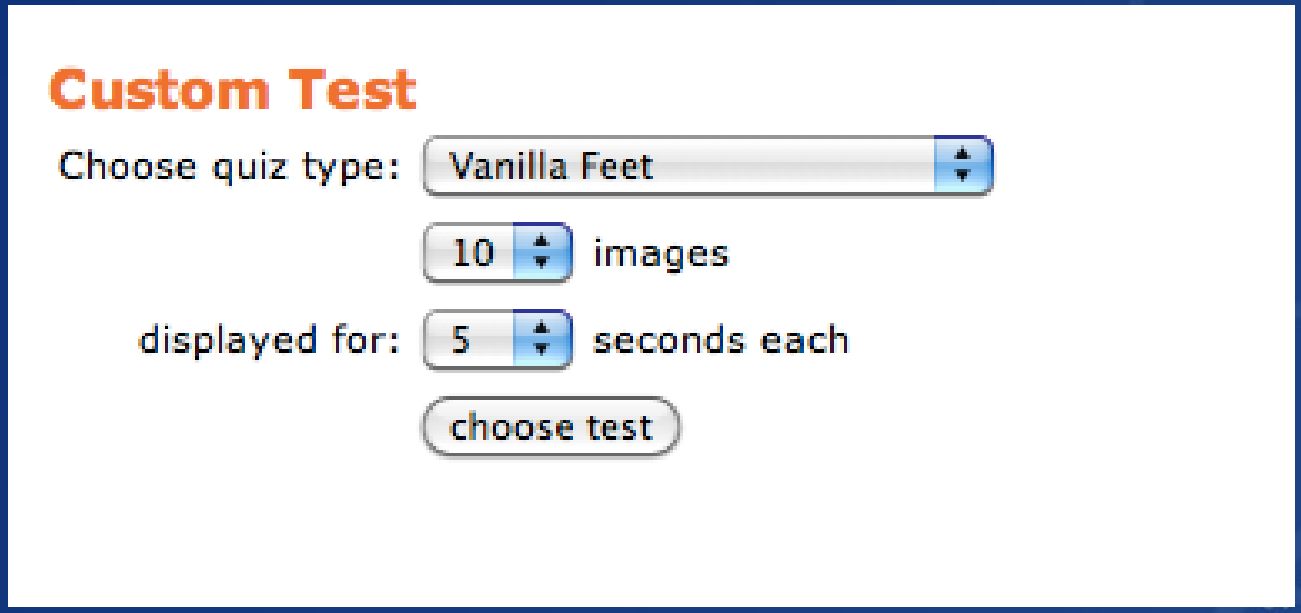
Graded Motor Imagery



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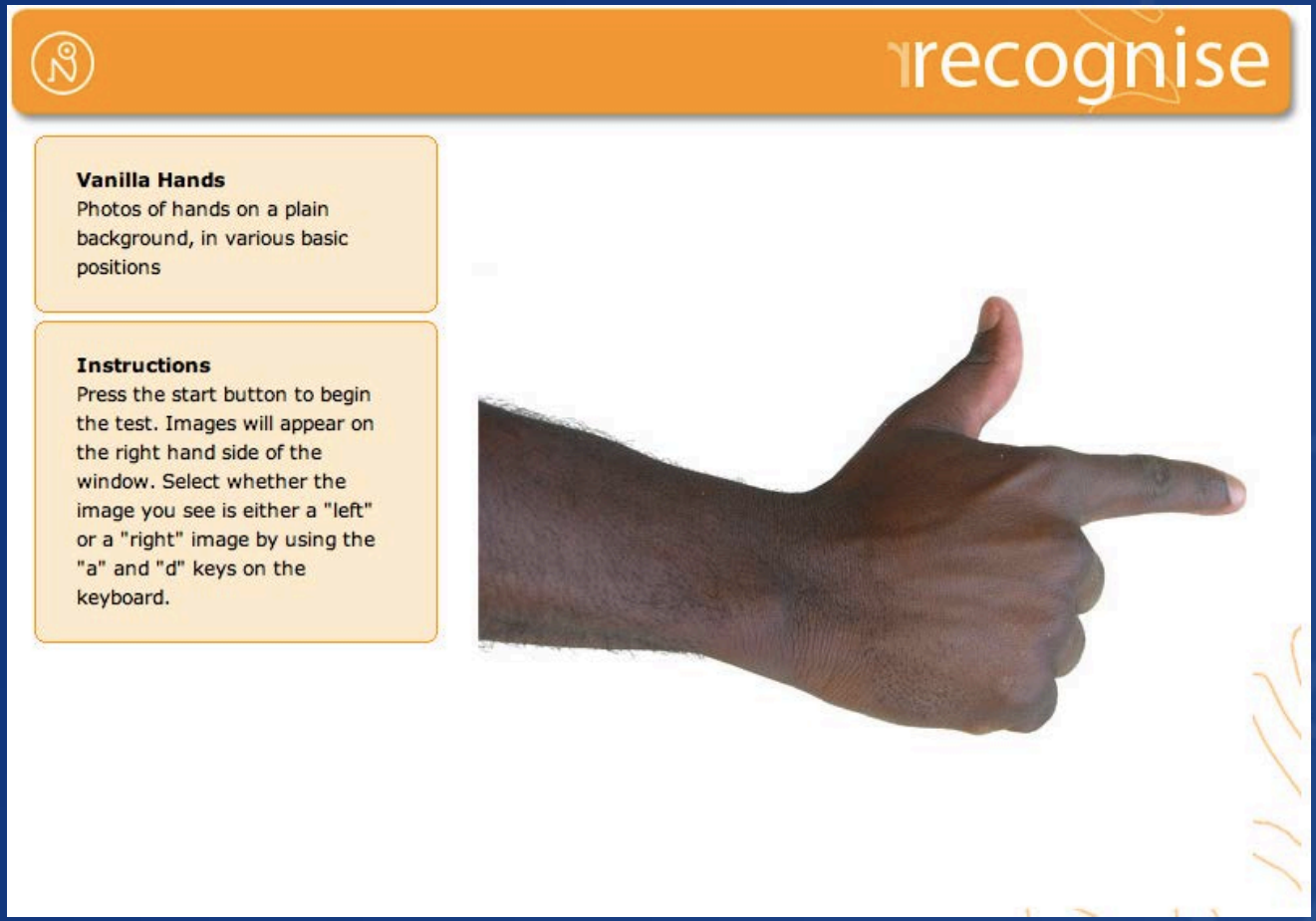

