CORTICAL PLASTICITY:
THE AMAZING ABILITY OF THE BRAIN TO ADAPT

Norbert Fortin, PhD

Bio Sci 38: Mind, Memory, and the Brain

OVERVIEW

- Cortical plasticity during development
  - Examples of the amazing ability of the brain to adapt

- Cortical plasticity in adults
  - The old dogma
  - Evidence showing that the dogma is way wrong

- Cross-modal plasticity
  - Blind individuals can use visual areas to process “touch” info
  - “Seeing” using other senses

CORTICAL PLASTICITY DURING DEVELOPMENT

AMAZING DEVELOPMENTAL PLASTICITY: HEMISPHERECTOMY

- >50 million people worldwide have epilepsy
  - recurrent unprovoked seizures, usually controlled (but not cured) by medication
  - A radical solution for drug-resistant epilepsy in young kids is to remove the hemisphere where seizures occur (hemispherectomy)

CORTICAL PLASTICITY DURING DEVELOPMENT

AMAZING DEVELOPMENTAL PLASTICITY: HEMISPHERECTOMY

The case of “Nico”

- Hemispherectory at age 3 because of debilitating epileptic seizures.
- At age 7-9, some difficulties drawing and writing, but otherwise not distinguishable from his classmates in standard elementary school.

CAT scan of his brain

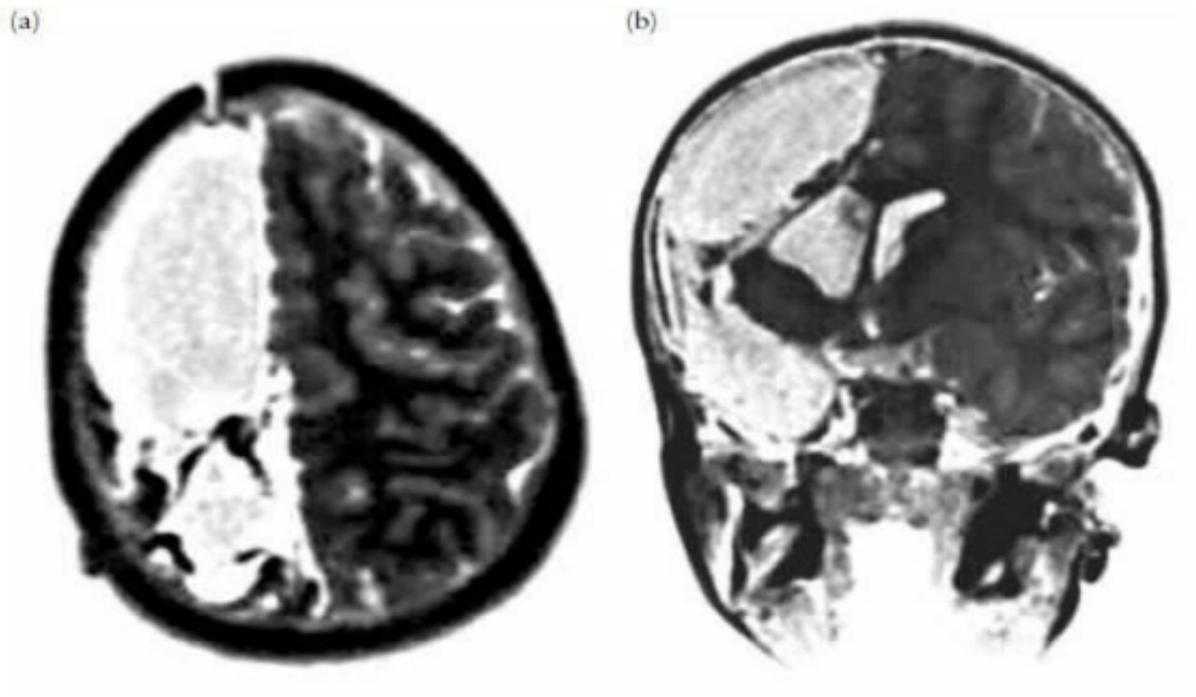
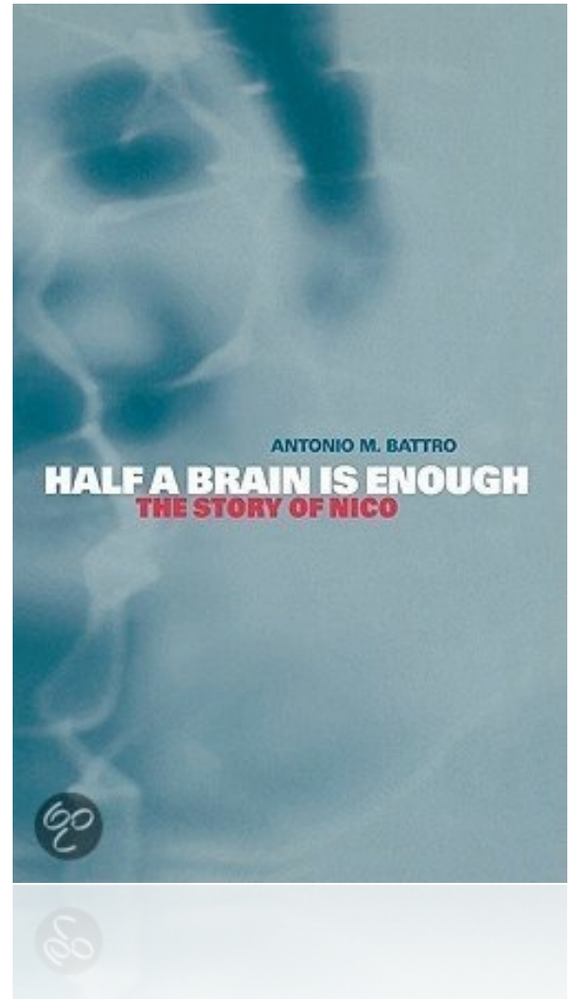


