

최신 신경과학의 이해가 신경재활의 진보에 미친 영향

Task-specific Training & Brain Plasticity



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Neural Rehabilitation,

과제 특이적 훈련(task-specific training)?

클라이언트가 원하는 목표에 구체적인 과제를 강도 높게 반복적으로 연습하는 것이다.

Task-specific training is the repetitive practice of task that is specific to the intended outcome (Sullivan KJ, 2007)



과제 특이적 훈련은 왜, 어떻게 해야 하나?

Task oriented training improves function and changes cortical activation.



- **Make it more real!**

Practice with real objects significantly improves reaching kinematics.



(단순히 베는 것이 아니라 점을 잡기 위해 베는다는. 단순히 점을 잡는 것이 아니라 마시고자 하는 의도가 있는 점잡기 일 때, 더 베기는 향상된다.)

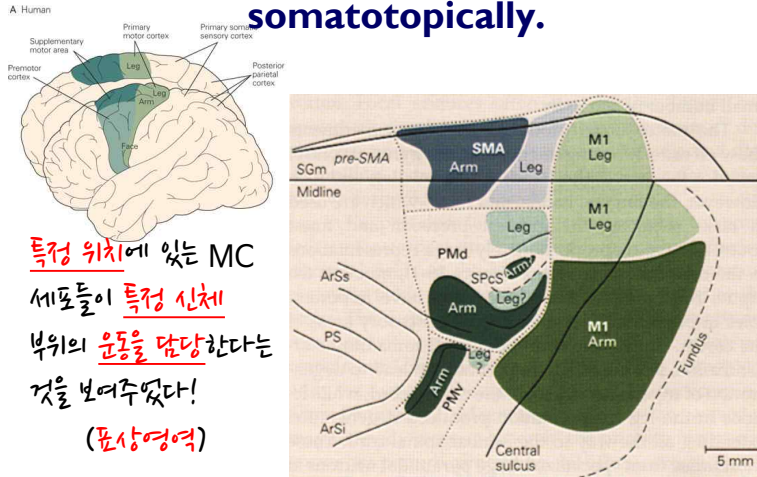
- **Transfer of practice**

Practice conditions need to match the **real life situation** as close as possible to facilitate daily tasks.

왜 과제 특이적 훈련이 효과적일까?
- 신경과학적 근거



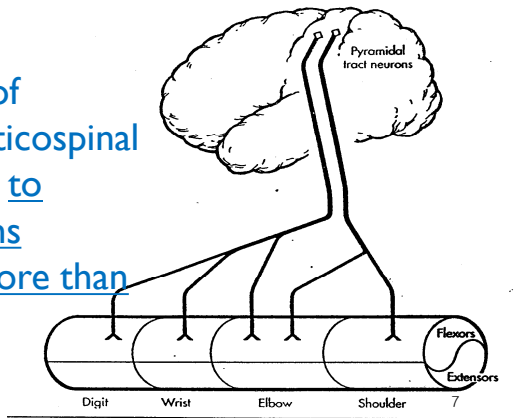
Motor cortical areas are organized somatotopically.



특정 위치에 있는 MC
세포들이 특정 신체
부위의 운동을 담당한다는
것을 보여주었다!
(표상영역)

Recent anatomical and physiological experiments (Kandel, 2000)

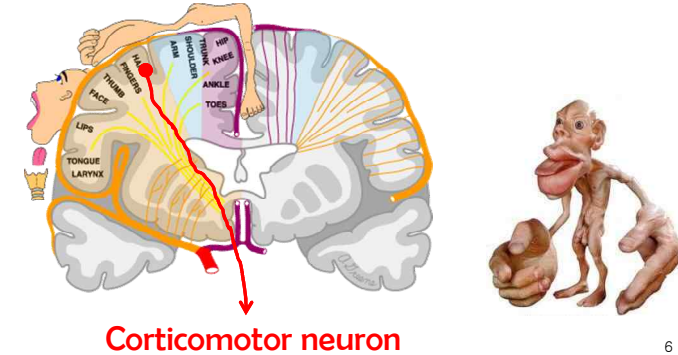
The terminal distributions of individual corticospinal axons **diverge to** motor neurons **innervating more than one muscle**



운동걸질의 지도는? Muscle map vs Action map?

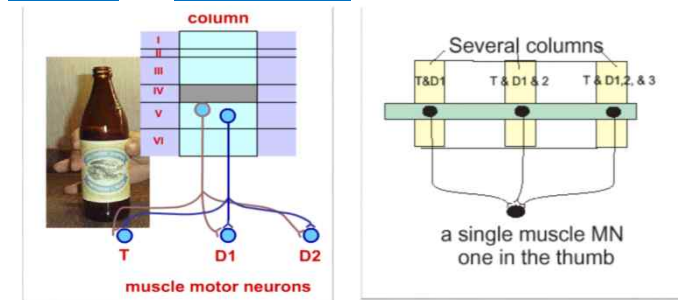
개별 근육 조절을 위한 것인가? VS

특정 동작(과제)을 위한 다수의 근육을 조절하는 것인가?



