Training Proprioception (Body Awareness) in Stroke

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Overview

Introduction of proprioception and brain lesions

PART 1 * Overview of cognitive multisensory rehabilitation*

PART 2 * Scientific evidence of mechanisms of cognitive multisensory rehabilitation

PART 3 * Current research: Preliminary study on brain imaging and behavioral outcome of cognitive multisensory rehabilitation in stroke

* also called: neurocognitive rehabilitation, cognitive therapeutic exercises, sensorimotor rehabilitation, method by Prof. Carlo Perfetti
What is proprioception or body awareness?

- Internal knowledge/awareness of
  - the body and its parts
  - relative to each other and in space
Brain lesions in stroke

Hemorrhagic Stroke: Hemorrhage/blood leaks into brain tissue

Ischemic Stroke: Clot stops blood supply to an area of the brain
Brain lesions in children with cerebral palsy

DURING PREGNANCY

MALFORMATIONS

PERIVENTRICULAR LESIONS

1\textsuperscript{st} trimester

2\textsuperscript{nd} trimester

3\textsuperscript{rd} trimester
Brain lesions in children with cerebral palsy

- **PREGNANCY AND BIRTH**
  - **(SUB)CORTICAL LESIONS**
  - **POSTNATAL LESIONS**

- 3rd trimester
- birth
- (stroke, infections, ischemia,...)
Impairments related to brain lesion in stroke

- brain injury (stroke or cerebral palsy)
- can result in hemiplegia (sensorimotor impairment)
- proprioception is often affected
PART 1

Overview of cognitive multisensory rehabilitation*

* also called: neurocognitive rehabilitation, cognitive therapeutic exercises, sensorimotor rehabilitation, method by Prof. Carlo Perfetti
Cognitive multisensory rehabilitation

Study and Research Center of Neurocognitive Rehabilitation/ Cognitive Therapeutic Exercises (Santorso, Italy)

Prof. C. Perfetti

Randomized Controlled Trials
An example of an exercise
Cognitive multisensory rehabilitation
The perceptive hypothesis = hypothesis of what is perceived

GOAL of the exercise

BODY as receiver of information

INFO is received and analyzed

STRATEGY used by the patient

Feedback from the therapist

PERCEPTIVE HYPOTHESIS
The perceptive hypothesis in the brain

- Supplementary motor area
- Premotor cortex
- Primary motor cortex
- Primary somatic sensory cortex
- Posterior parietal cortex
- Prefrontal cortex
- Cerebellum
PART 2

Scientific evidence of mechanisms of cognitive multisensory rehabilitation

Functional Magnetic Resonance Imaging (fMRI)
Passively guided somatosensory discrimination exercises

Which brain areas participate in the *cognitive processing of discriminating* shapes and lengths?
fMRI: Somatosensory discrimination exercises in healthy adults and stroke

fMRI: Somatosensory discrimination exercises in CP

Active/Passive movements and Tactile stimulation in CP
### fMRI: Somatosensory discrimination exercises in adults

<table>
<thead>
<tr>
<th>8 patients with subcortical stroke</th>
<th>10 healthy adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 men, 1 woman</td>
<td>6 men, 4 women</td>
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<tr>
<td>Average age: 59y (41-74 years)</td>
<td>Average age: 56y (44-77 years)</td>
</tr>
<tr>
<td>Right-handed</td>
<td>Right-handed</td>
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<tr>
<td>Normal cognitive functioning</td>
<td>Normal cognitive functioning</td>
</tr>
<tr>
<td>No visual neglect</td>
<td></td>
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<tr>
<td>Initial right hemiplegia at stroke onset</td>
<td></td>
</tr>
<tr>
<td>1/8 initial sensory loss at stroke onset</td>
<td></td>
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<tr>
<td>8/8 sensorimotor functioning well recovered when tested</td>
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</tbody>
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Van de Winckel et al., NeurolImage, 2005; Van de Winckel et al., Exp Brain Res, 2012
fMRI: Somatosensory discrimination exercises

8 people with subcortical stroke

Fig. 1 Location and extent of lesions (identified by red blobs) in all patients
Method

vertical axis in transversal plane

horizontal axis in transversal plane
Somatosensory discrimination in healthy adults (+/- 75% correct answers)

Van de Winckel et al., NeuroImage, 2005
I will let you discover your own (musical) AWARENESS and FOCUSED ATTENTION.