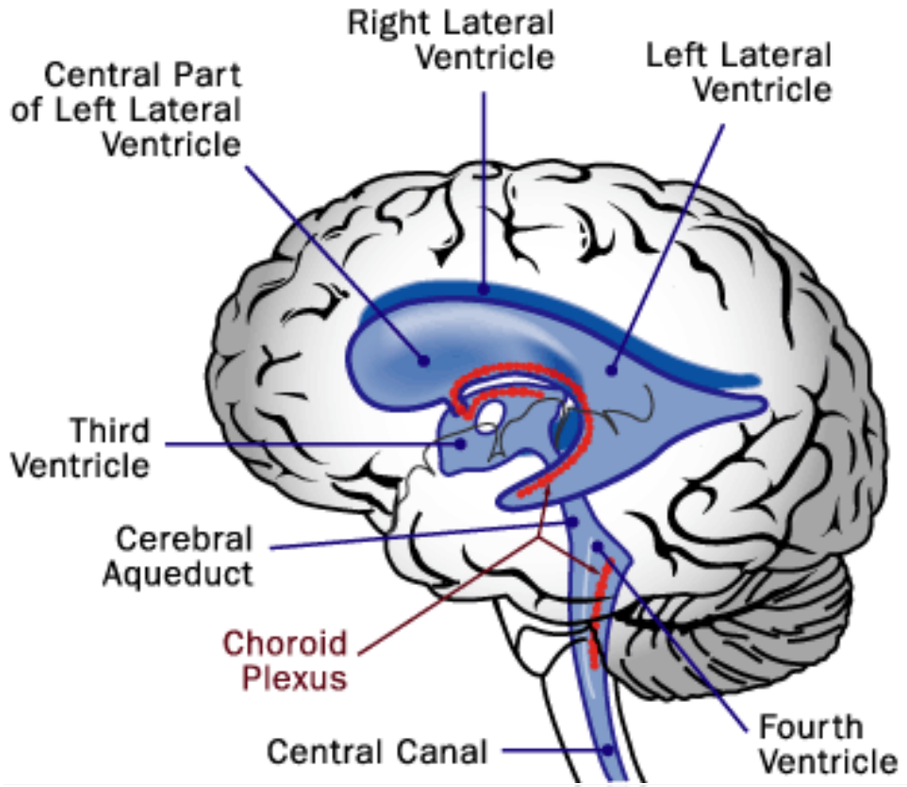
Figure 1.1 Two images of the functional right hemispherectomy. (Nico: three-years-and-seven-months): (a) horizontal (axial) view, (b) frontal (coronal) view. Only the left hemisphere is seen, most of the right hemisphere has been removed.



CORTICAL PLASTICITY DURING DEVELOPMENT

AMAZING DEVELOPMENTAL PLASTICITY: HYDROCEPHALY

Our ventricles are filled with cerebrospinal fluid (CSF), which offers mechanical and immunological protection to the brain.



- The CSF is continually produced by the choroid plexus in the ventricles, and your body is continually getting rid of the excess CSF.
- **Hydrocephaly** (“water head” in greek) occurs when the CSF is not evacuated quickly enough, which gradually enlarges the ventricles and produces brain damage.

