Aberrant Sensory Motor Learning in Dystonia: Learning Based Sensorimotor Training to Enhance Motor Control and Language

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October 4, 2006 Keck Initiatives

Lecture Purpose
– Theoretical Construct: CNS is plastic
– Neural adaptation (learning) can be positive or negative
– Example of aberrant learning: Focal Dystonia
  • Etiology, diagnosis, prognosis, treatment of FHd
  • Evidence for aberrant learning
– Integrating basic science findings in neuroplasticity to principles for training
  • General guidelines
  • Specific learning based sensorimotor training

Purpose of Lecture
– Learning Based Sensorimotor Training (LBSMT) for focal dystonia
  • Examples
  • Evidence effectiveness of LBSMT in patients with FHd
– Discuss implications of LBSMT on language and cognition
– Future directions
CNS is Adaptable
- Development
- Maturation interfaced with environment
- Aging, injury, disease, habit
- Attended, repetitive practice (learning)
- Increased repertoire of sensations and movements
- Increased myelination, complexity of dendritic and synaptic connections
- De-differentiation of topography
- Re-differentiation brain topography, upregulation of dopamine, increase in ACTH, BDNF, glutamate, myelination, complexity of neural networks

Potential for Neural Adaptation Variable
- Genetics
  - RNA/DNA variants/connections
- Structural anomalies
  - Spinal Cord, Cerebellum, Hippocampus, Corpus Callosum, Basal Ganglia, Amygdala, Thalamus etc
- Neurohormones/neurotransmitter
  - Dopamine, ACTH, BDNF, Glutamate, endorphines etc

Learning Potential Variable
- Signal noise ratios
  - Strong, weak or abnormal signals
- Neural activation
  - Excessive excitation; inadequate inhibition or visa versa
- Sensory coding
  - Temporal, gating, accuracy
- Environment
  - Enriched versus deprived
Normal Representation: Digits organized from D1 to D5 and from proximal to distal with each cortical penetration associated with a single receptive field (8 mm²) located on one segment and one digit. With training, receptive fields increase in density and decrease in size.

Structural Organization with Training: D1 to D5; proximal to distal; each cortical penetration = a single RF (8 mm²); RF located on one segment and one digit. With attended training, area of representation increases, RFs decrease size, increase density.

Example of Normal Representation—Organization and Positive Learning

A1 Normal → B1 Normal
A2 Trained → B2 Trained

CNS Learning is Multifactorial

- Receptors
- PNS
- Spinal cord
- Limbic system
- Thalamus
- Hippocampus, Corpus Collosum, Amygdala
- Cortex
  - Integration of learning
  - Perception, memory, language
- Cerebellum
  - Early learning: requires cerebellum to adjust sensory input to produce accurate motor output
- Basal ganglia
  - Provides flexible system for learning: associates sensory cues and motor movement
    - If flexibility lost; serious input-output mismatch results
  - Late learning: basal ganglia (globus pallidus) automates the task

Neuroplasticity is Not Infinite: Constraints

- Anatomical sources
- Convergent-divergent spread of inputs
- Time constants governing coincident inputs
- Time structures and achievable coherences of extrinsic and intrinsic cortical input sources
- Competition and demand for myelin production
- Modulatory control systems keeping track of motor, sensorimotor and somatosensory feedback
- Neuronal death post injury or disease
Learning Can be Aberrant

- Injury
- Negative expectations
- Habitual activities
- Stress
- Behaviors near simultaneous in time
- Inaccurate sensory inputs and/or feedback
- Low self esteem
- Reduced repertoire of motor movements
- Repetitive abnormal movement patterns to compensate for pain (limp)
- Repetitive erroneous neural signals (e.g. synergies, spasticity)

Examples: Aberrant Learning

- Habitual behaviors (e.g. smoking, drinking)
- Pathology
  - CNS dysfunction
  - Biomechanical limitations
- Impairments in structure or physiological mechanisms
  - Excessive cortical plasticity
  - Chronic pain
  - Repetitive, stereotypical, automatic, near simultaneous movements (focal, target specific dystonia?)