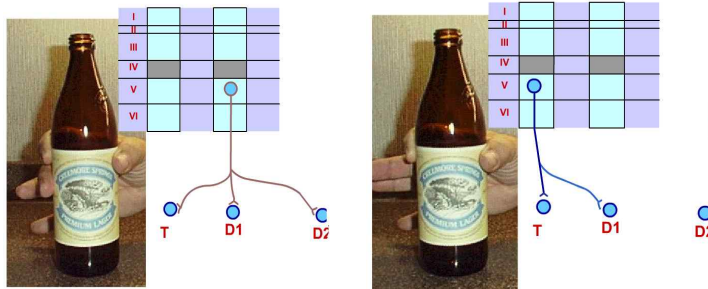
M1 is a map of the body's movement

개별 근육 VS 여러 부위 근육들을 조절하기 위한 설계인가?



A single muscle can be activated by a colony of columns. This is because a single muscle may be a synergist in a variety of different movements.

Columnar organization



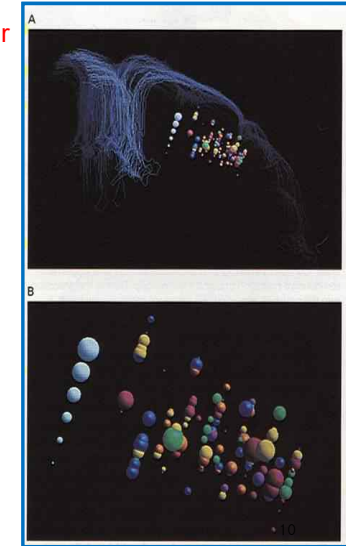
- Cells in the same column influence common synergistic muscles, **muscles that act together/cooperate in a movement**
 - Eg., the fingers required to hold a cup.

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Cortical neurons that govern finger movements are **distributed** throughout the hand-control area of M1

Each digit and wrist are a different color; diameter of sphere is proportional to the neuron's activity.

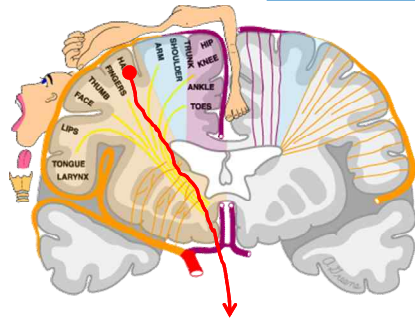
Neurons active for a particular digit or wrist are not grouped together



운동계획의 지도는? Muscle map vs Action map?

개별 근육 조절을 위한 것인가? VS

특정 동작(과제)을 위한 다수의 근육을 조절하는 것인가?

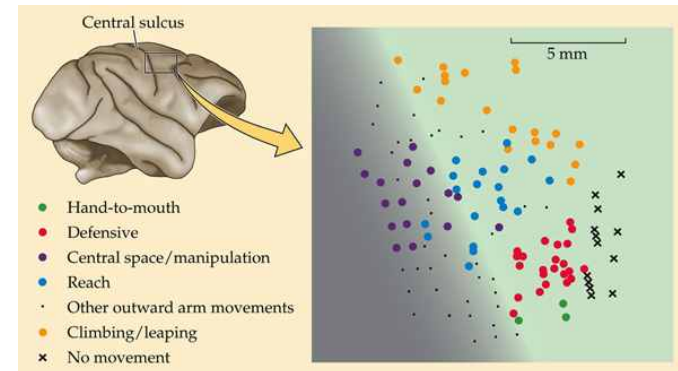


Corticomotor neuron



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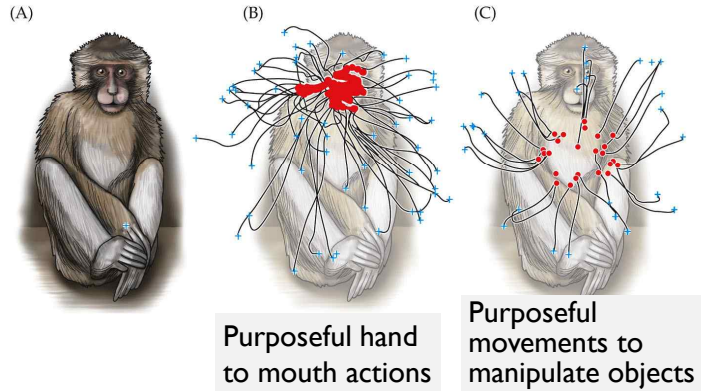
What Do Motor Maps Represent?



