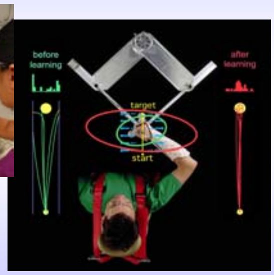
HUMAN ROBOTICS



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INTERESTS

Neuroscience

- models to investigate how the brain controls and learns movement
- towards efficient neural prostheses
- medical robotics, assistive devices
- bioengineering

Robotics

Bioengineering

THREE CURRENT PROJECTS

(I) How do humans perform unstable tasks?
(Neuroscience, using robotic tools and techniques)

(II) Virtual Reality Trainer for Micromanipulation
(medical simulation)

(III) Robotics Microassembly for Tissue Engineering
(microrobotics for Life Science)

(I) HOW DO HUMANS PERFORM UNSTABLE TASKS?

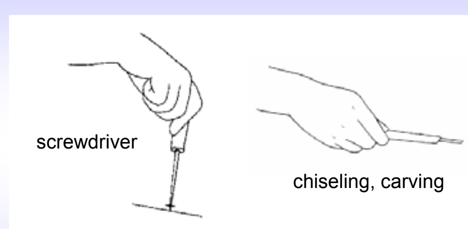
A. motivation: study the adaptation of movement to stable and unstable environments
B. psychophysical experiment: examine changes in trajectories, force and EMG waveforms over time
C. results and interpretation: measure hand stiffness in arm movements before and after learning
D. computational modeling: propose a neural mechanism to explain adaptation to arbitrary dynamics

with CHEW Chee Meng, TEE Keng Peng, Ganesh GOWRISHANKAR, NUS
Ted MILNER, David FRANKLIN, Simon Fraser University, Canada
KAWATO Mitsuo, OSU Rieko, ATR International, Japan

A: MOTIVATION

- to manipulate objects we have to compensate for the interaction dynamics
- stable tasks: opening a door, polishing – the object guides you
- unstable tasks: chiseling, carving – the tool slips
- control of unstable tasks is not yet well understood

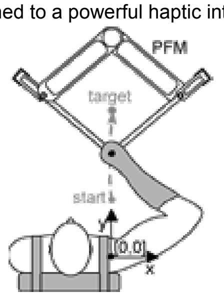
UNSTABLE TASKS



instability
-> motor variability or small disturbances can lead to large errors and unpredictability

TO INVESTIGATE STABLE AND UNSTABLE INTERACTIONS

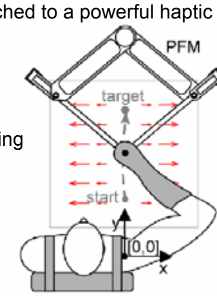
- Human subjects perform point to point movements with the hand attached to a powerful haptic interface



TO INVESTIGATE STABLE AND UNSTABLE INTERACTIONS

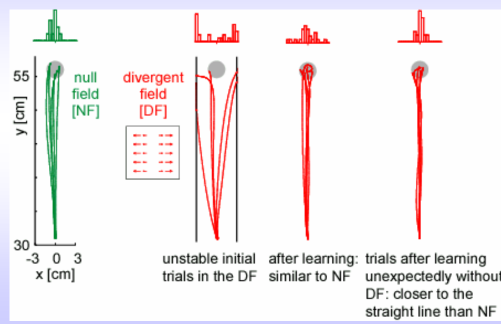
- Human subjects perform point to point movements with the hand attached to a powerful haptic interface

- forces diverting to left



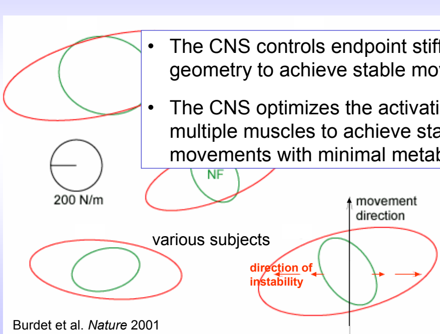
or to right

C. RESULTS AND INTERPRETATION



STIFFNESS BEFORE AND AFTER LEARNING THE DF

- The CNS controls endpoint stiffness geometry to achieve stable movements
- The CNS optimizes the activation of multiple muscles to achieve stable movements with minimal metabolic cost

