RMD Functional & Applied Biomechanics Section (FAB LAB)

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We currently support 14 protocols for investigators in NINDS (8), NICHD (2), NHGRI (2), CC (2)

Cerebral palsy

- Most prevalent motor disability originating in childhood (2/1000); highest global rehabilitation burden (WHO 7/19)
- Group of brain injuries or disorders with complex multifactorial etiologies much like ASD (50% preterm)
- No cure; however, neonatal head cooling and magnesium sulfate in preterm have decreased prevalence & severity
- Efforts now to diagnose CP earlier to intervene sooner (to capitalize on developmental neuroplasticity)

Research Overview
(6 Active Protocols)

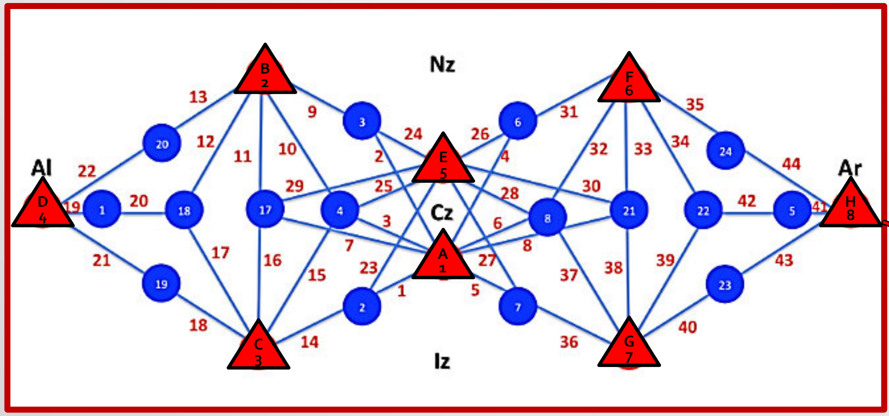
- 2008: Transform biomechanics laboratory to one that integrates biomechanics, neuroscience & neuroengineering to investigate motor impairments in CP
  - Mobile brain imaging of motor tasks (fNIRS & EEG)
- Goal: design & evaluate novel treatments to improve gait and other motor skills
  - EEG as real-time neural feedback for motor training
  - Rehabilitation robotics: 1st wearable pediatric exoskeleton (P.REX) and infant training device

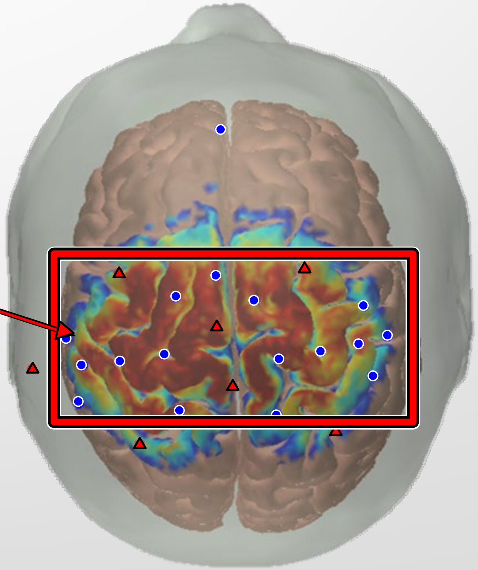
Mobile Brain Imaging (MoBI): fNIRS and EEG

- Unlike MRI, can study functional motor tasks in everyone; 50% with CP cannot do MRI
- Among the 1st laboratories to use fNIRS & EEG to study brain activity in motor tasks
- NIRS uses near IR light to monitor changes in concentration of oxy- and deoxygenated hemoglobin with brain activity (like fMRI)
- EEG records real-time electrical brain activity

Our Custom NIRS Probe Design

Specific source-detector (optode) geometry optimized for neuroimaging of motor cortex



