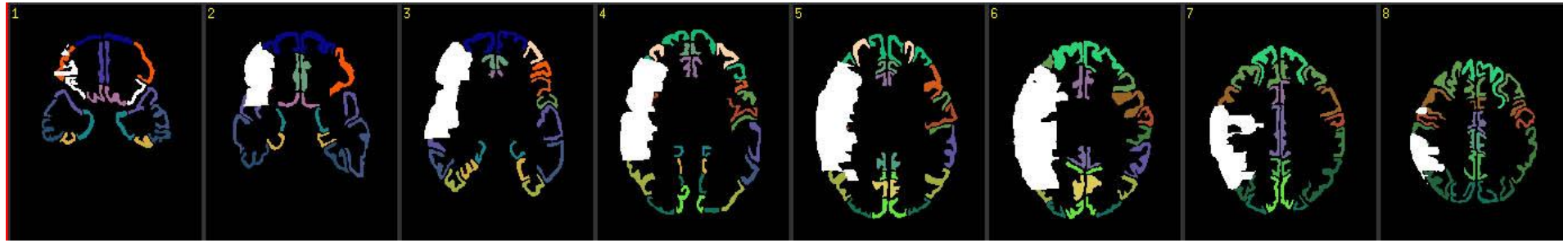
assessment of rehab contribution to upper-limb recovery



IAPRM Annual Meeting 2022 – Pre-Congress WS

Moderators: Nachum Soroker and Silvi Frenkel Toledo

Place & Time: Loewenstein Rehabilitation Medical Center (LRMC) – 4.12.22, 15:00-19:00

preface:

- most of the improvement observed in upper-limb (UL) function post stroke is accomplished in the early subacute period (up to 3m after onset) and reflects 2 processes:
  - *restitution*: true recovery, by adaptive plasticity, of basic operations (muscle tone regulation, force regulation, precision)
  - *compensation*: learning to use the residual capacity in new ways, to achieve desired goals, mainly in ADL

- restitution (true recovery) is widely thought to emerge from biological processes (accentuated plasticity in the early SA period) with only minor added value of structured rehab efforts (in most cases the final outcome is predicted in day 3, prior to rehab commencement; PRR)

- in order to know whether rehab contributes to restitution (true recovery), longitudinal assessment (before and after treatment) should use measures that are insensitive to compensation

- in this WS we evaluate clinical and instrumental tools used in the assessment of impairments that may emerge when stroke affects different parts of the motor network, we shall discuss the pros and cons of using these tools as rehab outcome measures

program:

- Nachum Soroker: types of stroke-related motor impairments
- Orit Wonderman, Justine Raz: FMA and ARAT
- Silvi Frenkel Toledo: MAS and TSRT
- Shay Ofir Geva: isolation of movement
- Jason Friedman: movement kinematics

--- coffee, food, lab visit ---

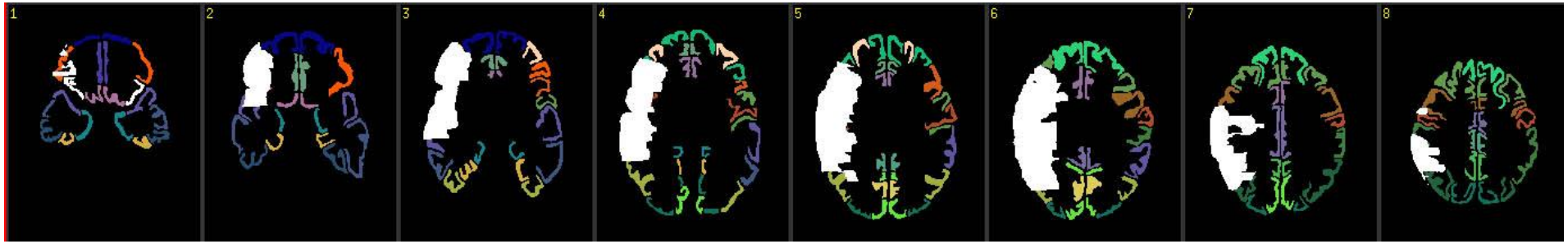
- Osnat Granot: motor planning, praxis
- Corinne Serfaty: motor programming, basal-ganglia & cerebellum disorders
- Nachum Soroker: MEP, TMS effects
- Silvi Frenkel Toledo: meaning of delta

