Cant we all just get along?

robotics and motor learning:

The problem is not with the robots- its with us

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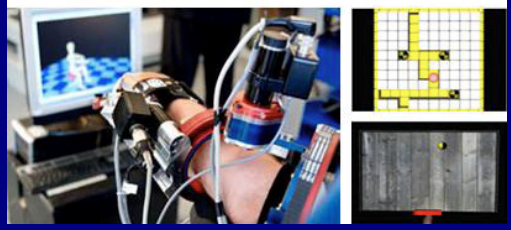
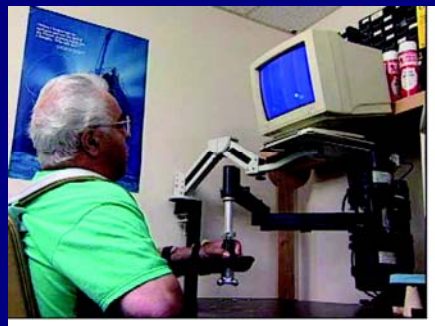
1. We have been using rehabilitation robots for about 10 years.

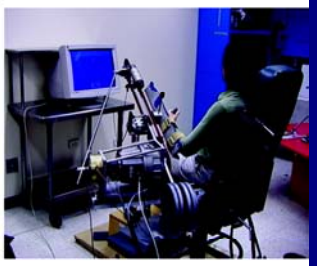
2. There is a need to critically appraise our performance and our progress, which has been modest

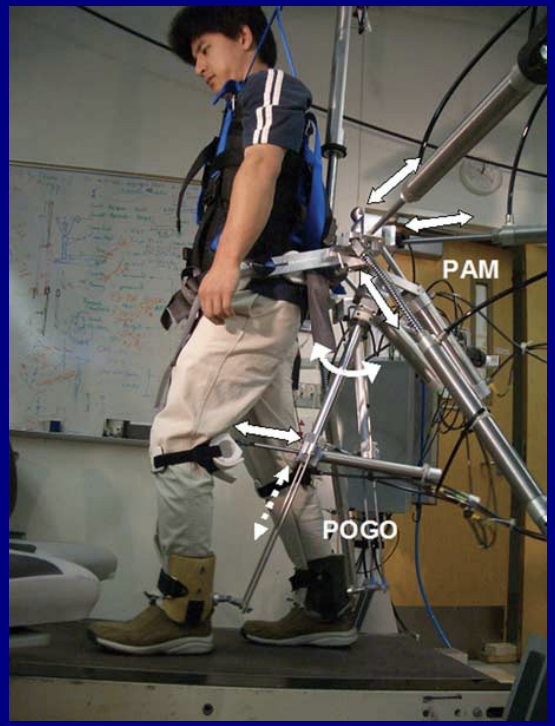
3. We need to develop a stronger theoretical/experimental framework, optimally-suited to the treatment of patients with injured brain or spinal cord

A collage of current robotic systems

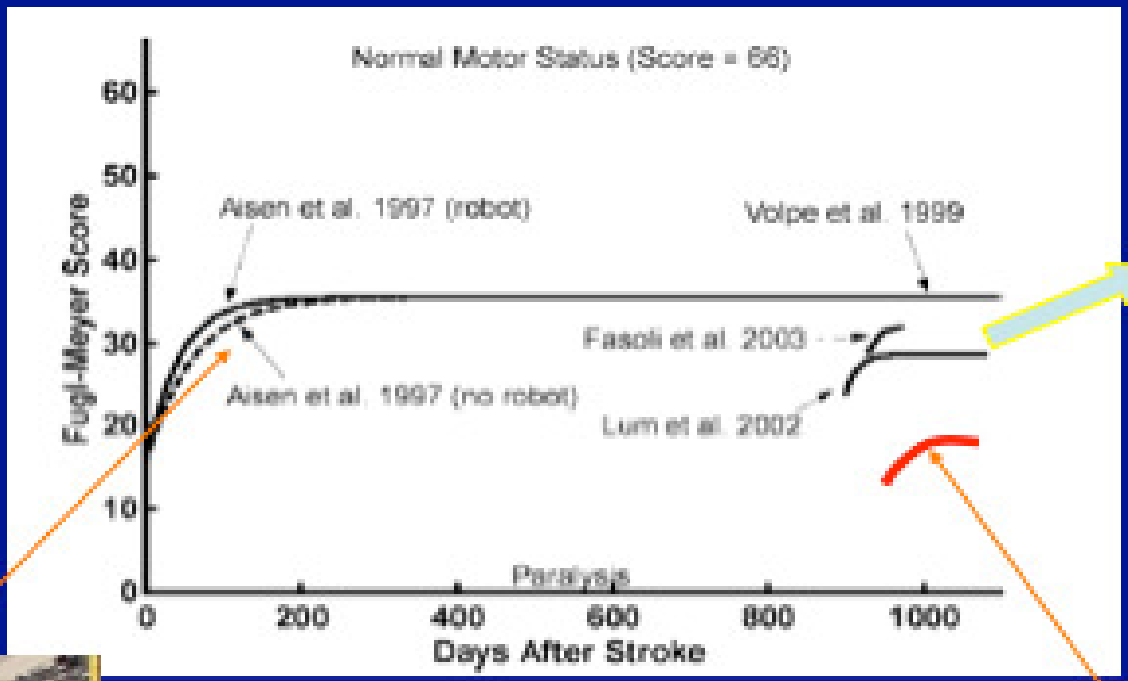








Robotic Therapy Training Gains are Modest (e.g. Fugl-Meyer score)



From
David Reinkensmeyer- UCI

T-WREX

Why are we not doing better ?

1. **We may have missed the right therapeutic window- perhaps it is in the first few days/weeks**
2. We may need more intense, more prolonged or different therapies.
3. We may need combination therapies

Perhaps----

Why are we not doing better ?

