



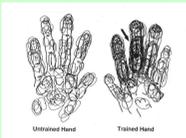
## Abstract

Using **VLSI** (Very-Large-Scale-Integrated-circuit) emulations to verify whether clinical symptoms of **dystonia** can be caused by certain neuronal abnormalities.

### Hypotheses:

1. Overlapping cortical representation causes motor overflow activities among fingers.
2. Tonic cortical drive to the cortex causes increased muscle activity.
3. Enlargement, de-differentiation in cortical representation (Byl & Merzenich 1997[1]) could contribute to overflow (Sanger 2000[2]).
4. Confusion on cortical representation can cause some types of dystonia.

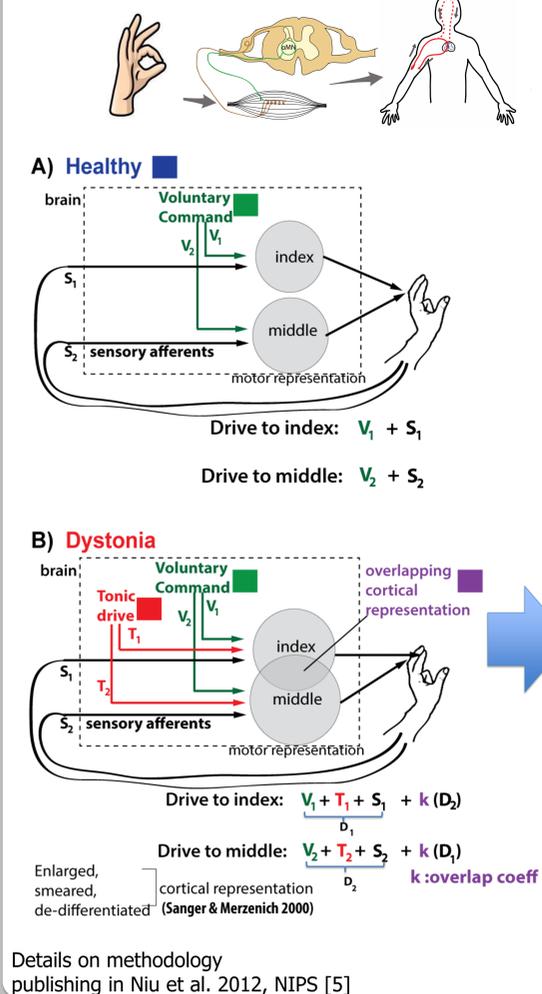
\* High plasticity could be the cause of abnormal cortical representation. (Rothwell 2006)



Sensory confusion (Byl & Merzenich)

## Methods: Dystonia Model

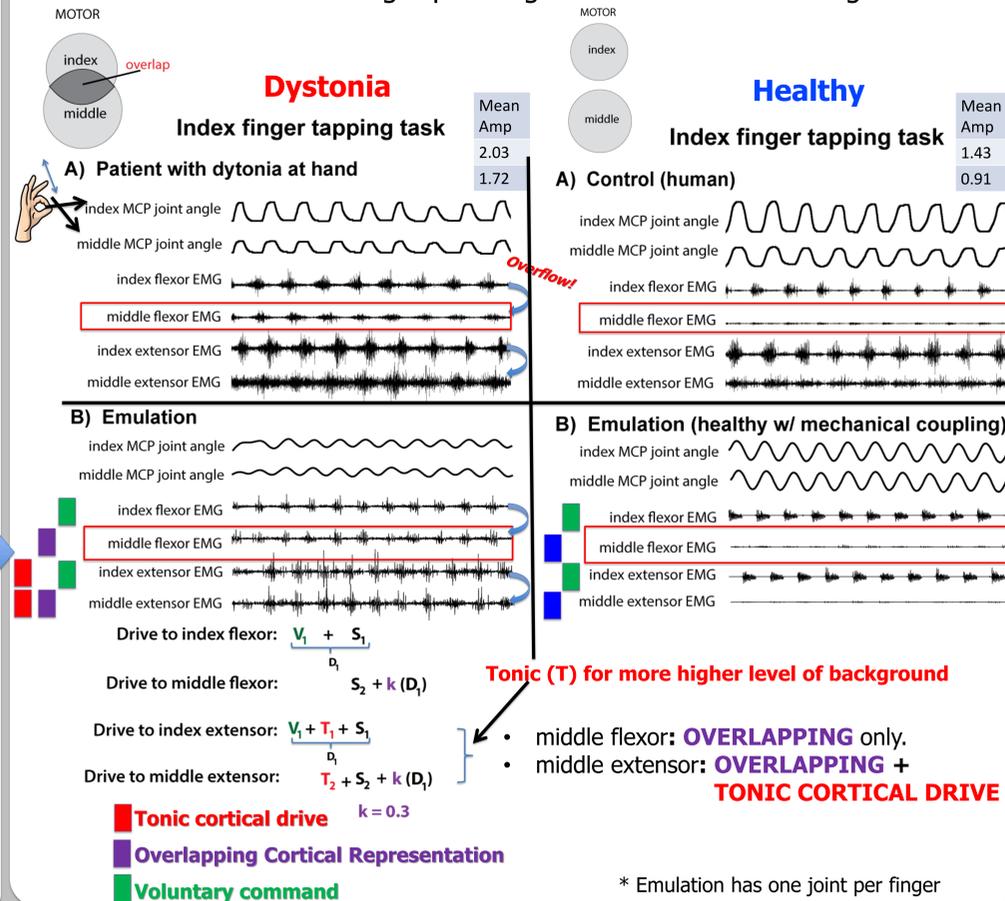
Emulated structures:



## Results: Motor overflow to an adjacent finger

**Hypothesis:** Abnormal sensorimotor representation leads to motor manifestation of overflow in dystonia in hand

Instruction: Do the finger pinching movement for index finger



## Conclusion

- Overlapping cortical representation & tonic cortical drive is sufficient to cause motor overflow symptom of dystonia
- VLSI emulation testbed allows verification of various kinds of models for clinical symptoms of neurological disorder.

