

Vagal activity, early growth and emotional development

Tiffany Field^{a,b,*}, Miguel Diego^a

^a *Touch Research Institutes, University of Miami School of Medicine, United States*

^b *Fielding Graduate University, United States*

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Abstract

A review of the research on infant vagal tone suggests that vagal activity is associated with both infant growth and infant socioemotional development. Vagal activity has been noted to increase following the stimulation of pressure receptors as in massage therapy. Vagal activity, in turn, stimulates gastric motility which mediates weight gain in infants. Vagal activity has also been notably elevated during synchronous mother–infant interactions and positive affect, providing confirmatory data for the Porges “social engagement system” model. In contrast, low vagal activity has been noted in prenatally depressed mothers (and prenatally angry and anxious mothers) and their infants, as well as in children with autism. These studies highlight the relations between vagal activity and the social behaviors of attentiveness, facial expressions and vocalizations.

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The vagus nerve is a key component in the regulation of the autonomic nervous system and socioemotional function. It is composed of afferent (sensory) and efferent (motor) fibers that innervate most organs in the body including the gastrointestinal and cardiovascular systems as well as the ears, mouth and voice (Chang, Mashimo, & Goyal, 2003; Kandel, Schwartz & Jessel, 2000). Heart rate variability has been used to estimate vagal activity and serves as a non-invasive measure of autonomic nervous system function and maturation that has been shown to reflect vagal regulation of the heart and the gastrointestinal system (Fox & Porges, 1985; Katoh et al., 2003; Task Force of the European Society of Cardiology, and the North American Society of Pacing and Electrophysiology, 1996). Several time and frequency domain methods have been used to estimate vagal activity from heart rate variability, yielding comparable results and include the Bohrer and Porges (1982) algorithm to estimate vagal tone, Lorenz plots on interbeat intervals to estimate the Toichi cardiac vagal index (CVI), and spectral analyses to estimate the high frequency component of heart rate variability (HF, RSA) (Allen, Chambers, & Towers, 2006; Task Force of the European Society of Cardiology, and the North American Society of Pacing and Electrophysiology, 1996).

Estimates of vagal activity from heart rate variability have been widely used in studies assessing infant development, affect and social interactions. In these studies, vagal tone, specifically baseline vagal tone has been variously treated as a correlate, a predictor, a mediator, a marker variable and even a causal variable of normal and abnormal behaviors and conditions.

* Corresponding author at: Touch Research Institutes, University of Miami School of Medicine, PO Box 016820, Miami, FL 33101, United States. Tel.: +1 305 243 6781.

E-mail address: tfield@med.miami.edu (T. Field).

The primary theme of this review paper is that baseline vagal activity may be considered a stable physiological state just as expressivity has been considered a primary behavior component of individual infant temperament. Secondly, low baseline vagal activity appears to be a marker of infant risk conditions such as prematurity and depression. Third, vagal stimulation in the form of therapies like massage may increase vagal activity, which then may partially mediate increased expressivity, growth and development.

1. Infant growth and development

Several studies have documented a relationship between vagal activity and infant development. Baseline vagal activity in preterm and full term infants is positively correlated with age, paralleling the normal maturation of the autonomic nervous system (Longin, Gerstner, Schaible, Lenz & Konig, 2006; Sahni, Schulze, Kashyap, Ohira-Kist, Fifer, Myers, 2000). Similarly, infant vagal activity is associated with the degree of maturation and integrity of the autonomic nervous system. For example preterm infants exhibit lower baseline vagal activity than full term infants, and infants who exhibit lower levels of baseline vagal activity are more likely to also exhibit less optimal neurodevelopmental outcomes (DiPietro, Caughy, Cusson & Fox, 1994; Doussard-Roosevelt, Porges, Scanlon, Alemi, & Scanlon, 1997; Fox & Porges, 1985; Porges, 1995).

2. Low vagal activity in preterm infants

Vagal regulation of heart rate has been used as a predictor of outcomes for risk infants including very low birthweight preterm infants. Vagal activity and maturational shifts in vagal activity between 33 and 35 weeks gestational age were recorded in a study on very low birthweight infants (Doussard-Roosevelt et al., 1997). These vagal activity measures predicted 3-year outcomes beyond the effects of birthweight, medical risks and socioeconomic status. Higher vagal activity was associated with better social skills, whereas greater vagal activity maturation was associated with better mental processing and gross-motor skills. When the sample was divided into those with birthweights of less than 1000 g versus those with birthweights greater than 1000 g, vagal activity maturation emerged as a strong predictor of mental processing, knowledge base and gross-motor skills in the less than 1000 g group. In a 6–9-year follow-up of a sub-sample of this very low birthweight infant group, neonatal risk measures were not related to school-age outcome measures, although vagal maturation was correlated with social competence, as measured by the child behavior checklist (Doussard-Roosevelt, McClenny, & Porges, 2001).

A similar assessment of very early vagal activity has also been conducted with low-risk fetuses between 36 and 40 weeks gestation (Groome, Loizou, Holland, Smith, & Hoff, 1999). The authors used respiratory sinus arrhythmia to measure vagal activity, and the efficiency of homeostatic control was quantified for each infant by the slope (SRSA) and correlation coefficient (RRSA) of the regression line relating fluctuations in heart period and fluctuations in RSA. To test their hypothesis, they examined the relationship between RSA and both SRSA and RRSA in low-risk fetuses. They found that the fetuses who were parasympathetic-dominated had larger SRSA and RRSA values and were more efficient regulators of homeostasis than those who were sympathetic-dominated.

3. Vagal stimulation for preterm infants

Vagal stimulation may promote growth and development in infants, and stimulation like kangaroo care and massage therapy may be non-invasive methods for increasing baseline vagal activity in infants. For example, a recent study on kangaroo care accelerated the maturation of vagal activity (Feldman & Eidelman, 2003). In this study, mother–infant skin-to-skin (kangaroo care) effects on autonomic functioning, state regulation and neurobehavior status were examined in preterm infants who received kangaroo care over a period of 24 days. Baseline vagal activity was calculated from 10 min of heart rate before the kangaroo care started and again at 37 weeks gestational age. Infants receiving the kangaroo care showed more rapid maturation of vagal activity between 32 and 37 weeks gestational age, as well as more rapid state organization including longer periods of quiet sleep and alert wakefulness and shorter periods of active sleep. Performance on the habituation and orientation items of the Brazelton Neonatal Behavior Assessment Scale also suggested a more mature neurodevelopmental profile.

Using a different form of skin contact, namely infant massage (tactile and kinesthetic stimulation), a group in Korea measured responses to the stimulation including baseline vagal activity, heart rate, and oxygen saturation (Lee, 2005).

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