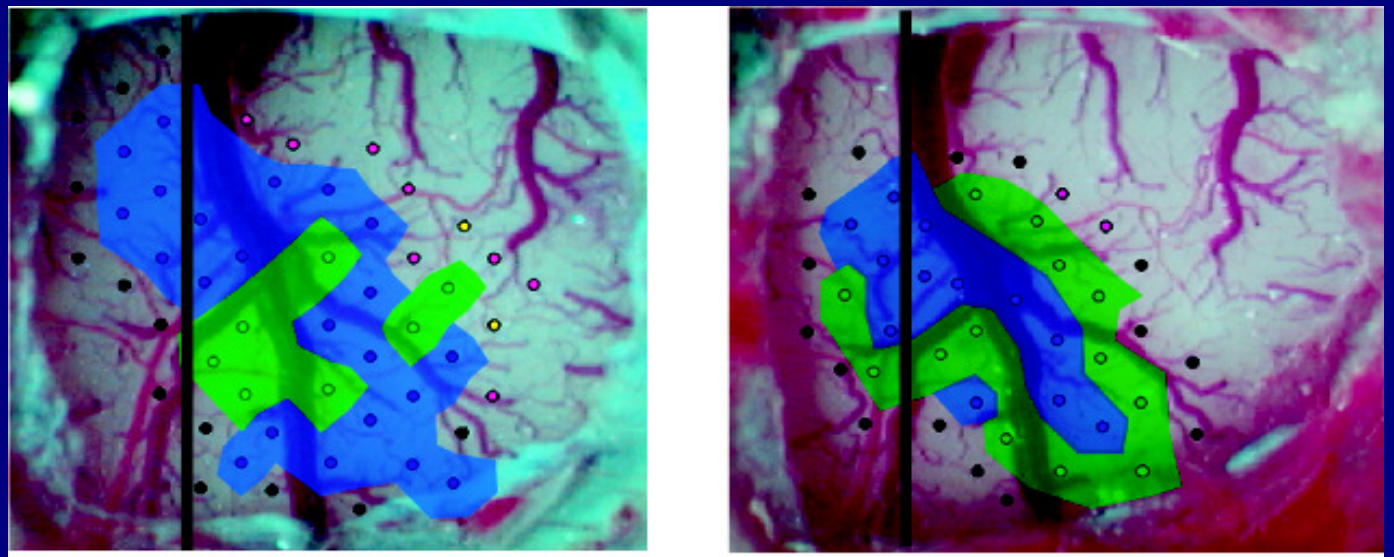
We have no coherent theoretical framework for the use of these robotic devices

- Should the robot emulate the actions of the therapist ?
- It is unclear how to characterize the actions of the therapist rigorously, and to determine which therapist actions are important.

Perhaps we can be guided by other areas of neuroscience

1. Neural plasticity- structural changes in neural circuits- MRI, DTI etc
2. Motor learning- improved motor performance for a given stimulus, with retention over time
3. Motor adaptation- changes in motor response to sustained stimuli
4. Motor skills acquisition – ability to perform complex tasks

Can cortical plasticity Guide Us?