types of upper-limb motor impairment post stroke

Nachum Soroker

Loewenstein Rehabilitation Medical Center (LRMC)

and Sackler Faculty of Medicine, Tel-Aviv University, Israel



IAPRM Annual Meeting 2022 – Pre-Congress WS

lecture overview

1. what is impaired in hemiparesis ?
2. other forms of stroke-related motor impairment
3. requirements from tools aimed to assess recovery

Brain Rehab Lab
Department of Neurological Rehabilitation, LRMC

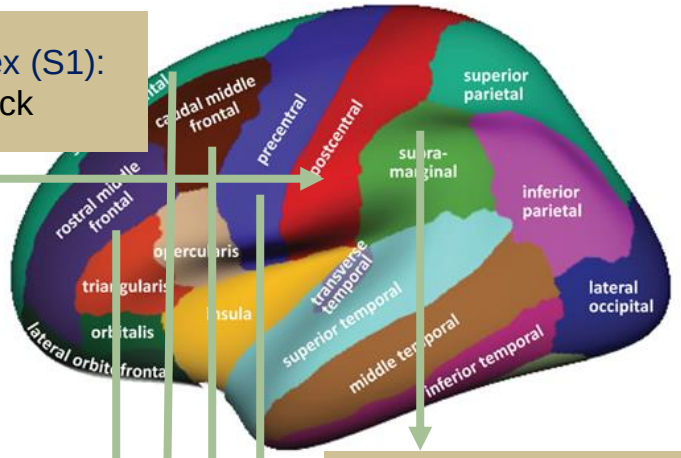
1

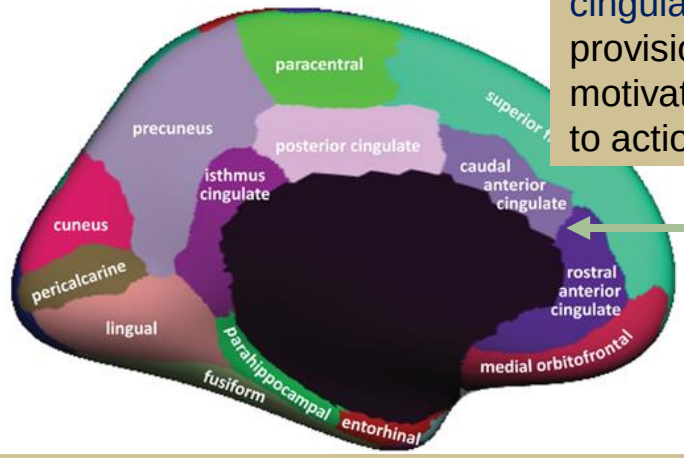
what is impaired in hemiparesis ?

- contra-lateral muscle force (note: there are also ipsilateral abnormalities)
  - failed recruitment of enough motor units in agonist muscle
  - failed relaxation of antagonist muscle (co-contraction paresis) – malfunction of inhibitory spinal interneurons
- precision in movement control
  - difficulty producing isolated movement out of synergy
  - execution of pathological synergies
  - loss of experience-dependent dexterity
- posture control
  - abnormal resting posture and impaired postural setting during voluntary movement
  - impaired postural reactions
- muscle tone regulation and reflex activity
  - dis-regulated hyper-excitable stretch reflex leading to spasticity and co-contraction
  - spastic dystonia
- sensory feedback
  - impaired sensory feedback (sensory dysmetria)

