

# The Science of Early Brain Development

**Stuart G. Shanker**

**Distinguished Research Professor of Philosophy &  
Psychology  
Director, Milton and Ethel Harris Research Initiative**





Time Magazine from the MEHRI Neuroscience lab

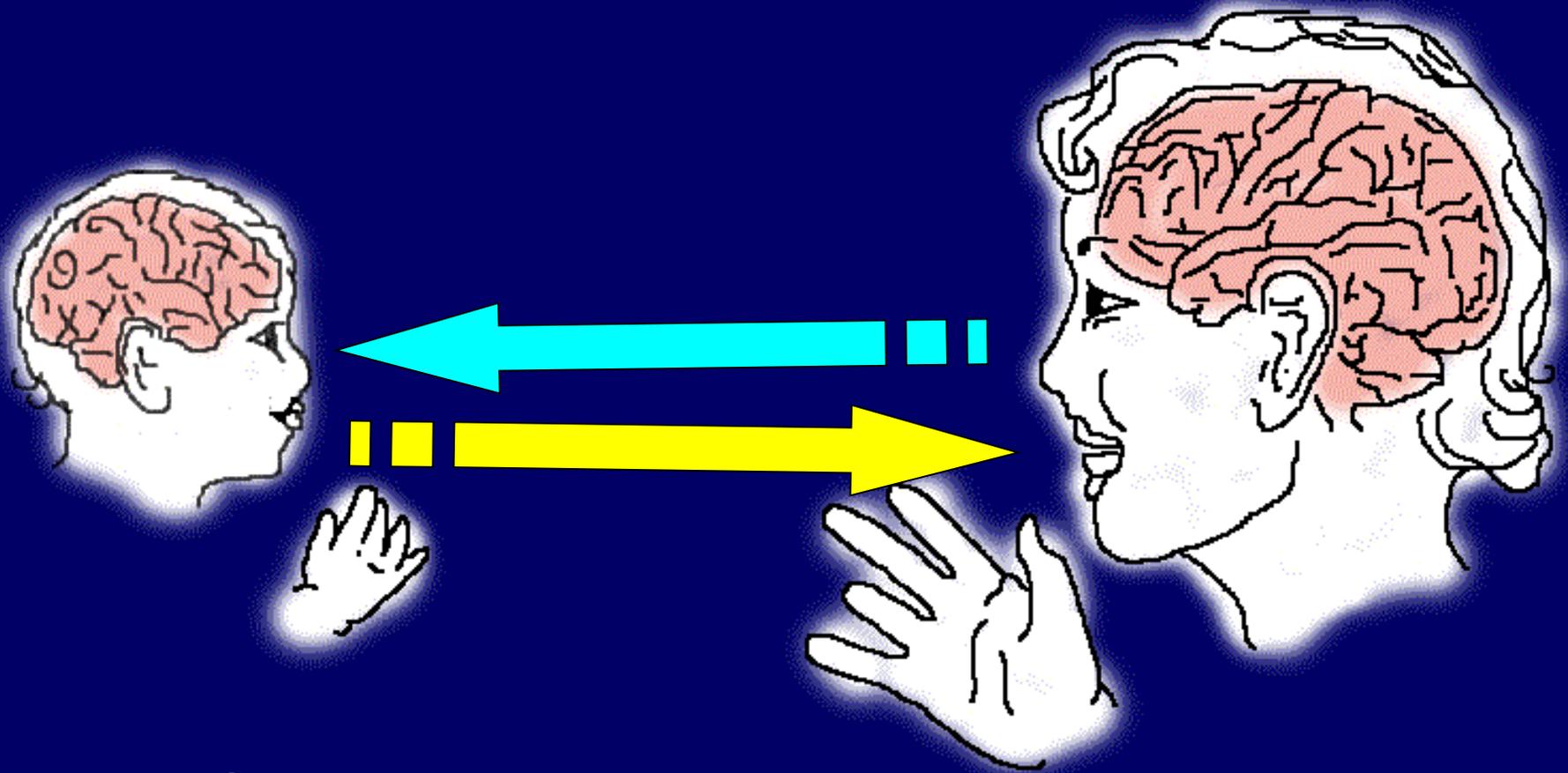




## Secondary Altriciality



- Plasticity enables child's brain to be highly attuned to environment in which she is born
- Synaptic growth in first 2 years is massive
- There is a huge over-production of synapses that at 8 months will start to be 'pruned' back
- Synaptic pruning is regulated by baby's dyadic 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 mental and physical health
  - perceptual, cognitive, and communicative skills