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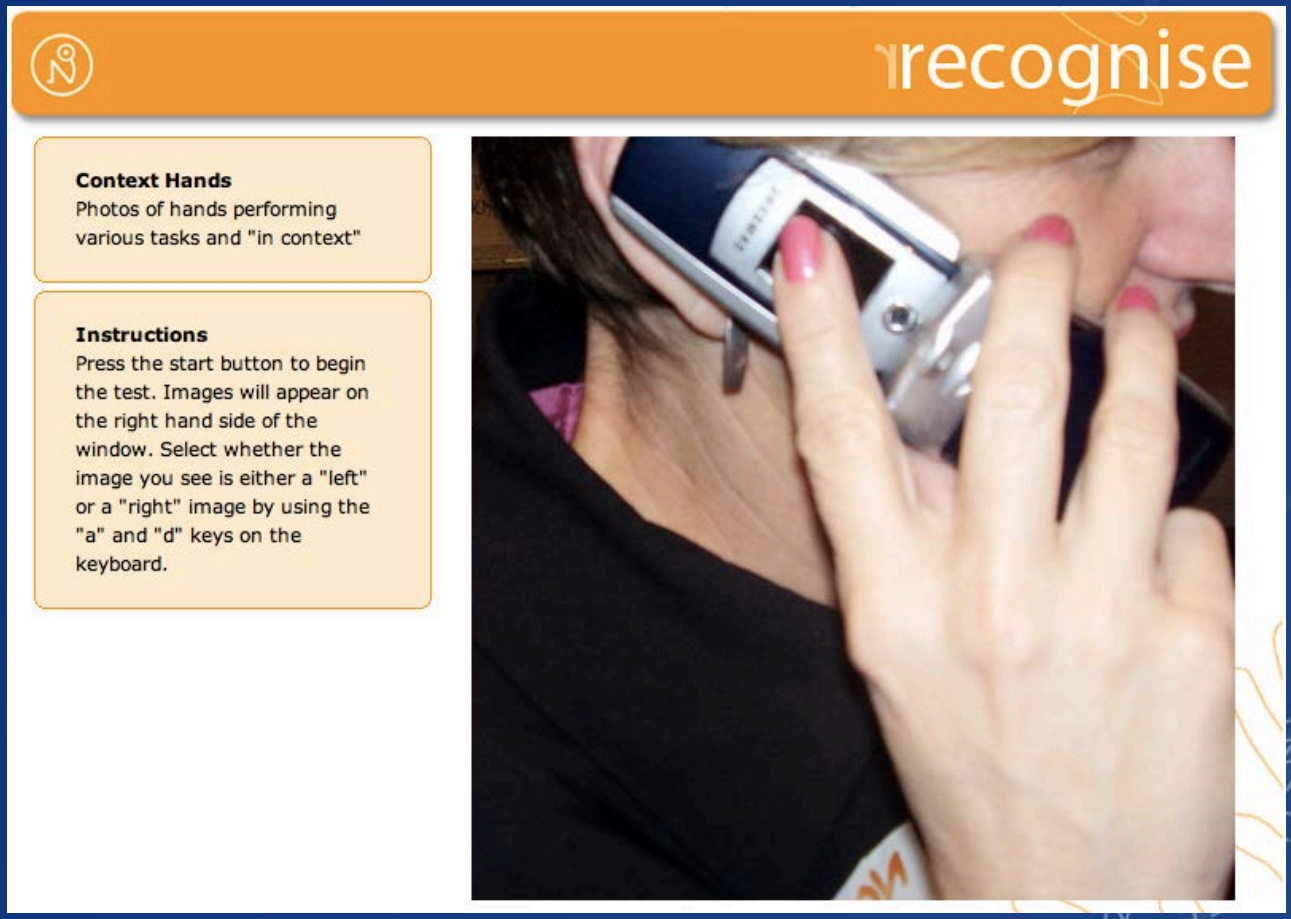


