Plasticity in the Developing Brain: Implications for Rehabilitation

Michael V. Johnston, 2009

http://teddmusic.com/wp-content/uploads/2010/12/15-musical-instrument-for-children1.jpg

http://i.telegraph.co.uk/multimedia/archive/01292/tennis_1292682c.jpg

Mechanisms for Plasticity in CNS

- Prenatal overproduction of neurons adaptive
- Neurogenesis persists into adulthood in select areas e.g. SVZ of lateral ventricles & subgranular zone of dentate gyrus of hippocampus
- Newborn neurons contribute to recovery & have protective effect after injury

Activity-Dependent Plasticity

- Synaptic plasticity = changes in strength of neurotransmission via past activity experienced by the synapse.
  - Long-term increases (LTP): rapid presynaptic stimulation, enhanced in immature brain compared to adult, associated w/memory formation
  - Long-term decreases (LTD): slow postsynaptic stimulation
- LTP & LTD form basis for activity-dependent reorganization and stabilization of neuronal networks in sensory-motor cortex

Overproduction & Pruning

- excess synapses, activity-dependent selection
- correlation between behavioral dev. & temporal periods of dynamic changes in synaptic # in specific cortical areas
- intelligence related to greater initial growth & prolonged cortical development
- Thus, prolonged overproduction & pruning → greater plasticity

HOWEVER, Plasticity's strength can be a weakness

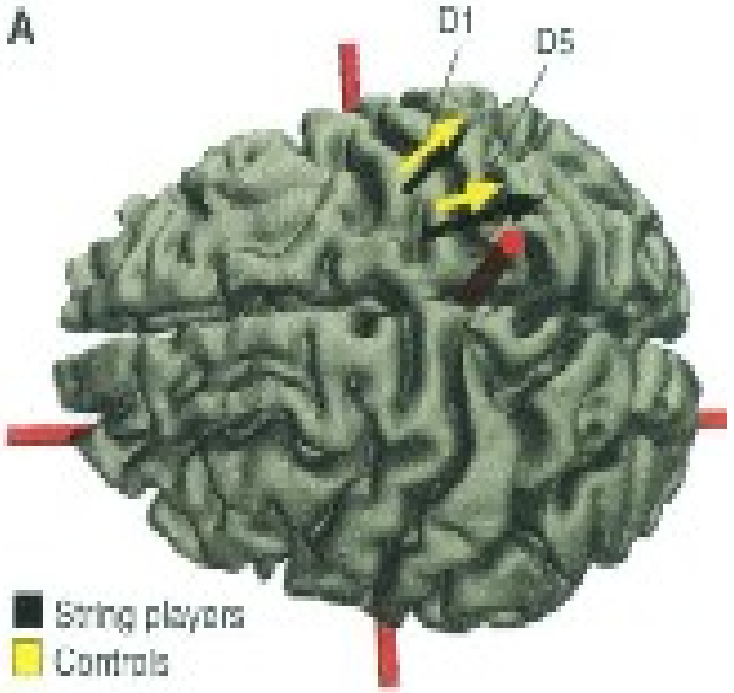
- Children's nervous system vulnerable to sensory deprivation & abuse
- Vulnerable to drugs that impair neuronal activity
- Enhanced excitability at glutamate synapses → seizures & excitotoxicity more likely
- Thus, greater plasticity does not always mean better recovery from injuries