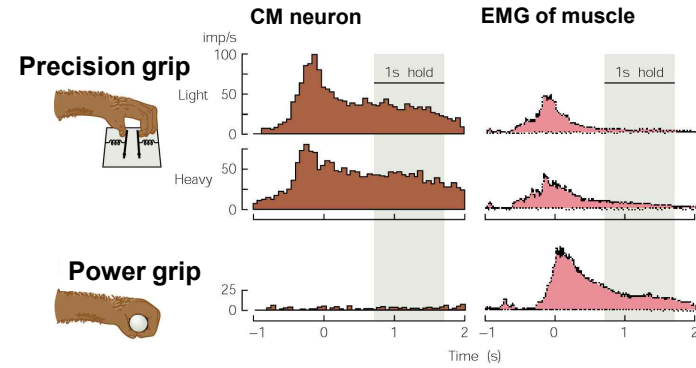
Initially thought to simply control individual muscles – on finer scale different regions code different repertoire of purposeful movement (Graziano 등, 2005)

Microstimulation of M1

Purposeful movements mapped in the M1

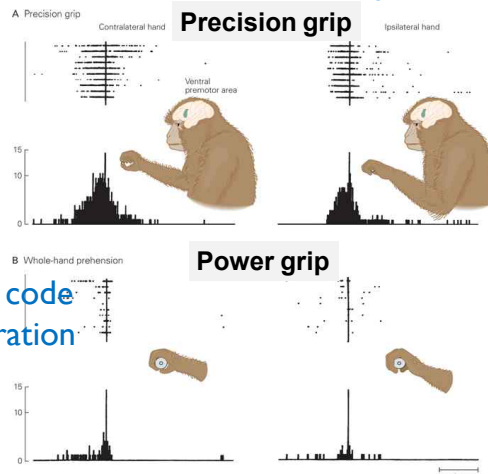


CM neurons are preferentially recruited for tasks requiring topographical precision

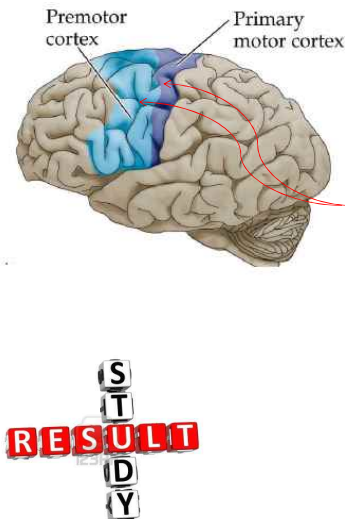


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Individual neurons in PMv (F4) fire during specific hand actions only



Neurons in PMv code for hand configuration of grasp



Motor cortex의 구성은 개개 근육 조절을 위한 것이 아니라 특정 동작이나 과제를 수행하도록 설계되어있다!

ST
RESULT
ID
Y

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이와 같은 뇌 구성은 **과제 특이적 운동(task-specific exercises)**이 **비목표 지향적인 운동(non-goal directed movements)**보다 더 효과적인지를 이해할 수 있는 직접적인 근거가 된다. (Frey SH et al. 2011)

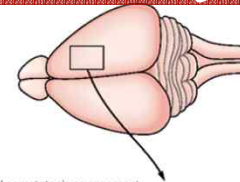
비목표 지향적인 운동



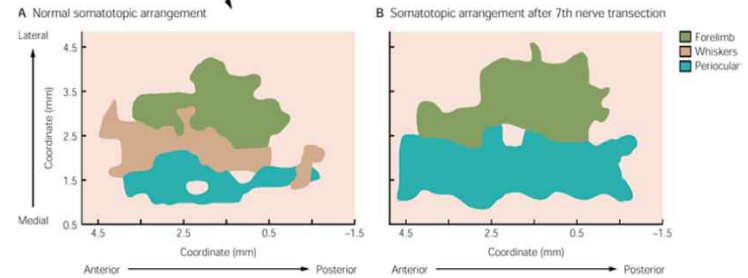
과제 특이적 운동



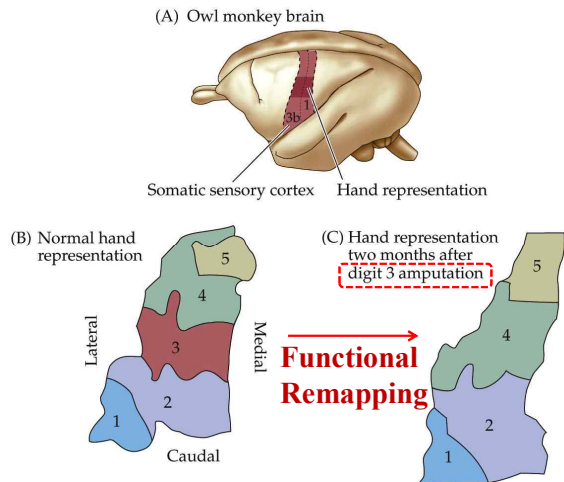
'작은인간'은 경험(경험 제거)에 의해 변화되는가?



