NEW INSIGHTS IN EARLY CHILDHOOD BRAIN DEVELOPMENT

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OUTLINE

I. A tutorial on brain development
II. How experience affects brain development
III. Case Studies:
   I. Toxic stress
   II. Early psychosocial deprivation

PART I.
INTRODUCTION TO BRAIN DEVELOPMENT
**PRINCIPLES OF BRAIN DEVELOPMENT**

- **Genetics** supplies basic blueprint for brain development.

- **Experience adjusts** the blueprint and shapes the architecture of its neural circuits, according to the needs and distinctive environment of the individual.

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**An Accelerated View of Brain Development**

- **Neuralation**
  - Days 18-24:
    - Conception occurs; zygote forms; embryo forms; embryo then forms 3 layers.
    - Outer region of embryo (ectoderm) becomes the **Neural Tube**.

- **27 weeks**
- **Full term brain**
- **Adult**

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[Image of brain development stages]
Immature brain cells (neurons, glia) begin to form; this continues first 1-2 years after birth.

Was previously believed most neurogenesis was complete at birth.

We now know that there is postnatal neurogenesis in at least one area (hippocampus, which is involved in memory) through at least middle age.
CELL MIGRATION

- To form the cerebral cortex, immature neurons migrate along thin fibers (radial glia fibers).
- Once a neuron reaches its target destination, it detaches from the fiber and stays in that location.
- By about 24 weeks gestation, all until 6 layers have formed.

DIFFERENTIATION AND APOPTOSIS

- Differentiation refers to:
  - Development of axons and dendrites
  - Formation of synapses and
  - Synthesis of neurotransmitters.
- Some dendrites and axons form as early as the 15th week; big increase after 25th week; continues into 2nd postnatal year.
- Not all cells differentiate; there is massive programmed cell death (apoptosis), during which 40 - 60% of cells die.

SYNAPTOGENESIS

- As with axons and dendrites, is an initial overproduction of synapses; the newborn brain has many more synapses than the adult brain.
- First synapses observed about 23rd prenatal week, with rapid proliferation that follows and continues postnatally.
- This is followed by retraction to adult levels.
- In human, rate of retraction varies from brain area to brain area.
RETRACTION OF SYNAPSES

- In visual and auditory cortices, adult levels of synapses are obtained in early childhood (2 - 6 years).
- In the middle frontal gyrus, adult levels are not reached until mid- to late adolescence.
- Thus, is delayed maturation of frontal lobe, which is responsible for higher cognitive ability (e.g., abstract thought) and emotion regulation.

MYELINATION

- Myelin is lipid/protein substance produced by glia.
- Myelin wraps itself around axon as form of insulation.
- Myelin speeds transmission of brain electrical activity.
- Implications for serial and parallel processing (e.g., multitasking).

- Myelination occurs in “waves” beginning prenatally and ending in young adulthood (and in some regions, as “late” as middle age).
- Earliest regions to myelinate are sensory regions; last are regions that are concerned with higher cognitive and emotional functions (e.g., emotion regulation; abstract thought).
- Thus, again we see delayed maturation of frontal lobe.
SUMMARY OF BRAIN DEVELOPMENT

PART II: NEURAL PLASTICITY

Does the structure of experience work its way into the structure of the brain? How so?
INDIVIDUALITY IS THE PRODUCT OF BOTH PERSONAL EXPERIENCES & BIOLOGICAL INHERITANCE

- Genetics specifies the properties of neurons and neural connections to different degrees in different pathways and at different levels of processing.

- But, because many aspects of an individual’s world are not predictable, the circuitry of the brain relies on experience to customize connections to serve the needs of the individual.

- Experience shapes these neural connections and interactions but always within the constraints imposed by genetics.

EXPERIENCE IS THE PRODUCT OF AN ONGOING, RECIPROCAL INTERACTION BETWEEN THE ENVIRONMENT AND THE BRAIN

- Specific experiences vary enormously under identical environmental conditions, depending on the history, maturation, and state of the individual’s brain.

- Brain maturity has impact on experience:
  - Different areas of the nervous system mature at different rates.
  - Lower level processing areas mature earlier than those at a higher level.
  - Thus, a less mature brain is affected largely by more fundamental features of the environment, such as patterned light or the speech train.