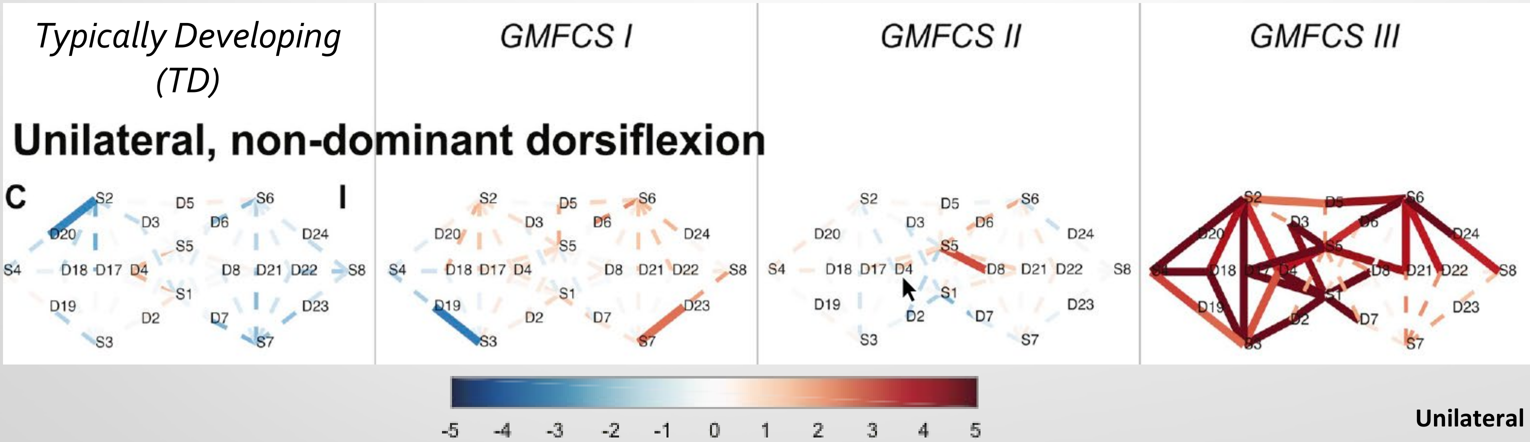


RED = Light Sources
BLUE = Detectors

HbT Differences by Group

L leg for UL tasks; R hemisphere activity expected

- Brain activation shown by filled channels with darker color indicating more activation and blue showing inhibition
- *Participants:* 14 ambulatory with cerebral palsy (CP) with GMFCS (motor levels I-II & 14 typically developing (TD) controls, age 9-45y
- *Task:* **Unilateral dorsiflexion**
- Tasks simple in controls are harder in CP, especially those with greatest involvement (GMFCS III)
- Less affected (ipsilateral) hemisphere in GMFCS III more active

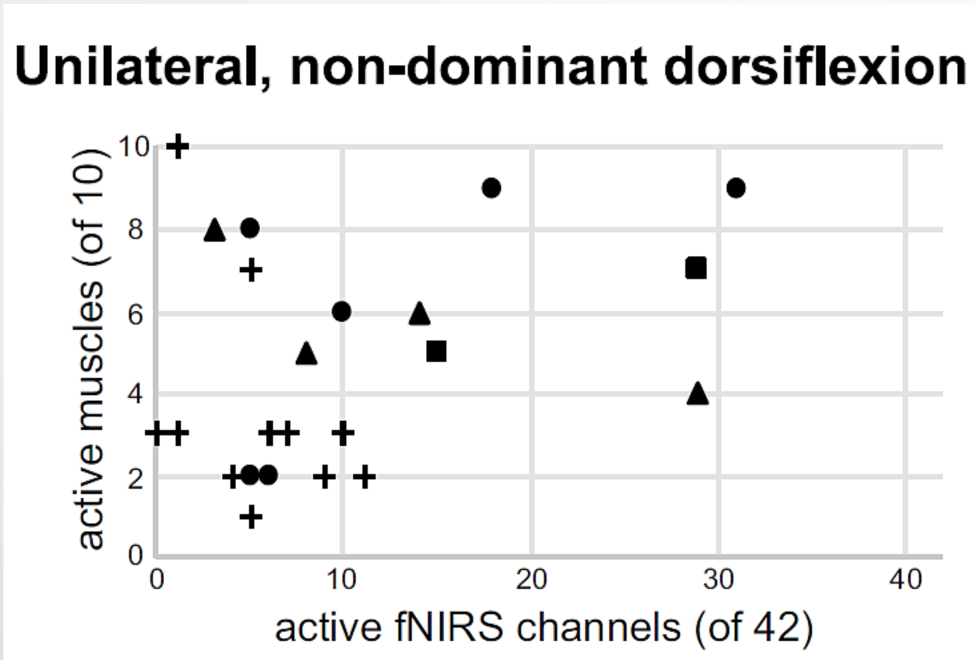


Sukal-Moulton, *Neuroimage*, 2018

Group comparisons HbT	Unilateral dorsiflexion
TD compared to GMFCS I	q < 0.001*
TD compared to GMFCS II	q = 0.183
TD compared to GMFCS III	q < 0.001*
GMFCS I compared to GMFCS II	q = 0.051
GMFCS I compared to GMFCS III	q < 0.001*
GMFCS II compared to GMFCS III	q < 0.001*

* indicates $q < 0.05$ or $p < 0.05$.