Graded Motor Imagery

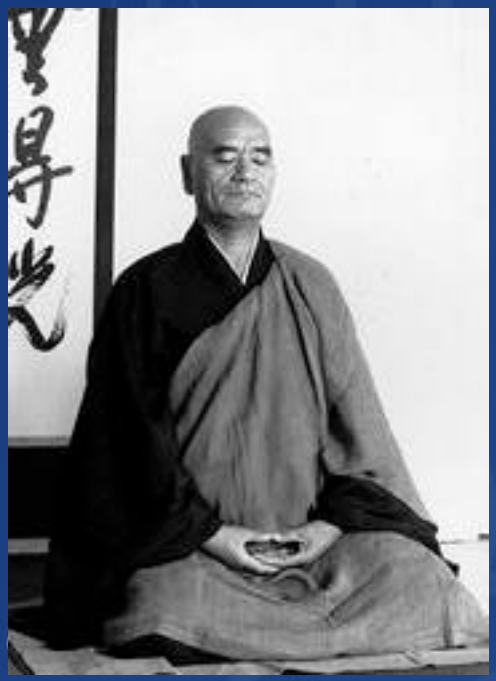
recognise

Graded Motor Imagery

- Motor (Explicit) Imagery:
  - Motor Imagery (MI):
    - The result of conscious access to the neurosignatures representing intention, preparation, carrying out and evaluation of a movement.
    - There is a high degree of overlap in brain regions involved in actual movements or imagined movements (essentially imagining movements and postures).
    - This is a **kinaesthetic** activation not a **visual** activation meaning the patient must imagine themselves doing the movement, not as an observer watching themselves do the movement.
    - It is likely that this will recruit mainly the broadly congruent mirror neurons.

Graded Motor Imagery

- Motor (Explicit) Imagery:
  - Watching movement and imagining movement:
    - Motor imagery has been around for years. It is known to improve performance in athletes.
    - It is widely used for neurological patients and can improve recovery of motor function following stroke (de Vries and Mulder, 2007).
    - Mirror neurons are a clear target.



Graded Motor Imagery

- Motor (Explicit) Imagery:
  - Watching movement and imagining movement (cont'd):
    - Imagined movements have been found to increase both pain and swelling in a patient with CRPS1 (Moseley et al, 2008).
    - This demonstrates that just activating the representation of the affected body part may be sufficient to ignite the individual pain neurotag.
    - It also shows that it is important to progress each stage only when appropriate.

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- Motor (Explicit) Imagery:
  - Watching movement and imagining movement (cont'd):
    - Imagery technique and progression:
      - Consider what it might feel like to have a body part in a certain position (or watch another person)
      - Consider what it might feel like to have a body part doing a certain movement (or watch another person)
      - Consider what it might be like to manipulate an object (or watch another person)
      - Consider what it is like to move like a certain person
      - Watching may be 'easier' on the brain than thinking about movement

Graded Motor Imagery

- Motor (Explicit) Imagery:
  - Watching movement and imagining movement (cont'd):
    - Imagery technique and progression:
      - **Techniques:**
        - » Recognize Online
        - » Picture books
        - » Movies
        - » People
        - » Work

Graded Motor Imagery

- Motor (Explicit) Imagery:
  - Watching movement and imagining movement (cont'd):
    - Imagery technique and progression:
      - **Progression:**
        - » imagine smooth, gentle movement of the body part
        - » Increase ROM
        - » Increase speed
        - » Bring in functional movement
        - » Increasing muscle activity
        - » Use tools
        - » Environmental context
        - » Social context

What else could you include?