motor impairment following damage to different cortical regions

primary somato-sensory cortex (S1): movement evaluation, feedback





cingulate cortex: provision of motivational valence to action targets

posterior parietal cortex (PPC): SM integration; motor learning and planning

hemiparesis

prefrontal cortex (PFC): behavior planning, executive control

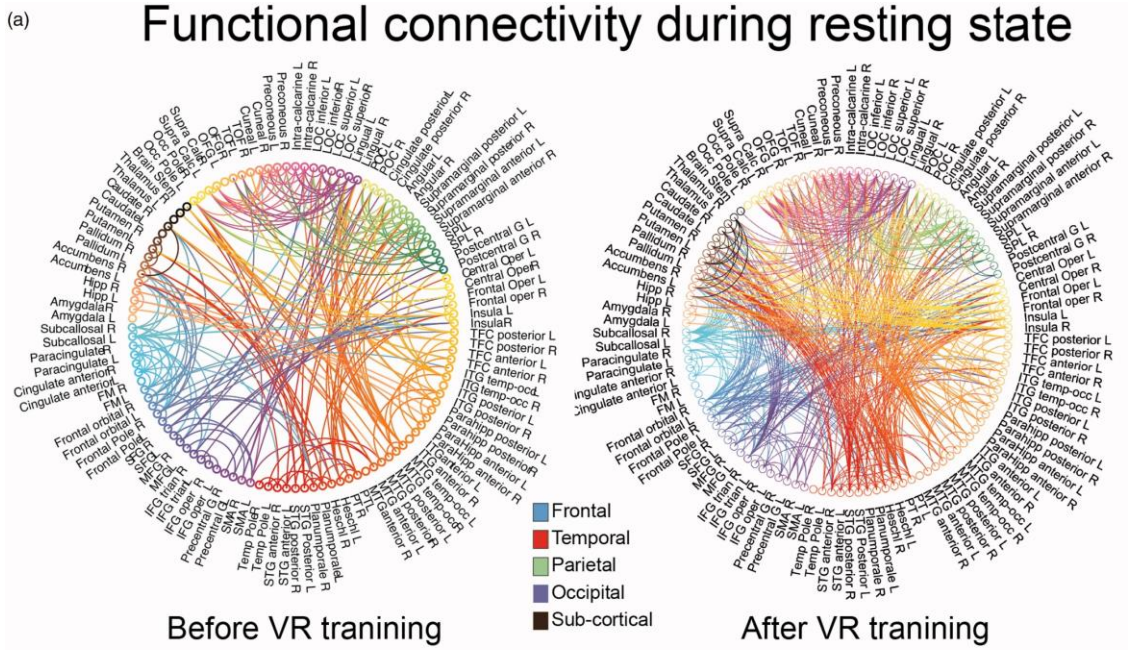
medial premotor cortex (SMA): motor planning, mainly top-down mode

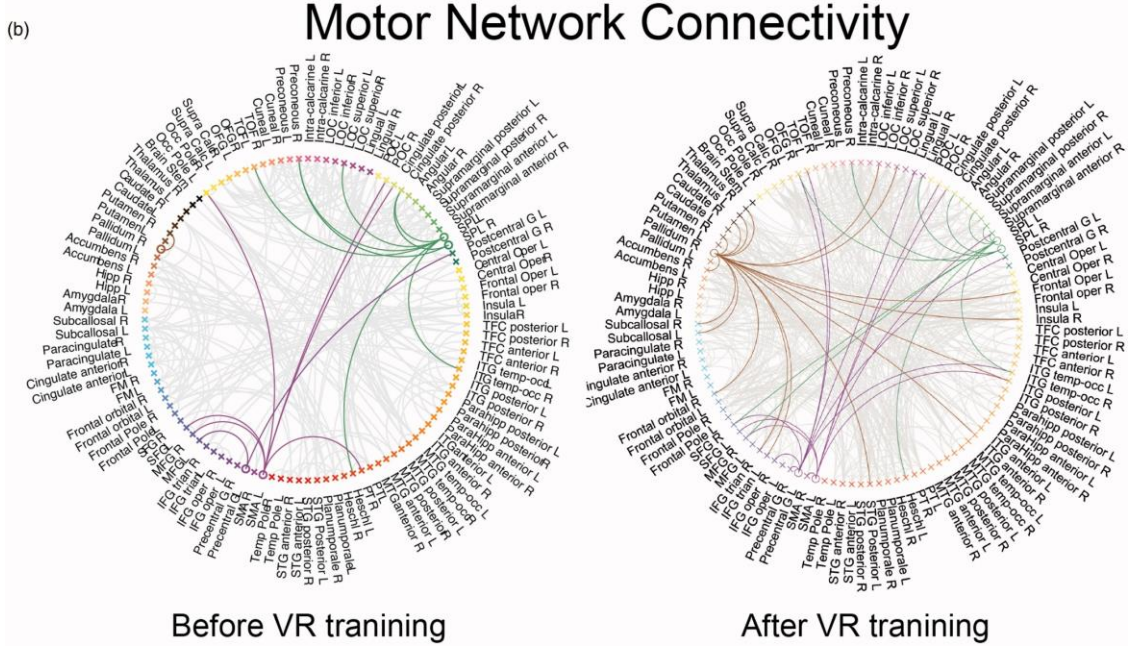
basal ganglia and cerebellum: motor learning; activation of appropriate motor programs