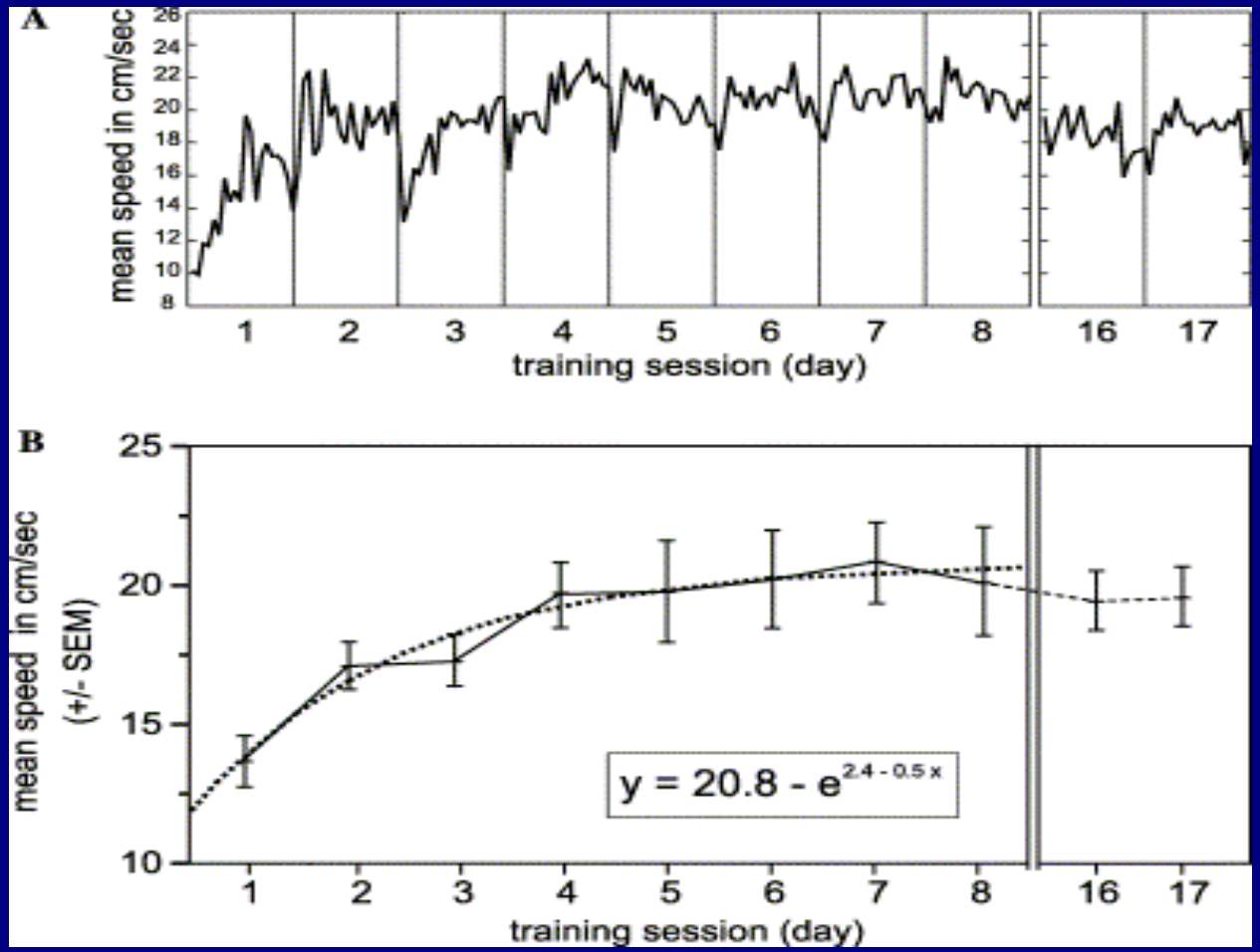


Potentially, but we do not know the relation
Between cortical plasticity, motor learning and skill acquisition

In Search of the Motor Engram: Motor Map Plasticity as a Mechanism for Encoding Motor Experience MARIE-H. MONFILS, ERIK J. PLAUTZ, and JEFFREY A. KLEIM NEUROSCIENTIST 11(5):471–483, 2005.

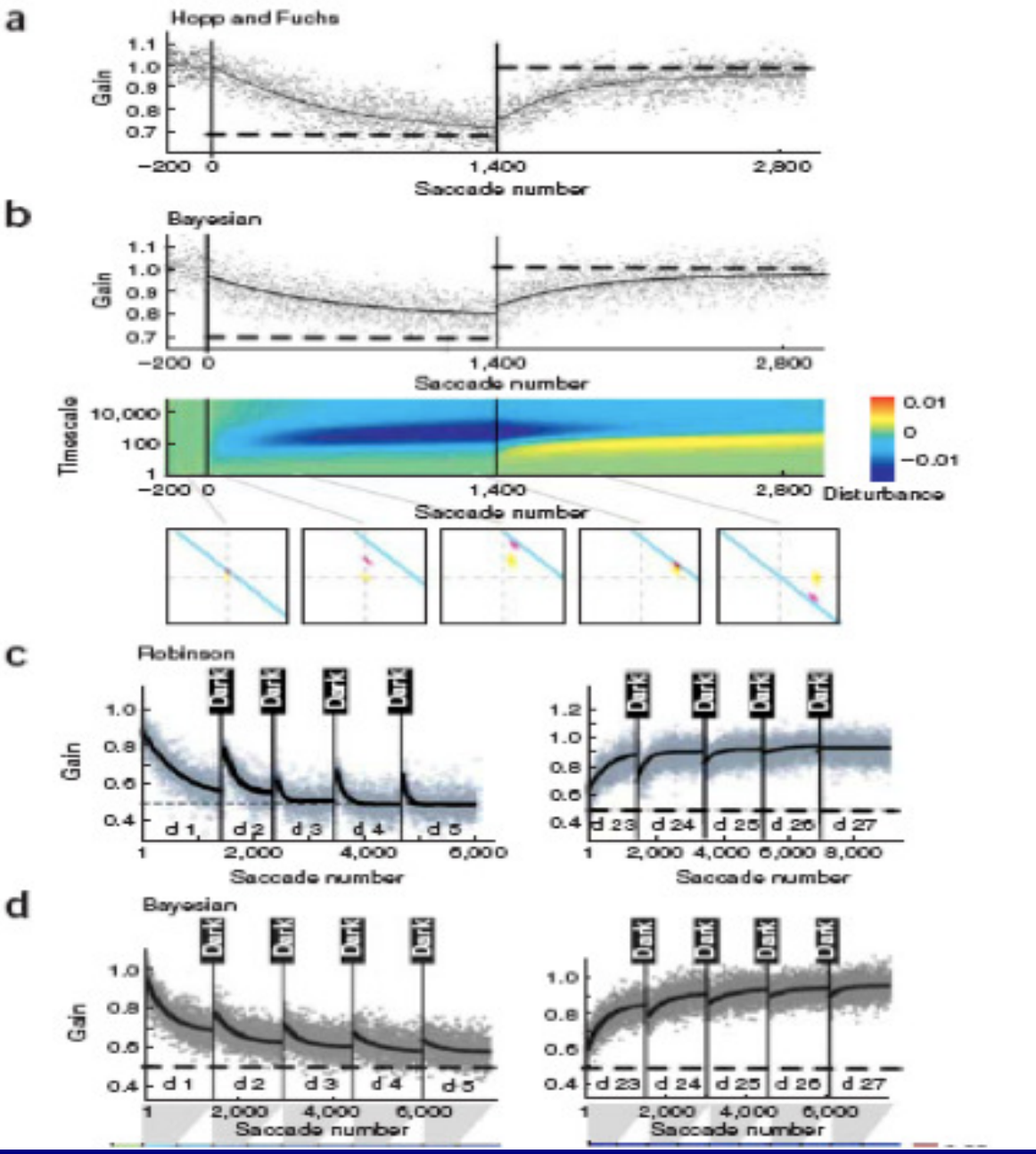
Does recovery involve motor skill learning?

Luft and Buitrago 2005



Two exemplary learning curves for two motor skill learning paradigms in rat. Both learning curves demonstrate within-session learning as well as a gradual improvement of mean sessions performance (intersession learning). (A) Maximum running speed mastered on an accelerating rotarod (cylindrical rod with a 7-cm diameter accelerating at 1 cm/s2) is plotted over time. Twenty running trials are performed per session. Sessions are separated by vertical dashed lines. (B) Success in reaching for a food pellet located outside of the cage (in percent of total number of reaching trials) is plotted over time. Each session consists of 100 reaching trials. Sessions are separated into quintiles of 20 trials to capture within-session performance gains.

