# The Science of Early Brain Development

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# Changes to the 'Human Developmental Manifold'

- Approximately 83% of Canadians live in cities
- Increasingly rare for children to be raised in extended family
- Children are exposed to vast amounts of stimuli far in excess of our evolutionary environment
- Toxins may also be a potent factor in increase in biological problems

***What is the impact of changes to a developmental system that evolved over millions on early brain development?***

***There is growing concern that we're seeing a dramatic increase in infants with low-level biological deficits.***

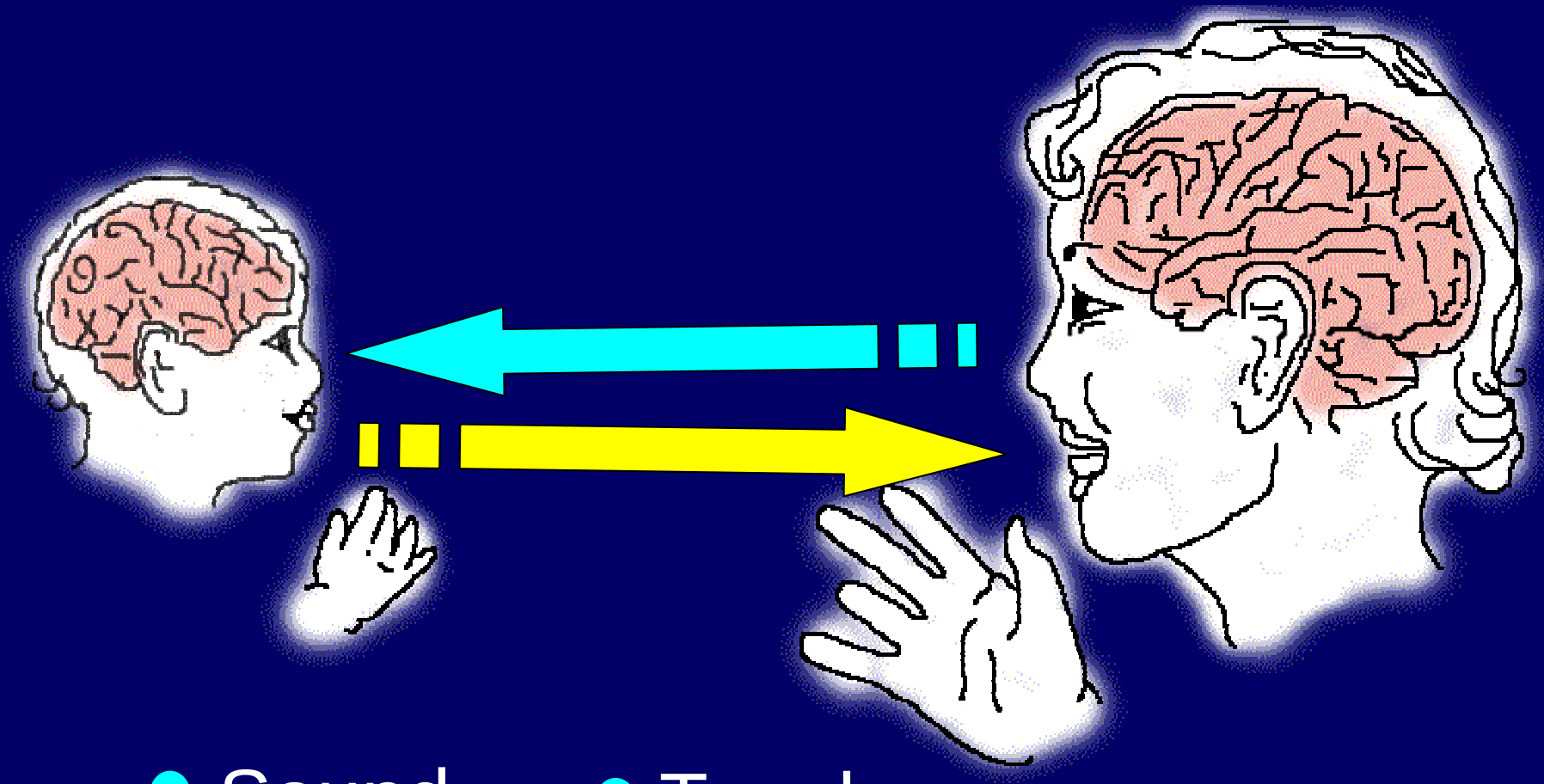
# What is the Extent of the Problem?