YES! It is now…YOUR turn 😊
Summary of the approach
Somatosensory discrimination in healthy adults

* SHAPE discrimination *(experimental condition)*

* MUSIC discrimination *(control condition)*

* Rest

VIDEO
Summary of the main objective

Define the brain areas related to the cognitive processing of discriminating shapes/lengths

SHAPE/LENGTH discrimination
- Passively guided movement
- Music stimulation
- General attention
- Cognitive process of discriminating SHAPE/LENGTH

MUSIC discrimination
- Passively guided movement
- Music stimulation
- General attention
- Cognitive process of discriminating MUSIC

SHAPE/LENGTH discrimination – MUSIC discrimination
- Passively guided movement
- Music stimulation
- General attention
- Cognitive process of discriminating SHAPE/LENGTH
Hypothesis about brain areas involved in the cognitive process of discriminating shapes

- Supplementary motor area
- Premotor cortex
- Posterior parietal cortex
- Area 5 Area 7
- Cerebellum
- Primary motor cortex
- Dorsolateral prefrontal associative cortex
- Somatosensory cortex
Results in healthy adults

SOMATO =
All types of somatosensory discrimination tasks – music discrimination

Van de Winckel et al., NeuroImage, 2005
Results in healthy adults

SOMATO = All types of somatosensory discrimination tasks – music discrimination

Van de Winckel et al., NeuroImage, 2005
Discrimination tasks in people with stroke (+/- 75% correct answers)

Van de Winckel et al., Exp Brain Res, 2012
Common brain areas in healthy adults and stroke

Z = 60mm

conjunction somato > music discrimination
- yellow: patients
- green: patients + controls
- blue: controls

Van de Winckel et al., Exp Brain Res, 2012
fMRI studies in typically developing children and children with CP
19 typically developing children

- 11 girls, 8 boys
- Average age: 14y (11-20 years)
- Right-handed
- Uneventful clinical history

17 children with right-sided unilateral CP

- 9 girls, 8 boys
- Average age: 14y (11-20 years)
- Able to open/close the hand
- Able to relax the fingers
- Able to understand test instructions
- No visual, mental, auditory impairments

Van de Winckel et al., Res Dev Dis, 2013a
1. **Tactile stimulation**: gently brushing the dorsum of the hand with a cotton glove (+/- match beat of the music)

2. **Active movements**: open and close the hand (match beat of the music)

3. **Passive movements**: the robot lifts the finger up and down (match beat of the music)
4. **Passively guided somatosensory discrimination**

* SHAPE discrimination  (*experimental condition*)

* MUSIC discrimination  (*control condition*)

* Rest
Results in TD and CP children

SHAPE DISCRIMINATION > MUSIC DISCRIMINATION

Van de Winckel et al., Res Dev Dis, 2013b
Results in TD and CP children

SHAPE DISCRIMINATION > MUSIC DISCRIMINATION

Crus I/II
Insula/parietal operculum

Van de Winckel et al., Res Dev Dis, 2013b
Results in typically developing children and CP

Insula
Results in typically developing children and CP

Crus I/II (cerebellum)
1. **Tactile stimulation**: gently brushing the dorsum of the hand with a cotton glove
   - Insula/parietal operculum and crus I/II activated

2. **Active movements**: open and close the hand
   - Insula/parietal operculum and crus I/II activated

3. **Passive movements**: robot lifts finger up and down
   - Insula/parietal operculum and crus I/II NOT activated

4. **Somatosensory discrimination exercises**
   - Insula/parietal operculum and crus I/II activated