Models of Saccade adaptation Kording et al, Nature Neuroscience 2007



What are the practical implications of motor learning theory?

- If there is learning within a session, and cumulative learning across sessions - can we assume that the two are closely linked?
- Disease states - stroke survivors can learn, but we do not know if they learn with a different time course.
- Motor learning in the ipsilesional hand is slower in stroke survivors, but we know relatively little about learning in the contralesional hand-

(see Winstein CJ, Merians AS, Sullivan KJ. Motor learning after unilateral brain damage. Neuropsychologia 1999)

What are the practical implications of learning theory?

- **How long should you learn (each session)?**

  Don't know- it is now a matter of convenience and insurance billing
- **How often should you learn?**

  Don't know, but mathematical models/simulations may help
- **How long do you rest ?** - is nocturnal delays different from other delays/ Apparently Yes
- **Can you learn while you sleep?** Apparently Yes
- **What do you do in between learning sessions?**

  Can you confound therapy by training in similar yet different tasks - apparently yes
- **How hard should we push?** Challenge point theory says we push to near failure. We rarely do this
- **Should Therapy be focused on meaningful tasks?** Potentially yes

- **WE NEED LEARNING RULES FOR CNS RECOVERY**

Background

Robotic therapy algorithms are currently ad hoc

- First generation robotic therapy controllers:
  - Moved the arms or legs along a desired path, sometimes rigidly, sometimes relying on thresholds or dead-bands to initiate assistance proportional to error
    - MIT-MANUS, MIME, ARM Guide, Lokomat, MGT
- Second generation robotic therapy controllers:
  - Adapt the level of assistance to the ability of the patient based on a measurement of error
    - MIT-MANUS, MIME, ARM Guide, Lokomat

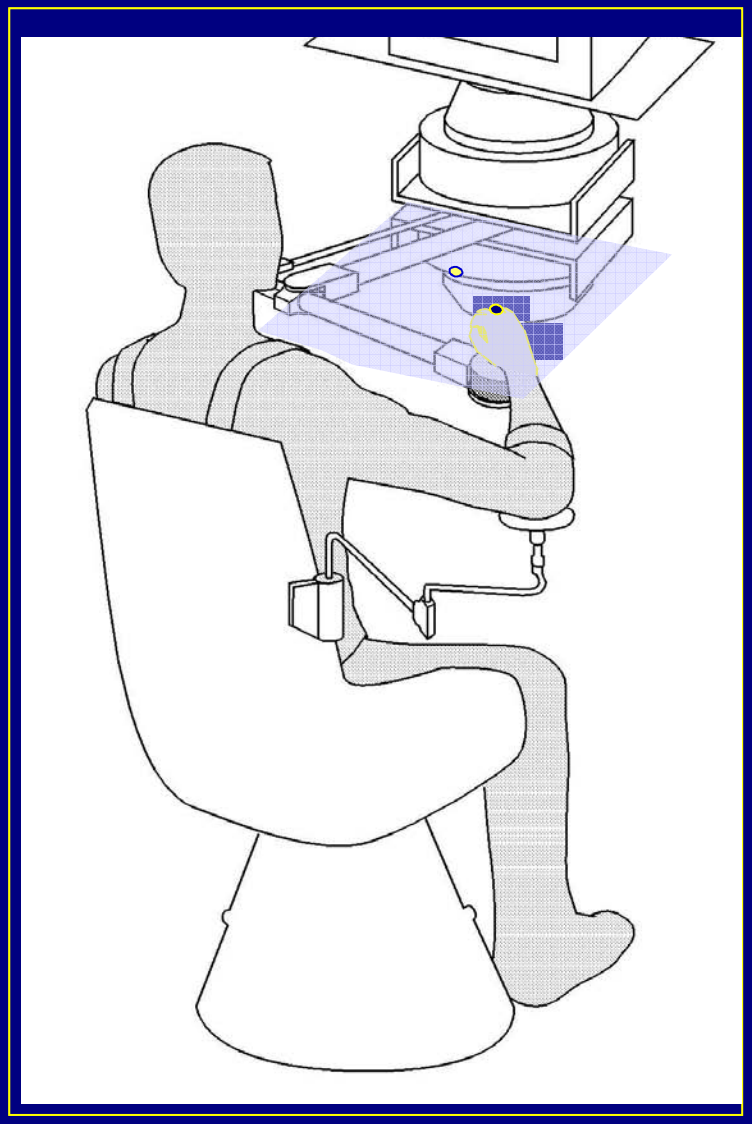
Rehabilitation Robots For upper extremity