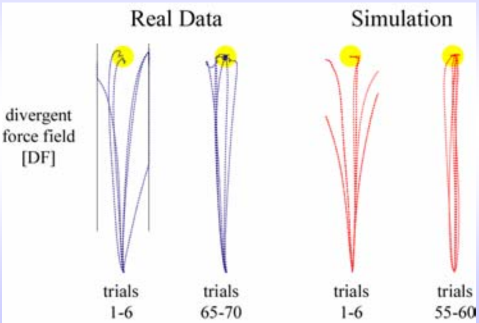


Burdet et al. *Nature* 2001

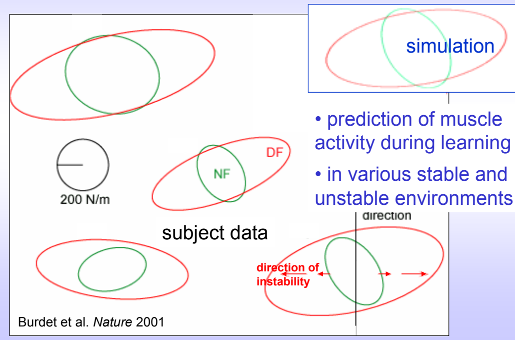
D: UNIFIED LEARNING OF STABLE AND UNSTABLE DYNAMICS (COMPUTATIONAL MODELING)

- a muscle space based approach
- as a muscle stretches, the reflex feedback updates the feedforward model on the next trial
- reflex information increases activity of antagonist muscles
- feedforward command gradually decreases to minimize metabolic cost

SIMULATED AND MEASURED TRAJECTORIES



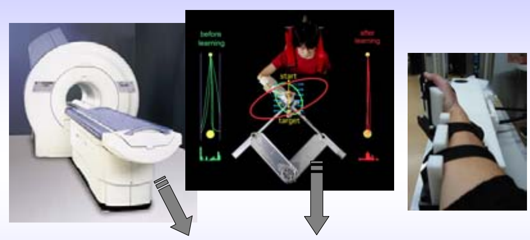
SIMULATED AND MEASURED STIFFNESS INCREASE



Such computational models, using measurable variables, can be used:

- as tools to investigate the neural control of posture and movement
- to simulate the effect of neuro-muscular disorders on control
- to develop better controllers for neural prostheses
- to simulate the outcome of different rehabilitation approaches
- to develop robot assisted rehabilitation protocols

fMRI COMPATIBLE HAPTIC INTERFACE



- how the brain controls motion and deals with stable and unstable dynamic environments
- to test our computational model
- MRI compatible robotic technology

NUS
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(II) VR TRAINER FOR MICROMANIPULATION

(with TEO Chee Leong, LIM Kian Meng, NUS; TIM Poston, JHS; LIM Beng Hai, NUH)

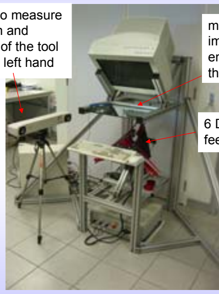
Operating with microscope requires significant learning:

- modified hand-eye coordination
- operate indirectly, not with fingers but via tools
- amplified tremor requires new motor strategies

JOHNS HOPKINS SINGAPORE
NUS
National University Hospital

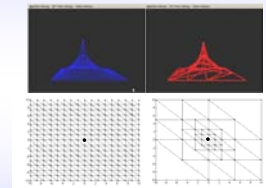
VR TRAINER FOR MICROMANIPULATION

VR TRAINER FOR MICROMANIPULATION



Simulation workstation with 3D visual and 6DOF haptic feedbacks

VR TRAINER FOR MICROMANIPULATION



- haptic forceps
- virtual microscope with controllable hand/eye relationship
- real-time haptic membrane for soft tissue simulation
- psychophysical experiments
- multisensory micromanipulation learning
  (visual, audio and haptic cues from Neuroscience)