De-differentiation of the Hand: Case of Repetitive Overuse

1. Large receptive fields
2. Receptive fields overlap digit segments, adjacent digits and glabrous and dorsal surfaces
3. Digits represented across large cortical surfaces
Principles: Neuroplasticity-Learning

- Preferred training environment
  - Wellness
  - Positive expectations
  - Positive self esteem
  - Decreased stress
  - Good health
  - Fitness
  - Adequate sleep
  - Good hydration and nutrition

- Make training behaviors
  - Fun
  - Attended
  - Repeated
  - Rewarded
  - Progressed in difficulty (incrementally)
  - Spaced over time
  - Reinforced with positive-corrective feedback
  - Coincident but not simultaneous in time

Learning Enhancement Strategies

- Use limbs in stress free way
  - Use limb in good biomechanical alignment
  - Use sensory information to guide movement (rough, sticky, different)
  - Strengthen the muscles inside the hand (do not strengthen extrinsic muscles)
  - Move normally
  - Stop abnormal patterns of movement

- Use imagery-mental practice for reinforcement

Clinical Example of Aberrant Learning: Focal Hand Dystonia

- Definition: Sustained end range, twisting postures created by involuntary co-contractions of flexors and extensors
  - Excessive excitation
  - Loss of inhibition
  - Sensory tricks used to decrease involuntary movements.
- General, task or body part specific
Focal Dystonia: Excessive plasticity in perfectionists?

- Famous Pianist - 10+ years disabled; return to performance following botulinum toxin injections and other therapies
- Famous Classical Guitarist - sensorimotor retraining - recovered normal function
- Famous writer: hand dystonia and spasmodic dysphonia (using alternative drawing pad but dysphonia new)

Incidence: FHd

- 15% or more of those working with computers have problems with repetitive strain injury (RSI); some develop FHd
- 50-60% musicians suffer from RSI - 10% of musicians with RSI develop FHd (Tubiana) - smaller % develop dystonia of the
  - tongue - jaw
  - lips - umbilicus
  - neck - jaw
  - foot

Controversies in Etiology of FHd

- Multifactorial
- Genetic
- Abnormal basal ganglia
- Lack of inhibition
- Excessive excitation
- Imbalance excitatory and inhibitory pathways of globus pallidus
- Personality type: perfectionist
- Psychological-perseverative, phobic

- Abnormalities in stretch reflex response
- Traumatic injury
- Stress
- Abnormal somatosensory, sensorimotor or cortical motor processing
- Excessive cortical plasticity
- Repetitive overuse - aberrant learning
Multifactorial Etiology FHd

- All individuals with genotype (Ge) for dystonia do not develop the phenotype (Pe)
- Focal dystonia is multifactorial
  \[ \text{Pe} = \text{Ge} + \text{Sd} + \text{En} + \text{Bp} + \text{P} + \text{N} + \text{Br} \]

- Sd = sensory dysfunction
- En = environmental risk factors
- Bp = behavioral-personal risk factors
- P = physical characteristics
- N = neurophysiology
- Br = behavioral- excessive, near simultaneous repetition (* Hallet, Dystonia Meeting 4/2005)

Risk Factors: FHd
- Long work hours with minimal breaks
- Type A personality
- Perfectionists
- High stress
- Phobic
- Unsafe biomechanical techniques
  - rapid alternating finger flexion/extension
  - near stereotypical simultaneous movement strategies
- Sensory discrimination
- Previous trauma to involved area
- Physical limitations
  - Neurovascular entrapment
  - Limited finger spread, (decreased abduction)
  - Poor posture
  - Tight fascia
  - Limited forearm rotation
  - Shoulder ext rotation
  - Dehydration

Specific Sensory Abnormalities in Focal Dystonia
- Presence of sensory trick: tactile stimulation can correct abnormal movement
- Abnormal proprioception (e.g. after botulinum toxin injections):
  - Weakens targeted hyperactive muscles
  - Muscles previously silent come into action
  - Secondary changes in firing pattern may get mapped on the sensory and motor cortex