Van de Winckel et al., Res Dev Dis, 2013a, 2013b
Conclusion of previous studies

- Proprioception is often affected after stroke
- Cognitive multisensory rehabilitation:
  - cognitive processes $\rightarrow$ \uparrow proprioception and sensorimotor function
- “Smiley” in the brain (fronto-parietal areas) + insula/parietal operculum, cerebellum
Current research

Developing a new motor scale: Awareness of Functional tasks with Arm and hand in Stroke (AFAS scale)

Preliminary study on brain imaging and behavioral outcome of cognitive multisensory rehabilitation in stroke

- AFAS scale in 100 adults with stroke
- MRI study in 22 healthy adults
- MRI preliminary study in 9 people with stroke
Serial and parallel processing in somatosensory networks involved in:

- sensation for perception (SI-SII-posterior insula)
- sensation of (object-centered) action (thalamus-SI-SII- PPC)
- body-centered information and internal sensations (SII-insula- PPC)

Dijkerman & De Haan, Eickhoff 2010
• SII (parietal operculum) divided into
  o OP1 (SII) for higher-order somatosensory processing
  o OP4 (parietal ventral area) for sensorimotor integration processes linking sensory feedback to motor action
• Both OP1 and OP4 connect closely with the AIP (IPS)-SI-thalamus
• Functional connectivity between motor areas
• Change in functional connectivity between motor areas after stroke during natural recovery and after therapy

• How do brain areas related to higher-order somatosensory processing connect with each other and with motor areas? (functional connectivity)
• How do these connections differ in people with stroke versus healthy adults?
• Can we influence and improve these connections with cognitive multisensory rehabilitation?
Research design

**PRE**
- Screening + clinical assessment
- MRI scanning

**POST**
- Cognitive multisensory rehabilitation (6w)
- Clinical assessment + MRI

**FU**
- 1 month FU clinical assessment + MRI
- 1 year FU clinical assessment
• **Inclusion criteria**
  o 18-99 years of age; 6 months or more post-stroke
  o medically stable; can understand instructions; available for 6 weeks of therapy

• **Exclusion criteria**
  o contra-indications for MRI
  o contractures that hinder relaxed outstretched arm
  o severe neglect, apraxia or aphasia
• **Screening tests**
  
  - Bell’s test
  - MMSE-brief version
  - Apraxia test (TULIA)
  - Aphasia Rapid test
  - Sensory tests
    (exteroception, proprioception, 2PD, stereognosis)
  - Edinburgh test (handedness)
• Behavioral data
  - MESUPES
    - http://www.strokengine.ca/family/mesupes/
MESUPES-arm test

Person-Item Threshold Distribution
(Grouping Set to Interval Length of 0.20 making 90 Groups)

- Hand to stomach
- Hand from stomach to side
- Arm abduction
- Arm adduction to side
- Hand from knee to table
- Hand to mouth
- Reach for bottle
- Hand on top of head

Van de Winckel et al., Clin Rehab, 2006
MESUPES-hand test

Person-Item Threshold Distribution
(Grouping Set to Interval Length of 0.20 making 55 Groups)

Van de Winckel et al., Clin Rehab, 2006
• Behavioral data
  o Jebsen Taylor Hand Function test
• **Kinematic data**
  o Motion Monitor

• **Behavioral data**
  o Sensory tests
  o Frenchay Activities Index
  o Warwick-Edinburgh Mental Well-Being Scale
  o Numeric Pain Scale
• **Structural imaging**
  o Anatomical image (T1)
  o Anatomical image to detect lesions (T2 FLAIR)
  o Diffusion Tensor Imaging (DTI)

• **Functional imaging**
  o Resting-state fMRI (connections at rest)
  o Task-based fMRI (brain activation and connections during somatosensory discrimination tasks)
4. **Passively guided somatosensory discrimination**
   * SHAPE discrimination *(experimental condition)*
   * MUSIC discrimination *(control condition)*
   * Rest
Clinical improvement is noted, even 7y after stroke

Pain and tremor disappeared

Quality of life and social life improved in all patients

Imaging data are currently being analyzed
Thank you for your attention!

Questions?