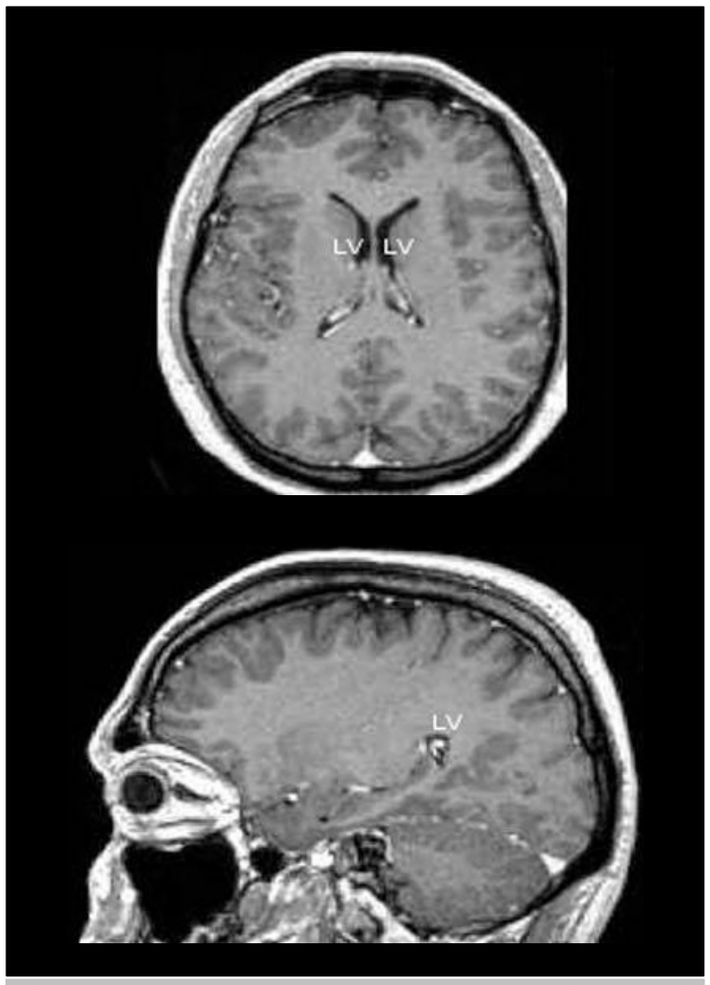
https://www.youtube.com/watch?v=yqK8DxXF7oQ

CORTICAL PLASTICITY DURING DEVELOPMENT

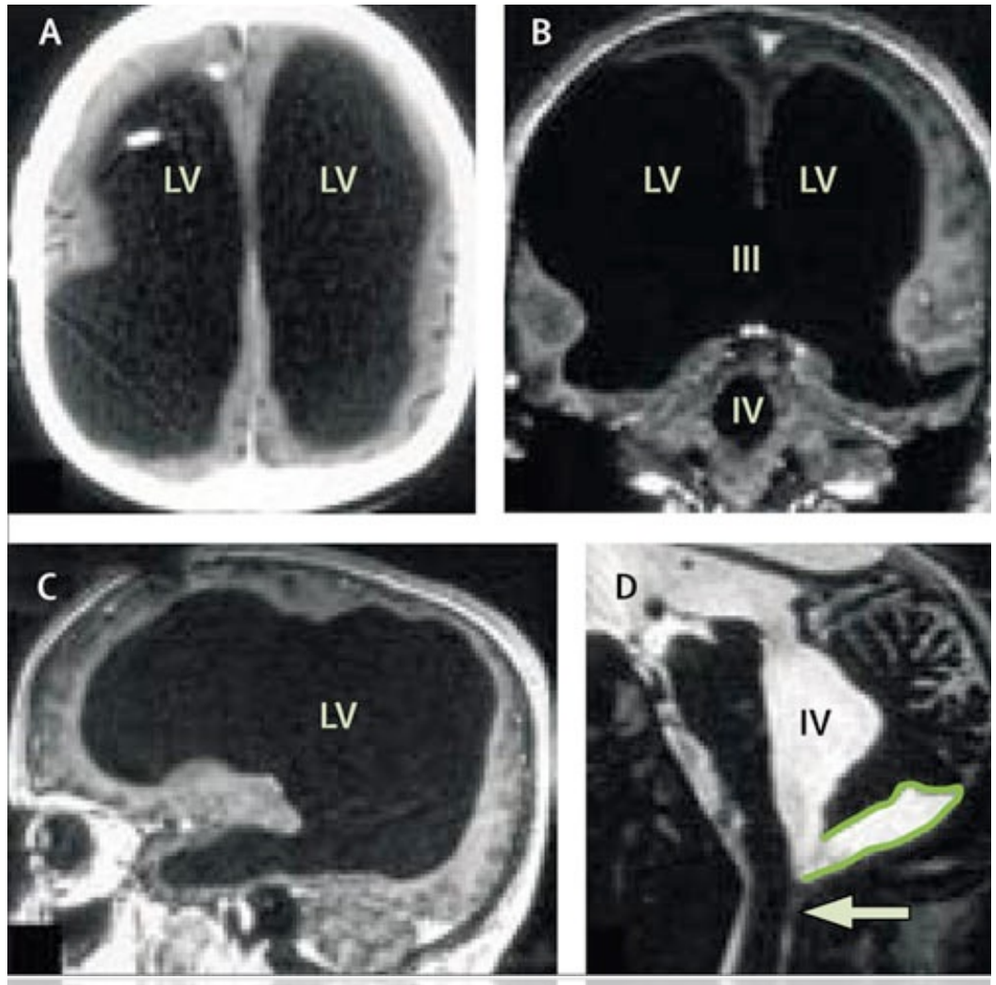
AMAZING DEVELOPMENTAL PLASTICITY: HYDROCEPHALY

- The case of a French government worker
  - complained to his doctor of “leg weakness”.
  - Married with kids, IQ in normal range.
  - Doctors treated him for this as a kid, but didn’t follow up properly.