(Kaji et al Sensory deficits in dystonia and their significance Advances in Neurology: Dystonia 4, 2004, 94, 11-17)
Sensory Abnormalities in Focal Dystonia (Area 1a and 3b)

- Blocking the muscle afferents (Ia) with lidocaine or stimulating Ia afferents (microcurrent) can decrease dystonic posturing
- TMS
  - Abnormally excites rather than inhibits movement potentials (short time frame)
  - At 30 msec, TMS over the premotor area does not alter N 30 amplitude in dystonic patients

Sensory Dysfunction in FHd

- Stimulation of premotor cortices
  - should be inhibitory
  - increases the amplitude of frontal parietal components in the median somatosensory evoked potentials
- Pre motor cortex in patients with FHd
  - may provide hyperactive action potentials;
  - failure to modulate excitability of the sensorimotor cortex to control movement

FHD: Sensory, Sensorimotor or Motor Disorder?

- Imbalance of excitation-inhibition in presynaptic firing
- Increased thickness gray matter in 3b
- Microstimulation of sensory cortex in FHd: subjects “feel” low intensity (< 0.2 μA)
- Multifactorial: all primary cortical areas
  - Lin et al (2004) reported abnormal topography of 3b, 3a and 4
Specific Sensory Abnormalities in Focal Dystonia

- Abnormal gating in FHd: possibly due to hypermetabolism or hyperexcitability of premotor cortex interfering with modulation of parietal generators

- Patients with Writers Cramp:
  - Abnormal gating of median SEP before movement (Murase et al)
  - Abnormal gating of the tibial SEP in individuals with leg dystonia (Kajii et al 2004)

- Abnormal kinesthesia, sensory, spatial and temporal spatial discrimination

- Sensory evoked potentials (SEP):
  - abnormal summation of dual sensory inputs
  - insufficient central surround inhibition at sensory relay nuclei

- Decreased accuracy in sensory discrimination (e.g. stereognosis, graphesthesia, vibration)

- Grey matter of somatosensory cortex is thicker than normal

Treatment of FHD

- Medical management
  - Medications
    - Botulinum toxin
    - Levodopa
    - Muscle relaxants
    - Baclophen
  - Surgery
    - Decompress ulnar nerve or median nerve
    - Release reticulum between finger flexors/extensors
    - Deep brain stimulation

- Rehabilitation strategies
  - Constraint induced therapy
  - Sensory motor retuning
  - Immobilization
  - Computerized training with pen
  - Electrical stimulation and biofeedback
  - Learning based sensorimotor training
Sensorimotor Learning Based Hypothesis of FHD: Aberrant Learning

Excessive, repetitive, stereotypical, nearly simultaneous stimulation to the digits degrades the cortical hand representation (motor, sensory, and sensorimotor) and interferes with voluntary motor control


Models for Studying Etiology: Dystonia

♦ Animal models
  - Mice
    • Genetic
    • MTPT
    • Blepherospasm
    • Torsian A
  - Rats
    • Repetitive overuse
    • Pain
    • MPTP
  - Primates
    • Repetitive overuse

♦ Human models
  - Imaging studies
    • fMRI
    • MEG
    • TMS
  - Electrophysiological mapping
  - Motion analysis
  - EMG

Aberrant Learning from Overuse: Animal Models

♦ Paradigm: (30 minutes 2x/day for 6 weeks)
♦ Results
  - Extensive acute local inflammation-trained limb
  - Inflammation spread to nontrained side
  - Chronic inflammation associated with degenerative changes
  - Rats working at high rate, high force developed motor control problems after forceful repetition
  - Degradation of the somatosensory and motor cortex
  - Ultimately loss of motor control (under review)
Aberrant Learning and FHd: Animal Models
- Byl, Merzenich, Jenkins, McKenzie, Blake and Nagajaran developed primate model
  - Stereotypic, rapid opening and closing or
  - Accurate simultaneous placement of digits for 1-2 hours a day, 5 days/week

Byl et al study Findings:
- Aberrant Learning: Loss of motor control and loss of precise representational specificity

1. Mild degradation of the somatosensory representation noted on the untrained side:
   a. Receptive fields 4x times larger than normal
   b. RF’s overlapped across adjacent digits less extensive than on the trained side.
Interpenetration Distance in Microns

Topography across the somatosensory cortex, different digits should be represented < 100 mm
In hand dystonia, overlapping receptive fields may continue to overlap up to 1600 mm.