## Things Learned & Interesting

- Mechanical coupling between fingers is high both in control and dystonia patient, but nearby finger shows high EMG activity only in dystonia. This is a result of overflow.
- Overflowed muscle activities could be due to enlarged / de-differentiation [1].
- There seems to be more background co-contraction in the finger extensors. This could be due to tonic cortical drive.

## Future Work

- Simulate development of abnormal motor representation by plasticity with dystonia models.
- Emulate: Could excessive cortical activities lead to 'overlapping' by plasticity models?
- Emulate: Could 'overlapping' model itself increase overall gain of sensorimotor loop?

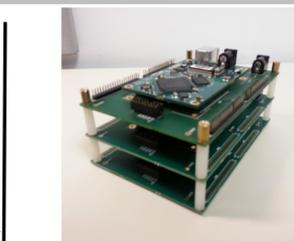
## Background



**Dystonia** is a movement disorder that exhibits (Sanger et al. 2003 [3]):

- **involuntary** muscle contractions, sustained or inter-mittent ;
- twisting and repetitive **movements**;
- persistent recurring **postures**;
- Increased joint **stiffness**;

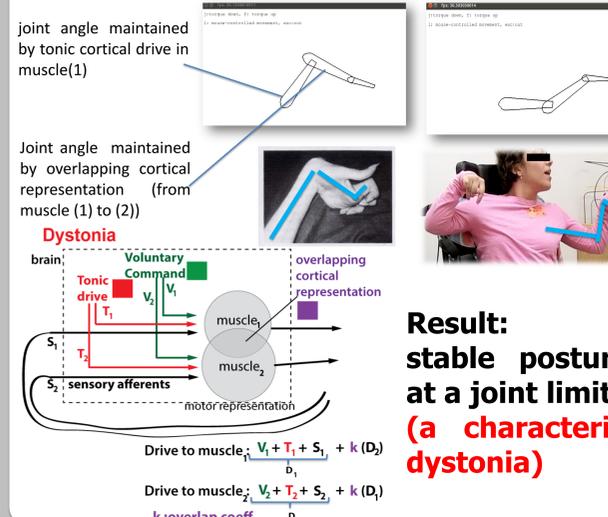
- muscle **overflow** - extra activity in muscles not directly involved in the desired movement.
- Physiological evidence relevant to modeling dystonia:
- Dystonia postures are associated with excessive stretch reflex (Doornik & Sanger 2009 [4]), which
  - has multiple components including **long-latency** ones
  - extra cortical activity is suggested to be a major cause of dystonia.



### Why FPGA hardware?

- Temporal resolution up to **0.001s**
- Describe from neurons to muscles
- **Fast**, scalable, portable, modifiable, easy to wire, etc.
- In this model: 4, 600 neurons emulated in up to speed of one year in a day

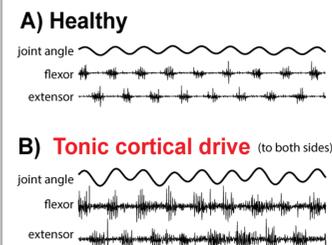
## Dystonic Fixed Postures with dystonia Model



**Result:**  
**stable postures not at a joint limit.**  
**(a characteristic of dystonia)**

## More results

### Voluntary arm swinging



- Model used:
- Spiking Neurons: Izhikevich 2003
  - Spindle: Meliusnic, et al. 2006
  - Connection: Sanger 2010
  - Muscle: Hill-type. Hill 1938

## References

- [1] Byl NN, Merzenich MM, Cheung S, Bedenbaugh P, Nagarajan SS, Jenkins WM. A primate model for studying focal dystonia and repetitive strain injury: effects on the primary somatosensory cortex. *Phys Ther.*1997;14(3):269-284
- [2] Sanger TD, Merzenich MM. Computational model of the role of sensory disorganization in focal task-specific dystonia. *J Neurophysiol* (2000)84:2458-64.
- [3] Sanger TD, Chen D, Fehlings DL, et al. Definition and classification of hyperkinetic movements in childhood. *Mov Disord.* 2010;25:1538-1549. doi: 10.1002/mds.23088.
- [4] van Doornik, J., Kukke, S., & Sanger, T. D. (2009). Hypertonia in childhood secondary dystonia due to cerebral palsy is associated with reflex muscle activation. *Mov Disord,* 24(7), 965-971. doi: 10.1002/mds.22282
- [5] Niu et al. Multi-scale Hyper-time Hardware Emulation of Human Motor Nervous System Based on Spiking Neurons using FPGA. NIPS 2012

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