Normal brain



Hydrocephalic brain



LV – lateral ventricle

How can this happen? The condition started early in development and progressed slowly.

CORTICAL PLASTICITY DURING DEVELOPMENT

AMAZING DEVELOPMENTAL PLASTICITY: HYDROCEPHALY

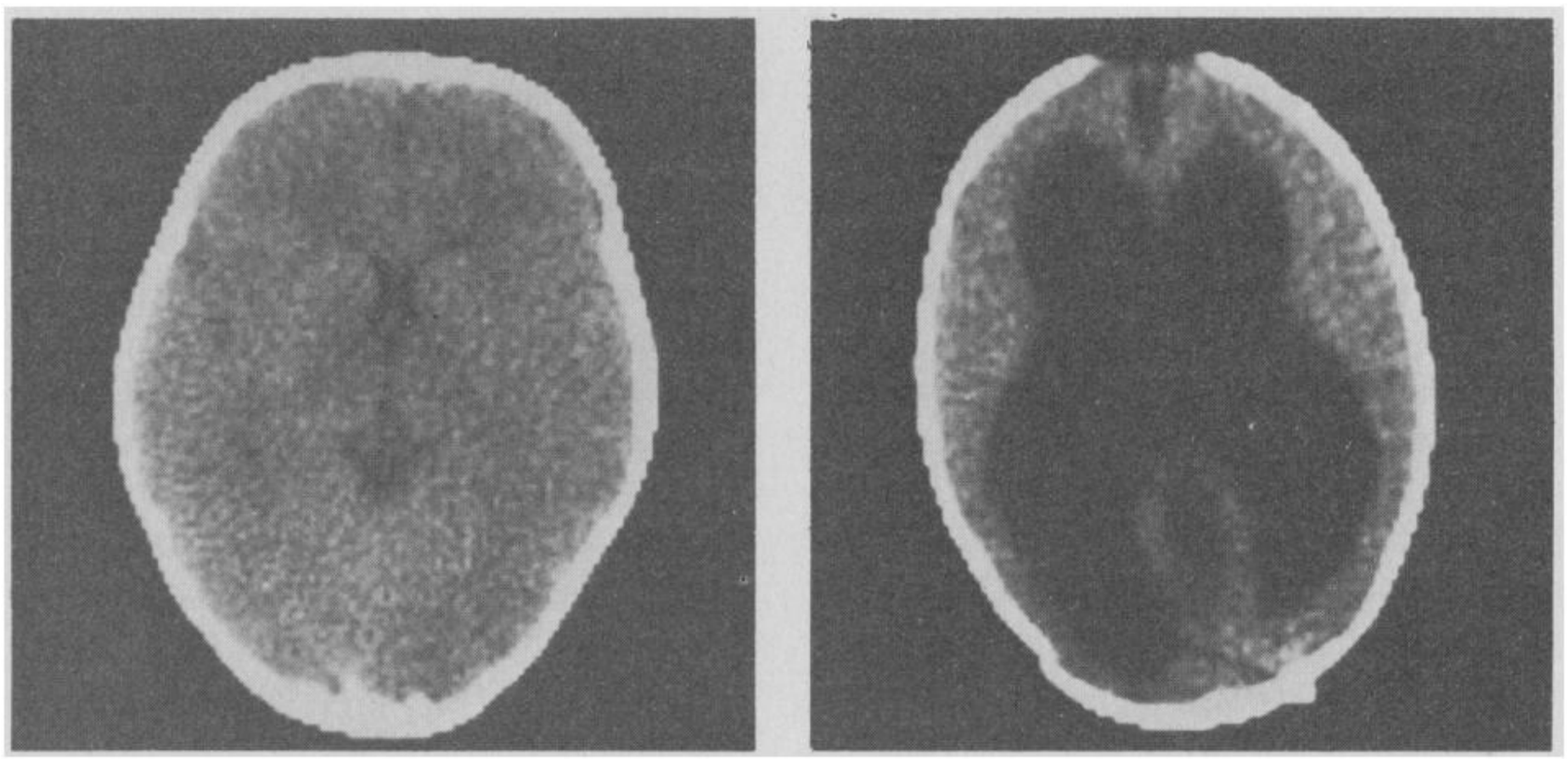
- The case of a British truck driver (age 55)
  - Reached emergency room after driving into a tree (in coma).
  - Scan revealed most of his frontal lobes (and some temporal and parietal lobes) were missing.
  - Made “full recovery”…

How can this happen? The condition started early in development and progressed slowly.