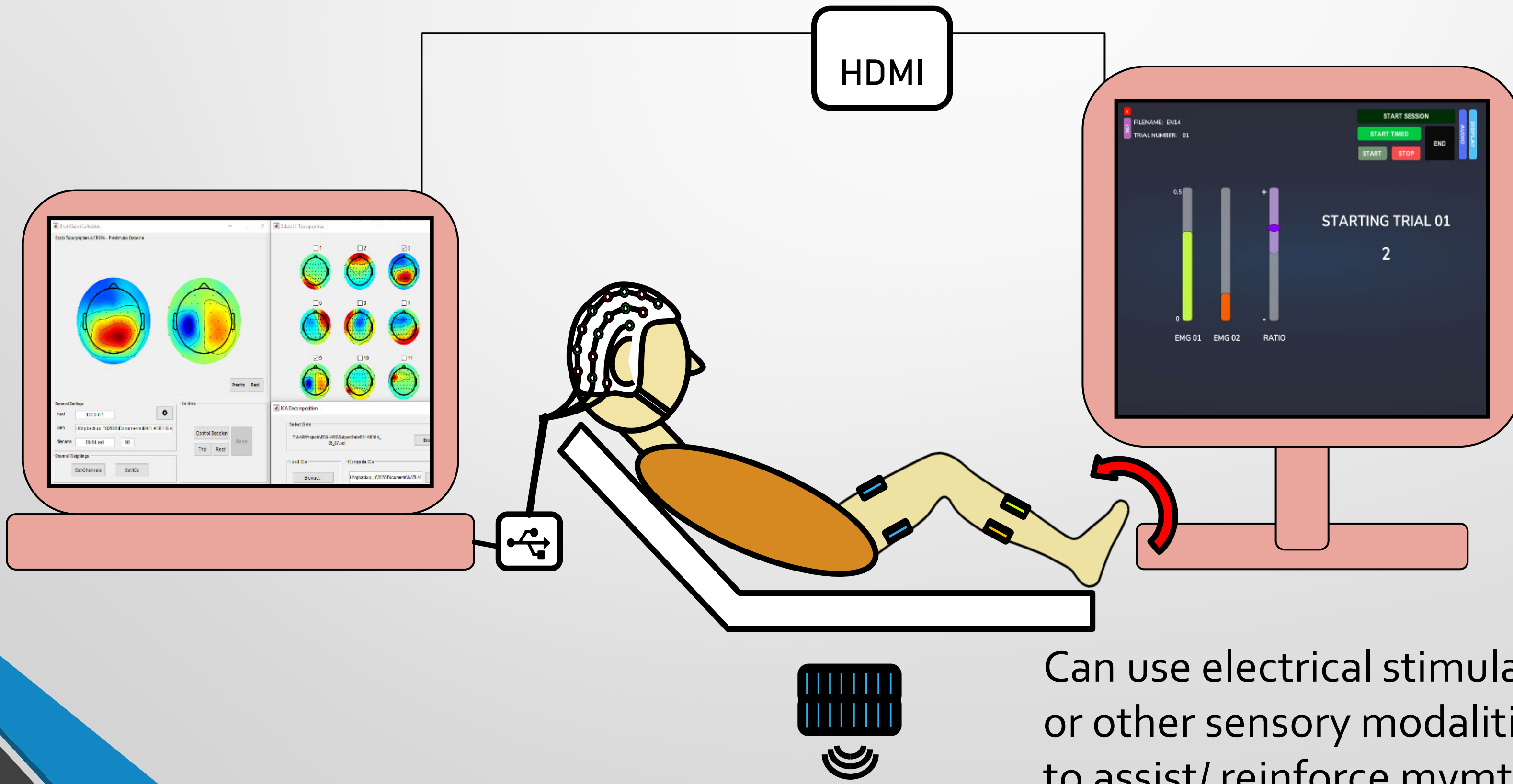
Relationship between Cortical and Muscle Activity



+*Typical Development* ▲*Gross Motor Functional Classification System* ●*GMFCSSII* ■*GMFCIII*

The number of active muscles was correlated with the number of active channels showing muscle effort is strongly related to brain effort and function ($p<0.05$)

Neural Feedback Set up for Ankle Dorsiflexion Training



Can use electrical stimulation or other sensory modalities to assist/ reinforce mvmt.

