Emulation of the origin and persistence of overflow in focal task-specific dystonia

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**Question**
How does overflow in focal task-specific dystonia develop and why does it persist?

**What did we find?**
Repetitive & correlated use of two distinct sensory regions is sufficient to cause development of motor overflow

**Introduction**

- **Focal task-specific dystonia** is characterized by excessive muscle contraction producing abnormal postures during selective motor activity that often involve highly skilled, repetitive movements.

**Commonly known for:**
- Writer’s cramp
- Musician’s cramp
- Occupational cramps

**Characteristic features:**
- Overflow
- Prolonged abnormal postures
- Permanent motor deficit
- Loss of fine motor control

**Physiological evidence:**
- De-differentiation in cortical representation (Bly et al. 1997)
- Abnormal tactile form perception and spatial and sensory processing (Bara-Jimenez et al. 2000)
- Loss of muscle selectivity in fingers (Young et al. 2011[1])

**Overflow idea**

- Growth of cross-talk synapses is sufficient to cause motor overflow to an adjacent finger.

**Cortical map**

**Sensory neurons**

**Crosstalk synapses**

**Blurred boundaries in sensory map** (Nudo 2003)

**What is the plasticity mechanism?**

- Spike-Timing-Dependent Plasticity

**Synaptic connections**

**FP (Field Programmable Gate Array)**
- Fast
- Rapid prototyping
- Scalable
- For high-speed emulations

**Development of overflow in dystonia**

**Questions:** What repetitive & correlated movement lead to the growth of cross-talk?
Will the disease perpetuate after the correlated movement has ended?

**Phase 1:**
- Two different stimuli to two input sensory neurons
- Pre-post synaptic activities are uncorrelated.
- Cross-talk is suppressed.

**Phase 2:**
- Coupled stimuli to two input neurons
- Pre-post synaptic activities are correlated.
- Growth of cross-talk (=De-differentiation in cortical map)
- Overflow develops

**Phase 3:**
- Uncorrelated inputs
- Inputs are the same as phase 1
- Pre-post synaptic activities still correlated.
- Overflow persists.

**How does the result relate to dystonia?**

- This is a model of development of overflow in focal task-specific dystonia.
- Blurred boundaries in cortical representation is found in dystonia and we showed how it could develop and eventually lead to motor overflow.

**Implication of the result**

- Once dystonia occurs, it sticks. (Hysteresis phenomenon).
- Temporal sensory abnormalities could lead to motor permanent abnormalities.
- De-differentiation in sensory cortex, increased receptive field size could increase sensorimotor loop gain. (Sanger & Merzenich 2000[2])
- Treatment should target suppressing the cross-talk.
- Amblyopia can also be simulated with the same mechanism shown here.

**Limitation**

- This is a reduced representation of neural structures

**Conclusion**

- Repetitive and correlated movement is sufficient to produce the development of overflow in focal task-specific dystonia
- Spiking neurons with mere STDP rule are sufficient to produce this
- High speed emulation with physiologically realistic learning rate over years.


This project is funded by NIH R01NS069214-02