Blake, Byl et al study findings

Blake, Byl and Merzenich Study

As motor degradation occurred sensory cortex reorganized; the fingers were replaced by the whiskers.

Blake, Byl and Merzenich: Findings

Size of Receptive Fields

OM 311 - dystonia of D4
OM 574 - dystonia 1,2,5
Note: affected dystonic receptive fields larger than unaffected
Human Studies: Descriptive

Subjects
- 9 controls working in jobs requiring repetitive hand use (39.2 yrs)
- 12 patients with FHd working in jobs requiring repetitive use of hand
  • 38.5 yrs
  • 11 right handed
  • Dystonia triggered by keyboard or musical performance

Procedures
- Magnetic fields recorded in shielded room
- Two 37-channel biomagnetometers to monitor: 1) sensory air puffs and 2) tapping
- Sensor covered circular area 144 mm in diameter
- Localization error of digitizer less than 2 mm
- Recorded latency and amplitude

Example of Normal MF, MEFI and SEF Responses

Motor (MF) and Somatosensory (SEF)

- MEF I: largest amplitude at 100 ms
- MF: largest peak in latency range 100 ms after stimulus

SEF: peak evoked field amplitude in latency range 30-70 ms around stimulus onset

Results: Controls and FHd Subjects
- MF: Amplitude significantly higher for FHd on affected and unaffected sides
- MEFI: Amplitude higher with severe and lower with mild FHd on affected side
- SEF: Amplitude significantly lower for patients with mild FHd compared to controls
- General: Subjects with FHd did not have consistent responses
**Results: SEF and MEFI Differences:**

Patients with Severe versus Mild FHd

<table>
<thead>
<tr>
<th>A</th>
<th>Severe FHd</th>
<th>B</th>
<th>Mild FHd</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MEFI</strong></td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
</tr>
<tr>
<td><strong>SEF</strong></td>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
</tr>
</tbody>
</table>

- A= Severe FHd
- B= Mild FHd

**Results: Spread and Area of Activation**

- Increase spread of activation of stimulus induced response on **affected** and **unaffected** side of subjects with FHd compared to controls
- Larger area of cortical activation (affected and unaffected side)

**Cortical Changes with High Repetition: Cause or Effect**

**Animal Studies**

- Inflammation initially trained side
- Inflammation spreads to untrained side
- Cortical changes worse on trained side but also present on untrained side (Barbe and Barr, 2004; Byl et al. 1996, 1997)

**Hypothesis:** Cortical changes and FHd a consequence of training; spread with severity and duration (Byl et al, 1996; Barbe et al 2001)

**Human Studies:**

1. Bilateral changes in the motor and somatosensory cortex and unilateral changes SEFI;
2. Abnormal firing and increased thickness of the grey matter in somatosensory cortex

**Hypothesis:** Abnormal somatosensory changes inherited or interaction genetics and risk factors. (Hallet, 1995, 2004, Tinazzi 1998, Barajimines 1999)
No Spontaneous Recovery and Healing: Dystonia

- No evidence of spontaneous healing and recovery
- No physiological treatment for primary, generalized dystonia of genetic origin
- Deep brain stimulators can improve function in patients with primary, generalized dystonia
- Secondary dystonia must retrain the brain