Brain Plasticity

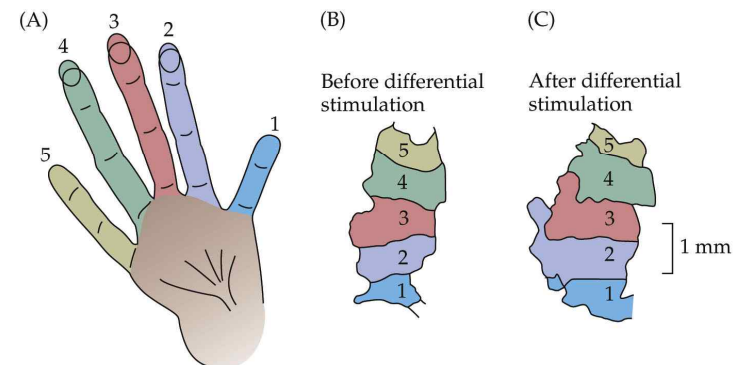


Functional Reorganization of Cerebral Cortex

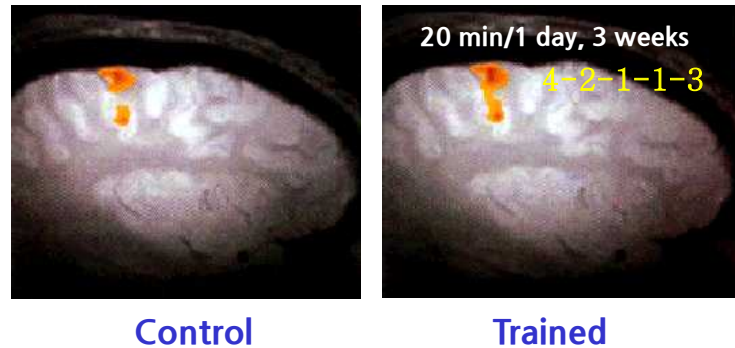


Plasticity from normal experience

Functional expansion of a cortical representation by a repetitive behavioral task (Jenkins et al, 1990)



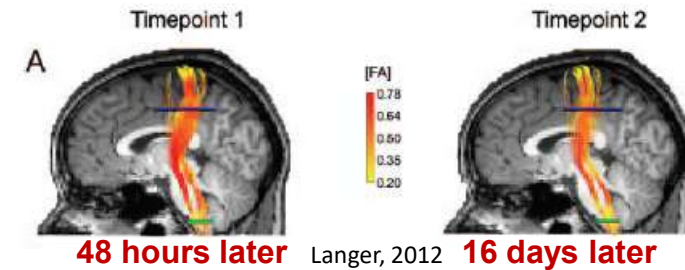
Practice and learning of finger sequence can alter motor representations in M1



Examples of Neuronal Plasticity in Human Motor Cortex: Expansion of Cortical Representation of Fingers **after Training** (Karni et. al.; 1995, 1998)

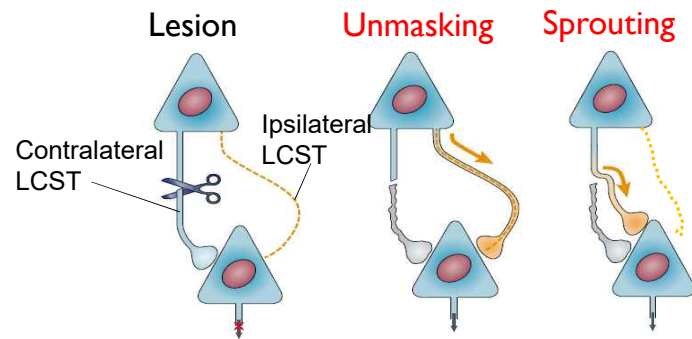
Structural changes in gray matter and white matter after reduced sensory and motor Input (10-20 yrs old)

- **Limb immobilization** caused **reduced nerve fiber density and cortical thickness** in the brain

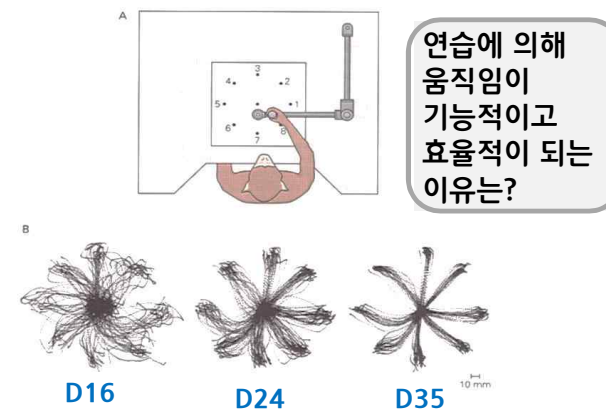


Brain Plasticity

The ability of the brain to respond to intrinsic or extrinsic stimuli by reorganizing its structure, function and connections.



