The Early Development of the Autonomic Nervous System Provides a Neural Platform for Social Behavior: A Polyvagal Perspective

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Acknowledgments

❖ Special thanks to:
  › C. Sue Carter, PhD
  › Keri Heilman, PhD
  › Larry Gray, MD
  › Elgiz Bal, MA
  › Emily Harden, BA
  › Greg Lewis, BA
  › Danielle Zageris, BA
  › Stephanie Aylward, BA
  › Danielle Coleman, BA

❖ Funding provided by:
  › NIH Grants MH-60625, MH-67446, HD 53570
The Polyvagal Theory: Adaptive Functions

Environment
outside the body
inside the body

Nervous System
Neuroception

Safety
Spontaneously engages others
eye contact, facial expression, prosody
supports visceral homeostasis

Danger

Life threat
Defensive strategies
death feigning/shutdown (immobilization)

Defensive strategies
fight/flight behaviors (mobilization)

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The Vagal Paradox

• Bradycardia are mediated by the vagus and a risk index
• Heart rate variability is primarily mediated by the vagus and a protective factor
Functions of the Vagal System

The vagal system involved in the regulation and coordination of heart rate, sucking, swallowing, digestion, vocalizations, and breathing.

The vagal system mediates apnea and bradycardia!
The Polyvagal Theory

1. **Evolution** provides an *organizing principle* to understand neural regulation of the human autonomic nervous system.

2. Three neural circuits form a *phylogenetically-ordered* response hierarchy that regulate behavioral and physiological *adaptation* to safe, dangerous, and life threatening environments.

3. “**Neuroception**” of danger or safety or life threat trigger these adaptive neural circuits.
Phylogenetic Organization of the ANS: The Polyvagal Theory

head
"old" vagus

limbs

viscera

trunk

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Phylogenetic Organization of the ANS: The Polyvagal Theory

Corticospinal Pathways

Sympathetic Nervous System

head

limbs

viscera

trunk

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Mobilization:
Fight/Flight Behaviors
Phylogenetic Organization of the ANS: The Polyvagal Theory

Corticobulbar pathways

head

“new” vagus

limbs

viscera

trunk

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The Heart-Face Connection: A Critical Component of a Social Engagement System

• At birth, the face is “hardwired” to the neural regulation of visceral state via a mammalian “neural circuit.”

• Metabolic demands, stress, trauma and illness retract the “mammalian” neural circuit with the resultant symptoms of a face that does not work and social engagement behaviors are absent.
The “Mammalian” Vagus and Social Engagement System

Cortex

Brainstem

Cranial Nerves V, VII, IX, X, XI

Muscles of Mastication

Middle Ear Muscles

Facial Muscles

Larynx

Pharynx

Head Turning

Bronchi

Heart

Environment

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Social Engagement
Social Engagement System: Self Regulation
Heart Rate Rhythms
Social Engagement System: Observable Deficits in Several Psychiatric and Behavioral Disorders

- Prosody
- Gaze
- Facial expressivity
- Mood and affect
- Posture during social engagement
- State regulation
- Auditory hypersensitivities
Social Engagement
Violation of Face-to-Face: An experimental manipulation

The Face-to Face Still Face Procedure
(Tronick, Als, Adamson, Wise, & Brazelton, 1978)

3 Phases:
» 2 minutes Social Play
» 2 minutes Still Face
» 2 minutes Reunion Play

Senta Furman (dissertation, in progress)
Reciprocal Interaction (play)

Senta Furman (dissertation, in progress)
Still Face (1)
Still Face (3)

Senta Furman (dissertation, in progress)
Violation Repaired

Senta Furman (dissertation, in progress)
Infant RSA during Mother-Administered FFSF

![RSA Amplitude (in msec)]

- Ages 3 to 6 months
- Ages 7 to 9 months
- Ages 10 to 12 months

Infant HR during Mother-Administered FFSF

![Heart Rate (beats/min)]

- Ages 3 to 6 months
- Ages 7 to 9 months
- Ages 10 to 12 months

Porges & Furman (2010).
Ratio of Axon Densities During Early Infancy: Unmyelinated to Myelinated Vagus Fibers (UVF/MVF)

Neural Platform for Social Behavior: A Developmental Model

**Function**
- Respiratory sinus arrhythmia (RSA)
- Regulate state by feeding
- Regulate state by social engagement

**Anatomy**
- Vagus myelinated
- Brainstem ingestive-vagal reflex
- Cortical regulation of ventral vagal complex

**Developmental Time Line**
- 3rd Trimester
- Term
- 6+ months postpartum

Building Blocks of Self-Regulation

- Homeostatic functions
- Coordinated neurophysiological processes
- Coordinated biobehavioral processes
- Environmental interactions
Hierarchical Model of Self-Regulation

Level I: Baseline Vagal Tone (RSA)

Level II: Regulation of the Vagal Brake

Level III: Motor Behavior Control

Level IV: Appropriate Social Interactions
Level I Assessments

Homeostatic Functions
Homeostasis

Porges (1992), *Pediatrics*
Neonatal Vagal Measures and Outcome at 3 Years

Neonatal Measures

(RSA) Vagal maturation

Outcome Measures

Social Skills

Mental Processing

Motor Skills

Doussard-Roosevelt, Porges, Scanlon, Alemi, & Scanlon (1997), Child Development

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Infant Vagal Tone (RSA) and Temperament (12 wks)