CON’T

- As the brain matures and changes with experience, more detailed aspects of the environment influence it.

- Thus, as an individual’s brain changes, particularly during the early developmental periods, the same physical environment can result in very different experiences.
I. The impact of experience on the brain is not constant throughout life.
II. Early experience often exerts a particularly strong influence in shaping the functional properties of the immature brain.
III. Many neural connections pass through a period during development when the capacity for experience-driven modification is greater than it is in adulthood.
IV. Such phases are referred to as *sensitive* or *critical* periods.

**CONCLUSIONS**

- Positive experiences
- Influence of experience
  - Speech and language development
    - Between 6 and 12 months, infants move from being able to discriminate phonemic contrasts from most languages, to specializing in discrimination of contrasts from native language
      - Thus, the perceptual window *narrows with experience*
    - At 6 months, an infant being reared in an English-speaking home can discriminate the speech sounds of most languages.
SPEECH AND LANGUAGE DEVELOPMENT

- Between 9-12 months, they begin to lose this ability (except for English)

- However, if 9 month olds given ~5 hours of exposure to non-native language (by live "tutor"), can recapture this ability

- But if exposure occurs via audio or videotape, no effects

FACE PROCESSING

- Evidence that experience plays essential role in development of face processing:
  - Infants who have congenital cataracts removed a few months after birth show remarkable recovery of general visual function but show persistent, subtle deficits in face processing
  - “Other race effect” in which adults are better at recognizing faces from familiar races (generally their own) vs. less familiar races
  - “Other species effect” (see next slides)

FACE PROCESSING (CON’T):

- “Other species” effect, in which
  - 6 month olds, 9 month olds, and adults can discriminate two human faces but only 6 month olds can discriminate two monkey faces (see next slide)
**FOLLOW UP STUDY**

- Is it possible to keep open the perceptual window with additional experience?

**EXPERIMENT 1: TRAINING INFANTS**

- Visit 1: 6-months
  - VPC
  - Sent home with monkey face book
- Visit 2: 9-months
  - Visual Preference (trained faces)
  - VPC (novel faces)
**SUMMARY**

- The “other species” perceptual window closes ~9 months, unless additional experience is provided.

- This experience must occur during a sensitive period; even adults who have extensive experience with monkey faces are not as good as infants if that experience was acquired as an adult.

**SO HOW IMPORTANT IS EXPERIENCE ANYWAY?**

- Sugita (January, 2008)

  - Reared monkeys from birth without access to faces (from 6-24 months)

  - When tested immediately after period of deprivation ended, all monkeys, regardless of deprivation, could discriminate monkey vs. monkey and human vs. human.

  - Then gave monkeys experience with either monkey or human faces; from that point on, could only discriminate faces from exposed category (lost the other)
SUMMARY OF FACE PROCESSING

- Appears infant brain possesses a general neural substrate for all-purpose face processing, but face specialization is entirely (?) experience-dependent.
- The perceptual window through which faces are viewed is broadly tuned early in life, and narrows with experience.
- Unknowns:
  - a) nature of experience (what exactly must be observed to drive typical development?),
  - b) timing (when must exposure occur?),
  - c) duration (how much exposure to faces required to drive system?).

SUMMARY

- In most cases sensory/perceptual development proceeds normally if such systems are “set” correctly during a sensitive period of development. Some aspects of emotional development adhere to this rule as well.
- It is not clear which aspects of cognitive development require experience at particular (e.g., sensitive) points in time, but it is clear they require maintenance (e.g., early intervention programs).