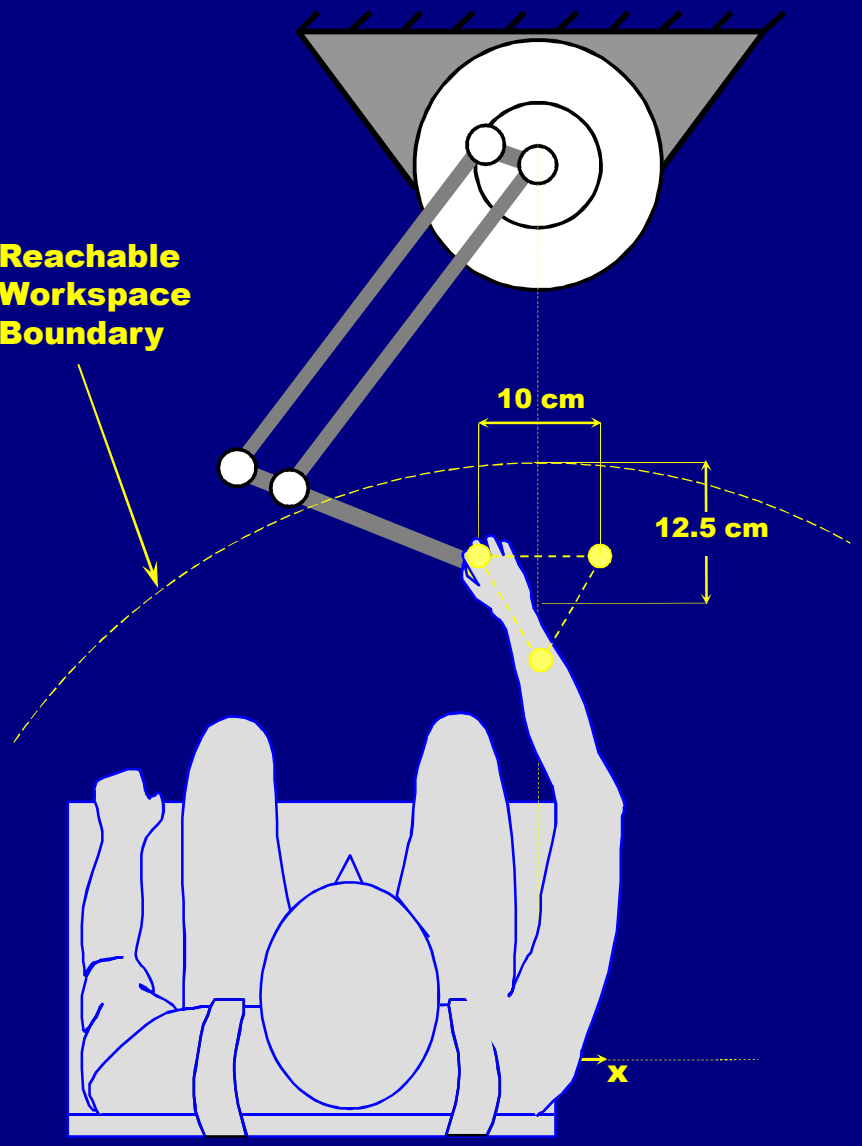
How should we deal with movement errors?

1. Error reduction - trajectory training

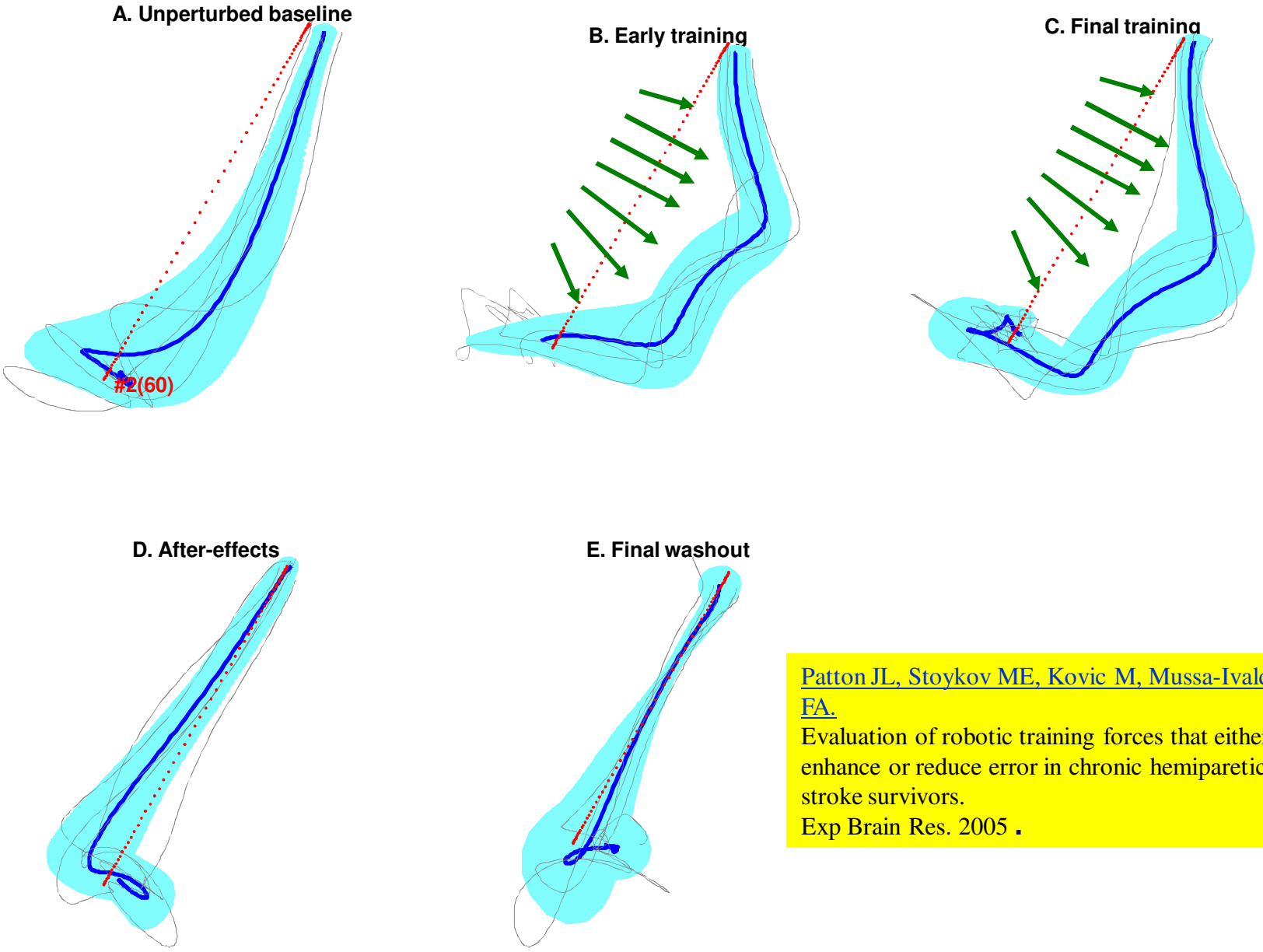
2. Error Augmentation - viscous force fields