Learning Based Training

- If focal dystonia is a case of aberrant learning, then motivated individuals should be able to retrain the brain
- Learning based training applies the principles of plasticity to intervention strategies
- In rehabilitation, sensory and sensorimotor training paradigms are categorized with perceptual training, not neuromuscular training
- Desired outcomes: improved fine motor control, functional independence, work as well as mental acuity

Learning Based Training: Principles

- Set the stage for learning
  - Eat well
  - Adequate sleep
  - Think positively about recovery
  - Join a gym, walk, run: cardiopulmonary fitness
  - Learn to use hands in stress free way
  - Learn to do mental imagery and mental practice
    - Healing
    - Relaxation
    - Stress management
    - Restoration of normal movement
Learning Based Training: Principles from Basic Science

- Basic learning behaviors must require:
  - Attention
  - Repetition
  - Positive feedback (errors, reward)
    - Nonstereotypical
  - Separation in time (nonsimultaneous)
  - Progression of difficulty
- Learning must be reinforced and spaced over time

Learning Reinforcement Strategies

- Make learning fun
- Stop abnormal movements
- Reinforce normal, quality behaviors
- Agree on goals: patient, therapist, educator and physician
- Educate pt and family about science of neuroplasticity
- Train sensory, motor and cognitive behaviors
- Image success
- Be confident
- Have positive self esteem
- Comply with practice schedule
- Integrate learning into all activities
- Be persistent to keep improving
- Provide pre event information (could be subliminal)

Learning Enhancement Strategies

- Retrain both hemispheres:
  - Contralateral (excitatory)
  - Ipsilateral (inhibitory)
- Include elements of surprise
- Do learning activities in all different positions
- Provide multisensory stimuli to generalize learning
- Progress difficulty small
- Minimally detectable difference
- Go back in time when you can image successful task performance
- Use different limbs for same functional task:
  - Write with foot
  - Play guitar with left hand
Learning Based Sensorimotor Training: Specific Guidelines

- Eliminate vision
- Incorporate all sensory modalities (tactile, proprioception, sound, vibration, gravity, temp)
- Use active and passive stimuli
- Make all tasks a forced choice
- Do sensorimotor activities in all positions
- Have sensory objects everywhere
- Add time as a variable

Learning Based Sensorimotor Training: General Principles

♦ Think sensory not motor
♦ Do sensory training in all positions; 3rd dimension?
  - Put subject and arm in position where least tension and neural firing
  - Begin sensory retraining in most stress free position (e.g. supine)
  - Progress sensory training to other positions: sitting, prone, upside down

LBSMT: Progressive Phases

♦ Phase I: Learn to imagine, look and move hands without abnormal movements
♦ Phase II: Improve sensory discrimination
♦ Phase III: Learn to perform graded slow controlled movements
♦ Phase IV: Improve sensorimotor skills
  - Challenge the regulation, quantity and quality of sensory information (initiation, isolated, functional tasks and fine motor movements)
  - Restore normal sensorimotor gating, activation thresholds, and feedback gains
♦ Phase V: Improve fine motor control
  - Without tremors or abnormal patterns
  - At nontarget and then target specific tasks
Learning Based Sensorimotor Training: Phase I

- Train ability to imagine using hands normally
- Train to look at “hands or involved limb” without abnormal movement or pain
  - Perceive laterality (note if right or left)
  - Visualize different hand positions
  - Mirror the hand positions
  - Move and copy the different positions (Moseley et al)

LBSMT: Phase II Sensory Discrimination

- Redifferentiate the sensory and motor cortical representations
- Improve sensory discrimination (haptic tasks)
  - Improve precision of sensory discrimination processing (inputs and feedback)
  - Re-differentiate targeted body parts (somatosensory, sensorimotor and motor topography of representation in the cortex, thalamus and basal ganglia) without abnormal movements
Phase II: Improve Sensory Discrimination (Stereognosis)
- Feel and match objects with eyes closed
- Learn to read Braille (may have to learn with unaffected hand first); learn one finger braille
- Paste buttons on cards and match buttons
- Put stickers on cards, and match stickers
- Feel and spell words with small alphabet letters
- Sort by size, surface coarseness