With **practice**, accuracy increases, movement paths are straighter and less variable



국소 뇌손상 원숭이에서 과제훈련의 효과

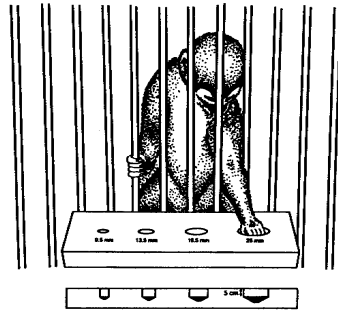
Experience modifies representations



Randolph J. Nudo

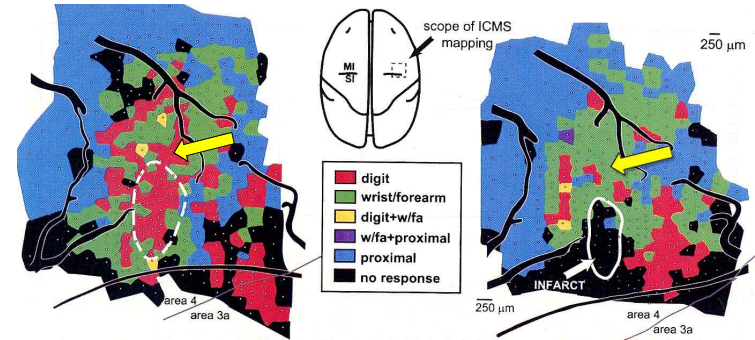
Nudo et al., 1992, 1996

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Motor cortex의 손가락영역 21%, 손목영역 7%를 손상된 경우, 3개월 후 손상시키지 않는 이웃 손가락 영역은 감소되었다.

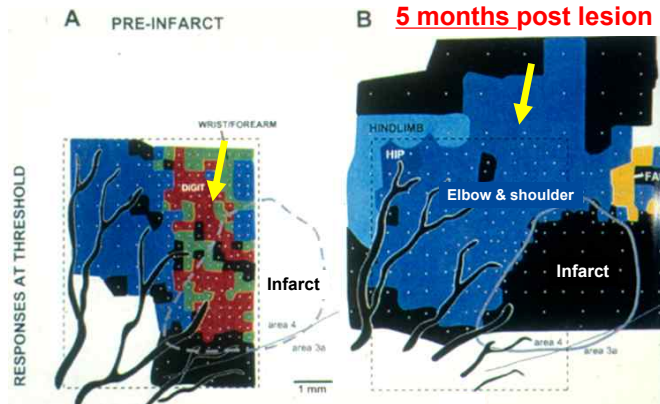
Before lesion 3 months post lesion



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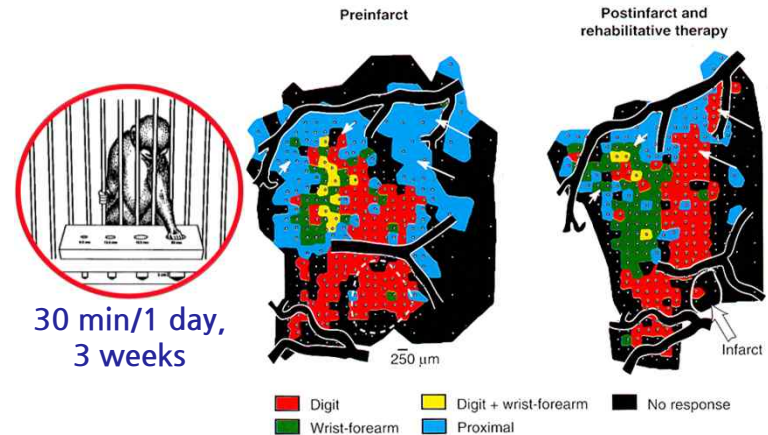
Nudo & Milliken, J Neurophys 1996

5개월 후, 손가락영역은 팔굽과 어깨영역으로 완전 대체되었다!



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손가락영역 22%를 손상시킨 경우, 과제훈련 후 여분의 손가락영역의 15%가 증가되었다!



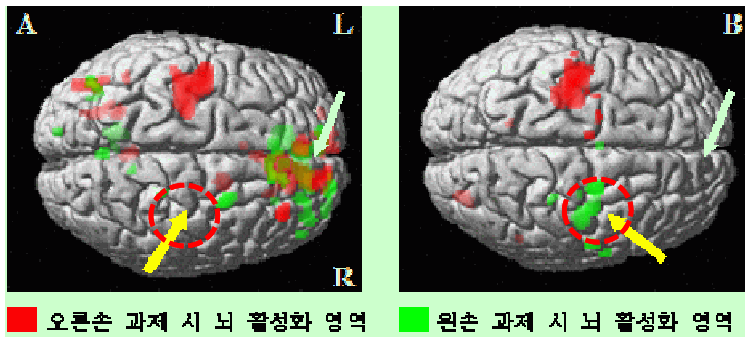
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Nudo et al. Science 1996

Results of Nudo et al., 1996

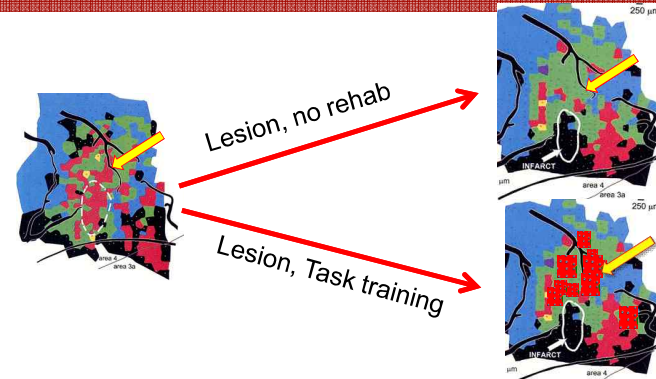
- The results emphasizes the **importance of practice in sensorimotor tasks** for rehabilitation following stroke and other focal brain damage.
- Remember: voluntary movements improve with practice. This may be associated with cortical reorganization (see Karni et al., 1995).