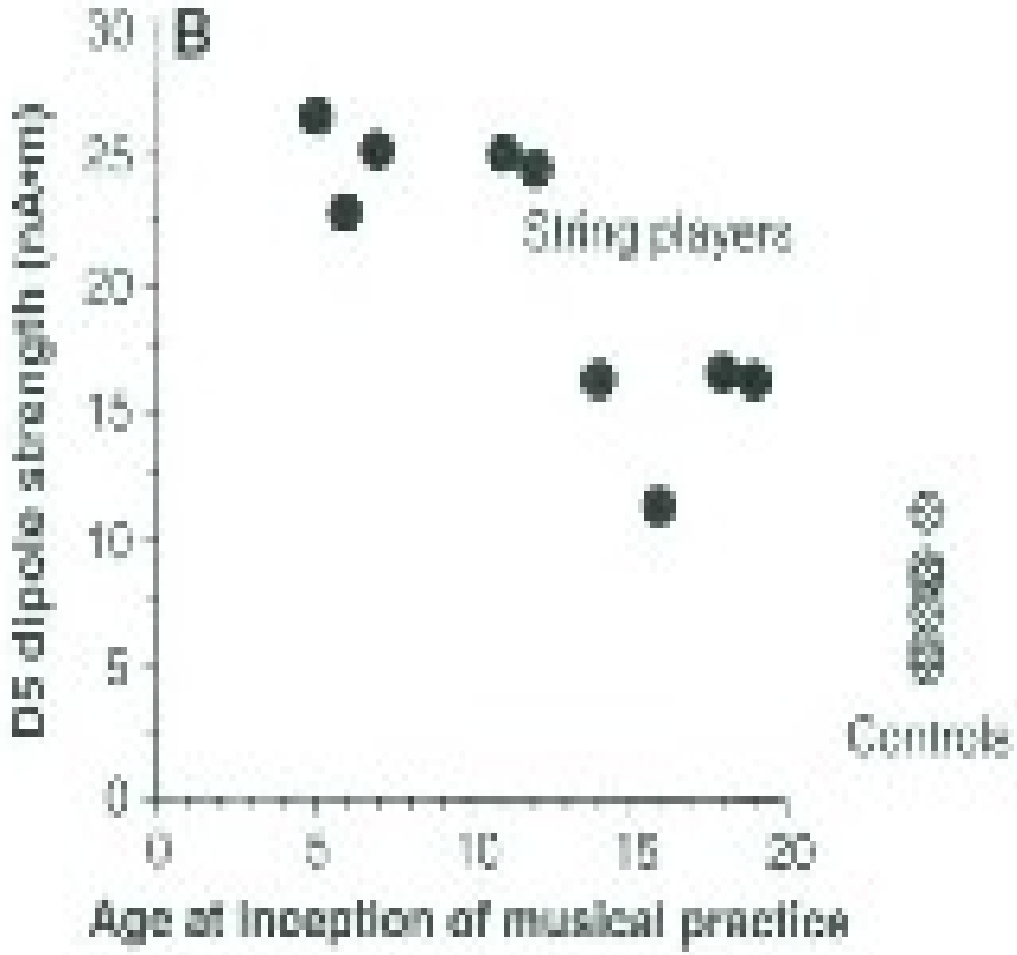
Structural Changes Via Exp.

- Primates' & humans' somatotopic map for hands & fingers much larger compared to other animals, importance of refined hand movements
- Relation between synaptic plasticity mechanisms & cortical map plasticity
- Cortical map plasticity continuously modulated by activity