SUMMARY (CON’T)

- Must consider several factors when modeling developmental plasticity:
  - Timing, dose, duration, and type of experience
  - Developmental status of brain when experience occurred
- Remember, different experiences will affect different systems differently at different times in development.
NEGATIVE EXPERIENCES

• Child maltreatment (specifically, neglect)

THE EFFECTS OF EARLY PSYCHOSOCIAL DEPRIVATION ON BRAIN AND BEHAVIORAL DEVELOPMENT

Bucharest Early Intervention Project

CHILDREN REARED IN INSTITUTIONS

• Children raised in institutions are at dramatically increased risk for a variety of social and behavioral problems:
  - disturbances of social relatedness and attachment
  - externalizing behavior problems
  - deficits in IQ and executive functions
  - syndrome that mimics autism
  - Growth stunting

• Developmental problems believed to result from deprivation inherent in institutional care
Why institutional rearing might be bad for the brain

- Insensitive care
  - regimented daily schedule
  - non-individualized care
- Isolation
  - no response to distress
  - unchecked aggression
- Lack of psychological investment by caregivers
  - rotating shifts
  - high child/caregiver ratio

EXTREME EXAMPLE OF INSTITUTIONAL CARE

Psychosocial Deprivation
Bucharest Early Intervention Project

- 136 institutionalized children between 6 and 30 months assessed at baseline
  - 68 randomly remain with routine care in institution
  - 68 randomly assigned to foster care
  - 72 never-institutionalized children (community sample) matched on age and gender = control group

- Children assessed comprehensively at 9, 18, 30 and 42 months; at 54 months, psychiatric screen and IQ test performed; complete assessment at 8 years and 12 year assessment currently underway
THREE PRIMARY AIMS

- Effects of institutionalization on brain and behavioral development
- Efficacy of foster care intervention
- Timing effects (sensitive period)

BRIEF SUMMARY OF FINDINGS

- EFFECTS OF INSTITUTIONALIZATION
  - Diminished IQ (mid 70s) and language
  - Profound disturbances in attachment (next slides)

ATTACHMENT IN BEIP
SECURE VS. INSECURE AT BASELINE

SECURE VS. INSECURE BY AGE OF PLACEMENT
42 MONTHS

A FUNCTIONAL LOOK AT ATTACHMENT: STRANGER AT THE DOOR AT 54 MONTHS

- Caregiver/mother and child answer door (pre-arranged).
- RA: “Come with me, I have something to show you.”
- Walk out the door and around the corner to find RA from previous home visit.
PATHOLOGICAL FORM OF ATTACHMENT: REACTIVE ATTACHMENT DISORDER (RAD)

- Are two types of RAD:
  - Emotionally withdrawn/Inhibited
  - Indiscriminately social/Disinhibited
RAD WITHDRAWN/DEPRESSED CAREGIVER REPORT

RAD DISINHIBITED CAREGIVER REPORT

EFFECTS ON TIMING OF PLACEMENT ON INDISCRIMINATE BEHAVIOR
CONCLUSIONS

- Attachment is profoundly compromised in institutionalized children
- Foster care ameliorates some attachment disturbances
- Earlier foster care is disproportionately effective

FINDINGS CON’T

- Reduction in head size, cortical volume, and EEG activity (next slide)

BRAIN DEVELOPMENT: ELECTROENCEPHALOGRAM (EEG)

- The EEG reflects the electrical activity generated by the entire brain, and provides a general measure of brain development.
- The EEG is recorded by placing sensors on the head, which detect the electrical activity generated by the brain.
SUMMARY OF EEG FOLLOW UP DATA

- If children placed in foster care < 24 months, their EEG at 8 years resembles never institutionalized group.
- If children placed in foster care >24 months, their EEG at 8 years resembles the institutionalized group.
- Thus, timing matters.
**Efficacy of Foster Care Intervention**

- In addition to increases in IQ, see benefits in language, attachment behavior, EEG activity, reduction in anxiety and depression
- ...but
- No effect on ADHD/disruptive behavior disorders
- No effect on executive functions

**Timing Effects**

- ...In IQ (24 months)
- ...In language (15 months)
- ...in attachment (~22-24 months)
- ...in EEG (24 months)
- ...but no timing effects in
  - Mental health

**Summary**

- Early psychosocial deprivation leads to profound delays and disorders in development unless
  - Children are placed in families...
  - Particularly before the age of 2 years
CONCLUSIONS

- Brain development begins a few weeks after conception
- Most of brain architecture laid down late prenatal and first few postnatal years but adult brain not evident (at least based on MRI data) till early adulthood
- Early experience exerts powerful effect on brain and behavioral development, during so-called sensitive periods
- What happens early can have a lasting impact many years later, including adult mental and physical health

THE END