집중적인 과제훈련이 뇌의 재구성을 유발하였고, 그 결과 손 기능이 증진되었다(김종만 등, 2002).



- Left Hemiparesis with TBI
- serial finger movements, 2 hr, 5 days

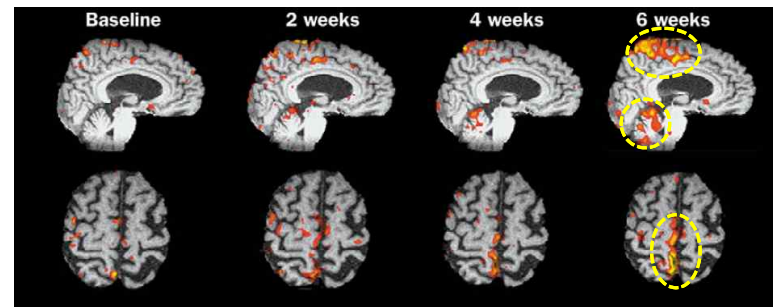
Use it or lose it? (Nudo, 2003)



대뇌겉질 기능은 겉질 손상과 운동기술 습득에 의해 수정되고, 이들은 서로 작용한다!

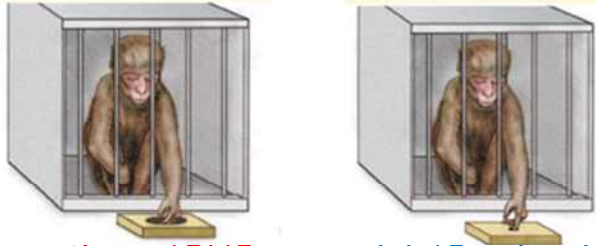
fMRI during ankle dorsiflexion in subject with chronic stroke

(Dobkin et al. Strategies for stroke rehabilitation. Lancet Neurol 2004)



- practice-induced representational plasticity associated with gains in speed, motor control, and kinematics for walking.

Representational Plasticity in MI — Use-Dependent or Learning-Dependent?

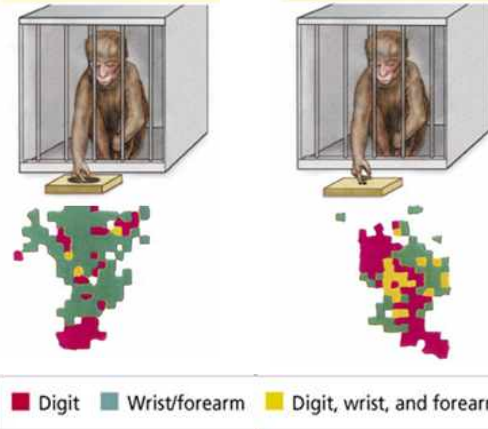


단순 반복적인 운동활동만으로, 결실 운동지도를 변화시킬 수 있는가? 아니면 운동기술 학습에 의해 일어나는가?

Plautz EJ, etal. Neurobiology of Learning and Memory 74, 27-55 (2000)

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Representational Plasticity in MI — Use-Dependent or Learning-Dependent?



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Repetitive activity is not enough (Nudo, 2003)

운동과제를 숙련되게 하려면, 많은 반복이 요구된다.

너무 쉽거나 의미 없는 과제를 반복하는 것은 신경 가역성을 생성하기에 불충분하다.



관심을 끌 수 있고, 도전적이고 의미있는 과제를 시행했을 때, 뇌 가역성과 운동기술 학습은 극대화되었다.

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Task-oriented rehabilitation (Bayona 등, 2005)

Rehabilitation outcomes are more successful when the tasks are meaningful to the patient. → 의미있는 것은 불가능을 가능하게 한다!

Repetition and consistent practice play important roles in inducing and maintaining cortical changes acquired in therapy.

Task-specific training results in long-lasting cortical reorganization of the corresponding areas being used.

잡기훈련시 손 표상영역이, 보행훈련시 발 표상영역이 확장되었다!

Low-intensity task-specific programs also produce cortical reorganization and functional improvements.

→ 과제훈련은 뇌를 변화시키고 기능을 증진시킨다!