# Arousal Regulation (Level 1) Underpins the other 4 Levels of S-R



- *Arousal regulation* is a function of Sympathetic Nervous System *activation* (e.g., adrenalin) and Parasympthetic Nervous System *inhibition* (e.g., cortisol)
- In effect, putting your foot on the gas or the brakes in order to deal with a stressor

# Continuum of Arousal Regulation



- There is a continuum of arousal, ranging from sleep to being flooded
- how much recovery is necessary or how much activation is needed for any particular task is going to vary from child to child and situation to situation

# Stages of Arousal



## Inhibition



1. Asleep
2. Drowsy
3. Hypoalert
4. Calmly focused and Alert
5. Hyperalert



6. Flooded

## Activation

# Driving Analogy



- helpful for understanding the subtle adjustments in arousal involved in regulating attention
- If goal is to maintain a speed of 100 km/hr constantly pressing and easing up on the gas depending on the state of the road, incline, wind speed etc.
- Furthermore, driving involves constant changes in speed limits or traffic conditions, so learning how to drive involves learning how to smoothly adjust the amount of gas or braking required for the current

# Optimal Regulation



- Children vary considerably in their capacity for optimal regulation: i.e., their capacity to make gradual and rapid changes across the arousal continuum, recover back to baseline, and modulate the highs and lows of energy within a given state
- Some children are constantly pushing too hard on the gas or the brake pedal, jumping erratically from one level to another, or not hard enough (Lillas & Turnbull 2009)

# Allostatic Load Conditions



- If child subjected to too much stress, the result can be an allostatic load condition:
  - Sudden transitions between energy states
  - prolonged over-activation of SNS and/or PNS
  - inappropriate activation of SNS or PNS (i.e., in situations not warranting a heightened stress response)
  - diminished ability to return to baseline after activation of the stress response

# Consequence of Over-Exposure to Stress



- Disrupts development of the brain (HPA pathway)
- Child becomes chronically hypoaroused or hyperaroused
- Child has difficulty staying focused and alert, which is the ideal state for learning to occur

# Chronic Hypoarousal



- Might be because of problems reaching a threshold to activate awareness of a stimulus
- or because this serves as a defensive mechanism because child finds certain stimuli or experiences overwhelming;
- Or because child has difficulty differentiating internal signals
- Child finds it soothing to be in a hypoaroused state

# Chronic Hyperarousal



- Child might be highly sensitive to certain kinds of stimulus (internal or external)
- he might be sensory craving and need to maintain a certain level of activity in order to feel fully aware of his body or to register certain kinds of sensation
- he might be experiencing too many stressors and his parasympathetic system is in constant overdrive

## Down-regulating and Up-regulating a Child



- caregiver's regulating behaviors a function of the situation and her reading of the baby's signals
- E.g., if it is time for social interaction and the child is listless and nonresponsive she might up-regulate the baby by heightening the intensity of her smiles, vocalizations, gestures
- If it is bedtime and the child is hyperaroused, with jerky movements or a wide-eyed stare, she might seek to down-regulate him via bath-time, story time, singing a lullaby, stroking

# Sleeping



- Sleeping is very much a self-regulating behavior, a critical way of restoring bodily functions, and an important part of the process of learning how to self-regulate involves learning how to register the visceral signals of fatigue and the need to lie down and restore
- But a child who sleeps excessively as a mechanism for avoiding stress needs to be up-regulated, which means addressing the causes of the child's distress

# Self-Regulation and Self-Control



- marked tendency to equate problems in self-regulation with poor self-control
- To be sure, some children find it much more difficult to control their impulses
- There is a strong tendency, dating back to the Ancient Greeks and Early Christian thinkers, to see these children as somehow to blame for their poor self-control

# A Change in Attitudes is Imperative



- We need a different understanding of why it is so difficult for some children to inhibit their impulses
- That is, we need to understand why some children have so much more trouble learning the skills that support self-control, and what we can do to help them master these skills

# The Transmission of Caregiving Practices



- Caregiver behaviors—e.g., broad smiles, affect-rich motherese, caressing, rocking – typically produce positive affect, which leads the infant to engage in dyadic interaction
- **These behaviors are not hardwired**
- They were slowly developed and passed down, from one generation to the next, over millions of years