**Recent research suggests that:**

- **Approximately 17% of 5 year-olds have a mild to severe developmental or behavioral disorder**
- **20% may have a functional challenge that falls short of DSM classification or diagnosed as PDD**
- **Approx. 25% have mental health problems, physical problems (auto-immune, obesity, hypertension, Type II Diabetes), social problems**

# Secondary Altriciality

- Early plasticity enables the child's brain to be highly attuned to the environment in which she is born
- Synaptic growth in the first 2 years is massive
- There is huge over-production of synapses that, at 8 months, will start to be 'pruned' back
- Synaptic pruning is regulated by baby's emotional interactions with her caregivers



- Sound
- Vision
- Smell
- Touch
- Proprioception
- Taste

# The Role of the Primary Caregiver in Early Brain Growth

- The primary caregiver serves as an 'external brain', regulating and stimulating the baby's brain
- Dyadic experiences are vital for:
  - The capacity to self-regulate
  - the development of emotions
  - Formation of the HPA pathway, which strongly influences subsequent mental and physical health
  - perceptual, cognitive, and communicative skills

(McCain, Mustard & Shanker, *EYS II*, chapter 1)

# The Critical Importance of Emotion

- Positive Emotion is the overarching mechanism that binds the dyad together
- The earliest emotions an infant experiences are pleasurable and aversive sensations
- She reflexively seeks out those experiences that are positive and avoids those that are aversive
  - i.e., an infant will only seek out dyadic interactions if she finds them pleasurable

# Dyad is a Self-Regulating System

- Every infant is unique in kinds of stimulation she likes, how much, when, and how she expresses this
- A caregiver unconsciously adjusts her behaviors
- Infants with acute hyper or hypo-sensitivities find interaction aversive and shut down
- Similar phenomenon in severely depressed or with addiction who fail to read the infant's cues

# Disorders are the Downstream effect of Biological Challenges

**Basic biological challenges:**

- **Sensory regulation and integration**
- **Information processing and motor control**
- **Hypo- and hyper-functioning neurohormonal systems**
- **Cortisolemia**

**•A child with such deficits may avoid the interactive experiences essential for healthy development or become entrenched in behaviors that lead to developmental, psychological & behavioral problems**

**•Extreme social challenges (e.g., deprivation, abuse) can lead to similar results**

# Epigenesis

- According to epigenesis, early experiences can control the switches that turn genes on or off
- These events can then have a dramatic effect on a child's developmental trajectory
- There is not an 'ADHD' or an 'autism gene', in the way that generative linguists once speculated that there might be a 'language gene'
- Rather, ADHD or autism are seen as *downstream disorders*, the result of initial neurogenetic factors that set the child on a developmental trajectory leading towards the disorder

# Sagvolden's Dynamic Developmental Theory of ADHD

- ADHD caused by hypofunctioning dopaminergic system that results in a shorter and steeper delay-of-reinforcement gradient and deficient behavioral extinction
- Dopamine is critical for synaptic activation in the parts of the brain that are associated with the evaluation and pursuit of goals (e.g., the NAS, ACC and OFC)
- If child is born with a short gene for dopamine transcription, there is a heightened risk that the gene will be turned off, these parts of the brain will not receive sufficient activation, and the child will experience delay as aversive

# The Allure of Linear Models

- The challenge that we face here is that we do not allow this argument to relapse into linear causal thinking
- That is, we do not want to treat DDT in the way that some have treated Barker's hypothesis, in *Fetal and Infant Origins of Adult Disease,* that the 20th century epidemic of coronary heart disease in Western countries (particularly hypotension and Type II diabetes) is the result of lower birth weight
- Lower birth weight is an indicator of a biological adaptation to what become metabolic and endocrine changes as the organism prepares for scarce food resources, but in the presence of plentiful food resources, results in heart disease