CORTICAL PLASTICITY DURING DEVELOPMENT

AMAZING DEVELOPMENTAL PLASTICITY: HYDROCEPHALY

- The case of an Honors student in mathematics
  - IQ of 126, socially normal
  - Doctors did a scan because of his slightly larger head…



Computerized Tomography (CT) scans

How can this happen? The condition started early in development and progressed slowly.

CORTICAL PLASTICITY DURING DEVELOPMENT

AMAZING DEVELOPMENTAL PLASTICITY: DEVELOPPING NEW CAPACITIES

Ben Underwood: The boy who sees without eyes

CORTICAL PLASTICITY DURING DEVELOPMENT

AMAZING DEVELOPMENTAL PLASTICITY: DEVELOPPING NEW CAPACITIES

More videos on Ben Underwood:

http://www.youtube.com/watch?v=qLziFMF4DHA

http://www.youtube.com/watch?v=G1QaCeosUmw

http://www.youtube.com/watch?v=ikpNZOx5FGk

http://www.youtube.com/watch?v=3Px-aPnk4ZU

http://www.youtube.com/watch?v=MNkJ1diTxOE

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CORTICAL PLASTICITY IN ADULTS

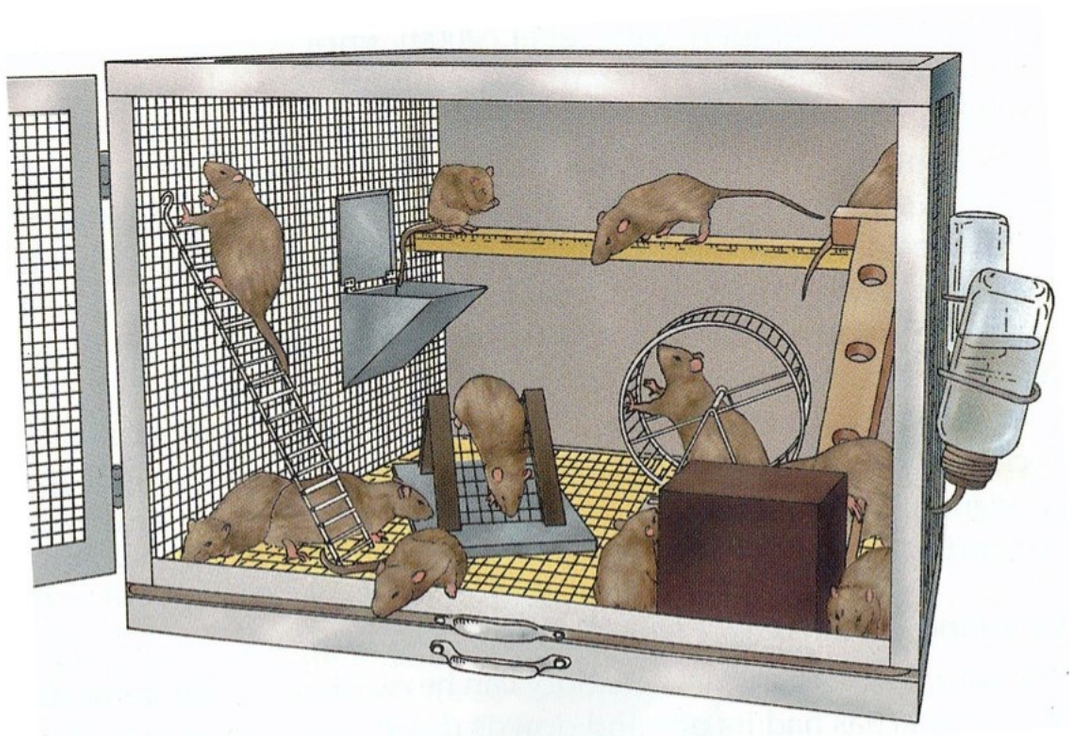
THE OLD (INCORRECT) DOGMA

"After developmental plasticity is completed (i.e., after the critical periods are over), the functional organization of the adult cortex is static and unchangeable"

CORTICAL PLASTICITY IN ADULTS

EFFECTS OF “ENRICHED” ENVIRONMENT ON CORTEX

An ‘enriched’ environment
for adult rats

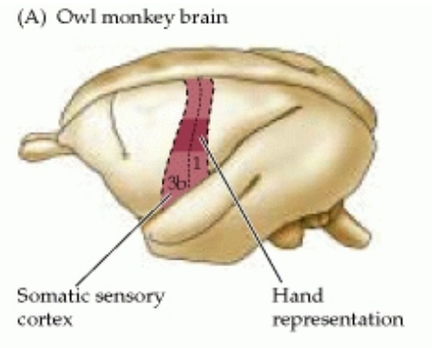


- Sensory cortex becomes thicker
- Neurons exhibited larger dendritic and axonal trees
- Larger amount of synapses and more complex capillary patterns
- Notably, such animals are typically better in problem solving tasks (e.g., mazes) than control animals