- Should there be some cues e.g. Descriptions, sounds, memories?
- Can I use relaxation and meditation in conjunction with MI? (Nunes et al (2007) J of Psychosomatic Research 63: 647-655)
- What about the environment? (Sale et al (2009) Trends in Neurosciences 32(4): 233-239)
- Writing and imagining "Best Possible Self" (Hanssen et al – Pain 2013)

Contextual change & graded exposure

Graded Motor Imagery

- Mirror Therapy:
  - Mirror therapy:
    - The use of a mirror to present the reverse image of a limb to the brain thus “tricking” the brain.

Graded Motor Imagery

- Mirror Therapy:
  - Mirror practicalities:
    - Below are some general suggestions for use:
      - Mirror therapy can be done for hands and feet.easily
      - Be guided by a clinician who understands brain function.
      - Presuming no jewellery on the affected side, remove wrist watches and rings. Try and make a **total illusion.**
      - Depending on the pain and disability state, decide on an appropriate activity(ies) to perform:
        - » Just looking at the mirror image to finger movements
        - » Taking weight through the hand
      - The more severe the problem (eg. CRPS) a small amount of movement performed often may be more appropriate.

Graded Motor Imagery

- Mirror Therapy:
  - Mirror practicalities (cont'd):
    - Below are some general suggestions for use:
      - Feel comfortable with selected movements ie. 'conquer the movement' before progressing to more challenging movement.
      - Once you feel comfortable with a movement, try and perform it in a different context (eg. With a song in your head, emotions).
      - Take care, if either hand hurts or sweats then you may have gone too far.
      - Take the painful limb into or just short of pain and then take the good limb further.

Graded Motor Imagery

- Mirror Therapy:
  - Mirror progressions:
    - Look at hand
    - Turn hand up and down via arm
    - Flatten hand
    - Flatten hand and take weight
    - Move individual fingers
    - Thumb to fingers
    - Tapping fingers
    - Increasing muscle activity
    - Use tools
    - Introduce clinicians hand
    - Move the hand in the box

Graded Motor Imagery

- Mirror therapy:
  - Dysynchiria:
    - If assessing the sensory perception of someone suffering CRPS using a mirror, it is frequent to find this phenomenon during which the person feels the perception of pain or pins and needles in their hidden, affected limb whilst looking at their virtual limb being tested in the mirror (Acerra and Moseley, 2005).
    - Interestingly this doesn't seem to affect people with other neuropathic pain states (Kraemer et al, 2008).

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- Does It Work?
  - The clinical reality: Science to the clinic:
    - In most recent randomized controlled trials, GMI package has demonstrated good effect for reducing pain and disability in CRPS1 (Moseley 2004, 2005) and CRPS1, phantom limb pain and brachial plexus avulsion pain (Moseley, 2006)
    - In a recent systematic review, it is the only recommended physical therapy modality for CRPS1 (Daly and Bialocerkowsi, 2008).

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- Does it Work?
  - The clinical reality: Science to the clinic (cont'd):
    - Some aspects of GMI (mirror feedback) have also been separately examined with CRPS:
      - McCabe et al (2003, 2008) found benefit with acute presentations of the syndrome but no benefit or worsening of pain in more chronic states.

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- Does it Work?
  - The clinical reality: Science to the clinic (cont'd):
    - Moseley (2006) examined the sequential order of GMI and found laterality training to have a positive benefit on pain and function, imagery had a positive benefit when following laterality, mirror exercises had a positive benefit when following imagery – but a negative effect if following laterality.
    - CRPS and phantom limb pain are severe neuropathic pain states. It would seem that the GMI process would be beneficial for other pain states such as overuse syndromes:
      - Focal dystonia
      - Repetitive Strain Injury
      - Cumulative Trauma Disorder
      - Various arthritic syndromes

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- Does it Work?
  - Some general anecdotal comments:
    - About 20% of CRPS patients do not respond to GMI – perhaps more if you consider that some trying the strategies may have had CRPS for some years and have it in 2 or 3 limbs.
    - There appear to be occasional ‘resettings’ with mirrors or laterality.
    - Stress may influence outcomes.
    - Although no data, suggest good neurobiology education is required. This could include neuromatrix discussions.
    - May help with performance eg. In elite sports.
    - It is not unusual to mix up treatment approaches as long as the **laterality is intact** ie. when laterality is reasonably equal and when the changes are being maintained.

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- Does it Work?
  - Some general anecdotal comments (cont'd):
    - Elements of all components of GMI could be used in the initial assessment of the patient with a complex problem:
      - Could Recognize be used to pick up inaccuracies and reduced response times (currently being studied with neck laterality)?
      - What about the use of mirrors in an initial assessment?
      - Is 2 point discrimination a routine part of evaluation for complex pain states?
    - These assessments may help to support a hypothesis of central processing changes and an altered virtual body.
  - This will guide the clinician to the appropriate course of treatment.

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THANK YOU!!

QUESTIONS?