Gassert and Dietz *Journal of NeuroEngineering and Rehabilitation* (2018) 15:46
https://doi.org/10.1186/s12984-018-0383-x

Journal of NeuroEngineering and Rehabilitation

REVIEW **Open Access**

Rehabilitation robots for the treatment of sensorimotor deficits: a neurophysiological perspective

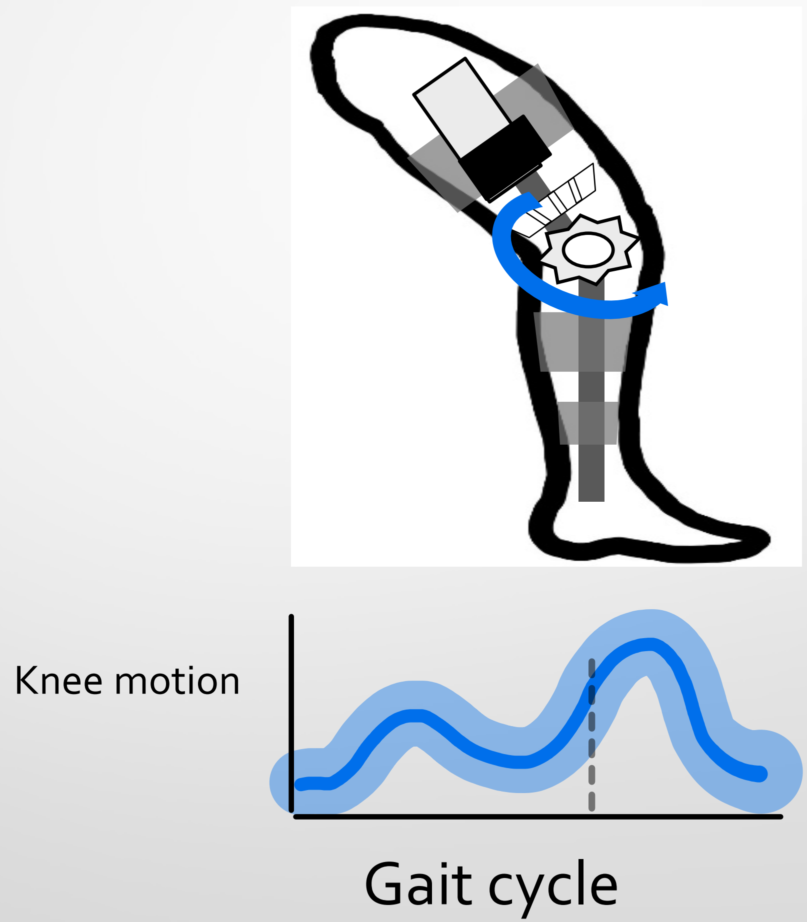
Roger Gassert[1*] and Volker Dietz[2]

- "Many of these innovations were technology-driven, limiting their clinical application and impact. Yet, **rehabilitation robots** should be designed on the basis of neurophysiological insights underlying normal and impaired sensorimotor functions, which requires interdisciplinary collaboration and knowledge".

Key Principles in Neurorehabilitation

- **EFFORT**: most effort exerted by the person, not the device or the therapist
- **ENGAGEMENT:** person should be cognitively involved in and motivated to do the task
- **ERROR:** person needs to be aware of and actively correct their movement errors

Most robotic devices use assist-as-needed (impedance) control



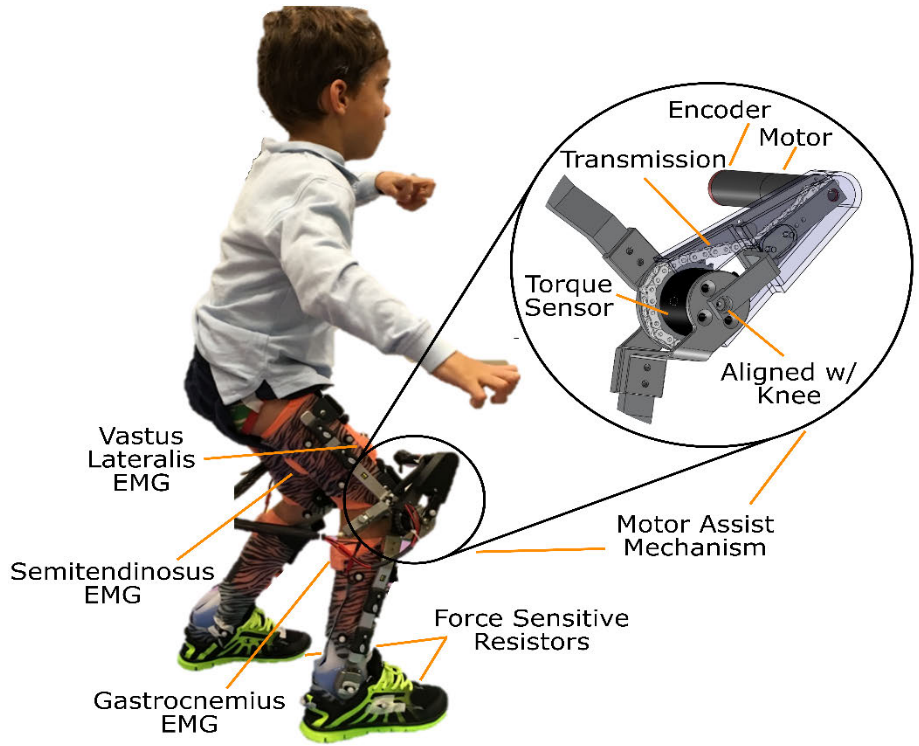
EFFORT & the "Slacking" Hypothesis (Reinkensmeyer)