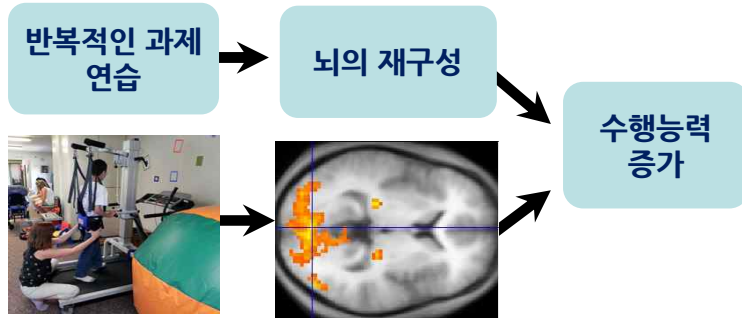
Specific treatment of visual neglect and perceptual disorders result in significant improvement in functional outcomes.

Bayona NA et al. The Role of Task-Specific Training in Rehabilitation Therapies. Top Stroke Rehabil 2005;12(3):58-65

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근거에 기초한 뇌졸중 재활

동작을 많이 반복하는 것은 근력 증가를 요구하고 동작을 수행하는 최적의 방법을 환자로 하여금 발달시키게 한다.
Bernstein in Latash and Latash 1994



Forced Use

Constraint-Induced Movement Therapy

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왜 환자들은 팔을 사용하지 못하게 되는가?



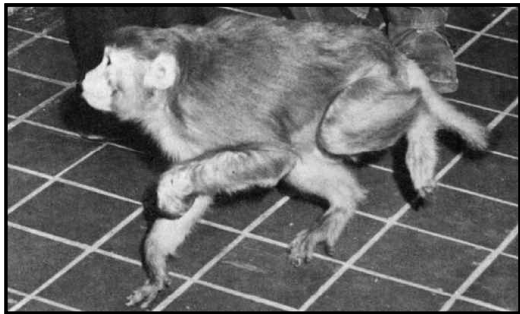
뇌는 학습장치다!

학습된 비사용 증후군
(learned non-use syndrome)

환자 사지가 기능할 수 있다는 것을
알 수 있게 하는 방법은 없을까?



Learned non-use



- unilateral dorsal rhizotomy 한 후에 상지 움직임 실패
- Bilateral DR 한 후 양쪽을 다 사용함
- 그렇다면, UDR 한 후 건측 억제, 환측 집중 사용한다면?
(Taub & Berman, 1968)

수술 수개월 후 과제 훈련



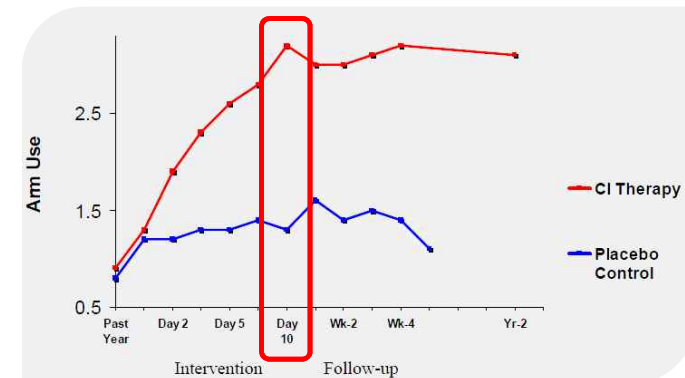
탈구심성 후 목적있는 움직임 거의 정상으로!!

Constraint-Induced Movement Therapy

- learned non-use syndrome을 극복하기 위해 만들
- Forced Use: 건측 팔을 구속하고, 환측 팔과 손으로 집중적인 과제 연습을 하도록 구성 (Fritz et al. 2005).



Outcomes from CIMT for Chronic Stroke Patients



Taub E, et al. Arch Phys Med Rehabil 1993

Constraint-Induced Movement Therapy (Wolf, 2006)

- Repetitive Task Practice
- Shaping (*adapted task practice*)
 - motor objectives are approached in small steps
 - By making the task more difficult in accordance with the pt's motor capabilities
 - Provide specific KR (feedback) about a pt's performance



치료 전

A

치료 후

B

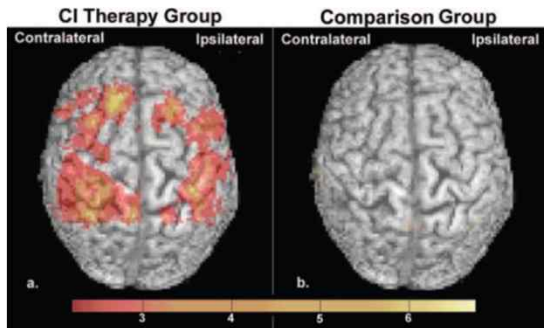
Motor Cortical Reorganization Following CNS Injury