lateral premotor cortex (PMC): motor planning, mainly bottom-up mode

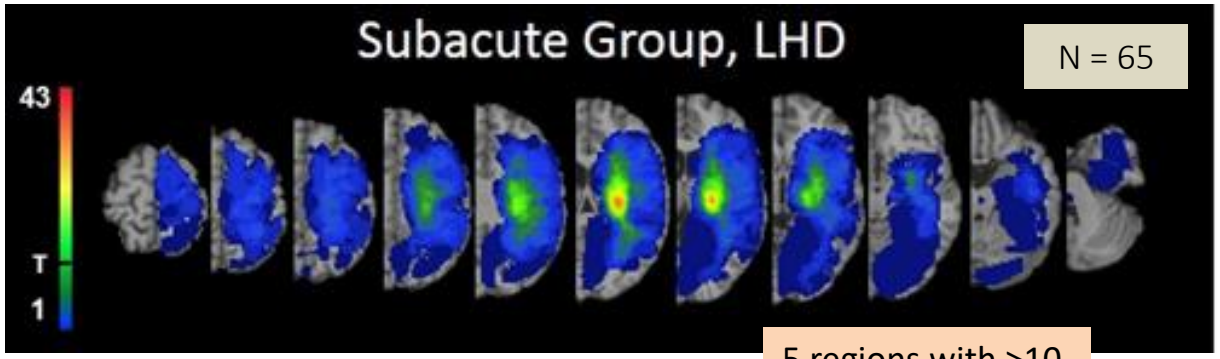
primary motor cortex (M1): cerebral command of movement execution via CST

rehab interventions (cross-education using VR in this case) affect connectivity within a widespread network of regions, both in the resting state and during upper-limb movement



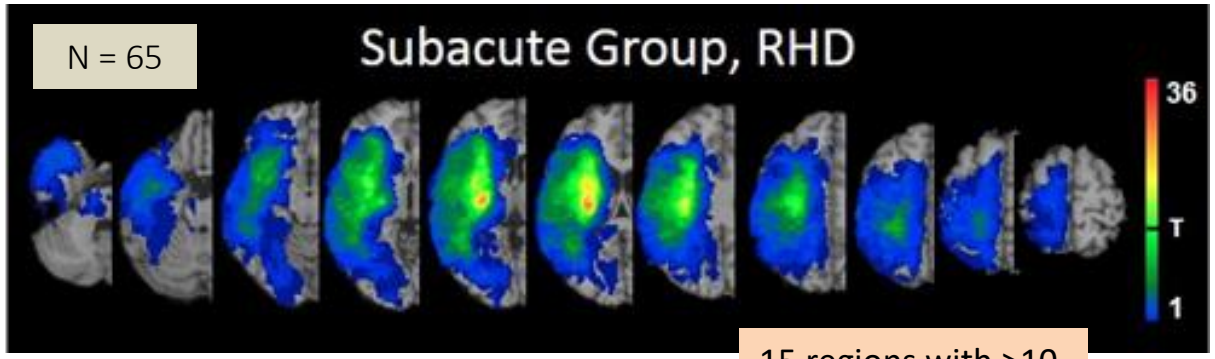


lesions exerting an impact on FMA-UE in the subacute phase, VLSM analysis



5 regions with >10 'significant' voxels

SCR (15.9%)
PLIC (8.4 %)
EC (6.7%)
Putamen, SLF (<5%)