Clinical Examples

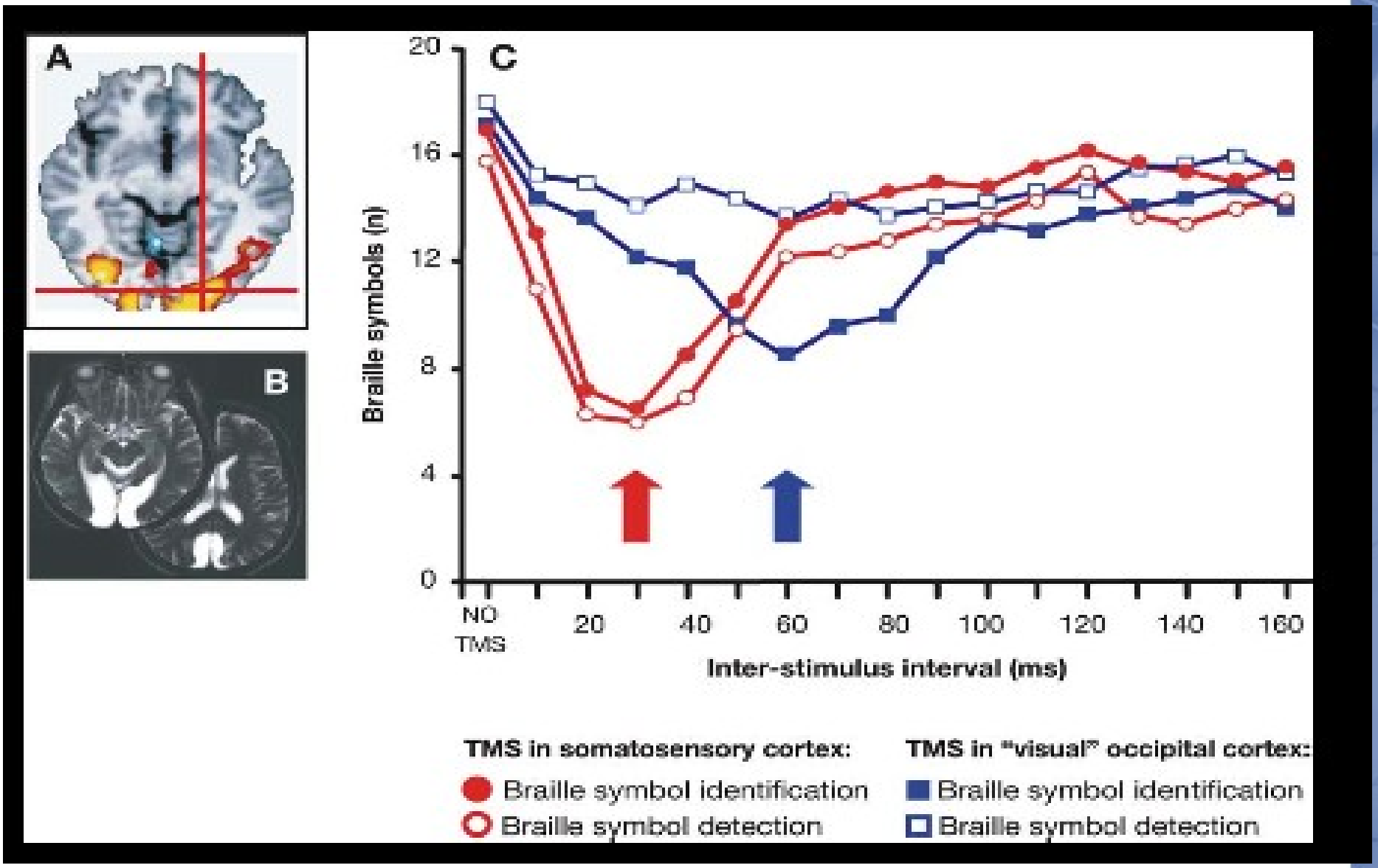
- (Elbert et al.. 1995)





Clinical Examples (Cont'd)

- (Sadato et al., 1996)



A) PET occiptal activation during Braille-reading in early-blind subject
B) Braille alexia following bilateral occiptal stroke in congenitally blind woman
C) Transient disruption of occipital cortex impaired tactile discrimination in blind subjects (i.e., w/ occipital impairment, felt Braille but couldn't “see” Braille)

Clinical Examples (Cont'd)

- Thus, importance of cross-modal plasticity: deprived cortical areas rewire to receive information from other senses

- = functional advantage to reduce disability impact

Plasticity w/ Epilepsy Surgery (hemispherectomy)

- Graveline et al., 1998: activation for motor & sensory function → opposite hemisphere
- De Bode et al., 2007: locomotor training (e.g. weight-supported treadmill exercise)
  - improved gait in children
  - incr. volume & activation strength of sensorimotor and somatosensory cortex
- Brain can reorganize after extensive removal of cerebral cortex & subcortical structures late into childhood

Structural Changes w/ Plasticity

- Maguire et al., 2000:

http://www.digikids.co.uk/digikids-site/image/taxi-cab-dog.jpg

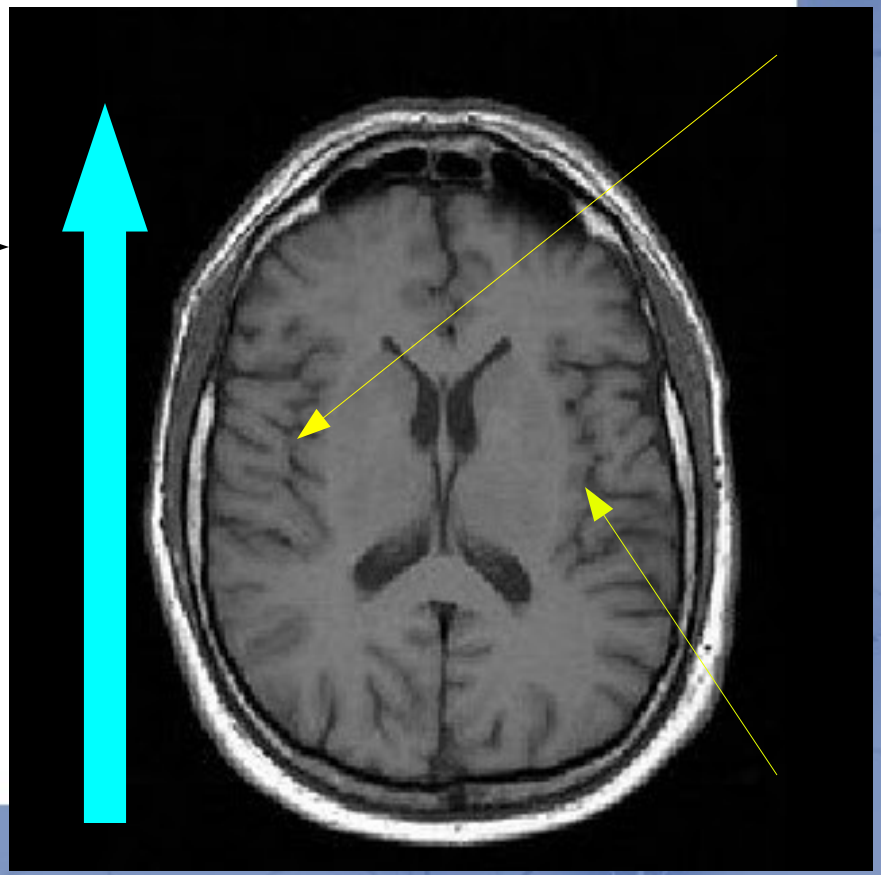
http://t1.gstatic.com/images?q=tbn:ANd9GcRPQB9WdtM4ozeNZZ3-v8qiRyJ0wZ7LcxEaN2MU-ZWUKdOmqWDE

Structural Changes w/Plasticity (Cont'd)

- Draganski et al., 2004:

http://enterthelaughter.com/cat-juggling.jpg

http://4.bp.blogspot.com/_LY8iyWm5fZk/SZrGAAXHWgI/AAAAAAAAAAU/8TiNXsgaGt8/s320/brain_mri_transversal_t1_002.jpg



Structural Neuroplasticity Post Hemiparesis Therapy

- CIMT + 'behavioral techniques' to help transfer therapeutic gains into real-world activities

→ (Gauthier et al., 2008): CIMT + behavioral intervention greater improvement (e.g., greater use of paralyzed arm in real-world situations, bilateral grey matter increases in sensory & motor areas, hippocampi) than CIMT-only control

Enhancing Plasticity w/Brain Stimulation

- Balance of excitatory (glutamate) & inhibitory (GABA) neurotransmission, affected by:
  - Drugs: Benzodiazepines, baclofen enhance inhibition, linked to impaired plasticity
  - Peripheral nerve stimulation (TMS, tDCS) can reverse cortical inhibition
- e.g., Stefan et al., 2002: repetitive stimulation to somatosensory cortex through median nerve paired with TMS pulses to motor cortex synergistically enhanced excitability of motor cortex

Plasticity in Children w/ CP

- Eyre et al., 2007: Progressive decrease in TMS responses + increase in axons from noninfarcted hemisphere in infants predicted poor outcome
- TMS & other stim. Techniques may be useful to correct postnatal imbalance in cortical activity to reduce functional disability
  - e.g., Jang et al., 2005: Therapy using virtual reality environment to stimulate use of hemiparetic hand switched cortical motor activation from ipsilateral to contralateral side

Maladaptive Plasticity Post Injury

- Use-dependent dystonia
  - (Quartarone et al., 2006): Musicians, writers: co-contraction of muscles due to less segregation of finger representations in somatosensory cortex
- Phantom limb pain
  - (Flor, 2008): Reorganization at multiple levels (spinal cord, brain stem, thalamus, cerebral cortex), representation of mouth area moves into previous arm area... thus, pain in mouth = pain in arm

Genetic Influences

- Brain derived neurotrophic factor (BDNF)
  - Role in hippocampal plasticity
  - (Egan et al., 2003): relationship between different alleles of BDNF and episodic memory, anatomy of hippocampus & frontal lobes

Conclusions

- Plasticity both negative & positive
- Activity-dependent plasticity at synapses + reorganization of motor & sensory maps

→ Adaptive plasticity post injury

- Exercise & electrical stimulation of brain can enhance recovery

Thanks!

http://tjvance.com/php/wordpress/wp-content/uploads/2007/09/n38205511_32733868_5682.jpg