# The Importance of Biology



- Infants are unique in the kinds of stimulation they like or dislike and how they express this
- Caregivers unconsciously acquire this knowledge and adjust their behaviors automatically
- Infants with hyper- or hypo-sensitivities can find interaction aversive and shut down
- We see a similar phenomenon in caregivers who are severely depressed or suffering from an addiction and fail to read their infant's cues

# What constitutes Healthy Functioning in a 6 year-old?



- Emphasis is on **functional capacities**
- ‘Healthy functioning’ is not characterized by how much a child *knows* or IQ
- How much a child who enters the school system is *capable* of learning is a function of the functional capacities they have developed in the first years of life

# Cognitive Functional Capacities



- attention
- pattern-recognition
- sequencing
- visuo-spatial processing
- causal thinking

# Social Functional Capacities



- self-regulation
- Theory of Mind
- prosocial attitudes
- Empathy
- Peer play (problem-based learning)

# Linguistic Functional Capacities



- co-regulation
- vocabulary
- grammar
- comprehension
- New language-discovery processes
- generalization

# 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 Phenomenon



- There are strengths and weaknesses both across and within domains
  - e.g., a child can be strong in language but weak in social development, or strong in grammar but weak in comprehension
- ‘disorders’ – developmental, psychological, behavioral – represent extremes on this continuum

# Nature/Nurture



- Healthy functioning is not maturational
- We see this from cases of extreme neglect
- Studies in epigenesis drive home just how important emotional experiences are for gene expression
- Nature and nurture together, inextricably, forge a child's developmental trajectory

# Developmental Trajectories



- The synthesis of biology and experience leads to a developmental trajectory that, because of synaptic pruning, becomes ever stronger
- What a school-entry child is capable of learning, or their social skills or behavior management are hugely influenced by the trajectory formed by their biology and early experiences

## Key Principles



*The later you attempt to change a trajectory  
the more energy that is required*

*Therefore a major effort has to be made in  
the early years when neural systems are  
most plastic and compromises or  
constrictions are most readily overcome*



- One of the most exciting developments in neuroscience has been the growth in our knowledge of the social nature of the brain
- The brain is primed to resonate with other brains
- Much of this is automatic: a “low road” in social interactions that operates beneath the threshold of consciousness

# The Role of the Amygdala



- The Amygdala modulates neural systems subserving cognitive and social behaviors in response to emotional cues
- The responsiveness of the amygdala to social stimuli is itself a result of secondary altriciality and not a hard-wired phenomenon

# Unconscious Processing



- A child's unconscious processing of affect signals and thus her basic capacity to understand what others are thinking and feeling are forged in the early years
- Connections between the amygdala and other neural systems influence how an individual responds to certain kinds of stimuli and how they think and how they act, not only in infancy, but for their entire life

# Current State of Developmental Science



- Psychometric tests record the downstream effects of a child's developmental history
- Tests taken at 3 years that are correlated with tests at 18 months do not identify a unilinear causal connection from the earlier to the later state
- Rather, it is the earlier biological/social condition and the experiences this promoted or constricted that has led to the later state<sup>34</sup>

# The Way Forward



1. To enhance the functioning of school-entry children or mitigate and possibly prevent a broad range of disorders, we need to focus on the early years
2. We need to understand what sorts of emotional experiences enhance healthy functioning or help restore an infant on an ‘at-risk’ trajectory onto a healthy trajectory
3. We need to study how these same emotional factors apply to later development.

## Further Reading



- Fogel, Alan, Barbara King & Stuart Shanker (2007) *Human Development in the 21<sup>st</sup> Century* (Cambridge UP)
- Goleman, Daniel (2006) *Social Intelligence* (Bantam)
- Gottlieb, Gilbert (1997) *Synthesizing Nature/Nurture* (LEA)
- Greenspan, Stanley & Stuart Shanker (2004) *The First Idea* (Perseus Books)
- Huttenlocher, Peter (2002) *Neural Plasticity* (Harvard UP)
- LeDoux, Joseph (1996) *The Emotional Brain (Touchstone)*
- McCain, Margaret, Fraser Mustard & Stuart Shanker (2007) *Early Years Study II: Putting Science into Action*