Phase II Sensory Discrimination (Graphesthesia)
Progress from writing letters and numbers to words and designs that get increasingly complicated. Must reproduce accurate (orientation, size, design); Reproduce on hand or paper

Phase III Graded Movements
- Place hand on treadmill
  - Keep the normal arches of the palm and digits
  - Let belt move under hand with no finger grabbing
  - Perform a functional task on the moving belt
- Place hand on a record as playing; do not change sound
- Touch fan blades; do not stop
- Hold hand on scale (different weights, different holding times)
Phase IV Sensorimotor Training
♦ Begin partial performance of tasks similar to target task
♦ Think about sensory aspects of performing functional tasks; let texture of object guide the hand
♦ Use a mirror image to facilitate normal sensory information and movement
♦ Progress nontarget task to completion with normal movements and good sensory awareness; progress difficulty

Phase IV: Sensorimotor Skills
♦ Improve sensory perception of affected and unaffected limbs without eliciting abnormal signs and symptoms
♦ Play games with eyes closed (e.g. solitude with braille cards, dominoes, dice games)
♦ Increase feedforward sensory input to facilitate normal motor recruitment (e.g. tape)
♦ Restore ability to place hand on target instrument to explore texture without creating abnormal signs and symptoms
♦ Watch a video or observe other hands performing target task; imagine the hands are “yours”

Phase IV Sensorimotor Skills
Left hand is behind the mirror and tries to move just like the mirror image
Right hand looks like left hand in the mirror; put dominoes in order
Feel and match keys seen in mirror with keys behind mirror
Phase IV Sensorimotor Skills

“Find 10 quarters in the beans”. Increase speed.
Eyes closed, feel letters and organize to spell words
Eyes closed, work puzzle

Phase V Fine Motor Control

- Attend to the position of the trunk when training fine motor control (posture and balance)
- Train the unaffected side (may have to do this before doing some tasks on affected side)
- Begin fine motor training on target task while performing gross motor task (e.g. walking on treadmill)
  - Begin with nontarget tasks
  - Practice specific isolated movements of target task
  - Practice target task
  - Increase speed of performance
  - Balance strength as necessary

Phase V Fine Motor Training

- May need to stabilize the hand
- Leave one finger free at a time
- May need to support adjacent fingers to enable control of involved digit
- Begin motor retraining in unrelated postures without task specificity; progress to nontarget tasks
- Progress training to working postures and target specific tasks
Phase V Fine Motor Control

- Practice normal fine motor movements slowly on the target task (use metronome and slowly increase speed)
- Use biofeedback to help minimize abnormal muscle firing patterns
- Provide feedback regarding accuracy and speed
- Progress complexity of fine motor movements on target task
- Increase endurance of normal performance at fine motor task
- Integrate performance of task at workplace

Phase V; Fine Motor Movements on Nontarget Task ("Steering Wheel")

Phase V: Fine Motor Nontarget Task: Reshape Hand
Phases V Practice Target
Activities in Unusual Positions

Lying supine on keyboard

Inverted: on keyboard

Phase V Target Fine Motor Task
(Alternative Environment)

Phase V Fine Motor Skills
(Target Task)

Change the way or performing the task; move around the shoulder and elbow
Change the Paradigm When Retraining

Learn to write in a nonhabitual but functional stress free way,

Phase V Fine Motor Training at Target Task (with biofeedback)

1. Use biofeedback for activation or inhibition
2. Use pressure into the palm to round the hand
3. Use lumbar roll to facilitate good posture.

