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Pacifier stiffness alters the dynamics of the suck central pattern generator

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Abstract Variation in pacifier stiffness on non-nutritive suck (NNS) dynamics was examined among infants born prematurely with a history of respiratory distress syndrome. Three types of silicone pacifiers used in the NICU were tested for stiffness, revealing the Super Soothie® nipple is 7 times stiffer than the Wee Soothie®or Soothie® pacifiers. Suck dynamics among 20 preterm infants were subsequently sampled using the Soothie® and Super Soothie® pacifiers during follow-up at approximately 3-months of age. ANOVA revealed significant differences in NNS cycles/min, NNS amplitude, NNS cycles/burst, and NNS cycle periods as a function of pacifier stiffness. Infants modify the spatiotemporal output of their suck central pattern generator when presented with pacifiers with significantly different mechanical properties. Infants show a non-preference to suck due to high stiffness in the selected pacifier. Therefore, excessive pacifier stiffness may decrease ororhythmic patterning and impact feeding outcomes.

Introduction

Observation of infant's oromotor patterns during their routine NICU follow-up visits revealed a pacifier preference between two different models of a popular silicone pacifier with identical external mold profile geometries yielding an oral displacement volume of 4 cm^3. There was a tendency for infants to spit out the blue Super Soothie® pacifier and infants who did retain the pacifier and latch did not appear to suck in a burst—pause pattern. However, infants offered the green Soothie® silicone pacifier appeared to enjoy the oral experience and demonstrated the highly organized burst—pause pattern associated with non-nutritive suck. Subjectively, the Super Soothie® pacifier felt stiffer than the Soothie® pacifier; however, no objective data on materials stiffness was available from the manufacturer (Children's Medical Ventures, Inc). These observations at the NICU

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follow-up clinic prompted the following questions: What is the mechanical stiffness of these two popular silicone pacifiers? If significant differences exist in the mechanical properties of the two pacifiers, does this affect infant's preference and alter the neural activity of brain stem circuits which regulate the suck central pattern generator (sCPG)?

Non-nutritive suck has been widely studied; however, few researchers have examined the physical properties of pacifier nipples such as size and thickness, or the effects of pacifier stiffness on the spatiotemporal patterning of the sCPG. Given the documented sensitivity of the sCPG to somatosensory inputs (Barlow and Estep, 2006; Finan and Barlow, 1996), it is hypothesized that varying pacifier stiffness will alter the spatiotemporal organization and patterning of the sCPG in human infants.

Background

Central pattern generators

Central pattern generators (CPGs) consist primarily of specialized networks of interneurons which produce rhythmic motor patterns (e.g. walking, breathing, flying, swimming, sucking) (Marder and Bucher, 2001). The suck central pattern generator, or sCPG, consists of a bilateral circuit of interneurons located in the brain stem reticular formation (Finan and Barlow, 1996; Iriki et al., 1988). Animal studies have revealed that ororhythmic movements can be evoked from this neuronal network when the slice preparation is localized to a segment of the pons between the trigeminal motor nucleus and the facial nucleus (Chandler and Tal, 1986; Nozaki et al., 1986). Interneurons that compose the ororhythm-generating circuits have intrinsic burst generating capabilities (Del Negro et al., 1998; Tanaka et al., 1999) which are tonically inhibited from lower brain stem sites. Thus, brain stem transection has been shown to disinhibit the rhythm generating circuits (Tanaka et al., 1999) which demonstrates that descending inputs from cerebral cortex play a modulatory role in ororhythmic generation (Barlow and Estep, 2006).

The act of sucking on a pacifier produces a rich stream of sensory cues from cutaneous and deep afferents which serve to refine the timing and magnitude of the efferent code delivered to trigeminal, facial, and hypoglossal lower motor neurons (LMNs) (Barlow and Estep, 2006). The lip vermilion and the tip of the tongue are areas with high densities of low-threshold, rapidly conducting mechanoreceptive afferents (Trulsson and Essick, 2004). These oral mechanoreceptors encode important information used by the baby during development to modulate the timing and magnitude of sCPG output. This form of neural adaptation plays a critical role in ororythmic behaviors and is important in the reconfiguration of the sCPG to meet changing task dynamics such as bolus volume and consistency or mechanical properties of the nipple (Finan and Barlow, 1996). Trigeminal sensory flow also modulates the sCPG by tuning the sensitivity of orofacial reflexes (Barlow and Estep, 2006; Barlow et al., 1993, 2001). Unexpected disturbances or changes to the environment, such as a stiffer pacifier, are ultimately encoded by trigeminal primary afferents which play a key role in modification of lip, tongue, and jaw movements for ororhythmic activity (Lund and Kolta, 2006a,b).

Experience plays a significant role in modulating these sensory signals which influence sCPGs (Barlow and Estep, 2006; Barlow et al., 2004; Estep et al., in press). Frequent exposure to self-generated orosensory events produces neural activity along the trigeminal lemniscus which is presumed to exert trophic effects on the formation and strengthening of central projections for suck development (Barlow and Estep, 2006). A reduction or qualitative change in the type of sensory input to the infant's face, often associated with procedures that restrict orofacial movements such as nasal cannulation or endotracheal intubation, may disrupt neurogenesis during a critical period of development (Bosma, 1973; Pascual et al., 1998). Environmental (sensory) deprivation represents another factor which negatively impacts mechanisms of cortical and cerebellar differentiation during the early postnatal period. Therefore, sensorimotor enrichment during early life is highly beneficial for the developing brain and suck development (Barlow and Estep, 2006; Pascual and Figueroa, 1996).

Structure of the non-nutritive suck

The non-nutritive suck (NNS) produced by a term infant normally cycles at a frequency of approximately 2 Hz and is organized into discrete bursts, consisting of 6–12 suck cycles, separated by pause periods as shown in the left panel of Fig. 1 (Finan and Barlow, 1996; Wolff, 1968). During NNS, the infant coordinates the burst–pause pattern with respiration (Goldson, 1987). Sucking on a pacifier or feeding nipple is one of the first oromotor tasks an infant is engaged to perform soon after birth. An infant with a less mature or damaged central nervous system (CNS) will often manifest a less developed suck pattern. Thus, sucking ability is