Planar Robots- MIT manus



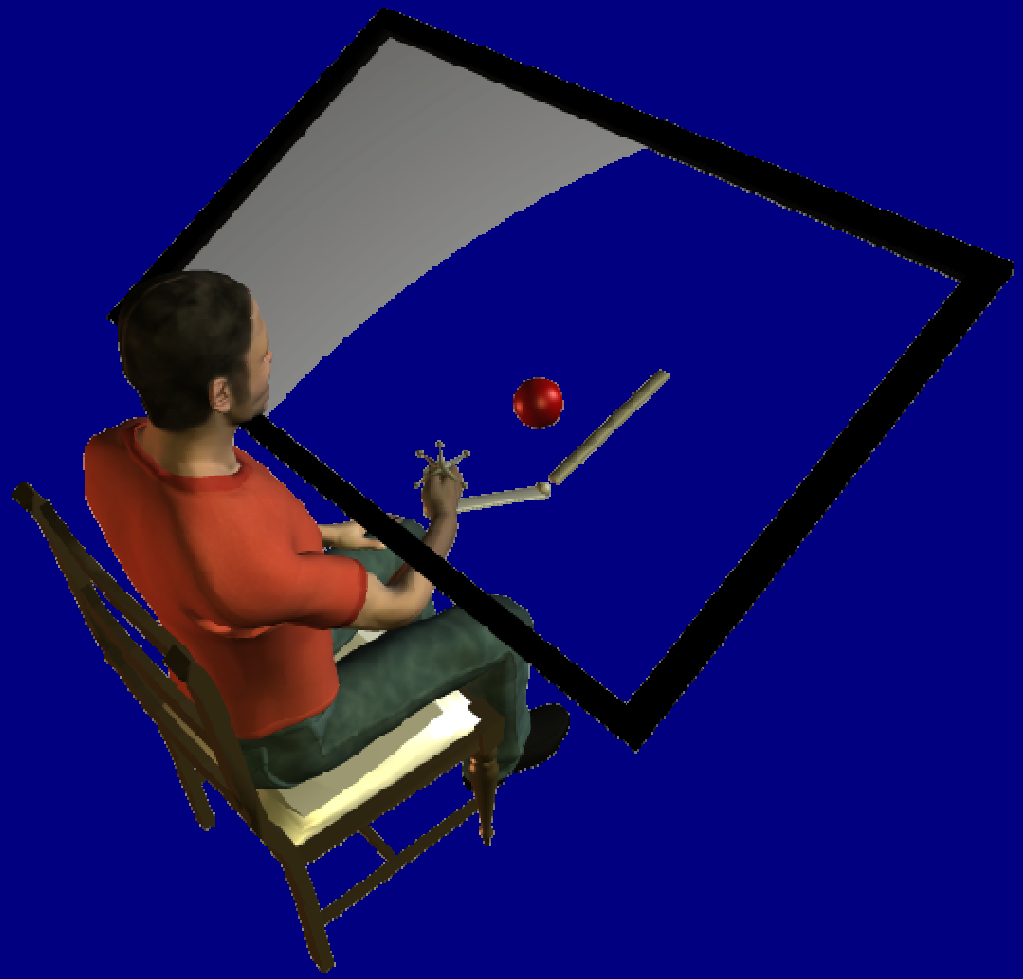


James Patton Ph.D & Sandro Mussa-Ivaldi Ph.D.



Patton JL, Stoykov ME, Kovic M, Mussa-Ivaldi FA.
Evaluation of robotic training forces that either enhance or reduce error in chronic hemiparetic stroke survivors.
Exp Brain Res. 2005 .

Error Augmentation (EA)