- With impedance control, user is "nudged" when they deviate from the target trajectory.
- Unconsciously, instead of fighting the device, users will just let the device do it
- SOLUTION: provide slightly less assistance than needed
- If you can prevent slacking, outcomes from assist-as-needed were superior in stroke

1st Pediatric Exoskeleton for Crouch Gait

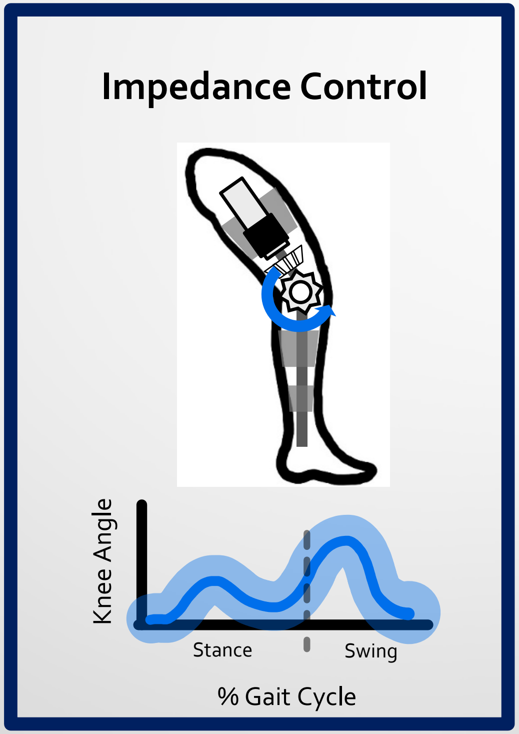
(Lerner, Damiano & Bulea, Sci Transl Med 2017)

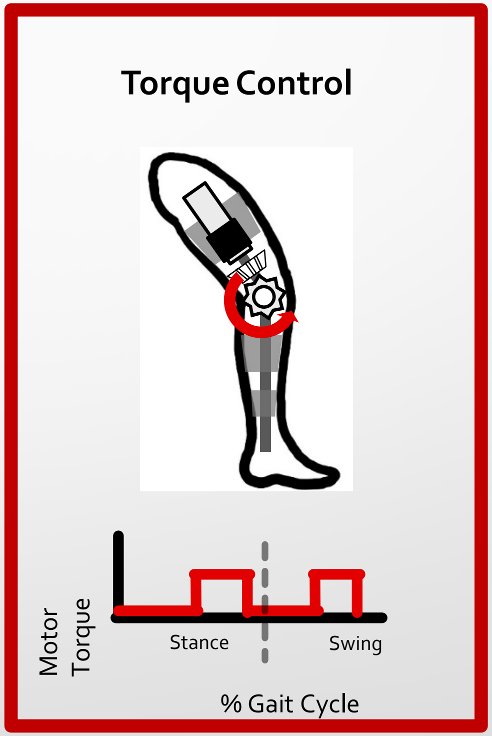
Blynn Shideler



- Custom molded orthotics
- Interchangeable motor assembly
- FES component to facilitate strengthening

Our Novel Controller





Earlier Intervention in CP

- Plasticity is greater in early development and capabilities may be lost permanently unless you intervene in time Hubel & Wiesel, 1981
- Overabundance of neurons at birth, then selective survival or death (nearly 50% neurons die in infancy)
- Synaptic no. & strength change rapidly (competition)
- Motor activity (or lack of) shapes these processes
- Brain does not receive expected inputs to develop normally in CP
- Animal evidence suggests window for neural recovery of motor system @ 3-6 months of age

Thank you for your attention!