15 regions with >10 'significant' voxels

EC, SFO (70-80%)
SCR, Putamen (50-60%)
SLF, ALIC, Insula (20-40%)
PLIC, ACR, IFO, PCR, R. operculum, Caudate, Pallidum (5-15%)
IFG-po (<5%)

- multiple regions beyond M1-CST
- marked differences between dominant and non-dominant hemispheres

Lesion location impact on functional recovery of the hemiparetic upper limb
Silvi Frenkel-Toledo, Gil Fridberg, Shay Ofir, Gadi Bartur, Justine Lowenthal-Raz, Osnat Granot, Shirley Handelzalts, Nachum Soroker
PLOS ONE | https://doi.org/10.1371/journal.pone.0219738 July 19, 2019

possible other issues in hemiparesis

- impaired drive for action
  - in limbic system and frontal damage
- impaired executive function and behavioral control
  - in PFC damage
- impaired selection and activation of appropriate motor programs
  - in BG and cerebro-cerebellum (cerebellar hemispheres) damage
- impaired ongoing correction of efferent motor commands using afferent input
  - in spino-cerebellar damage
- impaired sensory feedback from different modalities
  - e.g., in thalamus or sensory cortex damage

secondary problems:

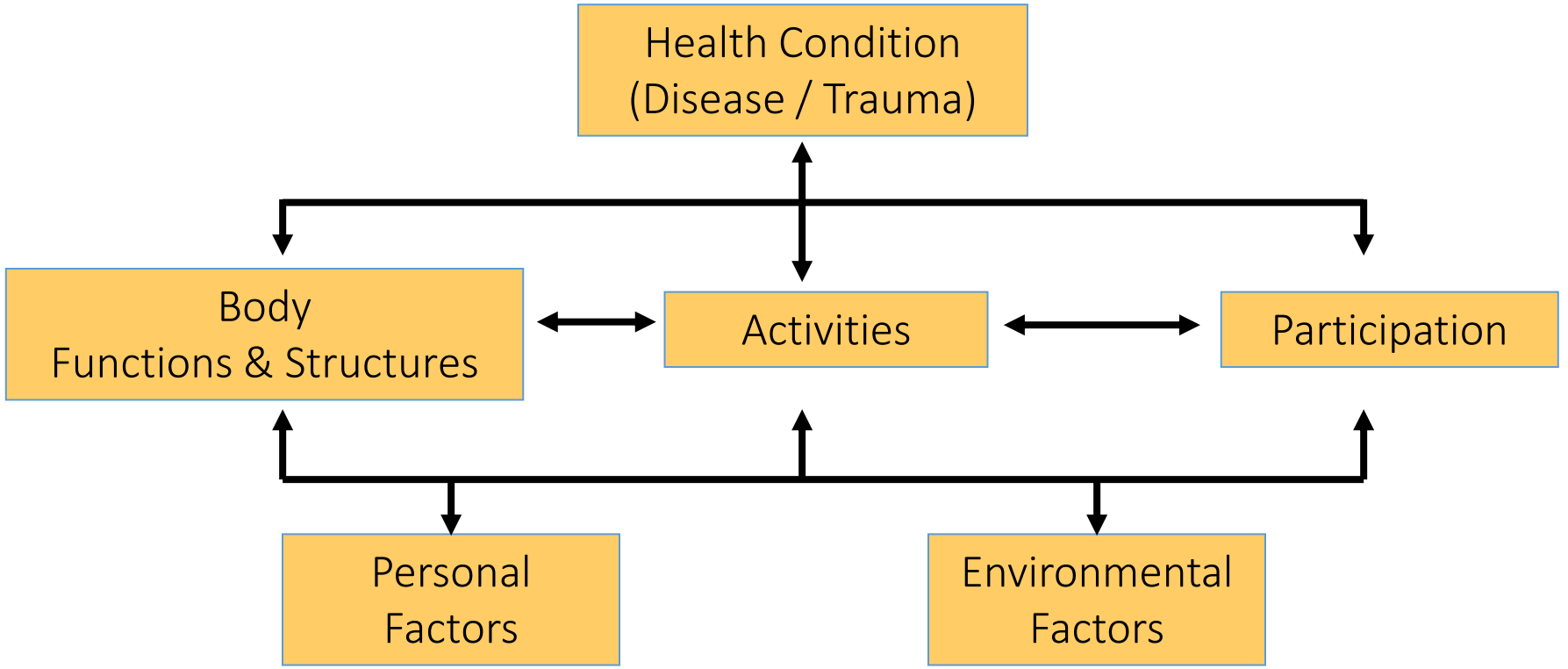
- learned nonuse
- learned bad use
- forgetting (degradation of engrams)