Study Population

5 Male, 6 Female
Age: 59.7 ± 12.7 years

Inclusion Criteria

Age > 18

Stroke at least 6 months earlier

Ischemic, Middle Cerebral Artery

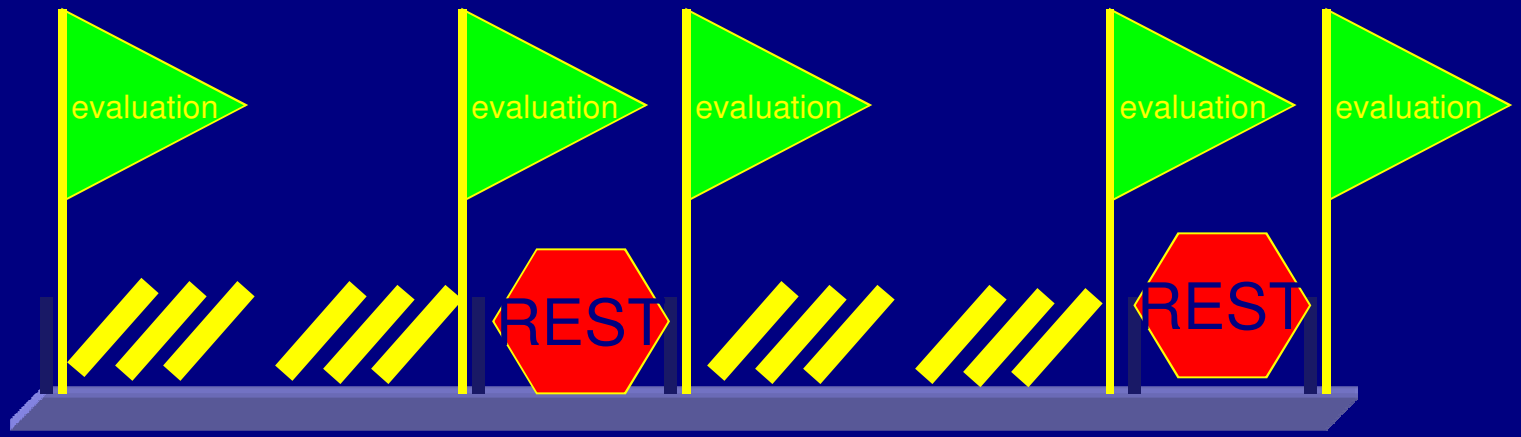
Hemorrhagic

Fugl-Meyer between 15 – 50

Randomized Trial Cross-Over Design

Error-Augmentation

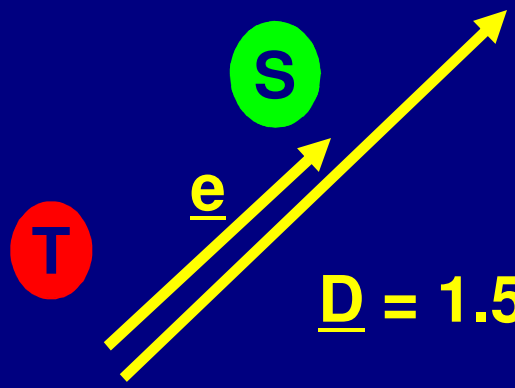
Control



2 weeks **1 week** **2 weeks** **1 week**

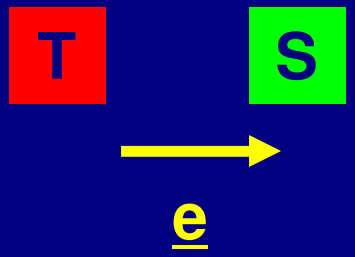
How is Error-Augmentation Achieved?

VISUAL



D = 1.5 e (m)

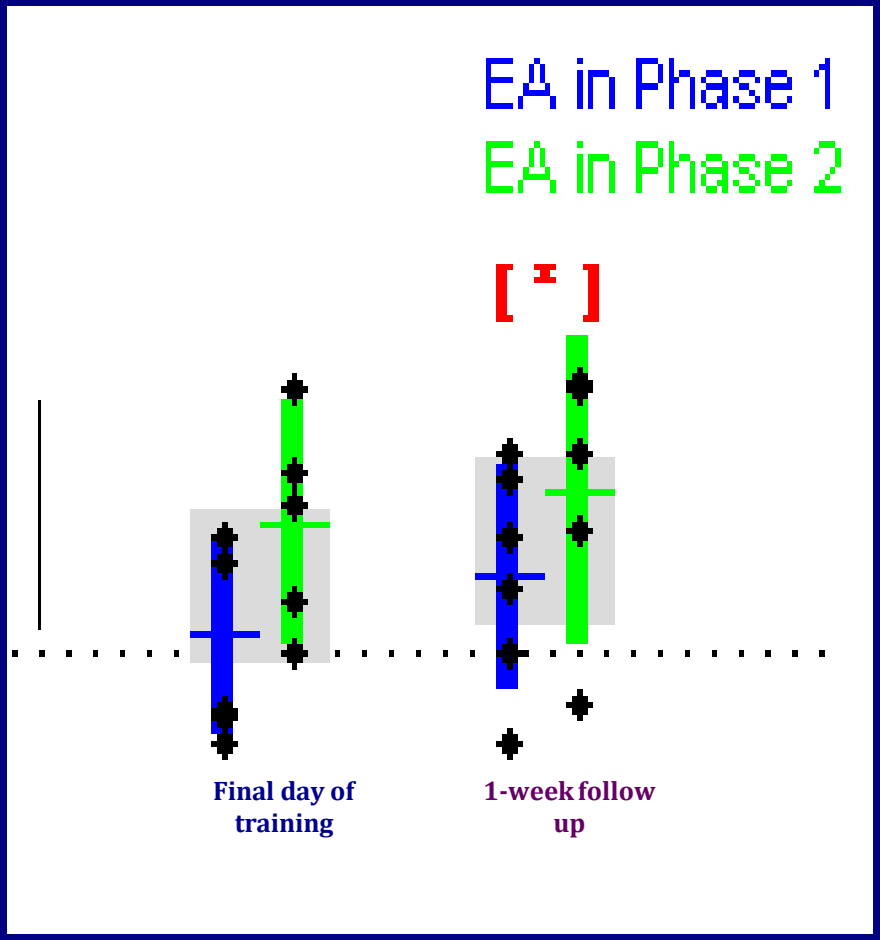
HAPTIC



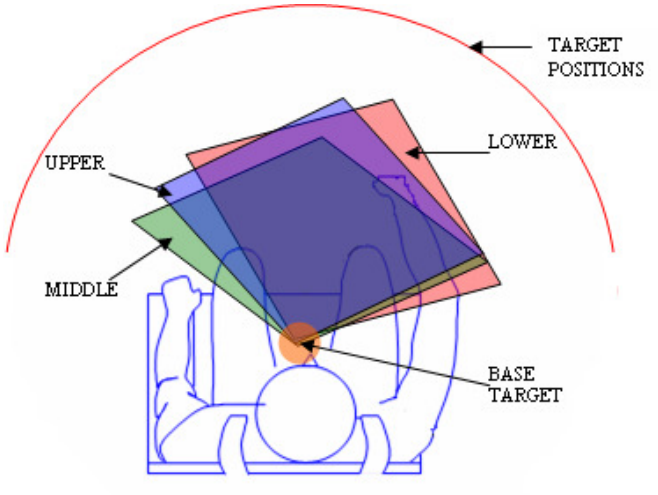
F = 100 e (N/m)