- 6명의 만성 뇌졸중 환자
- 2주 CIMT를 받음

Liepert et al., 1998

Remodeling the Brain

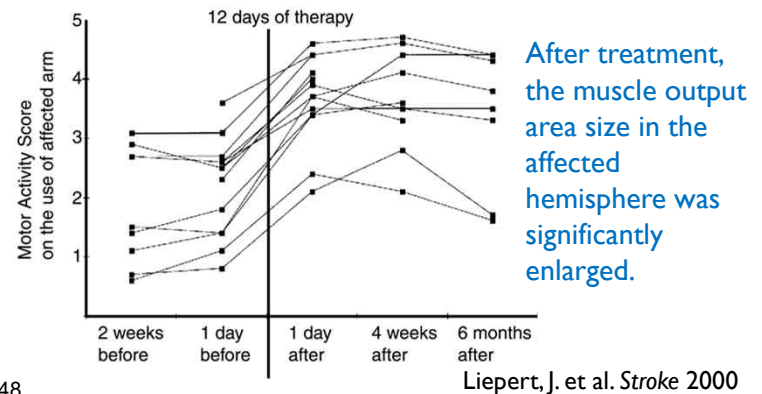
Plastic structural brain changes produced by different motor therapies after stroke (Gauthier 등, 2008)



- 대뇌겉질의 활성의 크기는 실제 생활에서의 상지 사용 증가량과 의미있는 상관관계가 있었다!

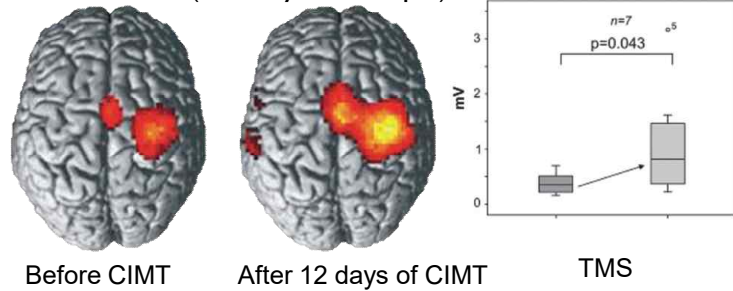
Constraint-induced movement therapy

The unaffected arm is restrained for 8 hours a day, 12 days. During this period, the affected arm is trained.



Motor Cortex Plasticity in Ischemic Perinatal Stroke

CIMT induces neuroplastic changes on the synaptic level, detected as increased excitability and increased task-related brain activation (10~20 yrs old, 5 pts)



Walther M, Jueger H, Kuhnke N, et al: Motor cortex plasticity in ischemic perinatal stroke: a transcranial magnetic stimulation and functional MRI study. *Pediatr Neurol* 41:171-178, 2009

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Reviews on the effectiveness of CIMT

(Taub & Morris, 2001, Barecca et 2003, Hakkennes & Keating 2006)

- Evidence that it works! (moderate for acute strokes, **strong for subacute and chronic**) – for patients with some active wrist and hand
- minimum 10 degrees wrist ext, 10 degrees thumb abd/ext, 10 degrees extension MCP/IP in 2 other joints (pick up washcloth)



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Evidence for CIMT Stroke for the U/E

There are 60 RCTs examining the use of CIMT post stroke as of 2015.

- Mean number of subjects was 46; mean PEDro of 5.9; only 35% had concealed allocation and 15% blinded assessment of outcomes.
- Acute stage:** There is **strong evidence of benefit of mCIMT** in comparison to traditional therapies in the acute stage of stroke.
- Chronic stage:** There is **strong evidence of benefit for CIMT and mCIMT** in comparison to traditional therapies in the chronic stage of stroke.

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라면 짧은 시간 과제 훈련이 효과가 있었는가?

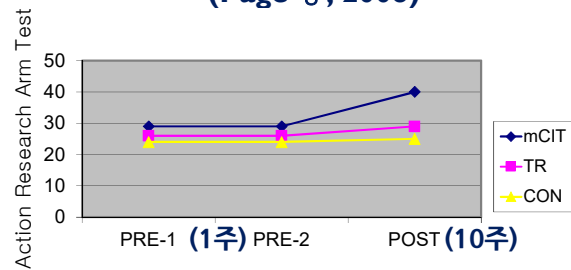


- 15분, task-specific training**이 걸질 재구성과 운동학습을 일으켰다(Classen 등, 1998, Butefisch 등, 1995).
- modified CIMT (30분X3일X10주 조형전략을 이용한 과제 훈련, 5시간 /1일 억제)**는 환측 상지를 더 많이 사용하게 하였고, 기능을 증진시켰다(Page 등, 2008).

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Modified CIMT in Chronic Stroke:

Results of a Single-Blinded Randomized Controlled Trial
(Page 등, 2008)



mCIMT (task-specific training, 30 min/day)
increases more affected arm use and
function!

신경과학에서 제시하는 신경재활 원리?

- 과제 **연습** 없이는 수행력 증진되지 않는다.
- 과제 연습에서 **반복** 요소 매우 중요하다.
- 연습은 단순 반복이 아니라 **복잡하고 의미 있는 과제**를 반복 연습하여야 한다.



감~사합니다!

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<http://neuropt.com>
<http://facebook.com/paulkjm>