# Danger of Linear Models

- It was quickly recognized that linear model is limited in the explanation of complex psychiatric disorders
- Even in the case of physical disorders, there is a growing uneasiness with the expectation that there is a direct path from gene to disease
- For example, the economic crisis that occurred during the 'Special Period' in Cuba demonstrates the relationship between reduced caloric intake and increased exercise, with a dramatic drop in type II diabetes and coronary heart disease

# Dynamic Systems Theory: Cascading Constraints

- ‘Changes in the cortex and subcortex involve a loss of *developmental freedom*
- A biological deficit might ‘constrain’ the scope of future developmental possibilities
- What is missing in the linear account of ADHD or autism is the question of how the experiences that drive the development of the mind can have a profound effect on the development of the brain, which in turn can have a profound effect on the development of the mind, and so on

# Application to ADHD

- If unchecked, the child's craving for instant gratification can deprive the brain systems regulating reward inhibition of the input needed for their maturation
- E.g, a highly anxious caregiver who perhaps herself has a hypofuntioning dopaminergic system may respond to her infant's delay aversion by constantly catering to the infant's need for rapid gratification, thereby exacerbating the under-development of the parts of the brain (e.g., the NAS, ACC and OFC) that help regulate the time window in which a behavior can be associated with a reward

# Application to Autism

- A child who, e.g., is hyper-sensitive to visual and auditory stimuli may find dyadic interactions highly stressful, even aversive, and withdraw into himself in order to avoid the very interactions critical for the development of his brain
- Such children are not born with autism *per se,* therefore, but one can see how a neurological deficit can lead to a reduced input of the social information that is necessary for activation of the neural areas involved in face processing, reading emotions, social orienting and social motivation

# Nature/Nurture Revisited

- The fact that biological deficits can have a profound effect on the child's interactive experiences hardly entails that an epigenetic event early in life sets the child on an unalterable developmental trajectory
- These deficits impinge on but do not control the dyadic interactions critical for the development of the mind and brain
- E.g., a caregiver who uses heightened affect to lengthen the time-period in which positive reinforcement can occur, or who helps the child to deal with distractions, can have a profound effect on the development of the NAS, ACC and OFC

# The Source of Brain System Regulatiries

- Our understanding of the neural systems implicated in ADHD is derived from neural imaging done on adult subjects
- Modularity theorists jumped to the conclusion that what we learn from developmental disorders is how evolutionary pressures produced pre-designed neural
- Neuroconstructivists have begun to show how structural regularities are the result of psychological experiences and the fact that the different kinds of cells in different neural systems are better suited for specific kinds of tasks
- The topographical regularities seen in the adult brain are thus result of synthesis of experiential and biological factors

# The Promise of Early Intervention

- The child's brain may constrain what is possible in her zone of proximal development but it is the child's motivation, interest, curiosity, pleasure, etc., that enable her to exert the effort required for that next step in development, which in turn forces her brain to develop the new connections needed for the task at hand
- Even a child with biological impairments can, if wooed into the experiences necessary for the growth of the mind, go through the stages of healthy mental development needed to provide the various parts of the brain involved in these tasks with the input that lays the connections that will open up her universe of future developmental possibilities

# Early Childhood Development and Societal Health

- A substantial body of scientific evidence suggests, therefore, that many behavioral and learning problems can be mitigated and overall education achievement enhanced by appropriate intervention at the earliest stages of childhood development
- Although the scientific evidence is compelling, there has been no large scale population study to test the possibility that the overall literacy, numeracy and social capacities of a nation's children can be enhanced by structured programmes of childhood development
- Such a study is of pivotal importance but presents financial and logistical challenges.