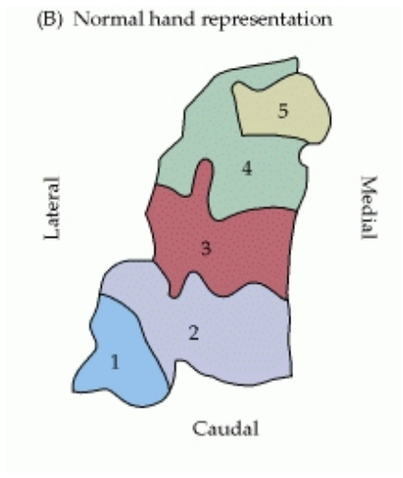
Clearly, the cortex can change a lot, even in adults

CORTICAL PLASTICITY IN ADULTS

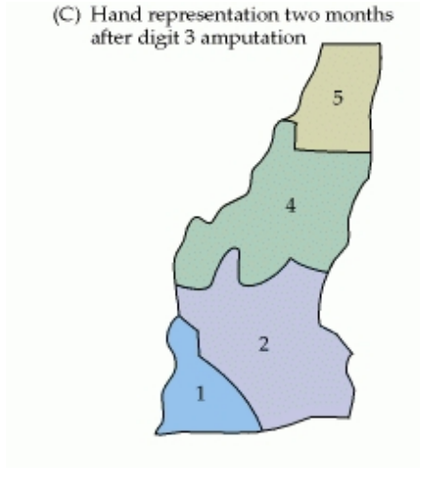
LOSING A FINGER LEADS TO REMAPPING IN SOMATOSENSORY CORTEX



Finger representation in monkey somatosensory area



Normal representation of the 5 digits (digit 1 is the thumb)



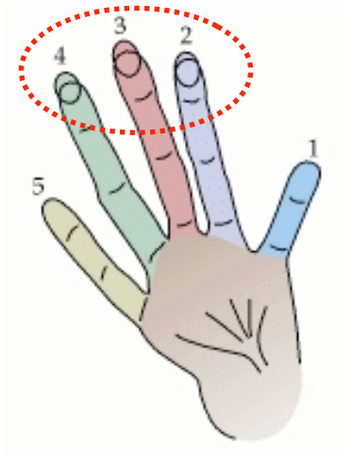
Representation a few months after middle digit (digit 3) was **removed**

Purves et al., 2001

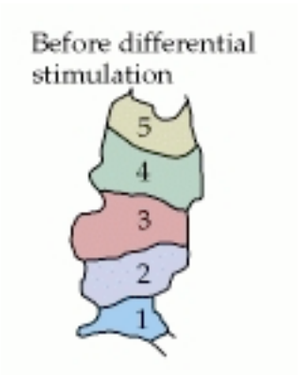
CORTICAL PLASTICITY IN ADULTS

TRAINING LEADS TO REMAPPING IN SOMATOSENSORY CORTEX

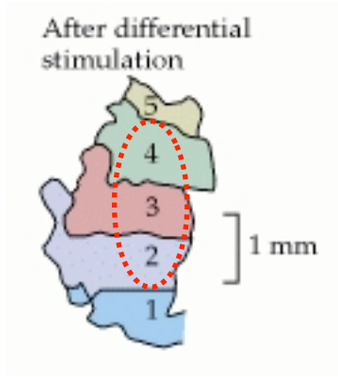
Finger-specific training on a difficult texture discrimination task