comprehensive assessment of motor function following brain damage

- contextual factors: ROM limitations // pain (reduced mobilization d/t pain) // hypoarousal, inattention
- intent (motor initiative): amount (right/left) // type (spontaneous, responsive)
- idea (executive control): behavioral goal setting, social context sensitivity
- plan-program: praxis - ability to activate task appropriate motor engrams // spatio-temporal organization // involuntary activation of movement (tremor, chorea, athetosis, hemibalismus, dystonia/dyskinesia)
- postural setting: posture control // muscle tone regulation (spasticity, rigidity, dystonia) // reflexes
- motor execution: quality (isolation / pattern) // force (paresis / co-contraction) // dexterity
- cerebellar coordinatination: dysmetria; ataxia.
- sensory control of movement: tactile, proprioception, visual, vestibular (sensory dysmetria, optic ataxia); postural reactions.
- organ overall function: upper-limb; oculomotor; oral; gait; …
- activity: whole-person motor functioning
- participation: environmental adjustment

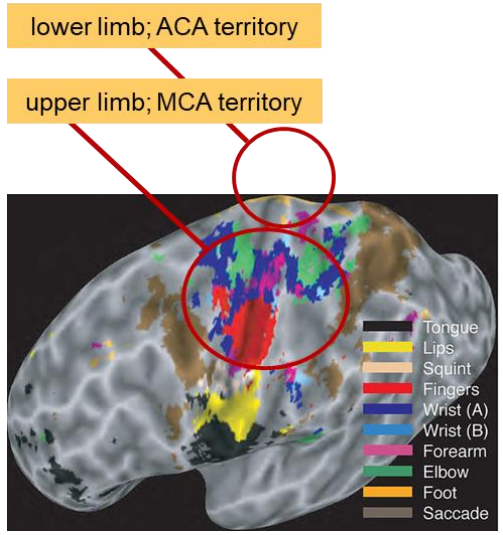
true recovery vs. improved function in WHO-ICF model

disability = impairment + activity limitation + participation restriction (negative aspect of functioning)
recovery = return to normal, or as possibly close to normal, mode of activity in the motor system
improved function = greater ability to cope with daily functional tasks



- **true recovery** – by repair + reorganization ⟷ body SF level
- **improved function** – by restitution + compensation ⟷ activity level

what factors affect true recovery ?



- past research found that most recovery at the impairment level (as judged by the FMA-UE test) is obtained in the first 4-6 weeks after stroke onset.

- claims have been made that this recovery depends on biological factors operating in a short time window, with little or no impact to the rehabilitation patients receive in current clinical practice.