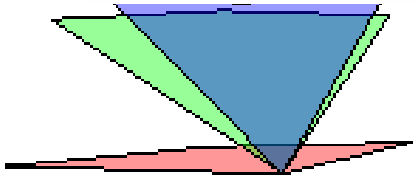
Saturates at 4N

Fugl-Meyer

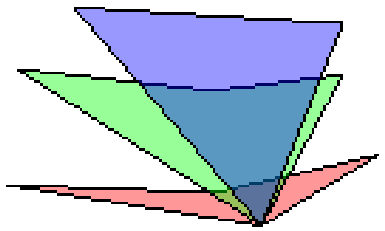

EA in Phase 1
EA in Phase 2
10%
Final day of training
1-week follow up

Range of Motion – a graphical report



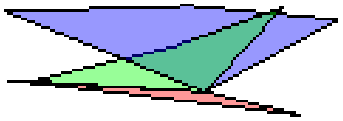


Post-Session 1

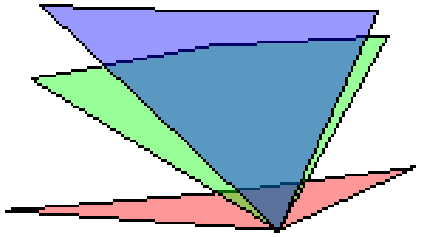


Post-Session 2

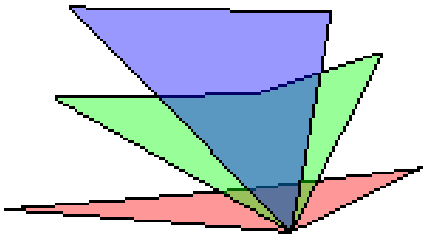
0.1m



Pre-Session 1

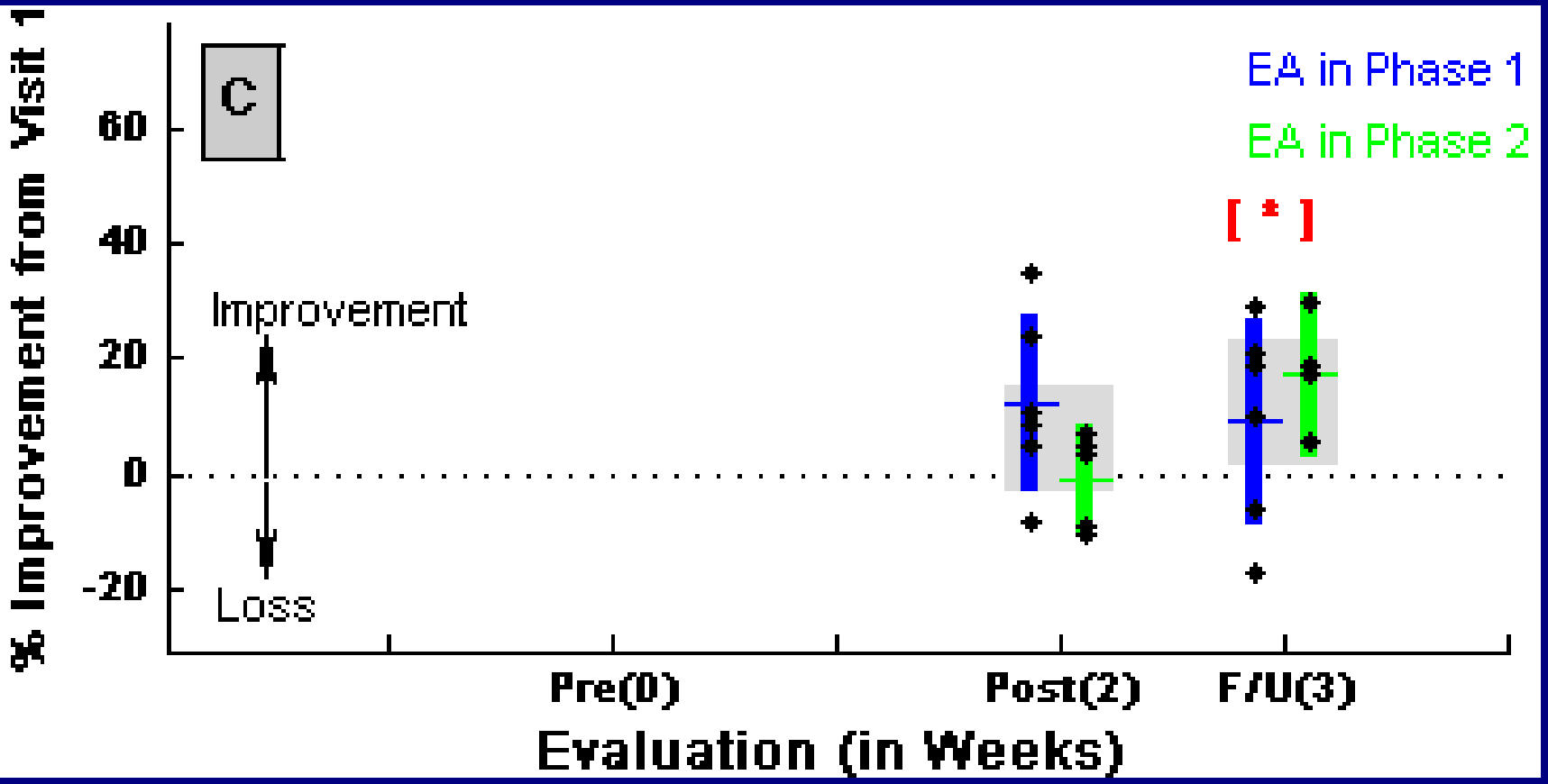


Pre-Session 2



One Week Followup

Reach Value


C
EA in Phase 1
EA in Phase 2
[*]
Improvement
Loss
60
40
20
0
-20
% Improvement from Visit 1
Pre(0)
Post(2)
F/U(3)
Evaluation (in Weeks)

A More Rigorous Approach

- Define a simplified motor task for which we can quantitatively describe the properties of motor adaptation
- Then, given this mathematical model of motor adaptation, derive a robotic intervention that enhances adaptation
- Demonstrate experimentally that adaptation is a forerunner of skill acquisition, and perhaps clinical improvement

So what is our position?

Robots are powerful and potentially effective tools to assist with rehabilitation of disabling neurological disorders, such as SCI and stroke

Our results to date are modest, although on average they are as good as or better that prevailing care methods, and they may offer cost advantages

But we need to develop testable mathematical models of learning in neurological disorders, and subject these models to experimental and clinical validation