Phase V: Fine Motor Training Facial Dystonia

Also, mirror image normal when head aligned; face distorted when head tilted

Two mirrors perpendicular
Mirror image of normal side of face looks like normal affected
Phase V: Fine Motor Target Task (Simulated Instrument)

Simulate activities on the target task with normal position and movement

On the target task, move from the shoulders and elbow; use the intrinsic muscles in the hand

Phase V: Fine Motor Target Task (Challenging Environment)

Treadmill walking: eyes open/closed; sideways, backwards

Effectiveness of LBSMT: Focal Dystonia

♦ 3 sequential case series FHd
♦ 2 case studies FHd
♦ One pre post test design (12 subjects)
♦ Current randomized controlled trial (10) in process
♦ Case monitoring: Cervical dystonia
Effectiveness of LBSMT

- 90-95% improved; only @ 5% complete recovery
- Normal sensory discrimination
- Improved fine motor control at target task (75-90%)
- Improved firing pattern of the muscles (MSI)
- Improved sequencing of digits (MSI)
- Improved somatosensory map (MSI)
- Return to work - 80%
- Return to musical performance - 50%

Effectiveness LBSMT

- Patients improved fine motor hand control if they:
  - Were compliant* with the program
  - Could imagine a return of normal function
  - Stopped the abnormal movements
  - Gave up performing the target task
  - Mentally practiced the task
  - Worked intensely on retraining several hours a day (1-6 months’ repetitive paradigms 50x/hr)
  - Integrating sensory tasks into all activities
- Patients improved word articulation and clarity of speech with LBSMT retraining

Current Randomized Clinical Trial

- 10 subjects
- Randomly assigned to Treatment group I and II
  - I= brain fitness program and LBSMT both at home (6 weeks)
  - II= brain fitness program home and LBSMT supervised 2 weeks, 4 hours/day and home 4 weeks
- Pre post test design
- Monitoring of neuroanatomical and neurophysiological function (MRI, MEG)
- Monitoring of clinical function
Status Patient Report: Current Randomized Clinical Trial

- Compliance for LBSMT highest among subjects doing *supervised* training (6/6)
- Compliance for Brain Fitness highest for those doing supervised LBSMT (4/6)
- Group LBSMT activities led to positive interactions and competition
- Patients doing Brain Fitness and LBSMT at the same time made the greatest improvements

Status Report: Current Randomized Clinical Trial

- Without supervision, despite weekly phone calls compliance POOR
  - Did not do either activity: (1)
  - Brain fitness but no LBSMT; (2)
  - Most brain training, limited LBSMT -improvement with writers cramp (1)
- Overall, improvement estimated 0-90%
- One patient asked to practice a skill 10x/hour and made most improvement
- MEG data not yet available

Randomized Clinical Trial: In Progress Brain Fitness (FHd)

- Brain Fitness and LBSMT together best
- Brain Fitness Training- Pros
  - Forced me to attend and to learn
  - My memory is better
  - Increased my compliance with sensorimotor training
- Brain Fitness Training- Cons
  - Cartoons inappropriate for adults
  - Boring
  - Sessions get longer and longer
  - Not fun for adults who do not have compromise of memory
  - Errors noted on the program
Effectiveness LBSMT-Stroke

- Three small experimental studies; measured significant improvement in
  - sensory discrimination
  - fine motor control
  - functional independence
- Observation, patient and family report
  - Improved expressive language
  - Improved word finding skills
  - Increased clarity of speaking

Conclusions

- More research is needed to clarify the type and intensity of behavioral training needed
- Clinicians need to be innovative to incorporate paradigms of neuroplasticity into treatment
  - Engaging, integrated, attended, rewarded, task specific training
  - Address sensorimotor aspects of movement
  - Include mental imagery and practice
  - Use mirror imagery for positive feedback
- Even individuals who want to get better need encouragement to stay compliant

Conclusions

- Effective strategies are integrative
- New strategies of intervention must be integrated into nontraditional treatment settings (e.g. YWCA, YMCA, fitness centers, schools)
- Fun computerized, robotic retraining programs could facilitate numbers of repetition, enable home training, and potentially keep patients interested
Conclusions

♦ Need interdisciplinary teams of clinicians, scientists and industry to design the best tools to facilitate neural adaptation and learning.

♦ New technology and robotics, partnered with dynamic attention and learning has the greatest potential.

♦ Cognitive and language gains accompany sensorimotor learning and needs to be studied further.