# Cuba Study

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- Such a study is of pivotal importance but presents financial and logistical challenges
- This took us to Cuba, and in particular, Educa a tu Hijo, which is just such a program

# Circulos Infantiles

- In 1961 the government introduced daycare centres for working mothers with children 6 weeks to 5 years
- Extensive research was devoted to the physical design of these centres and their curriculum
- In addition to having a pediatrician and health professional as part of every centre, teachers received extensive instruction in developmental pediatrics and psychology
- The idea was to provide early child educators with the tools needed to maximize every child's developmental potential and to detect signs of biological compromise as soon as these might present themselves

# Educa a tu Hijo

- So successful were these centres in terms of the cognitive and linguistic development and low rates of developmental and social problems that, in 1985, the country embarked on a national program, *Educa a tu Hijo*, which undertook to apply the same principles to the entire population.
- 99% of the population 0-6 is reported to be participating in the program today
- Children from *Educa* programmes match and even excel children from the *Circulos* in some areas of development (e.g., social and language)

# Educación

*“Work along with the child for the construction of a healthy life trajectory (health, learning and behaviour). Transmit cultural values. Provide the social skills necessary for an active social and political participation (a democratic, pluralistic world). Provide experiences that allow the child to relate herself with nature, so as to feel part of nature.”*

*“All these in a context that privileges playing, exploration and close emotional contacts.”*

# Key Principles

1. *To enhance the healthy functioning of all children, and/or mitigate and possibly prevent a broad range of problems, we need to provide parents and teachers with the tools afforded by modern developmental science*
2. *We need to focus on the emotional qualities that create mentally healthy children: their motivation, curiosity, empathy, emotional range, self-esteem, internal discipline, creativity, moral integrity.*

# Nature/Nurture

- Healthy functioning is not maturational
- We see this from cases of extreme neglect (e.g. Genie)
- Genes are a significant factor, but studies in epigenesis drive home just how important emotional experiences are
- Nature and nurture together, inextricably, forge the child's developmental trajectory

# What is Healthy Functioning?

- 'Healthy functioning' is not characterized by how much a child *knows*
- How much a child who enters the school system is *capable* of learning is very much a function of the basic emotional as well as cognitive and communicative capacities she has developed in the first years of life
  - in particular, the child's motivation, interest, curiosity, self-confidence, imagination

# Emotional Functional Capacities

- emotional differentiation
- emotional control
- ability to express of emotions
- ability to understand others' emotions (non-verbal cues)
- ability to empathize with others' emotions

# ‘Healthy functioning’ is not a zero-sum concept

- There is a continuum, and individual strengths and weaknesses, both across domains and within domains (e.g., it is possible for child to be strong in language but weak in social development, or strong in vocabulary and grammar but weak in comprehension)
- ‘disorders’ (developmental, psychological, behavioral) represent extremes on this continuum

# A Series of Challenges, in All These Domains!

- Daycare, preschool and school present challenges in all of the above domains
- At certain ages children are confronted with a whole new level of challenge
- E.g., there's a huge transition from daycare to preschool, or from SK to grade 1, that taxes a child's physical resources, capacity to self-regulate, pay attention, get along with other children, etc.

# Challenges in the Later Years

- Another big transition in grade 3-4, when reading problems become apparent in children who have largely relied on memory rather than pattern-recognition (visual and auditory)
- Grade/teacher transitions and school transitions place enormous demands on the child
- A child's capacity to think according to internal standards is stretched at the onset of puberty
- The final years are especially taxing in terms of focusing on life-long decisions and negotiating with peer pressures

# Developmental Approach to Children having trouble with these challenges

- For whatever problem a child is demonstrating – e.g., self-regulation, learning, social – we want to identify and address the underlying deficit(s)
- For example, in a child with ADHD, we need to try to curb the child's craving for instant gratification (which is biologically driven)
- A child who is having trouble with peers may be having trouble expressing a full range of emotions, or understanding nonverbal expressions of intention, feeling etc.

# Developmental Pathways Model

- Rather than trying to teach a particular skill directly, we work on developing the underlying capacities
  - E.g., in the case of reading, a child first be able to distinguish different sounds (“ba” and “ga”)
  - Once they can decode and make different sounds they can then match them to different shapes
  - But here too there is a developmental pathway that leads to the ability to recognize shapes

# Further Reading


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