- support for this claim is said to derive from the PRR, as it enables calculation, shortly after stroke onset (before active rehab starts), of the final outcome. $\Delta FMA = FMA_{3m} - FMA_{1\text{-}3d} = 0.7*(66\text{-}FMA_{1\text{-}3d})$

  (Prabhakaran,…, Krakauer, NNR 2008; Winters,…, Kwakkel, NNR 2015: $\beta = 0.78$)

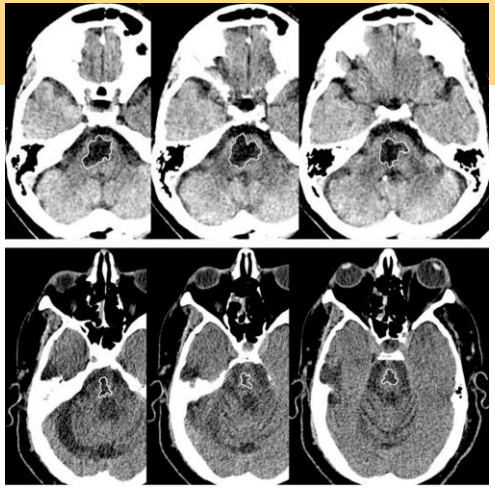
restoration & compensation in stroke motor rehabilitation

restorative approach

- target: impairment
- mode: repeated exercises aimed to restore the normal operation of the motor system.
- examples:
  - efforts to restore isolated movement.
  - repeated reach-to-grasp exercises.
  - grip-precision learning exercises.
  - treatment of spasticity.

compensatory approach

- target: activity limitation, restricted participation
- mode: providing external devices / teaching alternative behavioral strategies to compensate for permanent impairment.
- examples:
  - use of cane, wheelchair, AFO.
  - task specific training in ADLs using aids and compensations (e.g., trunk flexion replacing arm extension) as needed.



use in rehab of preserved ability to activate the soft palate voluntarily in locked-in syndrome

Nasal sniffing enables communication and environmental control for the severely disabled. Plotkin,…, Soroker, Sobel. PNAS, 2010

requirements from tools aimed to assess recovery

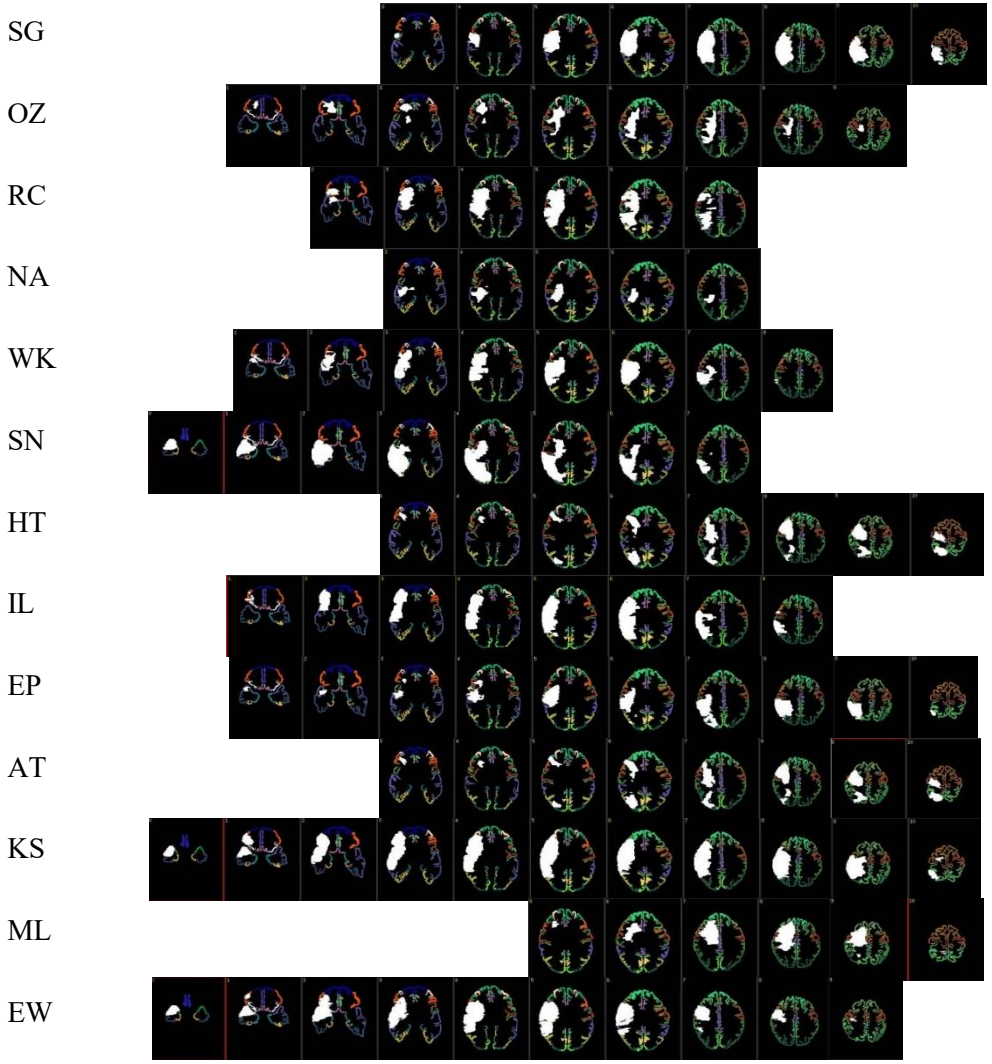
measures used in the assessment of true recovery:

- scoring should be non-sensitive to use of compensatory measures.
- behavioral measures: FMA, kinematics
- functional/structural neuro-imaging: RS-fMRI, activation patterns / lesion data, DTI
- neuro-physiology: MEP, IHI measures, focal transient perturbations, mu suppression,…

measures of improved function:

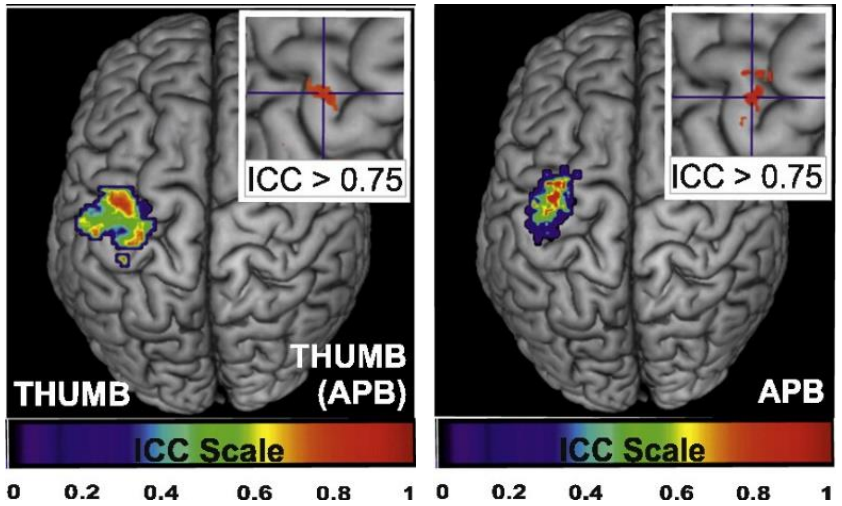
- scoring is regularly sensitive to both restitution and compensation.
- behavioral measures: ARAT, WMFT, JTT, B&B,…
- effect on overall function: FIM

a note on the importance of lesion analysis



fMRI

navigated TMS



- lesion studies point to causal relationships between focal damage and patients' symptoms and disclose important info on the functional architecture of the brain
- lesion characteristics exert a dominant effect on the severity of motor impairment following stroke and on the likelihood of obtaining natural and treatment-induced recovery
- information obtained from lesion studies and functional imaging paves the way to development of novel NIBS / EEG-BF rehab therapies

thanks for your attention

nachum@soroker.online

link to downloadable pdfs: Nachum Soroker (researchgate.net)