Only middle three digits (2-4) were trained in the task



Normal representation of the 5 digits **before training**



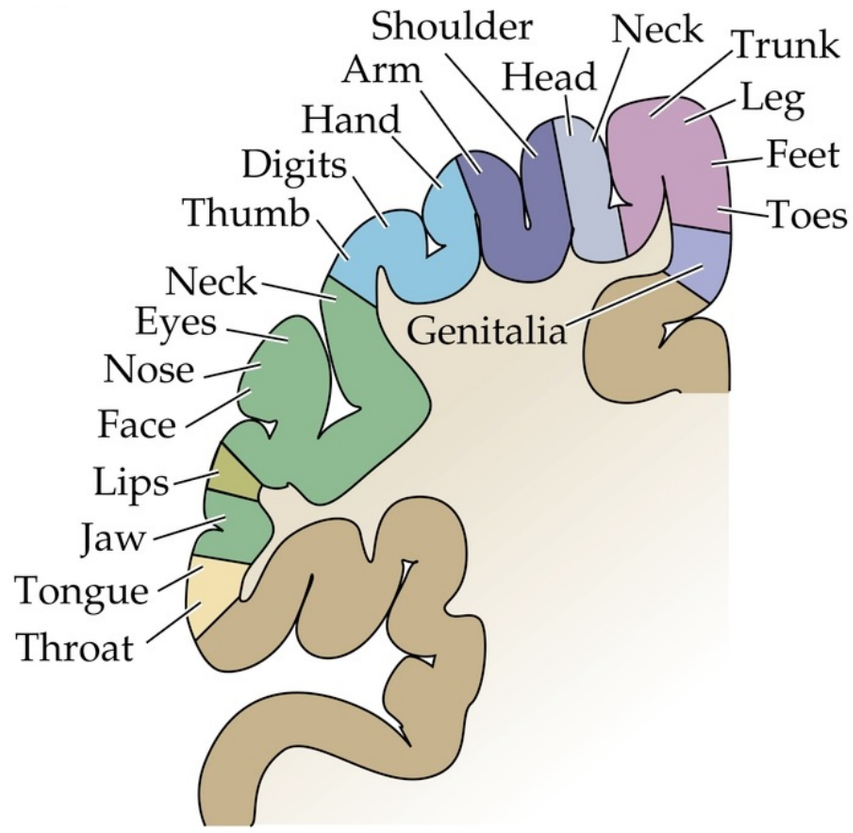
Expanded representation of trained digits **after training**

Purves et al., 2001

CORTICAL PLASTICITY IN ADULTS

THE SAME RULES APPLY IN HUMANS...

The cortical representation of the hand is taken over by the face after hand amputation



Purves et al., 2001

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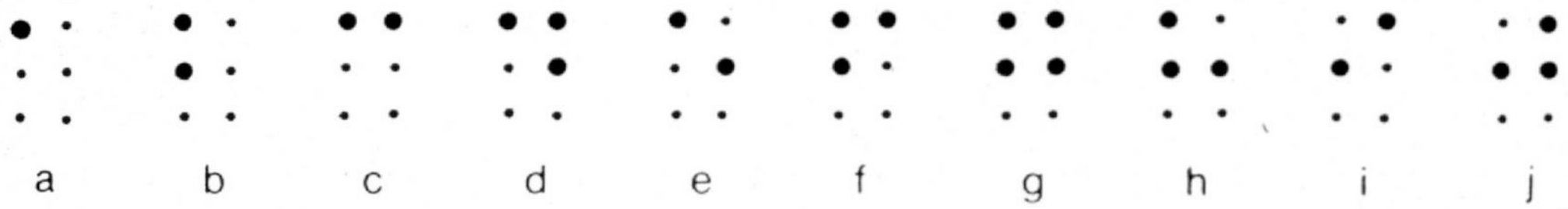
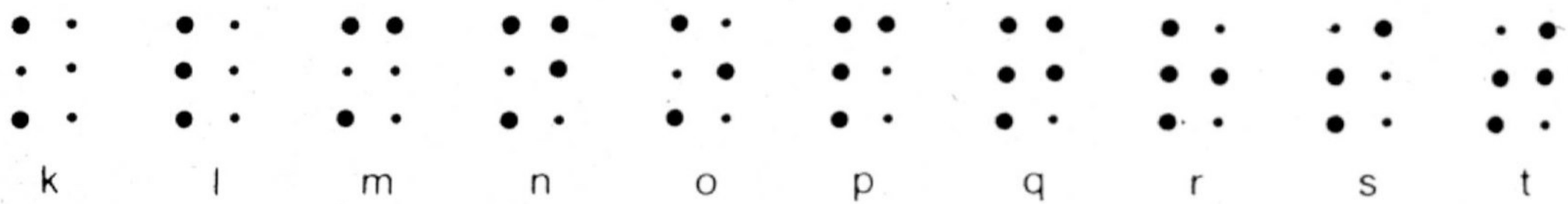
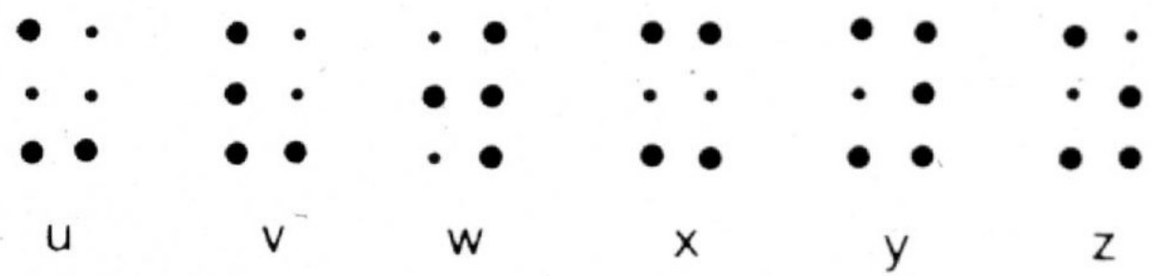
CROSS-MODAL PLASTICITY

WHAT'S BRAILLE?