Huffman, et al., 1998, Child Development
Challenge to and Regulation of Homeostasis
(“The cost of doing business”)
The Vagal Brake

an index of self-regulation
Vagal Regulation: Observed in the Neonate During Feeding

Portales, et al., 1997, Developmental Psychobiology
RSA during Feeding:
Vagal Regulation of Metabolism, Ingestion, and Digestion in Preterm Infants

Figure 1: Mean RSA natural logarithm of (ms)^2 during prefeeding, feeding, and postfeeding by gestational age groups.

Figure 2: Mean HP during prefeeding, feeding, and postfeeding by gestational age groups.

Suess et al., 2000, *Developmental Medicine and Child Neurology*
Vagal Regulation at 9 months of age and Preschool Behavior Problems

Atypical Vagal Regulation

Depressive behavior

Social withdrawal

Aggressive behavior

Total Behavior Problems

Porges, Doussard-Roosevelt, Portales, & Greenspan (1996), Developmental Psychobiology
Infant Crying and Developmental Outcome: A Biobehavioral Approach

NICHD Grant NIH Grant R01 HD053570

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A Violation of Social Engagement

http://www.babyreference.com/nutritionconsultations.htm
Atypical Vagal Regulation: Common Mechanisms

- Difficulties in social behavior
- Difficulties in state regulation
Defining A Fussy Infant

Group classification:
1. Infants defined as “excessive criers,” if they manifest distress (fussing, crying, and/or unsoothable crying) for more than 3 hours per day for 3 or more days in one week between 6 and 10 weeks of age.
2. Age when extreme fussiness is resolved (3 or 6 months).
Frequency of Excessive Crying

- Excessive crying at or before 3m – 20%
- Excessive crying NOT resolved by 3m – 7%
- Excessive crying NOT resolved by 6m – 3%
Specific Aims

1. To evaluate whether infants at 6-months, who are prone to excessive crying (but not crying or fussing while being tested), have a distinguishable autonomic response profile that can be measured during laboratory-based experimental procedures.

2. To evaluate whether infants, who are prone to excessive crying, have a compromised developmental outcome at 12 and 24 months.

3. To evaluate whether the autonomic response profile at 6-months, with or without the behavioral feature of persistent crying, is a marker for a compromised developmental outcome at 12 and 24 months.
Competing Hypotheses

- Excessive Crying + Poor autonomic & state regulation → Clinical Risk
- Excessive Crying → Clinical Risk
- Poor autonomic & state regulation → Clinical Risk
Experimental Model

Excessive Crying → Poor autonomic & state regulation → Clinical Risk

Parent reports
Cry Diary
Clinical history

Vagal brake (neural mechanisms of self-soothing & calming)

ADD, PDD, LD, etc (disorders associated with state regulation deficits)
Recruitment Model

Infants screened at 6-10 weeks

No excessive crying

Control

Excessive crying

Resolved by 3m

EC-3M

Resolved by 6m

EC-6M

Not resolved by 6m

EC-6M+
Cry Diaries

Estimated Marginal Means of MEASURE_1

Crying categories (4)

6-10 weeks                 3 months                   6 months

EC-6+
EC-6
EC-3
Control

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EC infants have dampened vagal reactivity
EC infants have dampened vagal reactivity
EC infants have dampened heart rate reactivity.
12 month assessments

- Infant Toddler Social Emotional Assessment (ITSEA) (Carter & Margaret Briggs-Gowan)

- Internalizing behaviors: depression/withdrawal, general anxiety, separation distress, inhibition to novelty

- Externalizing behaviors: activity/impulsivity, aggression/defiance, peer aggression
Predictors of 12-month Behaviors

Model 1: Cry/Fuss 3 months* + Vagal Reactivity* => Internalizing

Model 2: Cry/Fuss 3 months* + Vagal Reactivity* => Externalizing
Conclusions

• The Social Engagement System is an emergent neurophysiological system that phylogenetically developed to regulate contact with the external world and to modulate physiological and behavioral state.

• As the infant matures, the Social Engagement System shifts from a reflexive brainstem system, to a system under cortical control with an ability to initiate social behavior.

• RSA, a measure of vagal regulation measured in infants, is related to developmental outcome and especially to behavioral and psychological processes associated with social behavior, ingestion, and state regulation.

• Fussy-difficult infants, who by definition have state regulation problems and excessive bouts of crying, have atypical vagal regulation that may deprive them from the soothing effects of feeding.

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Conclusions

• During the first 6-months of life the measurement of vagal regulation during feeding provides an early marker of the developmental status of the neural platform for social behavior.

• During the first year of life, cortical pathways develop that regulate the striated muscles of the face and head and the vagus continue to myelinate to form an integrated social engagement system - the same circuits involved in feeding (ingestion) and state regulation.

• As the infant matures, social context displaces feeding as the most important regulator of behavioral state.