Braille system: method for blind individuals to read and write







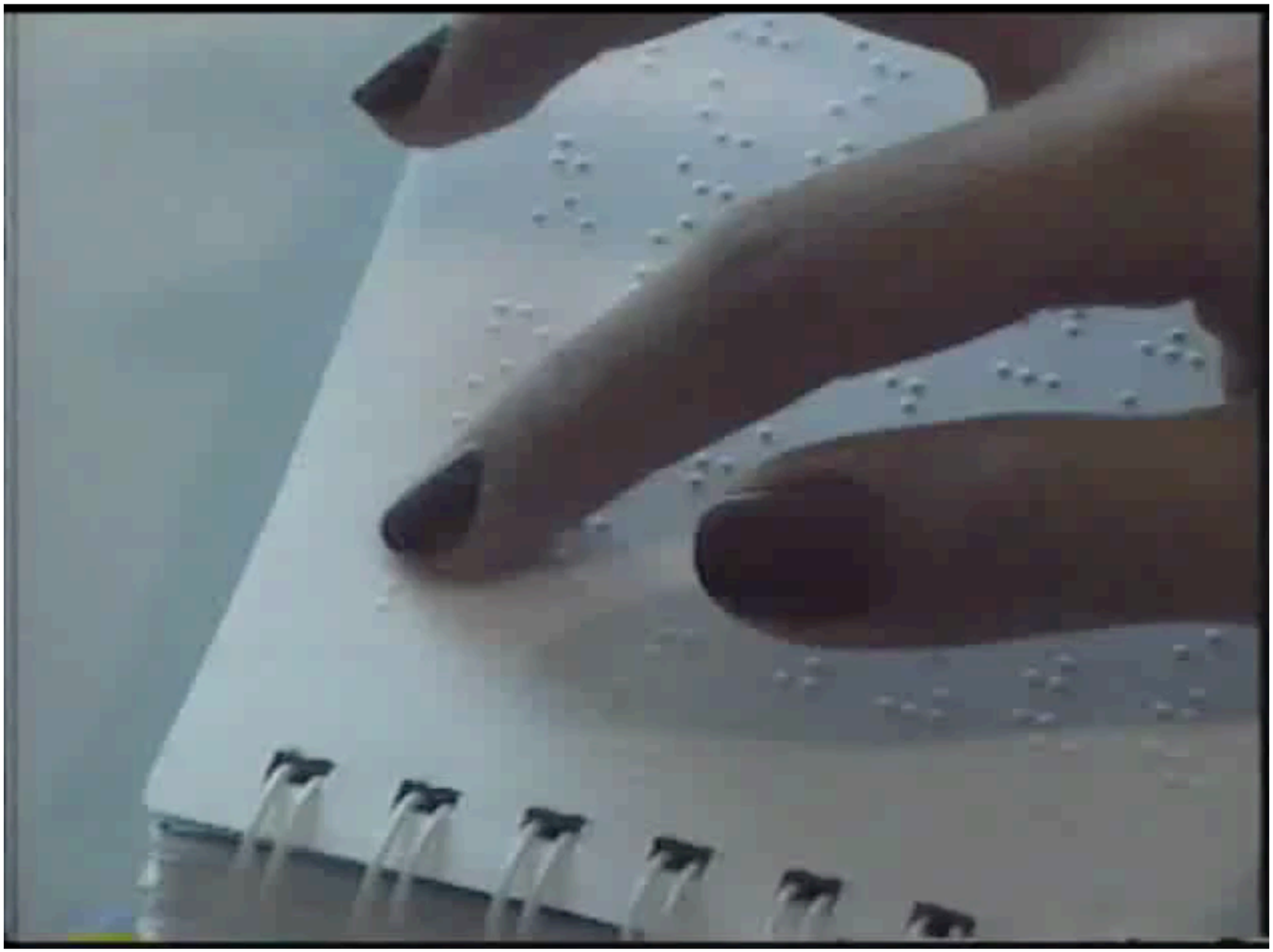
CROSS-MODAL PLASTICITY

BLIND SUBJECTS USE VISUAL AREAS TO PROCESS TOUCH INFO

CROSS-MODAL PLASTICITY

YOU CAN DO IT TOO!

After only a few days of no vision, V1 already plays a role in processing touch info



CROSS-MODAL PLASTICITY

“SEEING” USING OTHER SENSES

Mechanical substitution systems for the blind

Converting 2-D visual image to a 2-D somatosensory “image”

Forehead display

Tongue display

Using sounds to decode images